A NONLINEAR ANALYSIS OF STATICALLY LOADED PLANE FRAMES USING A DISCRETE ELEMENT MODEL

by

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Development of Methods for Computer Simulation of Beam-Columns and Grid-Beam and Slab Systems

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PREFACE

This report presents a method for the nonlinear analysis of plane frame structures. Geometric, material, and support nonlinearities are accommodated by a discrete element model of the frame members which is incorporated in a nonlinear frame solution.

This is the twenty-third in a series of reports that describe work under Research Project No. 3-5-63-56, "Development of Methods for Computer Simulation of Beam-Columns and Grid-Beam and Slab Systems." Reports No. 56-1, 56-4, and 56-21 provide background information for this report.

Duplicate copies of the program deck and test data cards for the example problems in this report may be obtained from the Center for Highway Research, The University of Texas at Austin.

Thanks are due to the members of the staff of the Center for Highway Research for their assistance in producing this report.

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LIST OF REPORTS

Report No. 56-1, "A Finite-Element Method of Solution for Linearly Elastic Beam-Columns" by Hudson Matlock and T. Allan Haliburton, presents a solution for beam-columns that is a basic tool in subsequent reports. September 1966.

Report No. 56-2, "A Computer Program to Analyze Bending of Bent Caps" by Hudson Matlock and Wayne B. Ingram, describes the application of the beam-column solution to the particular problem of bridge bent caps. October 1966.

Report No. 56-3, "A Finite-Element Method of Solution for Structural Frames" by Hudson Matlock and Berry Ray Grubbs, describes a solution for frames with no sway. May 1967.

Report No. 56-4, "A Computer Program to Analyze Beam-Columns under Movable Loads" by Hudson Matlcok and Thomas P. Taylor, describes the application of the beam-column solution to problems with any configuration of movable non-dynamic loads. June 1968.

Report No. 56-5, "A Finite-Element Method for Bending Analysis of Layered Structural Systems" by Wayne B. Ingram and Hudson Matlock, describes an alternating-direction iteration method for solving two-dimensional systems of layered grids-over-beams and plates-over-beams. June 1967.

Report No. 56-6, "Discontinuous Orthotropic Plates and Pavement Slabs" by W. Ronald Hudson and Hudson Matlock, describes an alternating-direction iteration method for solving complex two-dimensional plate and slab problems with emphasis on pavement slabs. May 1966.

Report No. 56-7, "A Finite-Element Analysis of Structural Frames" by T. Allan Haliburton and Hudson Matlock, describes a method of analysis for rectangular plane frames with three degrees of freedom at each joint. July 1967.

Report No. 56-8, "A Finite-Element Method for Transverse Vibrations of Beams and Plates" by Harold Salani and Hudson Matlock, describes an implicit procedure for determining the transient and steady-state vibrations of beams and plates, including pavement slabs. June 1968.

Report No. 56-9, "A Direct Computer Solution for Plates and Pavement Slabs" by C. Fred Stelzer, Jr., and W. Ronald Hudson, describes a direct method for solving complex two-dimensional plate and slab problems. October 1967.

Report No. 56-10, "A Finite-Element Method of Analysis for Composite Beams" by Thomas P. Taylor and Hudson Matlock, describes a method of analysis for composite beams with any degree of horizontal shear interaction. January 1968.

Report No. 56-11, "A Discrete-Element Solution of Plates and Pavement Slabs Using a Variable-Increment-Length Model" by Charles M. Pearre, III, and W. Ronald Hudson, presents a method for solving freely discontinuous plates and pavement slabs subjected to a variety of loads. April 1969.

Report No. 56-12, "A Discrete-Element Method of Analysis for Combined Bending and Shear Deformations of a Beam" by David F. Tankersley and William P. Dawkins, presents a method of analysis for the combined effects of bending and shear deformations. December 1969.

Report No. 56-13, "A Discrete-Element Method of Multiple-Loading Analysis for Two-Way Bridge Floor Slabs" by John J. Panak and Hudson Matlock, includes a procedure for analysis of two-way bridge floor slabs continuous over many supports. January 1970.

Report No. 56-14, "A Direct Computer Solution for Plane Frames" by William P. Dawkins and John R. Ruser, Jr., presents a direct method of solution for the computer analysis of plane frame structures. May 1969.

Report No. 56-15, "Experimental Verification of Discrete-Element Solutions for Plates and Slabs" by Sohan L. Agarwal and W. Ronald Hudson, presents a comparison of discrete-element solutions with small-dimension test results for plates and slabs, including some cyclic data. April 1970.

Report No. 56-16, "Experimental Evaluation of Subgrade Modulus and Its Application in Model Slab Studies" by Qaiser S. Siddiqi and W. Ronald Hudson, describes a series of experiments to evaluate layered foundation coefficients of subgrade reaction for use in the discrete-element method. January 1970.

Report No. 56-17, "Dynamic Analysis of Discrete-Element Plates on Nonlinear Foundations" by Allen E. Kelly and Hudson Matlock, presents a numerical method for the dynamic analysis of plates on nonlinear foundations. July 1970.

Report No. 56-18, "A Discrete-Element Analysis for Anisotropic Skew Plates and Grids" by Mahendrakumar R. Vora and Hudson Matlock, describes a tridirectional model and a computer program for the analysis of anisotropic skew plates or slabs with grid-beams. August 1970.

Report No. 56-19, "An Algebraic Equation Solution Process Formulated in Anticipation of Banded Linear Equations" by Frank L. Endres and Hudson Matlock, describes a system of equation-solving routines that may be applied to a wide variety of problems by using them within appropriate programs. January 1971.

Report No. 56-20, "Finite-Element Method of Analysis for Plane Curved Girders" by William P. Dawkins, presents a method of analysis that may be applied to plane-curved highway bridge girders and other structural members composed of straight and curved sections. June 1971.

Report No. 56-21, "Linearly Elastic Analysis of Plane Frames Subjected to Complex Loading Conditions" by Clifford O. Hays and Hudson Matlock, presents a design-oriented computer solution for plane frames structures and trusses that can analyze with a large number of loading conditions. June 1971.

Report No. 56-22, "Analysis of Bending Stiffness Variation at Cracks in Continuous Pavements," by Adnan Abou-Ayyash and W. Ronald Hudson, describes an evaluation of the effect of transverse cracks on the longitudinal bending rigidity of continuously reinforced concrete pavements. April 1972.

Report No. 56-23, "A Nonlinear Analysis of Statically Loaded Plane Frames Using a Discrete Element Model" by Clifford O. Hays and Hudson Matlock, describes a method of analysis which considers support, material, and geometric nonlinearities for plane frames subjected to complex loads and restraints. May 1972.

(P) indicates Preliminary Report.

ABSTRACT

A discrete element analysis which considers geometric, material, and support nonlinearities of statically loaded plane frames is developed. A computer program has been written to implement and verify the analysis. Frame geometry, loads, cross sections, and supports (nonlinear concentrated and distributed springs) can be sufficiently general to work practical frame problems.

The method of analysis is based on an iterative procedure called the tangent stiffness method. Unbalanced nodal point forces are applied to a temporarily linear structure whose position dependent stiffness matrix is the tangent stiffness matrix of the structure. The frame members are divided into a number of discrete elements. The member solutions necessary to define the load-displacement response of the members are made separately from the frame solution to reduce computer time and storage requirements.

Load-displacement equations for an individual discrete element are derived which are valid for large displacements. A numerical technique is used to determine the force-deformation response of a cross section with nonlinear stress-strain curves. Loads and nonlinear supports are input in normal engineering terms and can be referenced either to the structure or to the member axes. When necessary, the loads and nonlinear supports are internally transformed to member coordinates and discretized to concentrated values at the nodal points.

Castigliano's first theorem is applied to develop matrix expressions for the stiffness matrix of a general discrete element and these expressions are used to obtain the stiffness matrix for the specific discrete element used in the frame solutions.

A number of problems are worked and compared with existing analytical or experimental solutions. These example problems demonstrate the ability of the analysis to predict the general load-displacement response of (1) members which undergo large displacements, (2) steel frames, (3) reinforced concrete

frames, (4) continuous prestressed concrete beams, and (5) frames involving soil-structure interaction.

KEY WORDS: structural engineering, frame analysis, plane frames, computer program, discrete element, soil-structure interaction, nonlinear analysis, large displacements, nonlinear material properties.

SUMMARY

A computer program which uses a discrete element model for the nonlinear elastic analysis of complex bridge bents and other highway structures has been developed and is reported herein. Rigid frames, trusses, continuous beams, and other planar structures may be analyzed using the program.

The effects of nonlinear soil supports may be considered acting at the joints or distributed along the members of the frame. Cross sections may be quite general and are easily input without preliminary computations. Nonlinear stress-strain curves which need not pass through the origin may be specified for various parts of the cross section. This technique of inputting stress-strain data accommodates the solution of a wide variety of practical problems such as those which arise because of temperature and prestressing effects. The geometric effects of the interaction of axial force and lateral displacement and of the bowing or stretching of members due to bending are automatically considered as part of a complete large displacement analysis.

Loads and restraints may act both normal and parallel to the members of the frame. This allows the designer to consider both vertical and inclined piles as integral parts of the frame, even if a pile has nonlinear lateral and axial soil supports. The geometry of the frame and the directions of the static loads may be input in a manner both natural and convenient to the designer.

IMPLEMENTATION STATEMENT

A method of plane frame analysis which considers nonlinear supports, material properties, and geometric effects has been developed in this study. The computer program, documented in this report, can analyze skewed frames supported by laterally and axially restrained piles and subjected to a complex system of static loads.

The nonlinear soil support capabilities available in the program allow the highway structures designer to realistically model many problems of soil-structure interaction which previously had to be represented in a linear manner. The nonlinear soil characteristics are input as either concentrated force-displacement curves at the frame joints (Q-W curves) or distributed force-displacement curves acting along the members (q-w curves). This method of input allows a wide variety of practical problems, such as bridge bents on pile foundations, culverts below grade, retaining walls, and sign-support structures, to be handled by the same program.

The nonlinear material properties features of the program allow the designer to specify the cross section as a series of rectangles and thin-walled tubular pieces with different nonlinear stress-strain curves. Steel, reinforced and prestressed concrete, and other materials and construction techniques can be accommodated by the program. The yielding of members associated with plastic and limit design may be permitted or prevented at the discretion of the designer.

The nonlinear geometric effects of axial force-lateral displacement interaction and of the stretching of members due to bending are considered as a part of a complete large displacement analysis in the program.

The large number of problems which are worked using the program and the comparisons made with existing analytical and experimental studies show that agreement is favorable for all such comparisons.

Because of the generality and wide range of application of the program developed in the reported research, it may be less efficient for a linear analysis than previously reported linear analysis programs. Therefore, the program documented herein is recommended primarily for problems which cannot be solved accurately by previously documented programs.

Further research to demonstrate the full potential of the program to study prestressing, temperature, and other practical effects and the extension of this and previously documented linear frame analysis programs, to consider three-dimensional and dynamic effects, appear feasible at this time.

TABLE OF CONTENTS

CHAPTER 4. DISCRETE ELEMENT MODEL OF FRAME MEMBERS

CHAPTER 5. COMPUTER PROGRAM

NOMENCLATURE

Symbol	Typical Units	Definition
A	in^2	Cross-sectional area of member
A_i	in^2	Area of i^{th} sub-rectangle
A_s	in^2	Area of reinforcing or prestressing steel
AE	lb	Axial stiffness = $\Sigma A_i E_i$
$(AE_f)_{eff}$	lb	Effective AE of flange
AEY	lb-in	Axial-flexural stiffness $-\Sigma A_i E_i \bar{y}_i$
α	--	Cosine of angle between the x' and x-axes
b	in	Flange width for a wide flange section
b	in	Width of compression face of concrete member
b_i	in	Width of i^{th} sub-rectangle into which input rectangles are subdivided
b_j	in	Width of j^{th} rectangle used to input cross section
B_{ij}	lb/in, lb, and lb-in/rad	Increment in i^{th} end-displacement corresponding to a unit increment of the j^{th} internal deformation of a discrete element
$[B]$	lb/in, lb, and lb-in/rad	(3 X 6) incremental deformation-displacement matrix for discrete element

Symbol	Typical Units	Definition
$[B]^t$	lb/in, lb, and lb-in/rad	(6 X 3) matrix which is the transpose of $[B]$
β	--	Cosine of angle between the x' and y-axes
c	in	Distance from centroidal axis to outer fiber of member cross section
d	in	Depth of cross section
d	in	Distance from compression face to centroid of steel in concrete member
d_i	in	Depth of i^{th} sub-rectangle into which input rectangles are subdivided
d_j	in	Depth of j^{th} rectangle used to input cross-section
D_{ij}	lb/in, lb, and lb-in/rad	Increment in i^{th} internal force in discrete element corresponding to a unit increment in the j^{th} internal deformation
$[D]$	lb/in, lb, and lb-in/rad	(3 X 3) incremental internal force-deformation matrix for discrete-element
δ	in	Elongation of axially deformable bar in discrete element
δ	in	Axial displacement of member
$\{\delta\}$	inches and radians	(3X 1) matrix of internal deformations corresponding to internal forces in discrete element
$\{\Delta\delta\}$	inches and radians	(3 X 1) matrix of increment of internal deformations corresponding to internal forces in discrete element
Δ	in	Lateral displacement of member or joint
E	lb/in^2	Modulus of elasticity
E_c	lb/in^2	Modulus of elasticity of concrete

Symbol	Typical Units	Definition
E_i	lb/in^2	Slope of stress-strain curve for i^{th} sub-rectangle
EI	$lb\text{-}in^2$	Flexural stiffness = $\Sigma E_i I_i$
ϵ	in/in	Strain
ϵ_a	in/in	Average of ϵ_1 and ϵ_2
ϵ_b	in/in	Strain at bottom of cross section
ϵ_c	in/in	Strain at members x'-axis
ϵ_c	in/in	Concrete strain
ϵ_o	in/in	Strain at junction of parabola and straight line on Hogenstad's stress-strain curve
ϵ_t	in/in	Strain at top of cross section
ϵ_u	in/in	Ultimate concrete strain in compression
ϵ_y	in/in	Yield strain
ϵ_1	in/in	Strain when compression flange first yields
ϵ_2	in/in	Strain when compression flange is completely yielded
f_c	lb/in^2	Concrete stress
f_c'	lb/in^2	Maximum stress from test of standard concrete cylinder
f_c''	lb/in^2	Maximum stress on concrete stress-strain curve
f_i	lb and lb-in	Force on end of discrete element corresponding to i^{th} displacement
f_r	lb/in^2	Maximum concrete stress in tension

Symbol	Typical Units	Definition
f_y	lb/in^2	Yield stress of reinforcing steel
f_1, f_2, f_3, f_4, f_5, f_6	lb and lb-in	End-forces on discrete element
$\{f\}$	lb and lb-in	(6 x 1) matrix of end-forces on discrete element
$\{\Delta f\}$	lb and lb-in	(6 x 1) matrix of increments of end-forces on discrete element
F_i	lb and lb-in	Force corresponding to i^{th} member-end-displacement
F_1, F_2, F_3, F_4, F_5, F_6	lb and lb-in	Member-end-forces in member coordinates
$\{\widetilde{F}\}$	lb and lb-in	(3N x 1) matrix of incremental frame joint loads measured in structure coordinates
$\{FF\}$	lb and lb-in	(6 x 1) matrix of member incremental fixed-end-forces measured in member coordinates
$\{FF_i\}$	lb and lb-in	(3 x 1) matrix of member incremental fixed-end-forces at joint i in member coordinates
$\{\overline{FF}_i\}$	lb and lb-in	(3 x 1) matrix of member incremental fixed-end-forces at joint i in structure coordinates
$g(u)$	lb and lb-in	Function of u
$g'(u)$	lb/in and lb-in/rad	Derivative of $g(u)$, tangent stiffness
$[g'(u)]^{-1}$	in/lb and rad/lb-in	Reciprocal or inverse of $g'(u)$
$\overline{g}(u)$	lb/in and lb-in/rad	Secant stiffness
h	inches	Distance between concentrated rotational springs in discrete element model, one-half of element's length

Symbol	Typical Units	Definition
I	in^4	Moment of inertia of cross section about member's z'-axis
I_i	in^4	Moment of inertia of sub-rectangle i about the member's z'-axis
$\bar{I}_i$	in^4	Moment of inertia of sub-rectangle i about its own centroidal axis
k_{ij}	lb/in, lb, and lb-in/rad	Increment of i^{th} force corresponding to a unit increment in j^{th} displacement in discrete element
$[k]$	lb/in, lb, and lb-in/rad	(6×6) tangent stiffness matrix for discrete element
$[\tilde{k}]$	lb/in, lb, and lb-in/rad	$3(m + 1) \times 3(m + 1)$ member tangent stiffness used for member solutions
$[k]_C$	lb/in, lb, and lb-in/rad	Conventional portion of discrete element stiffness matrix $[k]$
$[k]_S$	lb/in, lb, and lb-in/rad	Initial stress portion of discrete element stiffness matrix $[k]$
$[k]_{ST}$	lb/in, lb, and lb-in/rad	Portion of discrete element initial stress stiffness matrix $[k]_S$ due to axial force
$[k]_{SV}$	lb/in, lb, and lb-in/rad	Portion of discrete element initial stress stiffness matrix $[k]_S$ due to shear force
K_{ij}	lb/in, lb, and lb-in/rad	Element of tangent stiffness matrix $[K]$ which represent the increment of force corresponding to the i^{th} displacement due to a unit increment of the j^{th} displacement
K_s	lb/in and lb-in/rad	Tangent stiffness of nonlinear Q-W curve
$[K]$	lb/in, lb, and lb-in/rad	(6×6) member tangent stiffness matrix in member coordinates

Symbol	Typical Units	Definition
$[K]_{MS}$	lb/in	(2 x 2) stiffness matrix which gives the effect of member springs in direction of structure coordinates
$[K]_{SM}$	lb/in	(2 X 2) stiffness matrix which gives the effect of structure joint springs in direction of member coordinates
$[\tilde{K}]$	lb/in, lb, and lb-in/rad	(3N X 3N) structure tangent stiffness matrix in structure coordinates
$[K_{ij}]$	lb/in, lb, and lb-in/rad	(3 X 3) member tangent stiffness matrix in member coordinates which represents the increments of forces at i due to unit increments of displacements at j
$[\bar{K}_{ij}]$	lb/in, lb, and lb-in/rad	(3 X 3) member tangent stiffness matrix in structure coordinates which represents the increments of forces at i due to unit increments of displacements at j
L	inches	Length of member
L'	inches	Projection of member along member's original undeformed axis
m	--	Number of discrete elements in frame member
m	--	Number of discrete energy absorbing springs like elements in discrete element model
m	--	Number of rectangles input for a cross section
M	lb-in	Bending moment
M_A, M_B, M_C, M_D	lb-in	Moments at points A , B , C , and D in frame
M_i	lb-in	Moment of stresses on i^{th} sub-rectangle
M_y	lb-in	Moment corresponding to no axial thrust and outer fibers just yielded

Symbol	Typical Units	Definition
M_1, M_2	lb-in	Bending moments at location of first and second rotational springs in discrete-element model
μ	-	Poisson's ratio
n	--	Number of rectangles into which input rectangles are subdivided to obtain linear stress-strain response over each sub-rectangle
n	--	Number of degrees of freedom of general discrete element
N	--	Number of joints in frame
p	--	Reinforcement ratio (A_s/bd)
$\{\tilde{p}\}$	lb and lb-in	$3(m + 1) \times 1$ member incremental load matrix composed of equilibrium errors at member nodal points (stations)
P	lb and lb-in	Load or force
ΔP	lb and lb-in	Equilibrium error, i.e., load not absorbed by structure
P_E	lb	Euler buckling load
P_i	lb and lb-in	Load at end of i^{th} load increment
ΔP_i	lb and lb-in	Load increment number i
P_m	lb and lb-in	Maximum load on structure
$\tilde{P}_i^1$, $\tilde{P}_i^2$, $\tilde{P}_i^3$	lb and lb-in	Applied incremental forces at joint i measured in structure coordinates (x-force, y-force, and moment about z-axis, respectively)
Ψ_1, Ψ_2	radians	Discrete angle changes which occur at rotational springs in discrete element
q	lb/in and lb-in/in	Distributed load intensity
$q_{\alpha\beta}$	lb/in and lb-in/in	Distributed load in the direction of the α-axis per unit of length along the β-axis

Symbol	Typical Units	Definition
Q	lb and lb-in	Concentrated load
Q_p	lb	Force to cause a mechanism based on simple plastic theory
Q_s	lb and lb-in	Resistive spring force from nonlinear Q-w curve
Q_α	lb and lb-in	Concentrated load in the direction of the α-axis
r	in	Change in distance parallel to member x'-axis between rotational springs in discrete element
R	lb-in/rad	Rotational restraint
s	in	Distance parallel to member y'-axis between rotational springs in discrete element
S_i	lb and lb-in	Internal force in discrete element corresponding to the i^{th} internal deformation
S_x	lb/in	Member spring in direction of structure x-axis
$S_{x'}$	lb/in	Spring acting at structural joint in direction of member x'-axis
S_y	lb/in	Member spring in direction of structure y-axis
$S_{y'}$	lb/in	Spring acting at structural joint in direction of member y'-axis
$\{S\}$	lb and lb-in	(3 X 1) matrix of internal forces corresponding to internal deformations in discrete element model
$\{\Delta S\}$	lb and lb-in	(3 X 1) matrix of increments of internal forces corresponding to internal deformations in discrete element
σ	lb/in^2	Stress
$\bar{\sigma}_i$	lb/in^2	Stress at centroid of i^{th} subrectangle

Symbol	Typical Units	Definition
σ_{oi}	$lb\text{-}in^2$	Intercept of stress-strain curve with stress axis for i^{th} sub-rectangle
σ_{rc}	$lb\text{-}in^2$	Residual compressive stress
$\bar{\sigma}_{rc}$	$lb\text{-}in^2$	Constant compressive residual stress over flanges
σ_{rt}	$lb\text{-}in^2$	Residual tension stress
$\bar{\sigma}_{rt}$	$lb\text{-}in^2$	Constant tensile residual stress over web
σ_y	$lb\text{-}in^2$	Yield stress
t_f	in	Thickness of flange of wide flange section
t_w	in	Thickness of web of wide flange section
T	lb	Axial thrust
T_i	lb	Thrust on i^{th} sub-rectangle
T_y	lb	Axial thrust corresponding to full yielded condition of cross section
[T]	--	(3 X 3) member coordinate transformation matrix
$[T]^t$	--	(3 X 3) matrix which is the transpose of T
θ	radians	Angle axially deformable bar in discrete element makes with member x'-axis
u	in and rad	Displacement
Δu	in and rad	Linear increment in u
u_i	in and rad	Displacement corresponding to i^{th} load increment

Symbol	Typical Units	Definition
Δu_i	in and rad	Increment of displacement corresponding to i^{th} load increment
U	lb-in	Strain energy of discrete element
V	lb	Shear force normal to axially deformable bar in discrete element
ϕ	rad/in	Curvature
ϕ_y	radians	Curvature corresponding to no axial thrust and outer fibers just yielded
w	in and rad	Member displacement
w_i	in and rad	Discrete element end-displacement number i
w_s	in and rad	Displacement at mid-element, used to enter Q-w curves and find resistive spring, force Q_s , and tangent stiffness of spring K_s
w_1, w_2, w_3, w_4, w_5, w_6	in and rad	End-displacements of discrete element
$\{w\}$	in and rad	(6×1) matrix of end-displacements of discrete element
$\{\Delta w\}$	in and rad	(6×1) matrix of increments of end-displacements of discrete element
$\{\tilde{w}\}$	in and rad	$(3m + 1) \times 1$ of member nodal point (station) displacements
$\{\Delta\tilde{w}\}$	in and rad	$3(m + 1) \times 1$ matrix of increments of member nodal point (station) displacements
W	in and rad	Joint displacement
W_i	in and rad	Member-end-displacement number i
W_1, W_2, W_3, W_4, W_5, W_6	in and rad	Member-end displacements in member coordinates

Symbol	Typical Units	Definition
$\widetilde{W}_i^1$, $\widetilde{W}_i^2$, $\widetilde{W}_i^3$	in and rad	Displacements of joint i measured in structure coordinates (distance along x and y , and rotation about z-axis, respectively)
$\{\widetilde{W}\}$	in and rad	(3N X 1) matrix of frame joint displacements in structure coordinates
$\{\Delta\widetilde{W}\}$	in and rad	(3N X 1) matrix of linear increments of frame joint displacements in structure coordinates
x, y, z	inches	Cartesian coordinate axes for frame structure coordinates
x'	inches	Distance along member x'-axis
x', y', z'	inches	Cartesian coordinate axes for member
y	inches	Distance to any point in cross section
y	inches	Displacement of member relative to member
$\bar{y}_i$	inches	Distance to centroid of i^{th} rectangle

CHAPTER 1. INTRODUCTION

The design and analysis of plane frames such as those which occur in buildings, highway bridge bents, and marine and offshore structures has become increasingly complex in recent years. Today the designer must not only check stresses and displacements under working loads, for which a linear analysis is often assumed to be sufficiently accurate, but in addition, he must often estimate the maximum load which his structure will support. If the responses of the soil and of the structure are considered simultaneously, additional complications arise.

Plastic design has been permitted by the AISC Manual (Ref 6) for some time. Standard 318 of the American Concrete Institute (Ref 5) does not specifically permit limit design; however, it does permit up to a 20 percent redistribution in the design moments based on the concepts of limit design. Both limit and plastic design are used to estimate a structure's maximum load and each method predicts the additional load capacity that a statically indeterminate structure possesses beyond the load at which one section in the structure reaches its maximum capacity. This additional strength is available only if the structure is sufficiently ductile to develop the necessary zones of yielding. These zones of yielding are often idealized as plastic hinges occurring at points. Both limit and plastic design are unconservative in certain cases unless modified for the more general nonlinear effects discussed later in this chapter.

Nonlinear behavior of many structures starts at stress levels well below the proportional limit of the material from which the frame is constructed. This nonlinearity is caused by the nonlinearity of the soil supporting the structure and the long unsupported lengths and heavy axial loads that the frame members often have.

When energy absorbing characteristics are important, as for earthquake and blast loads, the complete load-displacement history of the structure should be calculated. Such calculations are practical for real structures only with the aid of a digital computer program.

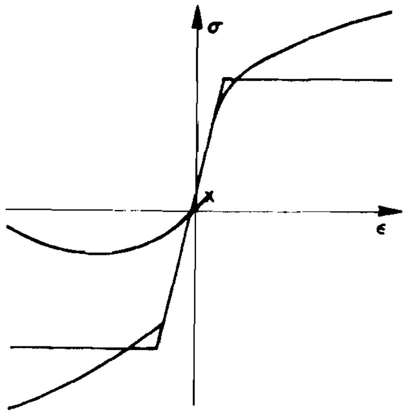
Linear Discrete Element Analysis of Complex Frames

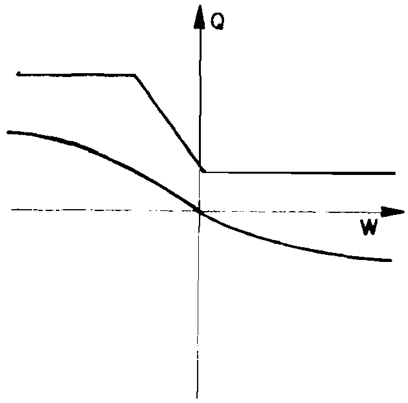
A research program entitled "Development of Methods for Computer Simulation of Beam-Columns and Grid-Beam and Slab Systems" is nearing completion at The University of Texas at Austin. The work has been sponsored by the Texas Highway Department and the Federal Highway Administration. The purpose of this research has been to develop techniques for analyzing structures for which no closed-form mathematical solutions are available. Hays and Matlock combined the discrete-element modeling techniques developed in previous beam-column research (Ref 40) with standard matrix techniques to develop a linear frame analysis program (Ref 27). That program is capable of analyzing large nonrectangular plane frames composed of nonprismatic members subjected to complex lateral and axial loading and elastic support conditions, but it does not consider any nonlinear effects. The present research is an extension of that work which will consider the nonlinear response of plane frames to static loads.

Sources of Nonlinear Behavior

Several nonlinear effects are possible in plane frames (Fig 1). Typical nonlinear stress-strain curves are shown in Fig 1(a). Using the nonlinear stress-strain curve for the frame materials gives a better prediction of the general load-displacement response of the frame than using idealized elastic-plastic moment-curvature relations (Ref 47). In particular the ultimate load is predicted more accurately by using the appropriate nonlinear stress-strain curves where the displacements interact with the axial forces, as pointed out by Adams (Ref 1). The stress-strain curves sometimes do not pass through the origin due to prestressing or temperature effects.

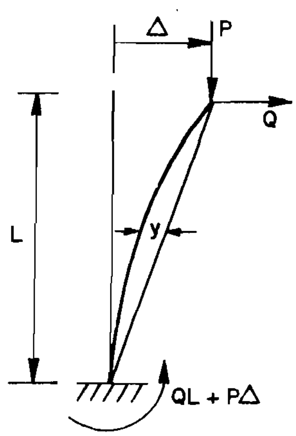
Elastic spring constants have been used (Ref 27) to represent supports and they are more realistic than rigid supports. However, support curves which represent the reaction-displacement (Q-W) relations can be nonlinear as shown in Fig 1(b), particularly when the support is some type of soil. Thus, an adequate representation of a support may require the description of a number of points on the support curve (Ref 41). Supports may occur at structural joints or may be distributed along the member, as for a grade beam or a friction pile.

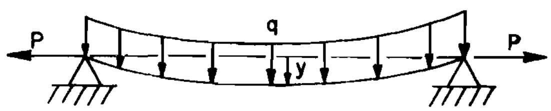




(a) Nonlinear stress-strain curves.

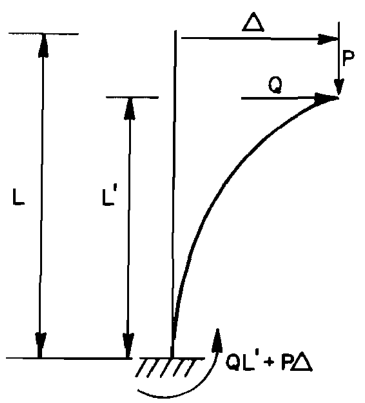
(b) Nonlinear support curves.

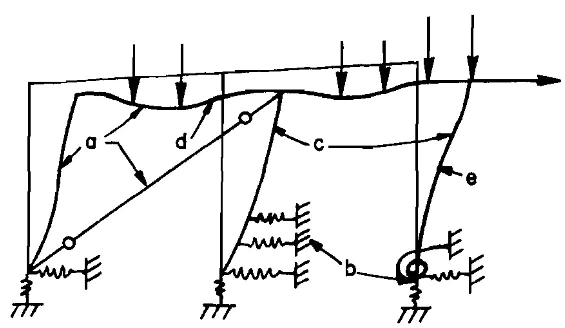




(c) Secondary bending moments.

(d) Membrane forces due to bowing.





(e) Large displacement effects.

(f) Plane frame with all nonlinear effects.

Fig 1. Nonlinear effects in plane frames.

All framed structures have members with axial forces present. The axial forces act on lateral displacements to cause secondary bending moments as shown in Fig 1(c). These moments tend to straighten a member and thus stabilize the structure when axial forces are in tension and increase the curvature in a member and thus decrease the stability of the structure when they are in compression. Two types of secondary moments occur in a frame member. The so-called $P\Delta$ moment is equal to the force P times the joint displacement Δ. The so-called Py moment is equal to the force P times the distance y, where y is the difference between the displacement of the member and the displacement of the member chord.

When supports prevent or reduce the axial movement of both ends of a member, as shown in Fig 1(d), a bowing or stretching of the member due to bending occurs. This causes an axial thrust which causes Py moments and makes the member's response to load highly nonlinear.

When extremely large displacements occur, the entire geometry of the structure is changed, as shown in Fig 1(e). The length of moment arms may change significantly, and the axial force and shear are not always parallel and perpendicular to the member's original axis.

When the stress in a material has exceeded the elastic limit, upon unloading the material follows a different path from the loading stress-strain curve. Generally the material unloads on a path parallel to the initial slope of the stress-strain curve. However, as borne out in the example problems presented herein, many structures undergo few if any such inelastic strain reversals, even when subjected to nonproportional loadings.

Residual stresses due to the cooling of rolled metal shapes and welded built-up sections cause different areas of a cross section to yield at different stress levels. The exact distribution of residual stresses is very complex and is seldom if ever known accurately. Thus, an extremely accurate analysis is unwarranted. An approximate method of handling residual stresses developed in this report is sufficiently accurate for bending of a wide flange section about its strong axis.

The effects of both nonlinear stress-strain and soil support curves can be classified as material nonlinearity. The other nonlinear effects discussed above can be grouped as geometric nonlinearities, since they occur because the structure displaces and causes its geometry to change. A plane frame, as shown in Fig 1(f), will be subject to both material and geometric nonlinearities.

Purpose of This Research

Considerable research has been done to develop design and analysis techniques capable of considering each of the sources of nonlinear behavior discussed above. However, no computer analysis is known that considers the effects of nonlinear stress-strain and soil support curves and all geometric effects. The purpose of this research was to develop such a computer analysis and to maintain the capabilities developed in Ref 27 to work problems dealing with a wide range of real frames.

Outline of Presentation

Chapter 2 reviews a general method of nonlinearly elastic analysis called the tangent stiffness method which is well suited for a discrete element solution of framed structures. In Chapter 3 the tangent stiffness method is applied to the nonlinear solution of frame joint displacements. The force-displacement equations for the discrete element model are developed in Chapter 4 and the tangent stiffness method is applied to develop the nonlinear solution of frame members. The associated computer program is discussed in Chapter 5, and an example is given to illustrate the use of the program. Several examples that illustrate the validity of the solution for single members are presented in Chapter 6. Chapter 7 presents the results of some previous research on steel frames and shows how well the program can predict the response of steel frames. Several concrete members and frames that had been tested were analyzed and a comparison of the observed and predicted behavior is presented for these frames in Chapter 8. Two examples of structure problems involving soil-structure interaction are worked in Chapter 9. These examples illustrate the versatility of the program.

Appendix A gives the linear stiffness matrix for prismatic members without elastic restraints and the transformation matrix to transform displacements and forces from member coordinates to structure coordinates. The numerical integration procedure used to obtain thrust, moment, and stiffness terms by integrating the stresses over the cross section for a specified axial strain and curvature is developed in Appendix B. The discrete-element matrices needed for the member solution are given in Appendix C. The transformation matrices needed to transform the stiffness of springs between structure and member coordinates are given in Appendix D. The remaining appendices include, respectively, the input guide, flow charts, FORTRAN notation, FORTRAN listing of the program, and examples of program input and output.

CHAPTER 2. NONLINEAR ELASTIC ANALYSIS

In this chapter an extremely powerful method of structural analysis called the tangent stiffness method is reviewed. The tangent stiffness method, when applied to a one-degree-of-freedom system, has a very simple and descriptive interpretation. The method, when extended to multi-degree-of-freedom systems, is well suited for the solution of framed structure problems, using a discrete element model of the frame members. The complete nonlinear frame solution is shown to contain an iterative solution for the individual members within the iterative solution for the structural joint displacements.

Modeling a Complex Structure

During the design-analysis cycle the structural engineer must model the real or prototype structure. The modeling process consists of three steps. First, the engineer creates a model that represents his complex prototype and yet remains simple enough to analyze. The model may be physical or analytical. Second, the engineer analyzes the model either experimentally or mathematically. Third, he interprets the results of the model analysis in relation to the prototype.

Actually, the process is seldom that simple. The original model may be too complex to be analyzed. Or, after interpreting the results, the engineer might decide that the model does not accurately represent the prototype. In either case a new and better model must be created.

Matrix Methods of Structural Analysis

Matrix methods of structural analysis are accepted techniques for modeling structural behavior. They are documented by many writers, including Przemieniecki (Ref 49), who states:

> Matrix methods are based on the concept of replacing the actual continuous structure by a mathematical model made up from structural elements of finite size (also referred to as discrete elements) having known elastic and inertial properties that can be expressed in matrix form.

Actually, "continuous" as used by Przemieniecki may be somewhat misleading, since a material such as steel is continuous only if viewed at the microscopic level or higher and materials such as concrete are continuous only if viewed at the macroscopic level or higher. One might consider that the continuum mechanics model is being replaced with a discrete or finite element model. Then, since the continuum model itself may have some errors in it, the results of any new model should be compared not only with continuum solutions but also with experimental results obtained from tests on structures made of real materials.

The words "finite element" and "discrete element" also deserve some discussion. As used herein, finite element (Ref 66) denotes an element whose displacements are described by a continuous mathematical function. Discrete element (Ref 27), on the other hand, is used to describe mechanical models that have discrete changes in rotation.

Finite and Discrete Element Methods

Both finite and discrete element methods allow the designer to subdivide a complex structure into a number of regions or elements. Each element may have different stiffness properties and loadings. The elements are connected at a finite number of nodal points, and in general the more nodal points used the more accurate the predicted response of the structure.

The development of finite and discrete element techniques has paralleled that of digital computers, as both techniques involve the solution of a large number of simultaneous equations, for which a digital computer is essential. These equations relating element properties and nodal point loads, displacements, and boundary conditions are the nodal point equilibrium equations.

Thus, in theory, any complex structure can be modeled by a large number of elements whose properties are representative of the structure. In practice, the number of elements which can be used is physically limited by the size of available computers and economically limited by the amount of computer time which a problem warrants.

Both finite and discrete techniques will give adequate results if enough elements are used. In general, finite elements are more complicated mathematically and more time is required to develop and generate the element properties, such as the element stiffness matrix. However, they can adequately represent smoothly varying loadings, stiffness changes, and support conditions with fewer elements than required for a discrete element solution of equal accuracy. Thus, finite elements may be more economical for modeling structures whose properties are very regular.

Discrete element models, on the other hand, are mathematically simpler, easier to visualize,* and require less development and generation time. Thus, structures which have widely varying and discontinuous loadings, stiffnesses, and support conditions may be more economically modeled using a discrete element model.

Problems in between the very regular and the very irregular may be modeled by either method. All other things being equal, a structure for which the nodal point equilibrium equations have a narrow band width is better represented by a discrete element model with its larger number of simple elements. A structure whose equations have a wide band width will be better represented by a finite element model which has a fewer number of more complicated elements.

A discrete element model was chosen for the plane frame solution developed herein to allow frame members to have widely varying loadings, stiffness changes (particularly since nonlinear material effects are being considered), and supports and because, as discussed later in this chapter, frame members have a very narrow band width when isolated from the rest of the frame.

Elastic Analysis

The elastic analysis of a statically loaded structure is basically a problem in simultaneously satisfying four sets of conditions. The governing conditions are 1) nodal point equilibrium, 2) compatibility of nodal point displacements, 3) any boundary conditions specified at the nodal points, and 4) the element force-displacement relations. It is assumed that the element force-displacement relations insure that equilibrium, compatibility, boundary conditions, and constitutive laws for the element are satisfied throughout the element.

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*Discrete element models were used to obtain qualitative results regarding structural behavior before digital computers made possible the economical use of a large number of elements to obtain accurate quantitative results. One of the best known examples is Shanley's inelastic buckling model (Ref 54).

Most methods of satisfying these conditions can be classified as either displacement or force methods based on whether the formulation is such that the basic unknowns to be found are nodal point displacements* or forces**. The force or flexibility method has advantages for certain structures but is not as easy to formulate in general terms as the displacement method. Hence, the displacement or the stiffness method is the only one considered herein.

Linearly Elastic Analysis

A set of linear simultaneous equations can be written that insure satisfaction of the four governing conditions using the direct stiffness method, discussed in Refs 27 and 36. The direct sitffness method is a technique by which the element stiffness matrices are formed in their own element coordinates and then transformed to the structural coordinates. Then the structure stiffness matrix is formed directly by adding in the element stiffness matrices in the appropriate positions. Premultiplying the unknown nodal point displacement vector by the known stiffness matrix and setting this result equal to the known nodal point force vector gives the desired simultaneous equations of nodal point equilibrium. These equations may be solved for the nodal point displacements which insure that all four governing conditions are satisfied. Using the displacements thus found, the governing conditions can be applied to find complete force and displacement information for the individual elements. It is well known that the solution of a set of linear simultaneous equations is unique. Therefore, there is no question of the uniqueness of the results of a linearly elastic solution and superposition may be freely and fruitfully applied.

Nonlinear Elastic Analysis Using the Tangent Stiffness Method

For a nonlinear but elastic analysis, the explicit writing of the nodal point equilibrium equations may be difficult or impossible, especially when some of the stiffness parameters of the structure are in other than equation

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*Herein the word "displacement" should be considered to mean either a translation or a rotation.

**Herein the word "force" implies either a translational force or a moment.

form; for example, a number of points on a nonlinear stress-strain or soil support curve. It is possible, however, to construct an algorithm for satisfying the four governing conditions that is mathematically equivalent to using the Newton Rapheson method (Ref 28) to solve the implied nodal point equilibrium equations. This algorithm is described herein as the tangent stiffness method which is an extension of the direct stiffness method to the solution of nonlinear but elastic structures and has been used by others (Refs 44, 34, and 65).

The tangent stiffness method uses an iterative process in which the nodal point displacements are successively corrected until the four governing conditions are satisfied. The corrections are made by applying the nodal point equilibrium errors to a fictitious temporarily linear structure whose stiffness matrix is position-dependent and properly reflects the stiffness of the structure in its deformed position.

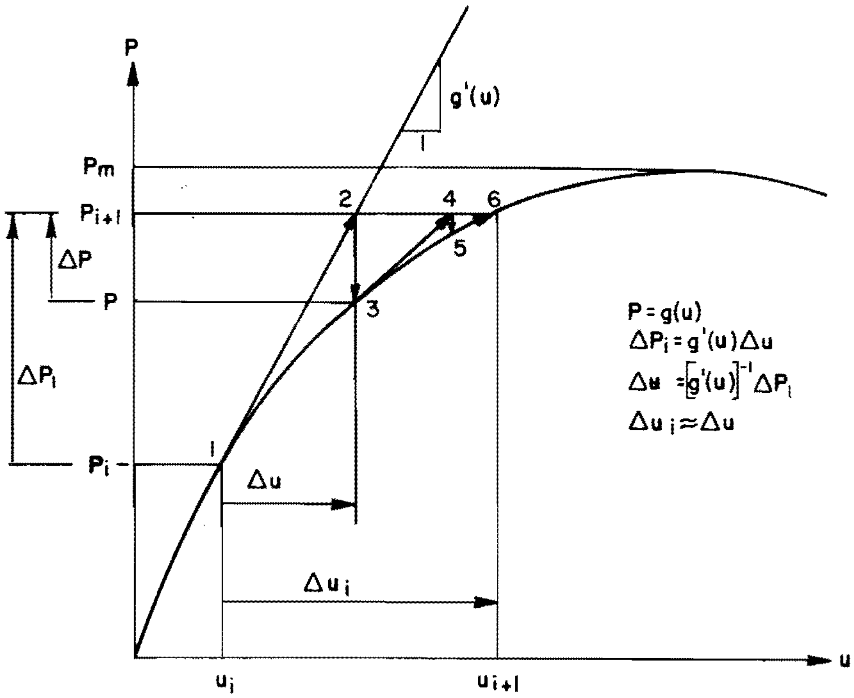
Because of the nonlinearity of the equations, superposition is not valid and in fact the uniqueness of the solution is not even guaranteed. However, Murray (Ref 44) offers a good argument that the result obtained by this technique is physically reasonable.

One-Degree-of-Freedom System

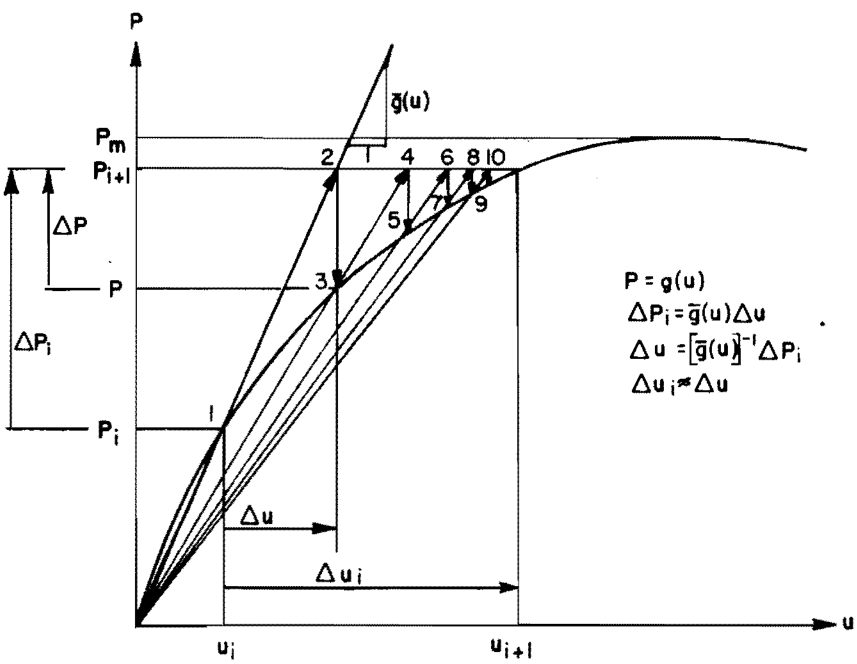
An oversimplified model is examined here to clarify the iteration technique for multi-degree-of-freedom systems. Consider a single-degree-of-freedom structure in which a single load P is a nonlinear function of a single displacement u. The nonlinear relation is shown by the curve of Fig 2(a) and is given mathematically by

$$P = g(u) \tag{2.1}$$

The function, or algorithm, for finding P need not be an explicit formula, but it must give a unique P for any given value of u. A fundamental problem in structural mechanics is to find, for a given value of P, the corresponding u. This u may not be unique, but normally, iterative processes will converge on a stable position. For example, in Fig 2(a), values of P below the maximum load P_m will converge on displacements to the left of the displacement corresponding to P_m. Points to the right of P_m may be obtained by a controlled displacement technique as discussed in the next chapter.



(a) Tangent stiffness method.



(b) Secant stiffness method.

Fig 2. Tangent and secant iteration techniques.

Assume that P_i and u_i at the end of the i^{th} load increment are known and that, given P_{i+1}, it is desired to find u_{i+1}. From Fig 2(a), the increments in P and u are seen to be ΔP_i and Δu_i and are defined by

$$u_{i+1} = u_i + \Delta u_i \tag{2.2}$$

$$P_{i+1} = P_i + \Delta P_i \tag{2.3}$$

The first derivative of the function $g(u)$ is $g'(u)$ and is defined as the tangent stiffness of the structure. From Fig 2(a)

$$g'(u) = \frac{\Delta P_i}{\Delta u} \approx \frac{\Delta P_i}{\Delta u_i} \tag{2.4}$$

Here Δu is the linear increment in u corresponding to ΔP_i and is thus a linear approximation to Δu_i. Thus, solving Eq 2.4

$$\Delta u_i \approx \Delta u = [g'(u)]^{-1} (\Delta P_i) \tag{2.5}$$

where $[g'(u)]^{-1}$ is the reciprocal, or the inverse, of $g'(u)$.

Thus, the following first approximation to u_{i+1} is evident. First, solve Eq 2.3 for ΔP_i. Then solve Eq 2.5 for an approximation to Δu_i. Then solve Eq 2.2 for an approximation to u_{i+1}. This corresponds to going from point 1 to point 2 on Fig 2(a).

The approximation of u_{i+1} can then be substituted into the algorithm for finding P (Eq 2.1). The value of P obtained will not equal P_{i+1} but P at point 3 on the curve. Obviously then, not all of the load P_{i+1} has been absorbed by the structure. A remnant or equilibrium error ΔP remains where

$$\Delta P = P_{i+1} - P \tag{2.6}$$

For this new value of ΔP the process can be repeated. Solving for another linear increment in displacement Δu, move to point 4; then correcting for equilibrium, move to point 5; and repeat the process until a sufficiently small ΔP is left. The flow chart of Fig 3 is thus suggested. The study of this flow chart is a critical step in understanding the nonlinear frame solution developed herein.

A similar technique can be developed using a secant stiffness $\bar{g}(u)$ as suggested by Fig 2(b). The secant stiffness will in general require more iterations but is more stable. Also, the secant stiffness is easier to compute than the tangent stiffness. However, due to the rapid convergence of the tangent stiffness technique and its potential for future inelastic work, it was used throughout this study.

Multi-Degree-of-Freedom Systems

The iterative process, which was demonstrated on a simple geometric basis for a one-degree-of-freedom system, can be extended to a multi-degree-of-freedom system by using Taylor series as done by Lee in Ref 34. The same algorithm applies except that the individual forces (P, ΔP, etc.) now become force vectors, the individual displacements (u, Δu, etc.) now become displacement vectors, and the single stiffness term $g'(u)$ becomes a square stiffness matrix. The stiffness matrix is not actually inverted to solve for the linear increments in displacements, but instead, an elimination technique is used to solve for the desired increments of displacement.

Incremental and One-Step Iterations

The iterative solution used might be described as an incremental loading iterative solution; that is, loads are applied in increments, and within each increment an iterative solution is performed until the full value of loading at the end of the increment is absorbed by the structure. However, in general there is no need to trace the complete load history of a structure if only the results at one high load level are desired. The program documented herein allows the user to specify a number of small increments, one large increment, or any combination desired. This was done because it was observed by Lee (Ref 34) and by the author that usually, the direct, or one-step, iteration process is the fastest and most economical. However, in some cases, more information about the loading history is desired, and some problems fail to converge at very high load levels unless a few intermediate increments are used. Thus, the program allows the user maximum flexibility for solving a wide range of nonlinear problems.

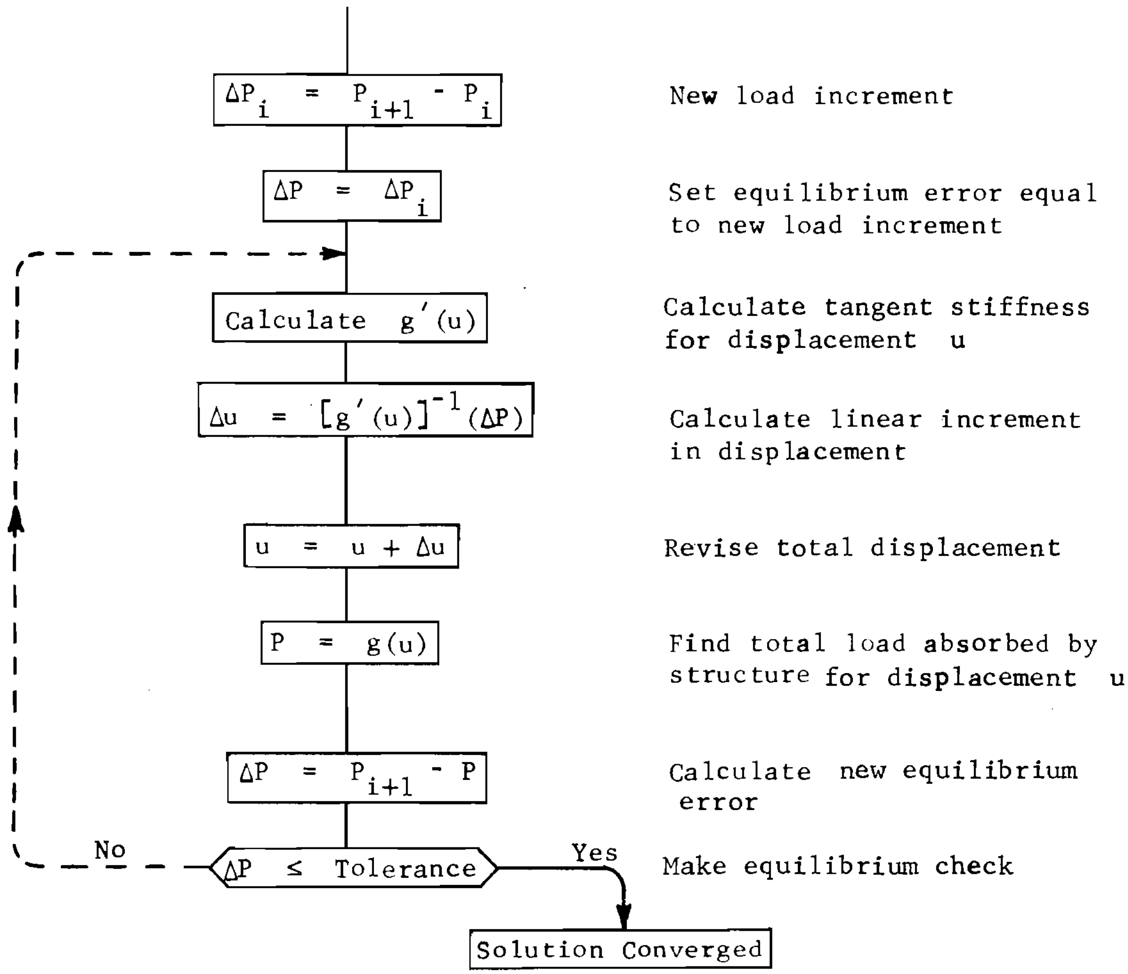


Fig 3. Tangent stiffness iteration for one load level.

Murray (Ref 44) proposed a modification of the tangent stiffness algorithm whereby the tangent stiffness was revised only between load increments thus not requiring a reformation of and a re-elimination of the stiffness matrix between load increments. Murray's technique is probably best when a large number of small increments are applied. However, when the size of the load increment may be fairly large it was felt that the more rapid convergence obtained by modifying the stiffness for every iteration was desirable, and that technique is used in the computer program developed herein.

Special Technique for Framed Structure

The framed structure when treated as a series of line members intersecting at a number of structural joints is well suited to using a large number of elements within each member. Thus, any actual variation of member properties, loading, or support conditions may be represented. It is possible to economically subdivide the members into a large number of elements by using a static condensation process (Ref 19). The large number of equations with their resulting large band width which would arise if all elements were combined into one system of equations need not be solved explicitly. Rather, the individual members can be solved separately using as many elements as necessary to obtain each member's stiffness and fixed-end-force matrices. These matrices may then be combined to form the structure stiffness and load matrices using standard matrix techniques. The only unknowns will be the structural joint displacements. This condensing of the equilibrium equations results in considerable savings in computer time and storage requirements for many problems which would otherwise require a large number of pseudo-structural joints.

Joint and Member Solutions

As just discussed, it is advantageous to perform the member solutions separately from the solution of structural joint displacements. Thus, for nonlinear frames, an iterative cycle for each member occurs within the iteration on structural joint displacements. (The members, with their current level of loading, converge on the latest set of joint displacements. Then the member-end-forces are found, and an equilibrium check of the joints is made. Then a new set of joint displacements is found, and the process is repeated.) Both iterations use the tangent stiffness method. No additional loops or iterations are required, as all sources of nonlinearity are handled simultaneously. A general flow chart of the two iteration processes is shown in Fig 4. The details of the frame solution are discussed in Chapter 3 and the details of the discrete element member solution are developed in Chapter 4.

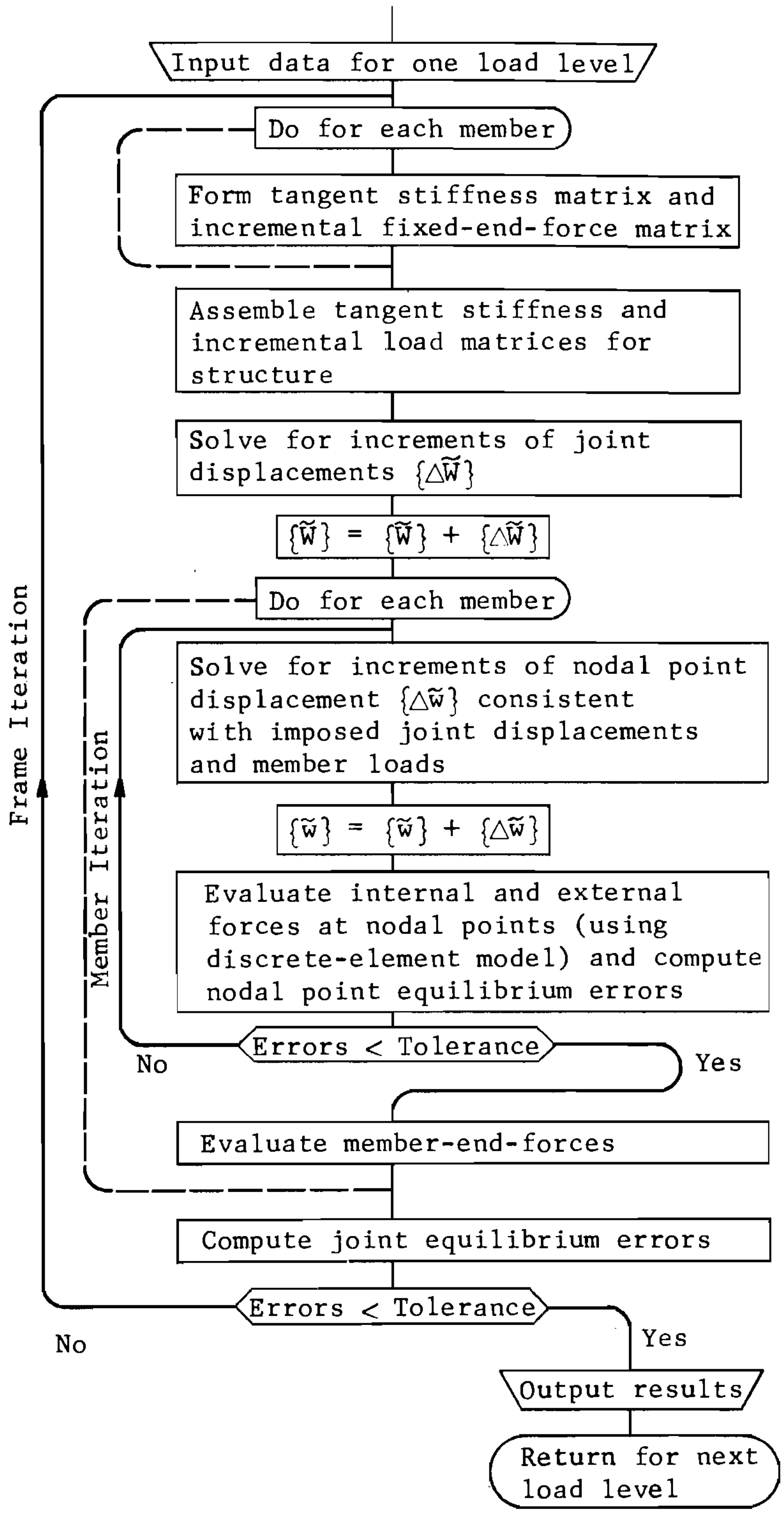


Fig 4. General flow chart for nonlinear analysis of frame with members composed of discrete elements.

CHAPTER 3. PLANE FRAME SOLUTION

The tangent stiffness method was reviewed in Chapter 2. The solution of a framed structure was shown to consist of an iterative nonlinear member solution nested within an iterative nonlinear solution for the frame joint displacements. The frame solution is developed in detail in this chapter, and in Chapter 4 the member solution is shown to be a simplified frame solution.

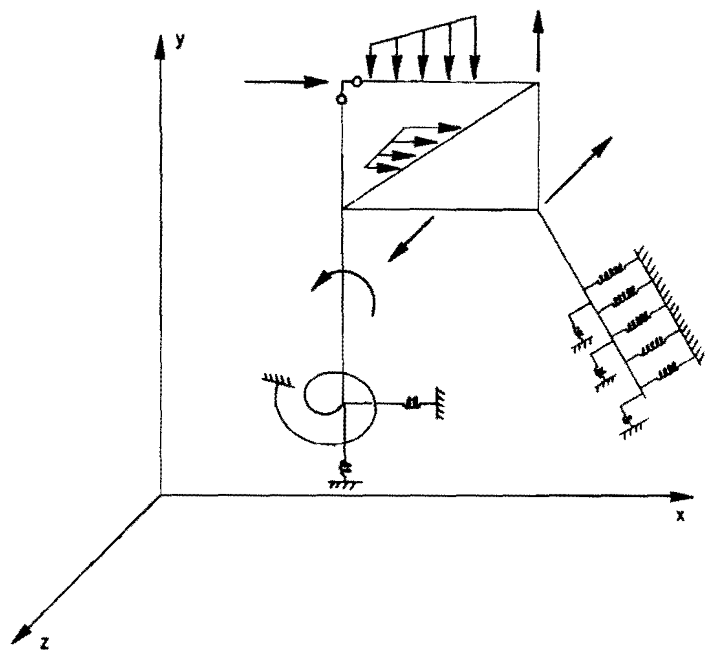
The plane frame problem is defined in this chapter and the assumptions and limitations of the proposed solution are given. Then a linearly elastic frame solution is reviewed and modified to accommodate the tangent stiffness algorithm. The nonlinear solution is presented and it is shown how the load may be incremented up to a structure's maximum load capacity.

Plane Frame Definition

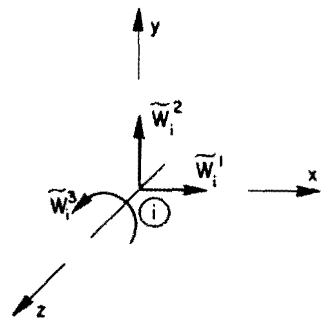
A plane frame such as that shown in Fig 5 is composed of straight-line members that lie in a plane, in which all loads and displacements occur. For convenience, the plane is taken to be the x-y plane of a right-hand Cartesian coordinate system.

The end of a member or the intersection of two or more members is a joint. A member may be either rigidly connected or pinned at a joint. All members rigidly connected at a joint rotate through the same angle and transmit moment to one another. When a member is pinned at a joint, it is free to rotate independently of the joint and other members intersecting at that joint.

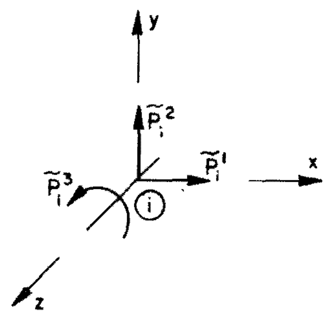
Each of the N joints has three degrees of freedom, $\tilde{W}_i^1$, $\tilde{W}_i^2$, and $\tilde{W}_i^3$, as shown in Fig 5. Translational displacements $\tilde{W}_i^1$ and $\tilde{W}_i^2$ must be equal (compatible) for all members intersecting at a joint. The rotational displacement may not be the same for all members at a joint, since some or all of the members may be pinned at the joint. Hence $\tilde{W}_i^3$ is defined as being the rotation of the joint, and the pin is assumed to be a part of the member occurring at an infinitesimal distance inside the member. When all members at a joint are pinned at the joint, the rotation of the joint is undefined.



(a) Plane frame.

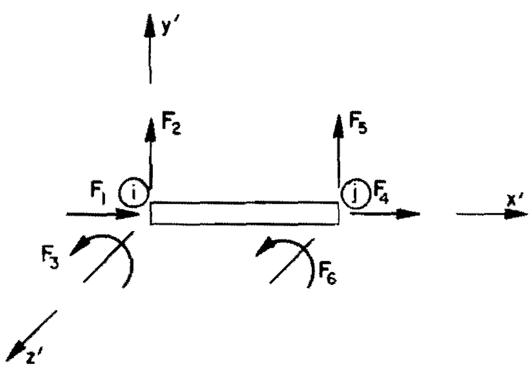


(b) Joint displacements.

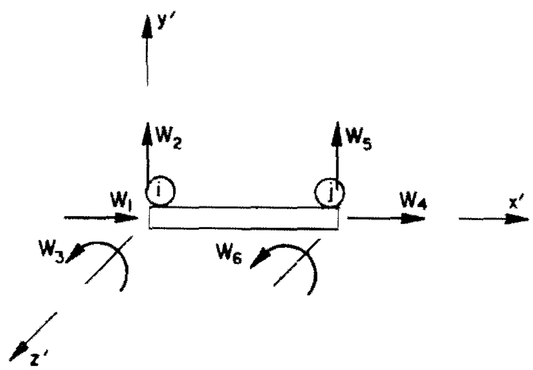


(c) Joint forces.

Fig 5. Plane frame.



(a) Member-end-forces.



(b) Member-end-displacement.

Fig 6. Member-end-forces and member-end-displacements
for a plane frame member.

The program developed herein allows such joints and outputs a very large rotational displacement to indicate that the rotation is undefined.

Joint forces $\tilde{P}_i^1$, $\tilde{P}_i^2$, and $\tilde{P}_i^3$, shown in Fig 5 can be applied at any joint. The joints can be supported by linear or nonlinear springs. Member loads and supports can be quite general, as discussed in Chapter 4.

Research discussed in a later chapter has shown that the size of a rigid joint has an effect on both the strength and the stiffness of a frame. The solution developed herein allows lengths of the member near the joint

(1) to be rigid,

(2) to be linearly elastic,

(3) to follow the member's stress-strain curve, or

(4) to be combinations of the above.

Assumptions and Limitations of the Solution

Although the solution developed herein covers a wide range of problems and considers large displacements, nonlinear stress-strain curves, and nonlinear soil supports, the solution is developed within a definite framework of assumptions. These assumptions, and limitations are as follow:

(1) Frame members are initially straight-line elements.

(2) Bernoulli's hypothesis of a linear distribution of strain through the depth of a member is valid.

(3) Shearing deformations are negligible.

(4) The deformations (strain and curvature) are of an infinitesimal order, even though the displacements (axial, lateral, and rotational) may be of any size.

(5) No out-of-plane loads or displacements occur. Thus, lateral or local buckling can be considered only by limiting strains for the material stress-strain curves, and members must be symmetrical about the x-y plane.

(6) The constitutive equations for the member can be satisfied by specifying nonlinear but elastic uniaxial stress-strain curves. Various portions of the cross section may have different stress-strain curves.

(7) The response of the structure to time-dependent loads (to consider creep or rapid loadings) is obtainable only if the appropriate pseudo-static stress-strain curves can be developed.

(8) Nonlinear but elastic Winkler-type springs can be used to represent the axial and lateral support characteristics of soil or other supports.

Linearly Elastic Frame Solution

Matrix methods of linear frame analysis are well documented (Refs 36 and 49) and will be discussed only briefly here. Figure 7 illustrates a linear frame solution from Ref 27. First the problem data are input. (Special attention was given in Ref 27 to developing input techniques that were versatile but still convenient for routine problems.) Next the member stiffness matrix and fixed-end-force matrix for the members are calculated in member coordinates (x', y', z', as shown in Fig 6). Member-end-displacements (axial, lateral, and rotational) and their corresponding member-end-forces (axial, lateral, and moment) are also shown in Fig 6, at the ends of the member.

Member stiffness matrix. The member stiffness matrix is a 6×6 matrix $[K]$ relating member-end-forces to member-end-displacements. A typical element of $[K]$ is K_{ij}. The i represents the i^{th} row and j represents the j^{th} column of $[K]$. For a linearly elastic member, K_{ij} represents the force corresponding to the i^{th} displacement due to a unit value of the j^{th} displacement. Thus, the j^{th} column of $[K]$ is the collection of member-end-forces due to a unit value of the j^{th} displacement. Prismatic members without distributed linearly elastic spring restraints have the well-known member stiffness matrix shown in Appendix A. A discrete element solution for more realistic members was developed in Ref 27 using the above unit displacement definition of the stiffness terms.

Member-fixed-end-force matrix. The member-fixed-end-force matrix is a 6×1 column matrix $\{FF\}$. Special cases for simple loadings are available. More general loadings can be handled by performing a discrete element solution of the member, subject to its member loads and zero end-displacements.

Structure stiffness matrix. The $3N \times 3N$ structure stiffness matrix $[\tilde{K}]$ is formed by first transforming the member stiffness matrix into structure

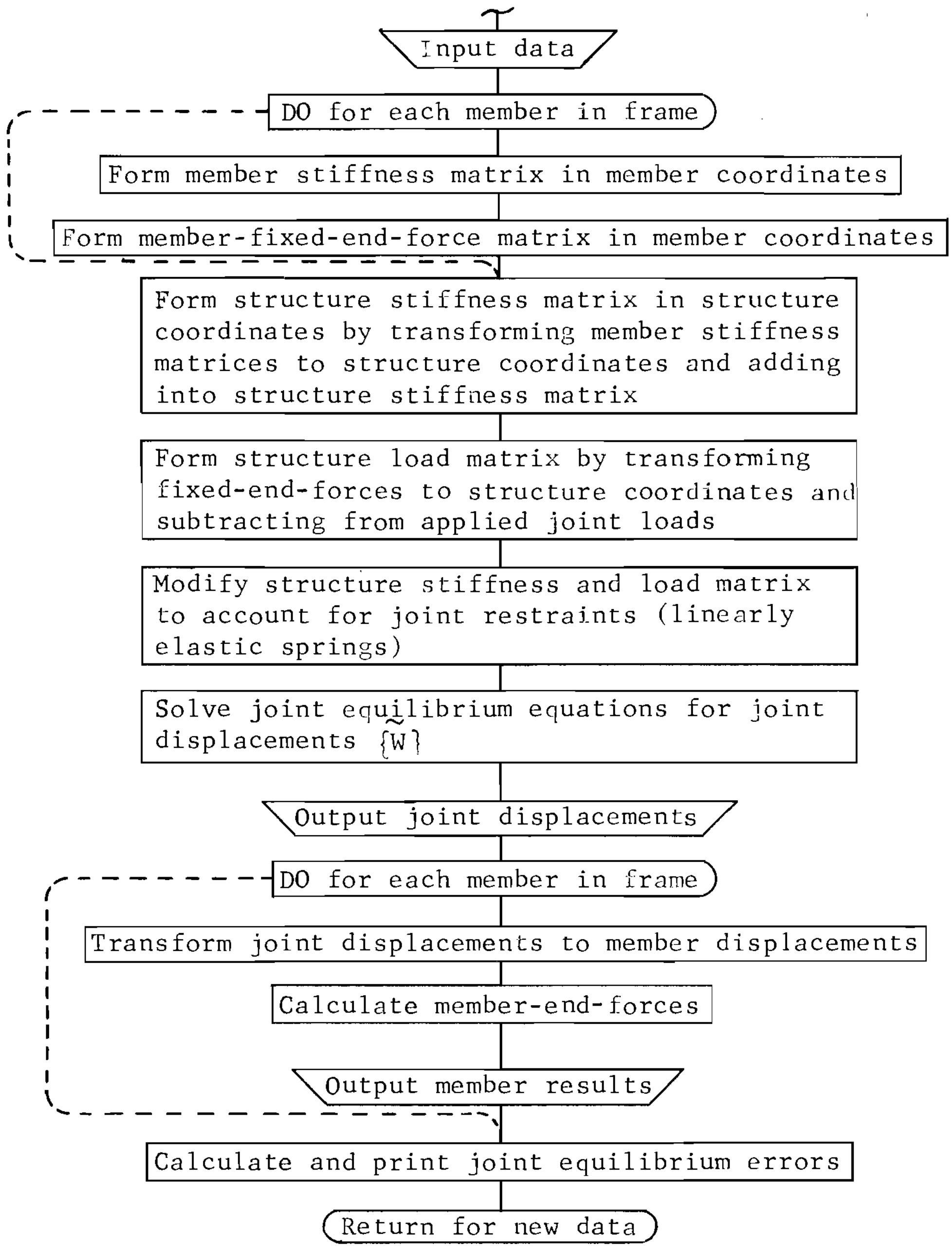


Fig 7. Flow chart for linearly elastic frame solution (Ref 27).

coordinates (x, y, z, as shown in Fig 5):

$$[\overline{K}_{ij}] = [T]^t [K_{ij}] [T] \tag{3.1}$$

where

$[K_{ij}]$ = (3 × 3) member stiffness matrix in member coordinates which represents the forces at joint i due to unit displacements at joint j ,

$[T]$ = (3 × 3) transformation matrix that transforms member displacements and forces into structure displacements and forces (shown in Appendix A),

$[T]^t$ = (3 × 3) transpose of [T] ,

$[\overline{K}_{ij}]$ = (3 × 3) member stiffness matrix in structure coordinates which represents the forces at joint i due to unit displacements at joint j .

The member stiffness matrices are divided into 3 × 3 submatrices for convenience in the next step, which consists of assembling the 3N × 3N structure stiffness matrix $[\widetilde{K}]$ from the member transformed stiffness matrices, using the direct stiffness method (Refs 27 and 36).

Structure load matrix. The member-fixed-end-force matrix is subdivided into 3 × 1 submatrices and transformed into structure coordinates by

$$\left\{\overline{FF}_i\right\} = [T]^t \left\{FF_i\right\} \tag{3.2}$$

where

$\left\{FF_i\right\}$ = (3 × 1) matrix of member-fixed-end-forces at joint i , in member coordinates,

$\left\{\overline{FF}_i\right\}$ = (3 × 1) matrix of member-fixed-end-forces at joint i , in structure coordinates.

The $3N \times 1$ structure load matrix $\{\tilde{F}\}$ is then formed by subtracting the transformed fixed-end-forces from the applied joint loads at all joints.

Joint supports. Any joint may have vertical, horizontal, and rotational linearly elastic support springs. If a joint displaces, support reactions will be generated equal to the negative of the displacements times the appropriate spring constants. These reactions must be considered in writing the joint equilibrium equations. If the support reactions are added to the equations, the effect is to add the corresponding spring term to the diagonal of the structure stiffness matrix $[\tilde{K}]$.

The effect of the other matrix terms becomes negligible as the spring term becomes very large compared to the other terms in any row of $[\tilde{K}]$. Similarly, the load term for that row becomes negligible.

Thus, a zero displacement can be obtained by specifying a very large spring restraint. Likewise, a specified displacement can be obtained by specifying a large spring restraint and a correspondingly large joint force equal to the desired displacement times the spring restraint.

Handling specified displacements in this way allows both real problems with finite values of support restraints and idealized problems with infinitely stiff supports to be solved by the same technique.

Solution of joint equilibrium equations. Premultiplying the structure joint displacement matrix $\{\tilde{W}\}$ by the structure stiffness matrix $[\tilde{K}]$ yields the structure load matrix $\{\tilde{F}\}$. Thus the joint equilibrium equations may be written as

$$[\tilde{K}] \cdot \{\tilde{W}\} = \{\tilde{F}\} \tag{3.3}$$

Equation 3.3 is solved by a recursion-inversion process previously developed (Ref 18). The solution considers the banding and symmetry of the stiffness matrix. A multiple load option allows significant savings in computer time when the same structure is analyzed for several loading conditions. This is possible since for a linear solution the stiffness matrix is independent of the loading. The joint displacements are then output.

Member-end-forces and equilibrium errors. The member-end-forces and other member data such as shears, moments, and displacements can be found by a discrete element solution of the members subject to their member loads and end-displacements (transformed from the structure displacements found in the frame solution to member coordinates). The sum of all forces acting at the joints (applied forces, member-end-forces, and reactions) should equal zero if the solution is correct. In practice there are some small round-off errors and discretizing errors. Thus, the joint equilibrium errors are an indication of the validity of the solutions, and it is wise to print these out as a check on programming errors and machine malfunctions.

Nonlinearly Elastic Frame Solution

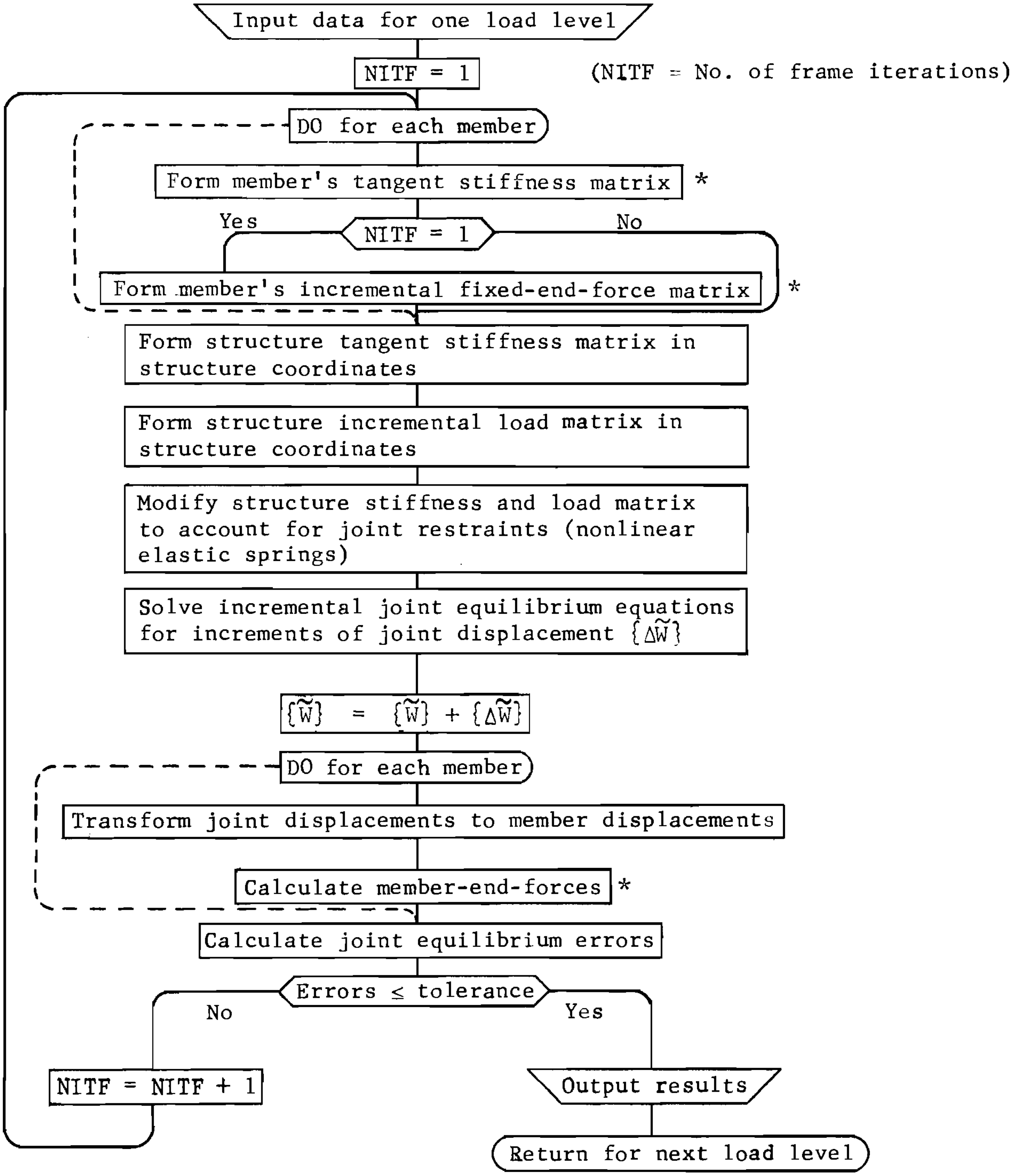
Figure 8 shows the general flow diagram for a nonlinear frame solution. It resembles the linear frame solution but the tangent stiffness algorithm discussed in Chapter 2 is incorporated in it. The iterative process shown can be used for any given load level and is thus valid for either a single load level or a series of load increments.

Member tangent stiffness matrix. The tangent stiffness matrices for the members are formed in member coordinates (undeformed) as in a linear solution. However, in the more general nonlinear solution a member tangent stiffness matrix is a nonlinear function of the member loads and member-end-displacements. Martin (Ref 37) points out that the definition of the element of a nonlinear member stiffness matrix in the i^{th} row and the j^{th} column K_{ij} is the partial derivative of the i^{th} force F_i with respect to the j^{th} displacement W_j , i.e.,

$$K_{ij} = \frac{\partial F_i}{\partial W_j} \tag{3.4}$$

Thus the member stiffness matrices are formed by six discrete element solutions similar to the linear unit displacement technique developed in Ref 27 except that the discrete elements have nonlinear force-displacement relations which are developed for the nonlinear discrete element model in Chapter 4 and the unit displacements are unit increments of displacement from the present position of the member.

Member incremental fixed-end-force-matrix. A fixed-end-force matrix for the members is formed only on the first frame iteration. Succeeding iterations include the effects of the member loads in the joint equilibrium errors. The member incremental fixed-end-force matrices $\{FF\}$ are formed by a discrete



* Discrete element solution (see Chapter 4).

Fig 8. Flow chart for nonlinearly elastic frame solution.

element solution for the increments of member loads with the member-end-displacements held in their present position (see Chapter 4).

Structure tangent stiffness matrix and incremental load matrix. The formation of the structure tangent stiffness matrix $[\tilde{K}]$ and incremental load matrix $\{\tilde{F}\}$ is the same as for the linear solution.

Nonlinear joint supports. Linearly elastic joint supports and specified displacements are handled as in a linear solution. For nonlinear joint springs the tangent stiffness of the spring's Q-W curve is added to the structure stiffness matrix. Since the incremental load matrix is being constructed, the resistive spring forces corresponding to the spring's displacement are not normally added into the incremental load matrix; instead the spring force is included in the joint equilibrium check. However, on the first iteration, from a zero displacement start, the force corresponding to zero displacement should be added into the structure incremental load matrix as a fixed-end-force.

Joint supports may be in the direction of the member axes rather than in the direction of the structure axes, as for an inclined pile that develops an end bearing force. Such a spring produces a force in the direction of both structure axes due to a unit displacement in either of the structure directions. The method of transforming spring stiffnesses from member directions to structure directions is given in Appendix D (Case a).

Solution of incremental joint equilibrium equations. The solution of the simultaneous equations is carried out as in a linear solution. However, the increments of displacement $\{\Delta\tilde{W}\}$ are obtained and are then added to the previous displacements $\{\tilde{W}\}$ to obtain the new estimate of displacements $\{\tilde{W}\}$.

Nonlinear member-end-forces and joint equilibrium errors. The new estimates of joint displacements are transformed into member coordinates and an iterative discrete element solution is made for all members, as discussed in Chapter 4. The discrete element solutions determine sets of member-end-forces compatible with the member-end-displacements, member loads, and restraints.

The sum of all forces acting at each joint should equal zero if an equilibrium position has been found. The magnitude of the joint equilibrium errors is an indication of the joint loads not absorbed by the structure in that estimated position. If the errors are greater than a specified tolerance, the cycle is repeated with the incremental joint loads taken as the equilibrium errors. When the joints converge, the results may be output and the program returns for a new load level.

The joint equilibrium error corresponding to a specified joint displacement is not well defined mathematically. In the present program when a large spring and force are used to specify a displacement, no internal equilibrium check is made corresponding to that displacement in the iterative process. The equilibrium error output corresponding to the specified joint displacement is actually the force required to enforce the displacement. The program interprets any force larger than 1×10^{30} as one used to specify a displacement.

More details of the actual program are given in Chapter 5 and the Appendices.

Maximum load analysis. By increasing the loads until the solution diverges or the value of a critical variable such as shear or strain in the compression flange becomes excessive, one may make an estimate of the maximum load that a frame can carry. The loads may be increased, proportionally or otherwise, as desired.

The nonconvergence of the solution at a given load level is often an indication that the frame is physically unable to come to equilibrium under that load condition. However, it is possible that the lack of convergence may be due to other reasons, such as

(1) using too severe a tolerance on the joint equilibrium errors or the member equilibrium errors,

(2) using incompatible equilibrium errors for the joint and member solutions,

(3) applying too large a load increment if the frame or one of its members undergoes a severe change in stiffness, or

(4) having a member in a state of zero stiffness, such that it will not come to equilibrium.

The first two possibilities can be virtually eliminated by the following technique: For the given frame, select as the joint tolerances a force and a moment that will have a negligible effect on the frame; the member force and moment tolerances can be chosen as one-tenth of the joint tolerances to allow for accumulation of errors in the member solution. This procedure gave good results for the wide range of problems for which the program was tested.

The other two possibilities are due in large part to the fact that a member solution is attempted separately from the overall frame solution. Thus the nonconvergence of a member may not correspond to the maximum load on the frame as a whole. The output from nonconverging solutions should be studied to see if the frame is actually near a failure condition. The steel frame with tie rods discussed in Chapter 7 illustrates these special problems and how they can be handled.

CHAPTER 4. DISCRETE ELEMENT MODEL OF FRAME MEMBERS

In developing the nonlinear frame solution in Chapter 3, it was assumed that there was a method for obtaining the member tangent stiffness matrix, the member incremental fixed-end-force matrix, and the member-end-forces corresponding to specified end-displacements and member loads.

In this chapter, the necessary member solutions are developed using a discrete element model of the members. The force-displacement and stiffness properties of the elements are needed for the member solutions just as the force-displacement and stiffness properties of the members are needed for the frame solution. Thus, the force displacement equations for a typical discrete element are developed early in Chapter 4. The stiffness matrix of the element is found by applying Castigliano's first theorem to the element force-displacement equations. Then the effects of member loads and restraints are discretized to the nodal points connecting the elements. Finally, the member solutions needed to define the force-displacement response and stiffness properties of the members are developed.

Existing Capabilities for Response of Nonlinear Members

A closed-form solution for a frame member with variable cross section, general loadings, and nonlinear material and support properties which considers all geometric effects has not been developed. Simple cases considering all geometric effects except axial shortening have been worked using elliptic integrals (Ref 21). Approximations of the nonlinear geometric effects have been made using finite element models by Jennings (Ref 32) and Saafan (Ref 53). Nonlinear material effects have been approximated by numerous investigators (Refs 59, 8, and 24). Nonlinear support properties, nonlinear material properties, and the Py and PΔ moments have been considered in a discrete element member solution (Ref 39).

Gunnin (Ref 25) has developed a frame solution which considers large displacements of structural joints and nonlinear material properties, as expressed in Ramberg-Osgood M-ϕ-T (moment-curvature-thrust) curves. However his member solution neglects the effects of member deformations on the statics of the member. His solution may be used for problems with significant Py moments only by subdividing members and inserting additional joints. Extra joints are also required at concentrated loads. Distributed loads are handled by specifying equivalent concentrated loads.

Alvarez (Ref 4) has a solution which considers inelastic unloading for an elastic plastic stress-strain curve, but it is restricted to rectangular steel frames made of wide flange members.

The discrete element solution that is developed herein allows for a more general frame member than previously possible.

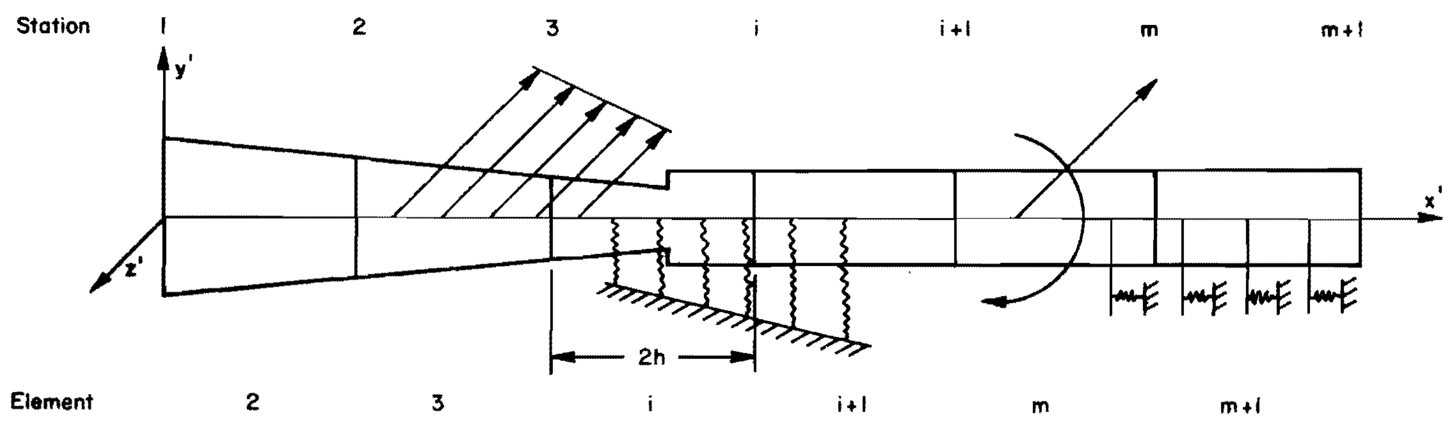
General Frame Member and Discrete Element Representation

A plane frame member is shown in Fig 9(a). Loads, linearly elastic restraints, and changes in a linearly elastic cross section may occur anywhere. Loads and restraints may be specified in either member or structure coordinates. Member restraints may be nonlinear and have a linear variation between structural joints. Cross sections may be defined as a series of pieces. Each piece can be either a rectangle or a thin wall tube. The dimensions and locations of the pieces can vary linearly between structural joints. Each piece in the cross section may have a nonlinear stress-strain curve. The coordinates of corresponding points on the stress-strain curves can vary linearly between structural joints.

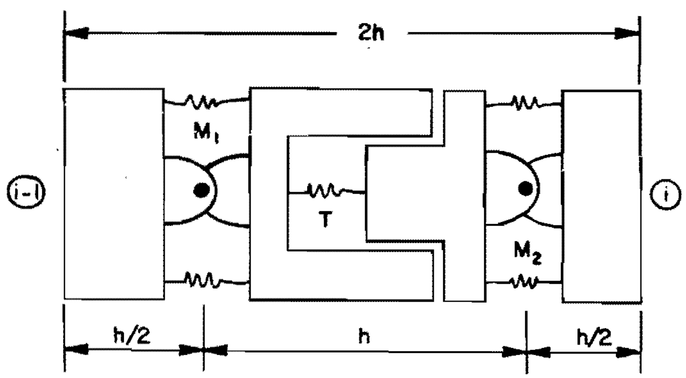
The member is assumed to be initially straight. All loads and displacements are assumed to occur within the plane of the frame, in which one of the member's principal axes lies. The members may be pinned or rigidly connected at the joints. The effects of shearing deformation are neglected.

The member is divided into m elements of length $2h$. The force-displacement equations can then be obtained for a general element. Member loads and restraints are discretized to the stations where the adjacent elements are connected and are fully compatible. Thus the member may be solved as a structure composed of a series of straight line elements.

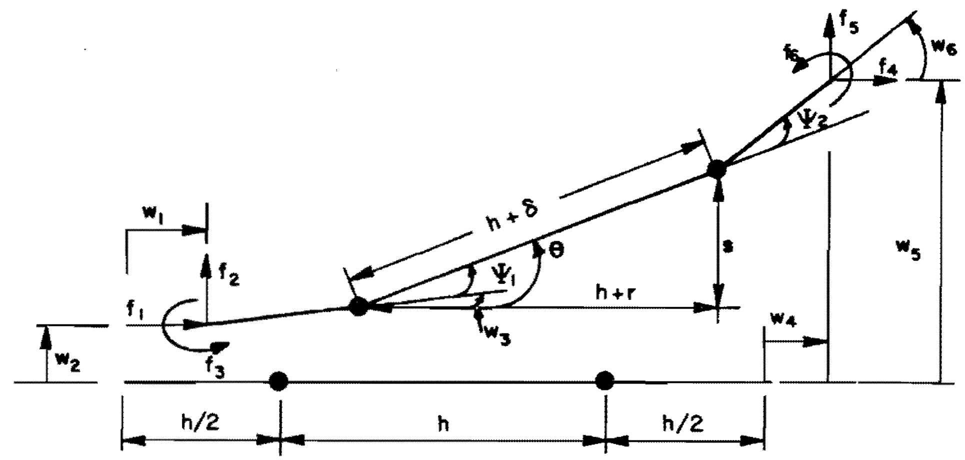
The discrete element shown in Figs 9(b) and 9(c) was developed by Hays and Matlock (Ref 27). They obtained the element force-displacement equations for linearly elastic response of the model and showed that these equations were an approximation of the "exact" differential equation solutions with an



(a) General frame member.



(b) Mechanical model of element i .



(c) Discrete line element model in undeformed and deformed positions.

Fig 9. Frame member and discrete element representation of one of its members.

error term of order $(2h)^2$. Discretizing the loads and distributed linear restraints with the astatic equivalencing technique of Mises (Ref 43) gives a similar error term. The second-order error term $(2h)^2$ gives a solution which converges rapidly with a decrease in element size.

An analytical determination of the error term for a general nonlinear element may not be possible due to the complexity of the differential equations. However, the force-displacement equations can be obtained from an analysis of the model and used to check nonlinear examples for which closed-form, numerical, or experimental solutions exist. With all the basic types of nonlinearity so verified, one will have confidence to work problems which contain all nonlinear effects.

In Chapter 6 an error study for cantilever beams indicates the good convergence properties of the nonlinear discrete element model. Several examples in later chapters also illustrate the discretizing error on real frames.

Discrete Element Model

A mechanical model of the discrete element is shown in Fig 9(b). It consists of two rigid end-blocks (the end blocks are rigidly connected to neighboring elements to preserve vertical, horizontal, and rotational compatibility at the nodal points), two rotational springs, which give bending moments M_1 and M_2, and a rigid piston with an axial spring which gives an axial thrust T. A discrete line-element interpretation of the model is shown in Fig 9(c). The end blocks of Fig 9(b) become rigid bars, the rotational springs reduce to point size, and the piston is replaced by a bar that is rigid in bending but axially extensionable. Discrete angle changes ψ_1 and ψ_2 occur, corresponding to the bending moments M_1 and M_2, and a discrete axial shortening δ corresponds to the axial thrust T.

Deformation-Displacement Relations

The element-end-displacements w_1 through w_6 completely define the deformations ψ_1, ψ_2, and δ. The deformations can be calculated by a simple geometric analysis of the model.

From Fig 9(c) it is seen that the horizontal projection of the deformable center bar is

$$h + r = w_4 - w_1 + 2h - \frac{h}{2}(\cos w_3 + \cos w_6) \qquad (4.1)$$

The vertical projection of the center bar is

$$s = w_5 - w_2 - \frac{h}{2}(\sin w_3 + \sin w_6) \qquad (4.2)$$

The length of the center bar $(h + \delta)$ is the hypoteneuse of the triangle. Thus,

$$\delta = \sqrt{s^2 + (h + r)^2} - h \qquad (4.3)$$

The angle θ which the bar makes with the x'-axis is given by

$$\theta = \tan^{-1}\left(\frac{s}{h + r}\right) \qquad (4.4)$$

The discrete angle changes ψ_1 and ψ_2 are found from

$$\psi_1 = \theta - w_3 \qquad (4.5)$$

$$\psi_2 = w_6 - \theta \qquad (4.6)$$

Equations 4.1 through 4.6 are the deformation-displacement equations for the element and correspond to the strain-displacement equations of elasticity. They are valid for large values of displacement, since they contain no small-displacement approximations.

Force-Deformation Relations

The force-deformation equations for the model which correspond to the stress-strain equations of elasticity may be obtained by integrating the stress-strain curves over the cross section. For the case of linear material properties, the equations of Ref 27 may be used:

$$M_1 = \frac{EI\psi_1}{h} \tag{4.7}$$

$$M_2 = \frac{EI\psi_2}{h} \tag{4.8}$$

$$T = \frac{AE\delta}{2h} \tag{4.9}$$

where EI and AE are the average product of modulus of elasticity times moment of inertia and area, respectively, for the element. M_1 and M_2 are the bending moments at the two discrete rotational springs and T is the axial thrust in the center bar.

Equations 4.7 and 4.8 are the statements that the moments are equal to EI times the curvatures, where the curvatures at 1 and 2 are taken as the discrete angle changes ψ_1 and ψ_2 divided by h . For these equations to be correct, the curvatures, and hence ψ_1 and ψ_2 , should be small, even though the displacements need not be. Similarly, Eq 4.9 is the statement that the axial thrust is equal to AE times the axial strain, where the axial strain is taken as the discrete change in length δ divided by 2h .

For nonlinear stress-strain curves the more complex relations can be obtained by the numerical integration technique developed in Appendix B. Symbolically, Eqs 4.10 through 4.12 can be used to represent any function g that occurs:

$$M_1 = g(\psi_1 , \delta) \tag{4.10}$$

$$M_2 = g(\psi_2 , \delta) \tag{4.11}$$

$$T = g(\delta , \psi_1 , \psi_2) \tag{4.12}$$

Thus, M_1 and M_2 are the moments at the location of the two rotational springs and T is the average of the two thrusts at the two rotational springs.

The numerical integration procedure developed in Appendix B allows a cross section to be specified as a series of up to 10 pieces. Each piece may be either a rectangle or a thin wall tube. Several cross sections that can be input in this manner are shown in Fig 10. Each piece is assigned a non-linear stress-strain curve by the user. The curves need not be the same for all pieces at a section. The stress-strain curves are specified by inputting a number of points to define the curves. Up to eleven points may be used; thus, the full range of the appropriate curve may be input and idealizations such as assuming bilinear curves or equal properties in tension and compression are not necessary.

This method of specifying cross section and material properties allows a wide variety of practical problems to be handled by one program. Steel, reinforced concrete, and prestressed concrete examples are worked in subsequent chapters. Other construction materials, such as aluminum and composite steel and concrete, could be handled by the program by inputting the sections and the appropriate stress-strain curves.

Equilibrium Equations

The equilibrium equations for the element are easily obtained by applying the laws of statics to free bodies of the center bar and the two end bars. The shear force V normal to the center bar of Fig 9(c) is found from a free body of the bar to be

$$V = \frac{(M_2 - M_1)}{(h + \delta)} \tag{4.13}$$

Then, summing forces and moments on the end bars gives Eqs 4.14 through 4.19:

$$f_1 = -T \cos \theta - V \sin \theta \tag{4.14}$$

$$f_2 = -T \sin \theta + V \cos \theta \tag{4.15}$$

$$f_3 = -M_1 + f_2 \frac{h}{2} \cos w_3 - f_1 \frac{h}{2} \sin w_3 \tag{4.16}$$

$$f_4 = -f_1 \tag{4.17}$$

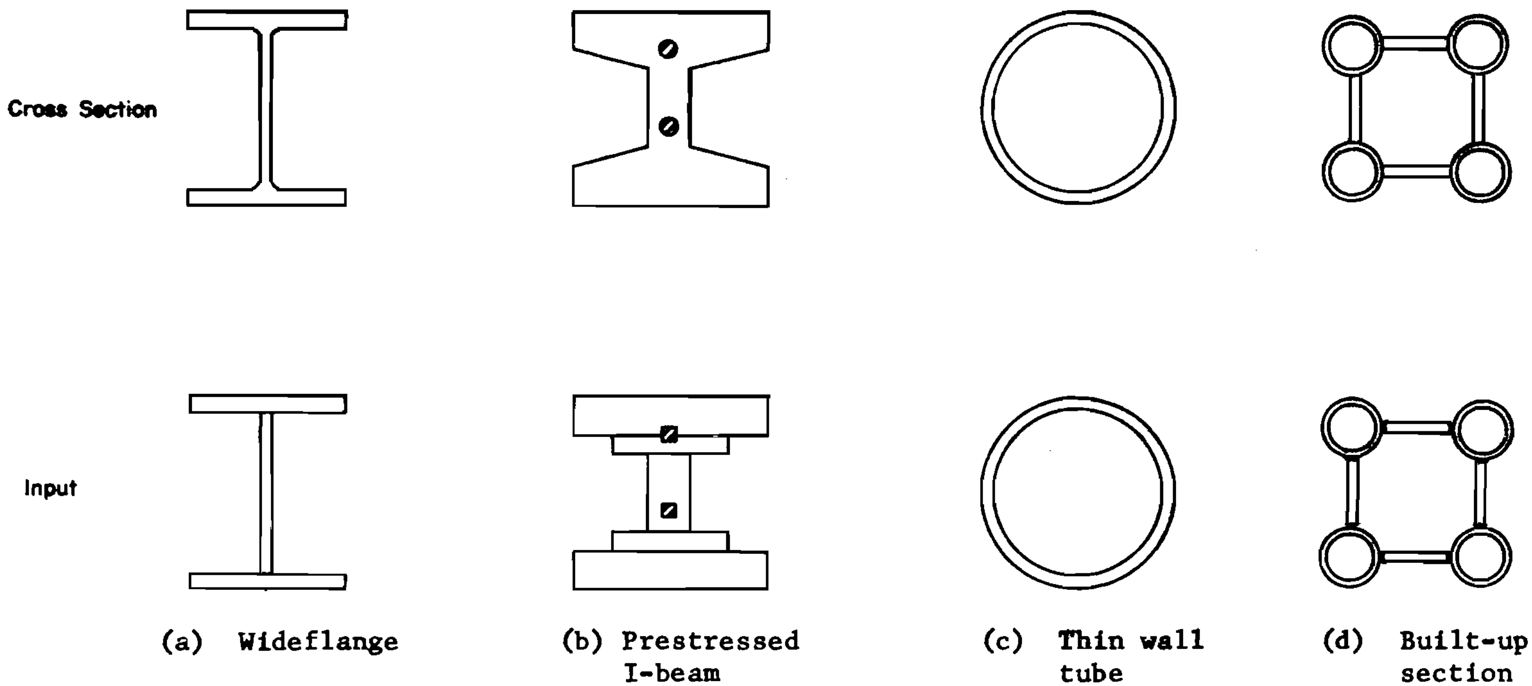


Fig 10. Representation of cross sections with rectangles and thin wall tubes.

$$f_5 = -f_2 \tag{4.18}$$

$$f_6 = M_2 + f_2 \frac{h}{2} \cos w_6 - f_1 \frac{h}{2} \sin w_6 \tag{4.19}$$

Force-Displacement Equations

Equations 4.1 through 4.19 comprise the element force-displacement equations. They could be combined to form one set of equations but may be solved by the following straightforward procedure. For a given set of displacements, the deformation-displacement equations are solved for the deformations. Then, using these deformations, the force-deformation equations are solved for the internal forces. Then, using the deformations, internal forces, and displacements, the equilibrium equations are solved for the element-end-forces.

Discrete Element Stiffness Matrix

The analytic differentiation of the element force-displacement equations to obtain the element 6×6 stiffness matrix would be a laborious task. A numerical differentiation of the relations in the computer program is possible, as demonstrated in Ref 34, but this procedure was tried and found to take excessive computer time; up to 30 significant figures were required to perform the numerical differentiation for problems that were near instability. Thus, a derivation of the stiffness matrix was made using Castigliano's first theorem. This theorem, applied to the discrete element equations, gives a method which organizes the analytic differentiation process so that is is manageable and also gives some physical insight into the problem.

Consider a discrete element with n element end-forces $\{f\}$ related to n element end-displacements $\{w\}$ by n force-displacement equations of the form shown in Eq 4.20 ($n = 6$ for the plane frame element being considered herein):

$$f_i = g(w_1 , w_2 , w_3 \dots w_i \dots w_n) \tag{4.20}$$

Since Eq 4.20 will not, in general, be linear, it is not possible to write a matrix equation relating the forces and displacements by a constant stiffness matrix as is done in a linear analysis. However, a linear approximation of the relation between the increments in forces $\{\Delta f\}$ and the increments in displacements $\{\Delta w\}$ is given by

$$\{\Delta f\} = [k] \{\Delta w\} \tag{4.21}$$

where $[k]$ is the $n \times n$ tangent stiffness matrix with variable coefficients. The coefficient of the i^{th} row and the j^{th} column, k_{ij}, is given by

$$k_{ij} = \frac{\partial f_i}{\partial w_j} \tag{4.22}$$

Assume that there are m discrete energy absorbing springs in the element with m internal forces $\{S\}$ related to m deformations $\{\delta\}$ as given by m force-formation equations such as Eq 4.23 ($m = 3$ for the plane frame element):

$$S_i = g(\delta_1 , \delta_2 , \delta_3 \ldots \delta_i \ldots \delta_m) \tag{4.23}$$

Here, too, only a linear approximation is in order, relating increments of internal force $\{\Delta S\}$ to increments of internal deformation $\{\Delta \delta\}$ by

$$\{\Delta S\} = [D] \{\Delta \delta\} \tag{4.24}$$

The $m \times m$ matrix $[D]$ is the incremental force-deformation matrix, and D_{ij} is given by

$$D_{ij} = \frac{\partial S_i}{\partial \delta_j} \tag{4.25}$$

The element deformation-displacement equations relating δ and w are given by m equations of the form

$$\delta = g(w_1 , w_2 , w_3 \ldots w_j \ldots w_n) \tag{4.26}$$

Linear increments in deformation $\Delta\delta$ are related to linear increments in displacement Δw by

$$\{\Delta\delta\} = [B]\{\Delta w\} \tag{4.27}$$

where $[B]$ is the $m \times n$ incremental deformation-displacement matrix, and

$$B_{ij} = \frac{\partial \delta_i}{\partial w_j} \tag{4.28}$$

Castigliano's first theorem, which is applicable for nonlinear but elastic structures (Ref 66), gives the i^{th} force f_i as

$$f_i = \frac{\partial U}{\partial w_i} \tag{4.29}$$

where U is the strain energy of the element and may be expressed in terms of the energy absorbing spring forces and deformations as

$$U = \sum_{k=1}^{m} \int S_k \, d\delta_k \tag{4.30}$$

The differential of deformation $d\delta_k$ is

$$d\delta_k = \frac{\partial \delta_k}{\partial w_i} dw_i \tag{4.31}$$

Thus, combining Eqs 4.29 - 4.31 gives

$$f_i = \frac{\partial}{\partial w_i} \left(\sum_{k=1}^{m} \int S_k \frac{\partial \delta_k}{\partial w_i} dw_i \right) \tag{4.32}$$

The successive integration and differentiation that are implied negate each other. Hence,

$$f_i = \sum_{k=1}^{m} S_k \frac{\partial \delta_k}{\partial w_i} \tag{4.33}$$

Equation 4.33 was derived in a slightly different manner by Austin (Ref 10). Differentiating Eq 4.33 with respect to w_j gives

$$k_{ij} = \frac{\partial f_i}{\partial w_j} = \sum_{k=1}^{m} \left(S_k \frac{\partial^2 \delta_k}{\partial w_i \partial w_j} + \frac{\partial \delta_k}{\partial w_i} \frac{\partial S_k}{\partial w_j} \right) \tag{4.34}$$

But using the chain rule for partial derivations gives

$$\frac{\partial S_k}{\partial w_j} = \sum_{\ell=1}^{m} \frac{\partial S_k}{\partial \delta_\ell} \frac{\partial \delta_\ell}{\partial w_j} \tag{4.35}$$

Combining Eqs 4.34 and 4.35 gives the desired expression for k_{ij} as

$$k_{ij} = \sum_{k=1}^{m} \left[S_k \frac{\partial^2 \delta_k}{\partial w_i \partial w_j} + \frac{\partial \delta_k}{\partial w_i} \left(\sum_{\ell=1}^{m} \frac{\partial S_k}{\partial \delta_\ell} \frac{\partial \delta_\ell}{\partial w_j} \right) \right] \tag{4.36}$$

Since k_{ij} is composed of two terms, the stiffness matrix $[k]$ can be considered to be composed of two portions, $[k]_S$ and $[k]_C$. Thus,

$$[k] = [k]_S + [k]_C \tag{4.37}$$

where $[k]_S$ is called the initial-stress stiffness matrix and is made up of all the k_{ij} that would arise if only the first term of Eq 4.36 were used. The term initial stress was used by Murray (Ref 44) and comes from the fact that if an element undergoes a rigid body displacement, no internal forces S_k will develop and $[k]_S$ will be zero regardless of how large the rigid body displacements are.

The initial-stress stiffness matrix for the frame element was computed by taking the indicated second partial derivations of the strain-displacement equations (Eqs 4.1 through 4.6). It was further noted here that for the frame element, $[k]_S$ could be subdivided into two portions, one due to the internal axial force $[k]_{ST}$ and one due to the internal shear force $[k]_{SV}$. Both $[k]_{ST}$ and $[k]_{SV}$ are given in Appendix C.

The conventional portion of the stiffness matrix $[k]_C$ could be computed coefficient-by-coefficient using the second term of Eq 4.36; however, it is easy to show that identical results will be obtained if this portion is formed by the conventional triple matrix product

$$[k]_C = [B]^t[D][B] \tag{4.38}$$

Matrices [B] and [D] are as previously defined, and $[B]^t$ is the transpose of [B] . Both [B] and [D] are given in Appendix C for the discrete element used herein.

Discretizing Member Loads

Member loads were not considered in developing the force-displacement equations for a single discrete element. Rather they are discretized into concentrated loads acting at the member stations. Such forces can then be incorporated into the member solution as nodal point forces.

The idea of replacing a complicated loading system with a simpler statically equivalent system is not new. Newmark's classic paper (Ref 45) gives a good practical discussion of the concept and a theoretical treatment is given in a paper by Mises (Ref 43), who points out the lack of generality of St. Venant's principle and gives better criteria for the replacement of one load system by another.

By use of Mises criteria a system of loads may be replaced by an equivalent system if the static difference of the two systems is zero and remains zero when the two systems are rotated through an arbitrary angle. Such systems are said to be astatically equivalent. Then, if the real loading system and the astatically equivalent loading system are contained in a circle with a diameter of 2h (the length of an element), the difference in the resulting stresses and strains a short distance away from the loads will be of order $(2h)^2$.

In Ref 27 it was shown that axial loads, lateral loads, and couples could all be discretized by the same formulas and satisfy Mises requirements. The formulas are based on applying the loads to a series of simple stringers supported at the member stations. The discretizing is done in the program developed herein so that the user can specify his loads in a normal engineering manner (see Appendix E). However, the user should be aware of this discretization and how it affects his solution.

Consider a simply supported beam, as shown in Fig 11. The beam is 40 feet long and has a concentrated load of 20 kips at 19.75 feet from the left end. For a 40-element solution $(2h = 1 \text{ ft})$, the normal load, shear, and moment diagrams are compared with the discretized diagrams in Fig 11.

The maximum shears are equal in both cases and the difference in maximum moments is only 1.25 percent. The difference in the area of the two moment diagrams, shown shaded in the figure, is a function of $(2h)^2$ and thus the curvature diagram and the resulting rotations and deflections will be of order $(2h)^2$, illustrating Mises principle.

Distributed loads are handled by finding the resultant load on each stringer and then distributing it to its adjacent stations.

Output shears, axial forces, and bending moments are the average values at stations where concentrated lateral loads, axial loads, and couples can cause double values to exist.

Member Restraints

Member restraints are also discretized to concentrated station values, i.e., discrete nonlinear springs. In Ref 27 it was shown that the formulas used to discretize loads could be used to discretize linear springs except where extremely large springs are used to set a member's displacement. Thus, the computer program developed herein permits only distributed spring supports for members. Concentrated springs are input at the structural joints where they are handled as described in Chapter 3. Distributed linear spring restraints are discretized to station values by the technique used in Ref 27.

Nonlinear Member Restraints

When a member displaces against a supporting medium such as soil, distributed forces q are developed which are often a nonlinear function of the member displacements w. For stable supporting media, the forces will oppose and hence be of opposite sign to the displacements. Criteria are available to

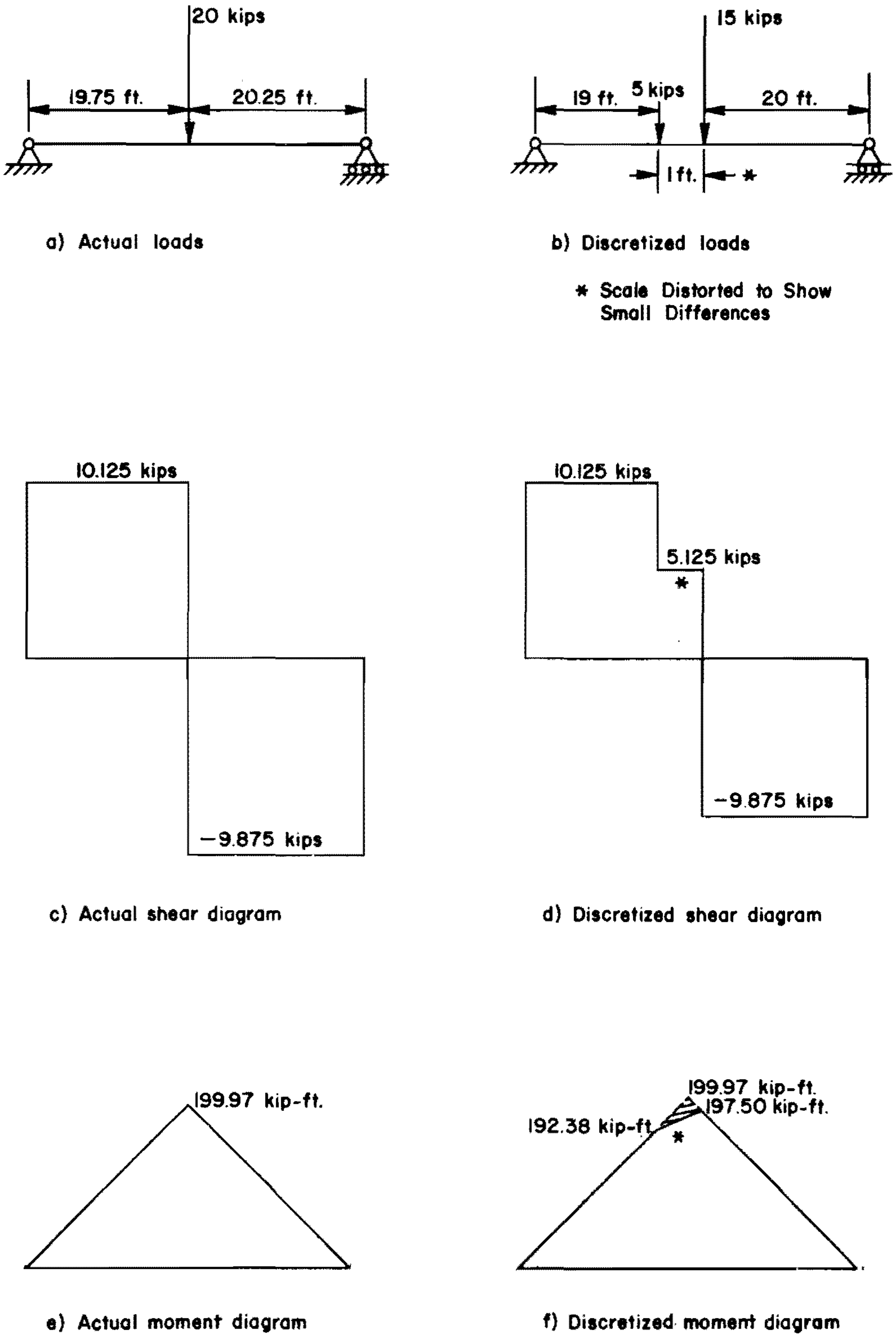


Fig 11. Discretizing a concentrated load.

determine q-w curves (Refs 38, 17, and 48) that can represent the axial and lateral response of sandy and clay soils.

Distributed nonlinear member restraints may be visualized as a bed of nonlinear springs, such as the lateral springs shown in Fig 12(a). However, axial and rotational springs are also allowed by the program. Any of the spring restraints may be defined with reference to either the member or the structure coordinates.

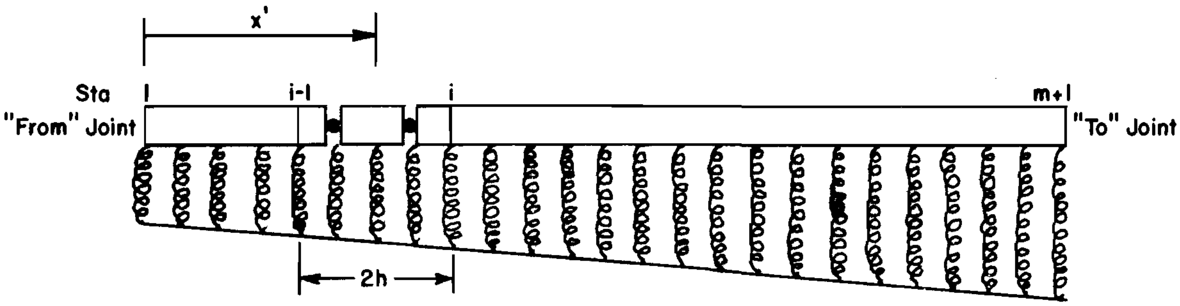
The distributed force-displacement properties of the supporting medium are defined by inputting a q-w curve at each end of the member, as shown in Fig 12(b). The curves input at the "From" and "To" joints must both have the same number of points.

In the program, a continuous nonlinear support is discretized as a series of concentrated nonlinear springs at the member stations by the following procedure: first, as shown in Fig 12(b), a q-w curve is obtained at the middle of each element by interpolating along the length of the member with respect to both force and displacement. Interpolation is between corresponding points on the end curves. Then the distributed values of force q are multiplied by 2h to obtain concentrated values of force Q at mid-element and generate the Q-w curve of Fig 12(c). Next the stiffness K_s and the resistive spring force Q_s are found for the temporary spring displacement w_s at mid-element by a linear interpolation between adjacent points on the Q-w curve, as shown in Fig 12(c). The concentrated values K_s and Q_s are then replaced in the solution by half-values at the two stations at the ends of the element.

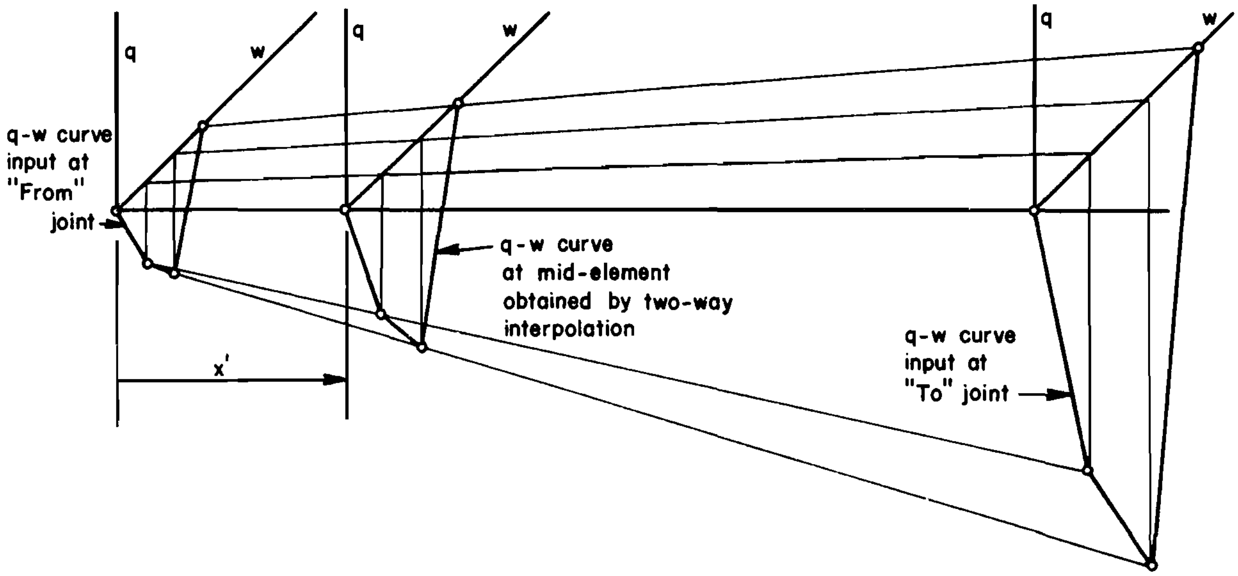
Specification of Member Data in Member and Structure Coordinates

Member loads and stiffness properties are needed in member coordinates for the discrete element member solutions; however, it may be convenient to specify loads or restraints in structure coordinates.

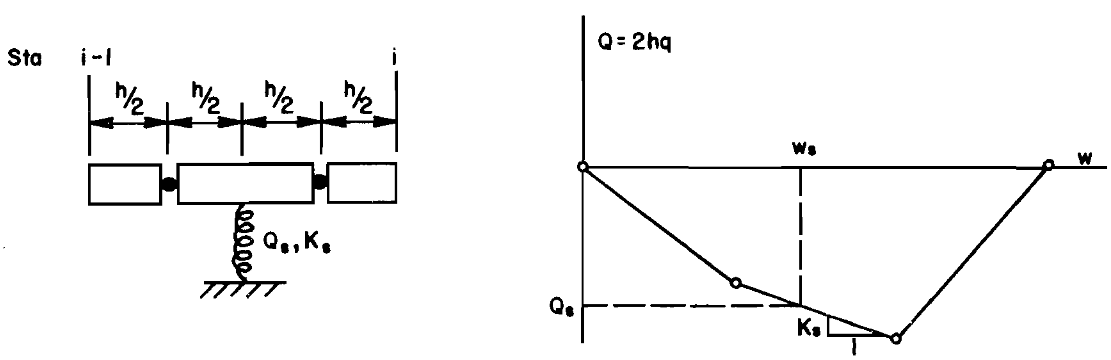
The computer program developed herein allows considerable freedom in this respect, thus extending the usefulness of the method. Member loads may be specified in the direction of either member or structure coordinates and may have their intensity (for distributed loads) specified along either the member or the structure axes. For instance, gravity loads on an inclined member may be specified as acting in the direction of the structure y-axis per unit of length along the member x'-axis. All the options are illustrated in Appendix E. The equations to transform the data to member coordinates are given in Ref 27.



(a) Distributed nonlinear springs.



(b) Interpolation along length of member.



(c) Discretized nonlinear spring at mid-element.

Fig 12. Nonlinear member restraints.

Member restraints (linear and nonlinear springs) may be specified as parallel and perpendicular to the member or parallel to the structure x and y axes. Restraints that are specified in the structure axes must be handled differently from those specified in member coordinates, since a displacement parallel to the member produces forces in both x and y structure-oriented springs. The necessary transformations are given in Appendix D (case b).

Member-End-Forces by Discrete Element Solution

During the iterative frame solution it is necessary to find the member-end-forces corresponding to a member's loads and the current estimate of frame joint displacements (transformed to member coordinates). An iterative solution of the member is made, similar to the frame solution. The structure being analyzed by the direct stiffness method is now the individual member composed of m discrete elements connected at the $m+1$ stations (Fig 9). The member solution is somewhat simpler than the frame solution since all of the discrete elements have their axes parallel to the member axes.

The element force-displacement equations are developed earlier in this chapter, as are the element stiffness matrices, and the effects of member loads and restraints have been discretized to station values. The member solution for a particular set of member-end-displacements is outlined in Fig 13.

The incremental member-end-forces necessary to enforce the increase in member-end-displacements (from the previous solution of the member) are equal to the increase in member displacements times the large spring values at the member ends. The large springs and corresponding large forces are used to enforce the member-end-displacements from the frame solution. The station equilibrium errors are used throughout the member solution as the member loads; hence, the equilibrium errors at the end stations are set equal to the necessary, large incremental end-forces.

Next the element-end forces are evaluated for each discrete element in its current position. The element-end-displacements are known and hence the element deformations may be found from Eqs 4.1 through 4.6. The internal forces may then be found from Eqs 4.7 through 4.9 for a member with linear material properties. The internal forces are found by the numerical integration procedure of Appendix B for members with nonlinear material properties.

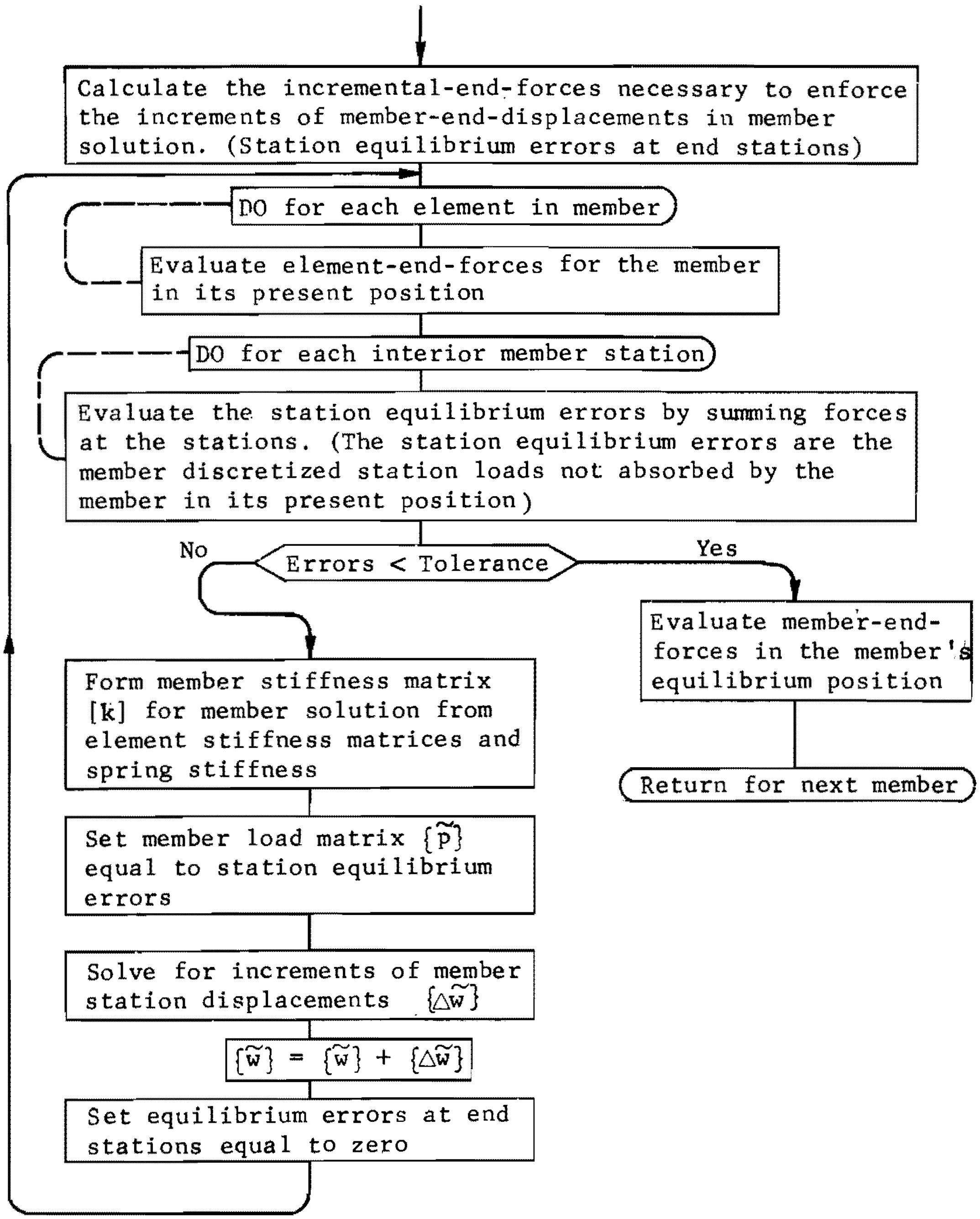


Fig 13. Iterative solution of member to find member-end-forces in equilibrium position.

Then the equilibrium equations (4.13 through 4.19) can be solved for the element-end-forces.

Next the station equilibrium errors at all interior stations $(i = 2,m)$ are evaluated by summing all forces acting at the stations (element-end-forces, discretized member loads, and discretized spring forces). A check is then made to see if the station equilibrium errors are less than the specified tolerance. If they are then the member is considered to be in equilibrium. Next the member-end-forces are evaluated for checking joint equilibrium in the frame solution. The member-end-forces are the element-end-forces at the end stations when corrected for the discretized member loads and spring forces at the end stations.

If all frame members are in equilibirum and all joints are in equilibrium when subjected to the member-end-forces and other joint forces, then an equilibrium solution for the frame has been found and the latest member results along with the joint displacements and reactions can be output. The axial forces and shear forces for the members are output with respect to member undeformed axes. The internal computations for thrust and shear, however, are made with respect to the deformed axes, as previously discussed. The user may transform the output forces to the member's deformed position, if desired, since the member rotations are also given.

If any of the equilibrium errors is larger than the specified tolerances, the member is solved as a structure composed of the discrete elements and subjected to the station equilibrium errors.

The element stiffness matrices and the spring stiffnesses are combined to form the $3(m+1) \times 3(m+1)$ member stiffness matrix $[\tilde{k}]$. The $3(m+1)$ member load vector $\{\tilde{p}\}$ is formed directly from the station equilibrium errors. The incremental member equilibrium equations are given by

$$[\tilde{k}]\,\{\Delta\tilde{w}\} = \{\tilde{p}\} \tag{4.39}$$

Equation 4.39 is solved for the $3(m+1)$ increments of member displacements $\{\Delta\tilde{w}\}$ using the recursion-inversion technique discussed in Chapter 3.

The new estimate of member displacements $\{\tilde{w}\}$ is found by adding the increments to the previous member displacements:

$$\{\tilde{w}\} = \{\tilde{w}\} + \{\Delta\tilde{w}\} \tag{4.40}$$

Then the station equilibrium errors at the end stations are set equal to zero for the subsequent member iterations, since the member-end-displacements will not vary during these iterations. The solution is then repeated until convergence occurs or a limiting number of iterations is reached.

Member Stiffness Matrix by Discrete Element Solution

The 6×6 member stiffness matrix $[K]$ needed for the frame solution is formed by applying 6 unit increments of displacement from the member's present position. The incremental end-forces found from a member solution due to a unit increment of the j^{th} member-end-displacement are the j^{th} column of $[K]$. Since the tangent stiffness of the member is sought it is not necessary that the 6 member solutions be iterative as was the member solution for a set of specified end displacements. Rather a single member solution is made for each unit increment of displacement and the incremental member-end-forces are found by premultiplying the increments of member displacements by the end-elements stiffness matrices and correcting for the discretized loads and incremental spring forces at the end stations. The stiffness matrix so found is the stiffness matrix that a linear member would have if all of its elements had a linear stiffness matrix exactly like the elements' present tangent stiffness matrices. Furthermore, the stiffness of the member does not change during the six member solutions and, hence, the member stiffness matrix $[\widetilde{k}]$ does not change and the multiple-load features of the recursion-inversion equation solver are used to good advantage.

Member Incremental Fixed-End-Force Matrix by Discrete Element Solution

The 6×1 member fixed-end-force matrix $\{FF\}$ is found by a discrete element solution for the member's incremented loads with the member fixed in its present position. Here too, as in obtaining the member 6×6 stiffness matrix $[K]$, a single pseudo-linear solution will define the linear increments of fixed-end-forces and no iterations are required. The incremental end-forces are found as for the member stiffness matrix.

Summary of Chapter 4

The nonlinear force-displacement equations for the individual discrete elements were developed considering large displacements. Material nonlinearity was incorporated into these equations through the nonlinear force-deformation equations relating axial thrust and bending moment to axial strain and curvature.

Castigliano's first theorem was applied to develop matrix expressions for the stiffness matrix of a discrete element with n external degrees of freedome and m discrete energy absorbing springs. These expressions were then used to obtain the tangent stiffness matrix for the discrete element used for the plane frame members.

Member loads and distributed nonlinear spring supports are discretized to concentrated loads and springs in order that the problem may be described in normal engineering terms. Axis transformations are provided to allow member data to be referenced to either member of structures axes.

The iterative solution to determine the force-displacement response of the frame members was developed as a simplified frame solution. The structure being solved was seen to be the member composed of a series of individual discrete elements. The unit displacement technique was used to determine the 6×6 member stiffness matrix needed for the frame solution. Finally incremental loads were applied to determine the incremental member fixed-end-force vector.

CHAPTER 5. COMPUTER PROGRAM

Computer program FRAME 51 was written for the nonlinearly elastic analysis of plane frames and is subject to the limitations outlined in Chapter 3.

This chapter, after a brief descritpion of the computer program, discusses the input and output features of the program and gives an example problem to familiarize the reader with the use of the program. This example problem was chosen to illustrate the input of dimensions, loads, and basic stiffness data. An example problem in Chapter 9 illustrates the complete nonlinear capabilities of the program. Input and output for these two example problems are given in Appendices H and I. Other problems, discussed in Chapters 6, 7, 8, and 9, illustrate the validity of the program for modeling a wide range of nonlinear effects, however, input and output are not given for these problems.

Program Description

FRAME 51 is written in FORTRAN IV and conforms to the requirements of "American Standard FORTRAN" (Ref 7). The program has been implemented and checked out on the CDC 6600 computer at the Computation Center of The University of Texas at Austin. Only minor modifications are necessary to convert the program to other machines.

Program flow charts, the glossary of notation, and the FORTRAN listing of programs are in Appendices F, G, and H, respectively. The reader interested in developing a full understanding of the computer program may wish to study these appendices after reading this chapter. In particular, the flow diagram for subroutine FRAM51 should prove helpful.

The program is presently dimensioned to work a moderate size frame, and requires only 73000_8 words of storage. The detailed input guide in Appendix E gives the limits for the number of members (40), number of joints (20), number of different cross sections (20), etc. The FORTRAN listing of the program has a dimensioning guide to enable easy modification of the dimensions of the program.

The data input subroutines (JTCORD, MEMLOC, JNTDAT, RDMST, RDMLD, and ITCONT) were programmed using overlays, thus reducing the storage requirements, but the program can be used without overlays by removing the cards marked OVERLAY in columns 73-79 and replacing them with the comment cards marked NONOVER.

Input Tables

Table 1. Program Control Data - consists of two cards which are required for all problems. The first card specifies the problem type and the tables for which data from the previous problem are held and allows the user to suppress output. The second card specifies the number of new data cards in Tables 2 through 7. Data cannot be held on the first problem of a computer run. A type 1 problem is one in which all displacements are assumed to be zero at the start of the solution. In a type 2 problem the displacements of the previous solution are the starting values for the new solution.

Table 2. Frame Geometry Data - defines the location of the structural joints of the frame. Joints are required at the intersections of two or more members and at the ends of members. Joints need not be input at concentrated loads but are required at locations of supports (concentrated springs) and at hinges (points of zero flexural stiffness). In addition, joints are required at any point where a change in the nonlinear member stiffness properties occurs (see Table 5A).

The first card of Table 2 gives the total number of frame joints, the reference joint, its coordinates, and the joint location tolerance. The reference joint may be any joint and it may have any coordinates, except that any joint must have coordinates less than 1×10^{50} .

Additional cards as necessary follow to specify the location of the remaining joints and check the location of as many joints as desired. These cards give the offsets of new joints with reference to previously defined joints. For example, if joint 3 is the reference joint, the second card could locate joint 7 with respect to joint 3. The next card could then locate joint 1 with respect to either joint 3 or joint 7. When several joints are in a straight line and have identical offsets, they may be located with only one card. Joint offsets need not be given at every place where there are members, but all joints must be located at least once.

When joints are located more than once the program compares the old and new coordinates as an aid to spot input errors. If the difference in either coordinate (x or y) is greater than the joint-location tolerance, a computer diagnostic appears; otherwise, the program averages the old and new coordinates and continues.

The input data are echo-printed in Table 2 and in addition the computed joint coordinates are given.

Table 3. Member-Type Location - locates the members of the frame between the joints defined in Table 2. The use of member stiffness and load types reduces the volume of input required for large frames with repeated members. Two or more members can be designated with the same stiffness type if they have identical stiffness properties and lengths and have their member axes parallel and similarly directed. Two or more members can have the same load type if they have the same loadings, same length, and similarly directed parallel member axes.

The first card of Table 3 contains the total number of stiffness types and load types in the frame and the number of discrete elements to be used in the member solutions. The number of elements per member can be any even number between, and including, 4 and 40. If the number of elements is not specified, 40 elements are used. The second and succeeding cards give the locations of the members in the frame and their stiffness and load types.

The members are input as going from the "From" joint to the "To" joint. This orients the member x'-axis in the direction of the "To" joint. The orientation is given with the member output for interpreting results.

When several members with the same stiffness and load type are connected in a straight line, they may be input with only one card.

The stiffness and load types on a data card replace any values for a member which may exist. Thus if stiffness and load types from the previous problem change for only a few members, the data may be held in Table 3 and only the new values of stiffness type and load type given. Both stiffness type and load type must be given, even if only one of them changes.

The input data are echo-printed and in addition the computed member numbers, lengths, and offsets are printed in Table 3.

Table 4A. Joint Loads and Supports (Linear Restraints) - gives joint loads and linear supports in the direction of the structure (x, y, z) axes. Frame supports may be specified as linearly elastic restraints (springs). Real values can be used, if available, or large fictitious values can be used to simulate unyielding supports.

A completely fixed support is obtained by specifying large horizontal (x), vertical (y), and rotational (z) springs at a joint. A pinned support would omit the rotational restraint and the free end of a cantilever would have no restraints.

A specified displacement can be enforced by inputting a large spring and a corresponding large force equal to the spring restraint times the desired displacement. To enforce a specified displacement, the force should be greater than 1×10^{30} . Such a force is a cue to the program to skip the equilibrium check during the iterative process, since an equilibrium check corresponding to a specified displacement is invalid.

Each card of Table 4A contains joint loads and restraints for one joint. Cards are required only for joints with nonzero values. No special order of the joints is required. The table is accumulative and in addition to the echo-print of the data the accumulated joint data are printed.

Loads are positive if in the direction of the structure axes; thus, counterclockwise couples are positive loads. Springs corresponding to stable supports will always have positive values; however, the program accepts negative values.

<u>Table 4B. Nonlinear Joint Supports</u> - gives the numbers of the nonlinear Q-W support curves at the joints, if any, and the multipliers for the curves. The final values of Q and W used for the joint support curves are the Q and W values given in Table 4C times the multipliers in Table 4B. Curves may be input with forces and displacements parallel to the structure x and y-axes, or with rotational restraints about the z-axis, or parallel to a member's x' and y'-axes. If the curves are referenced to member axes then the stiffness type of a member should be given to orient the joint springs. The stiffness type given to orient the joint spring does not have to be, although it often will be, one of the members that meet at the joint.

The curve numbers input for a joint on any one card, including zero, replace the old curve numbers if any at the joint. Thus, all curve numbers for a particular joint must be specified on the same card. A joint may have both linear supports, which are specified in Table 4A, and nonlinear supports, specified in Table 4B.

If the curves are specified parallel to a member then the ratio of the final Q-values to the final W-values should not be extremely large. If these values are unrealistically large, numerical problems arise because these values are combined with the realistic stiffness values of the members of the frame, which are many orders of magnitude lower. No problem will be encountered if actual physical values are used to represent the supports or if the supports are in the direction of the structure axes, since in this case the large values are restricted to the diagonal of the stiffness matrix, where they do not cause any numerical problems.

Table 4C. Nonlinear Support Curves - gives the Q-W curves which were located in Table 4B. The curves must be input so that the final W-values are in increasing algebraic order. Stable joint supports give a force opposite to the displacement, and they are input so that the final Q-values are opposite in sign to the final W-values.

Symmetrical curves (actually antisymmetrical, since displacements which are equal in magnitude but opposite in sign produce forces which are equal in magnitude but opposite in sign) may be input by specifying only the positive displacement branch of the curve. The first point on a symmetrical curve must be the zero, zero point.

Table 5A. Member Stiffness Types - specifies the stiffness data for the various stiffness types in the frame. One or more data cards are required to define each new stiffness type. Stiffness types must be input in ascending order. When Table 5A is held from a prior problem, if there is a new stiffness type, the first one input must be one more than the last stiffness type in the prior problem.

Prismatic members with a constant modulus of elasticity which do not have elastic spring restraints require only one data card. Members with variable cross sections, specified stress-strain curves, or elastic-spring restraints require two or more data cards and the first card indicates how many additional cards follow.

If the nonlinear option is left blank and additional cards are used, then the second and succeeding cards describe variations in linear stiffness properties within the member. The modulus of elasticity is held constant but the moment of inertia, area, and linear restraints (spring constants) may vary freely in the member. Distances to locations of changes in stiffness are given from the member's "From" joint and are in member coordinates. This format is illustrated on page 15 of Appendix E.

If any of the member stiffness properties are nonlinear, the nonlinear option is set equal to one, and cross section numbers, q-w curve numbers and q-w multipliers are input on the second card for the "From" and "To" joints. Then the cross sections, stress-strain curves, and q-w curves are defined in Tables 5B, 5C, and 5D. The final q and w values are the q and w multipliers times the q-w curves input in Table 5D.

In Table 5, either partial (end-forces only) or complete member output may be requested for each stiffness type and all members with that stiffness type will have the specified output.

Connections of members to a joint, either pinned or rigid, are indicated on the first card for each stiffness type. This option either pins or rigidly attaches the member to the joint but does not provide a support for the frame.

Members are pinned to a joint by specifying the joint option as +1. A zero joint option indicates the member is rigidly attached to the joint. If the joint option is -ij(i and j are digits $\leq$ 9), the member is rigidly attached to the joint and the first i discrete elements away from the joint remain rigid. Actually, some very small deformations occur; the program uses a modulus of elasticity E equal to 10 times the slope of the stress-strain curve at a zero strain and the stress in the element is computed by multiplying the strain by this large E value and adding on the stress corresponding to zero strain, if any. If the nonlinear option is zero, then the E value used for the rigid elements is 10 times the input value of E . The i rigid elements may be followed by j elements which remain linearly elastic regardless of the stress level. This is accomplished by using the slope of the stress-strain curve at a zero strain as E and computing the stress in the elements by multiplying the strain by this constant E value and adding on the stress corresponding to zero strain, if any.

The axis option allows member distributed linear and nonlinear springs to be in the direction of member coordinates (axis option = 1) or in the direction of structure coordinates (axis option = 2). In both cases the distributed spring values are per unit of length along the member axis. If there are no distributed springs on a member then the axis option may be either 1 or 2.

Table 5B. Cross-Section Properties - describes the member's cross section and gives the stress-strain curve number for each piece in the section and the stress and strain multipliers. The final stress-strain curve used at a joint is the product of the stress-strain curve input in Table 5C and the stress and strain multipliers.

The cross section is described as a series of up to 10 pieces; each piece may be either a rectangle or a thin wall tube. The input for a rectangular piece is the width and depth of the rectangle and the distance from the rectangle's centroid to the x'-axis of the member. The distance is positive if in the direction of the positive y'-axis. The input for a tube is the outside diameter of the tube, the thickness of the tube, and the distance from the centroid of the tubular section to the x'-axis of the member. The distance is positive if in the direction of the positive y'-axis.

The program interpolates linearly between joints to define the cross section properties of each discrete element at mid-element. Therefore the cross section should have the same number of pieces at both joints, and corresponding pieces should be input in the same order. The linear variation in depth, width, etc., provides for higher order variation in section properties such as moment of inertia and elastic and plastic moduli.

Table 5C. Stress-Strain Curves - gives the stress-strain curves which were located in Table 5B. The input of the stress-strain curves is similar to the input of Q-W curves of Table 4C except that normally the sign of the stress and strain values will be the same. A stress-strain curve at mid-element is found for each piece in the discrete element by linearly interpolating along the length of the member with respect to both stress and strain. Thus stress-strain curves at both joints of a member on the same piece should have the same number of points.

Table 5D. Nonlinear Member Supports - gives the q-w curves which were located in Table 5A. The input of the q-w curves is similar to the input of the Q-W curves in Table 4C except that the final q values have the units of force per unit of length. The q-w curve for an element is obtained by linear interpolation along the length of the member with respect to both q and w . Thus q-w curves at both member joints should have the same number of points.

Table 6. Member Load Data - specifies the loadings for the various load types. One or more data cards are required to define each new load type. Load types must be input in ascending order and when Table 6 is held from a prior problem, the first new load type must be one more than the last load type in the prior problem. A load type may be increased a certain percentage over its previous value if the hold option for Table 6 is input as 2 in Table 1. All loads on members of this load type have their values increased by the percentage indicated in the card. For example, if 25.0 is input as the percent increase in a load type and the load type previously had two concentrated loads of -20.0 and +30.0, their new values would be -25.0 and +37.5, respectively. If the hold option is 2 all old load types must have a percent increase specified. To decrease loads, input a negative percent increase.

Members with only uniform loads over their full lengths may be defined with only one data card. Other loadings require two or more cards and the first card indicates how many additional cards follow. Four axis options are provided to permit the user to describe the member loads in the most convenient manner (see page 16 of Appendix E). Loads are positive if they are in the direction of the chosen axes; thus, counterclockwise couples are positive. Distances to concentrated loads and changes in distributed loads are given from the member's "From" joint and are positive in the direction of the chosen axis.

Table 7. Iteration Control - specifies the maximum number of iterations allowed in the frame and member solutions and the maximum allowable equilibrium errors. The equilibrium errors should be specified by the procedure discussed in Chapter 2 unless the user has his own special requirements.

Monitor members and joints should be specified to study the convergence or nonconvergence of the solution. The member numbers input are the member numbers assigned by the program in Table 3. The members are numbered in the order in which their stiffness and load types are input in Table 3.

Monitor joints and members have iteration data output in Table 7 which may be used to study the closure process. During the member solutions the displacements and equilibrium errors at the first station inside the member's "From" and "To" joints and at the middle station of the member are printed out for each monitor member. Off-curve messages are generated for all members if the limits of the member's stress-strain or q-w curve are exceeded in a particular iteration, and the number of iterations a member undergoes and whether or not it is in equilibrium are printed for each member.

A summary of the displacements and equilibrium errors for the monitor joints is printed in Table 7 at the end of the problem with any off-curve messages that might have been generated for the monitor joint Q-W curves.

The iterative process is stopped if any member fails to converge within the specified number of member iterations during any one of the frame iterations or if the solution for joint displacements fails to converge within the specified number of frame iterations. The output from a solution that does not converge is tagged with appropriate warning statements and should not be used for design purposes.

Off-curve messages for all members and all joints for the final solution of the problem are given in Tables 8 and 9.

Output Tables

Table 8. Joint Displacements and Reactions - gives displacements and reactions for all frame joints. Only supported joints (those with spring restraints) will have nonzero reactions.

Undefined displacements, such as the rotation of a joint to which all members are pinned and the three displacements of a joint to which no members are connected, are indicated in the output by extemely large displacements. If the final displacements of a joint are such that the limits of the Q-W curve are exceeded, an off-curve message is printed for that joint.

Table 9. Member Results - gives member-end-forces or detailed output for all members, as requested in Table 5A. Member-end-force output consists of the axial forces, shears, and bending moments at the ends of the member; complete member output lists the axial, lateral, and rotational displacements as well as the axial force, shear, and bending moment at every station (nodal point) along the member.

For either choice of output, the axial forces, shears, and bending moments are in a normal member sign convention. Positive axial force produces tension in the member; positive shear tends to raise the end of the member nearest the origin of the member's x'-axis; and positive bending moment produces tension on the bottom side of the member. Positive displacements are in the positive direction of the member axes; thus, positive rotations are counterclockwise. The axial force is parallel to and the shear force is normal to the member's original undeformed x'-axis. The direction of the member's x'-axis is as input in Table 3 and is given with the member output for convenience.

The values of axial force, shear force, and bending moment are the normal engineering values except that average values are given when there is a double value at an interior point due to a concentrated load or couple.

If the final displacements or strains in a member are such that any of the limits of the q-w or stress-strain curves are exceeded an off-curve message is printed for that member.

<u>Table 10. Joint Equilibrium Errors</u> - gives the equilibrium errors at all joints from the final solution of a problem. The errors will all be less than the specified limits if the solution converged, except at a joint where a specified displacement was enforced. The equilibrium error corresponding to such a displacement is the force absorbed by the structure in enforcing the displacement.

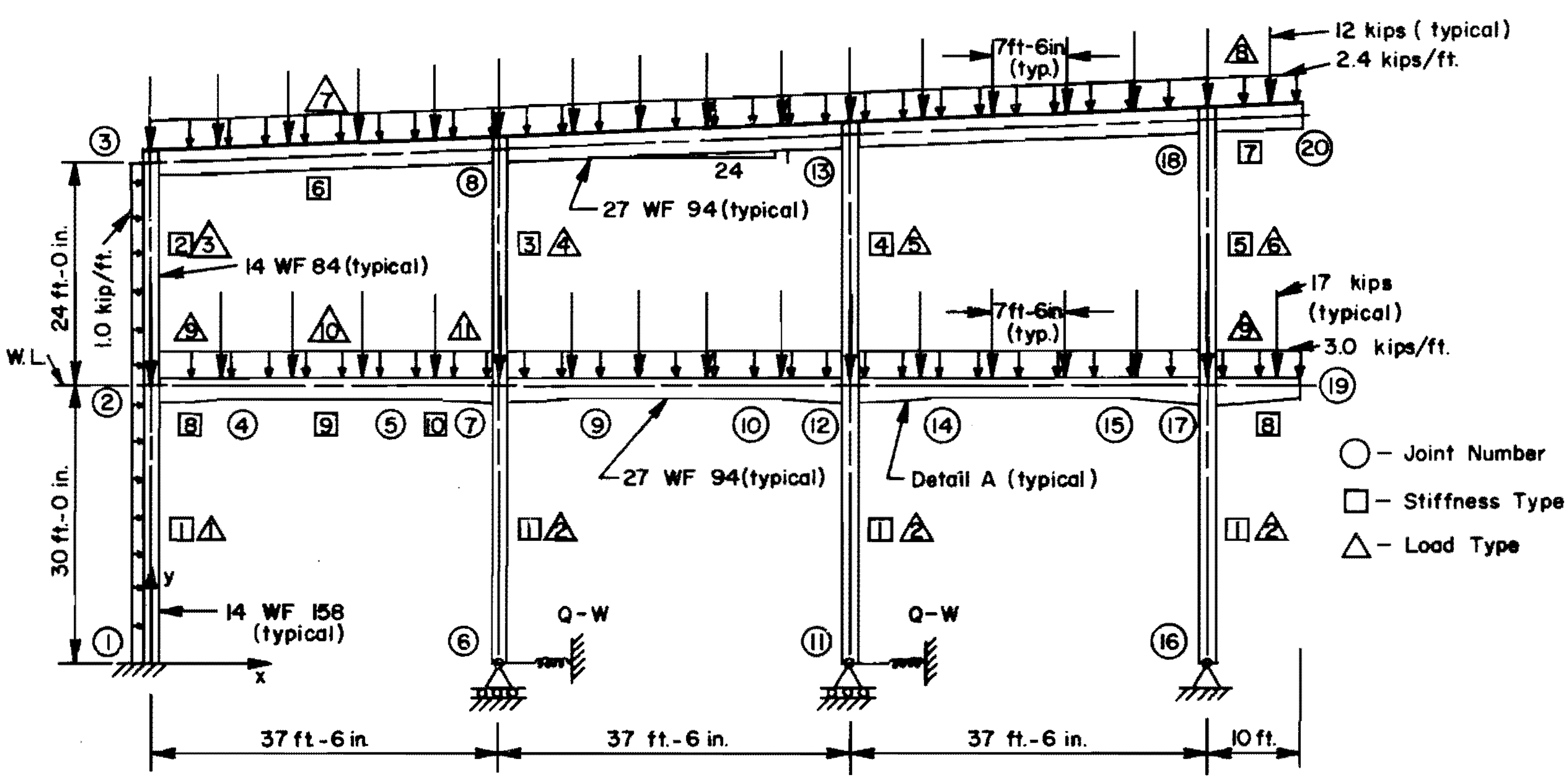
Example Frame

The frame shown in Fig 14 was chosen to illustrate the input features of the program. All of the input tables except Table 5D are used in coding the frame. The use of the distributed soil support curves defined in Table 5D is illustrated in Chapter 9. The input and output for the frame may be found in Appendices H and I (Problems 501 and 502).

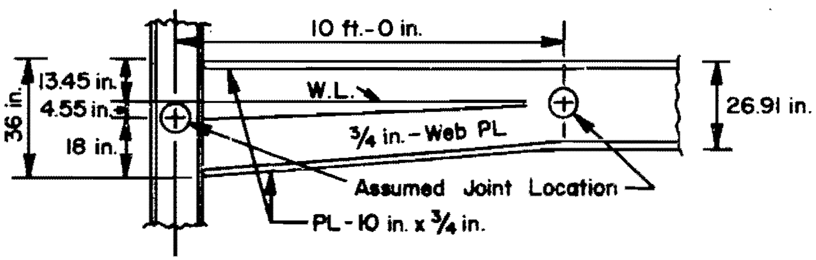
Location of Joints

The first step in coding Problem 501 is to number the joints. In general, the most efficient solution, in terms of time and storage requirements, is obtained by numbering the joints back and forth across the short direction of the structure, as illustrated by the encircled joint numbers if Fig 14(a). Joints 4, 5, 9, 10, 14, and 15 are located at the junction of the rolled section and the built-up section (see Detail A). These joints would not be required if the entire girder between adjacent columns were to be input as one member with linear stiffness properties.

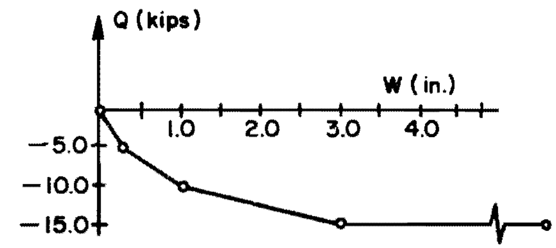
Joints 2, 7, 12, and 17 are located at the intersection of the column centerlines and the centroid of a vertical section through the tapered girder. This does not give a theoretically correct centroidal axis for a tapered section, since a section perpendicular to this axis is not quite symmetrical.



(a) Frame elevation.



(b) Detail A.



(c) Q-W support curve.

Fig 14. Example frame to illustrate input formats.

However, the angle of taper between the two flanges is less than 5°, and the error is insignificant. In addition, the representation of a member whose outer fibers are not parallel to the centroidal axis is not exact. However, Osgood (Ref 46) showed that the error involved in computing stresses by the common flexural formula is less than 5 percent for a taper angle of up to 20°.

The exact location of a tapered member's axis is not important. However, the variation in the section properties within the member is. Note that while the depth varies linearly the moment of inertia varies as the square of the depth for I sections and as the cube of the depth for rectangular sections. This variation in member properties is easily handled by the program. More information on the design of tapered connections is available in Ref 20.

The joint locations are input in Table 2. The first card gives the location of a reference joint. Joint 1 is chosen as the reference joint and is placed at the origin merely for convenience. The joint offsets are input to the nearest 1/10 inch; therefore, a reasonable tolerance of 3/10 inch is allowed. Joints 6, 11, and 16 are located from Joint 1 with only one card since they are all an equal distance apart and on a straight line. All joints are located with respect to one of the previously located joints. One check is made by inputting the hand calculated distance from Joint 20 to Joint 1. The joint check is satisfied and the computed joint coordinates are printed along with an echo print of the data. No joint checks are required by the program; however, for larger or more complex frames several checks are advisable.

Location of Members in Frame

All of the lower columns have the same length and cross section; hence, they were assigned the same stiffness type (type 1) in Table 3. The connections are different at the bottom of the columns, but this difference can be accommodated in defining the joint supports (Table 4). Only one of these columns has any lateral load acting on it and it is assigned load type 1. The other lower columns have only their own weight as a member load and are assigned load type 2. If the weight of the columns were neglected, these columns could be assigned zero load type and no loading would have to be defined for them in Table 6. The upper columns all have different lengths and are all assigned different stiffness and load types. However, the areas of the columns are all equal and these need only be defined once in Table 5B.

All of the upper girders except the overhang may be given the same stiffness type (6) and load type (7) and input with a single card. The members are numbered internally in the order the members are input; thus, these three members will have successive numbers. The computed member numbers and the member lengths and x and y offsets are output in Table 3 in addition to an echo print of the data. The three stiffness and three load types for one typical haunched girder are used for all the haunched girders.

Joint Loads and Supports

The joint loads are specified in Table 4A, in structure coordinates. The idealized fixed support at Joint 1 is obtained by specifying three large linearly elastic spring constants which effectively prevent horizontal and vertical movement and rotation. The roller supports at Joints 6 and 11 are obtained by specifying only a large vertical spring restraint at these joints. The nonlinear horizontal support at these joints is specified by the Q-W curve discussed below. The pinned support at Joint 16 is obtained by specifying large horizontal and vertical restraints but no rotational restraints. This effectively pins the end of the member at the joint whether or not the member has a pin specified at this end in Table 5A.

The soft nonlinear lateral joint support at Joints 6 and 11 in combination with the rigid vertical support might occur if the column were supported on a pile or piles passing through a relatively soft soil layer and then resting on a very stiff layer. Of course the vertical support would not be truly rigid. In fact, as discussed in Chapter 9, the entire pile support could be studied using the program either separately or as a part of the frame.

The Q-W curve which defines the lateral response of the foundation is specified by inputting the curve number in Table 4B and then defining the curve in Table 4C. Different curves could, of course, be defined for different joints.

Member Stiffness Data

For the purpose of this problem, all of the members' stress-strain responses were assumed linear; thus, all the stiffness types could have the nonlinear option left blank and have their stress-strain curve defined by merely inputting the modulus of elasticity E .

However, to illustrate both methods of input several of the member stiffness types are assigned a nonlinear option of 1 and a linear stress-strain curve is input for these stiffness types. The modulus of elasticity for all members was assumed as 30,000 ksi, and it was assumed that it was desirable to keep the stress level below 24 ksi. By inputting the stress-strain curve as two points, 0, 0 and 24.0, 0.0008, the desired E is obtained. Furthermore, the off-curve message indicates when the stress level exceeds the maximum stress specified on the curve. The stress check is made at the location of each discrete rotational spring in the members (two checks per element). The stress found by the program is the same as one would calculate by adding the axial stress P/A to the bending stress Mc/I , with due regard for sign.

Stiffness type 1 is input in Table 5A with the nonlinear option equal to 1 and the area numbers at the column ends are assigned area number 1. The area of the 14WF158 will then be described as area number 1 in Table 5B. The number of cards following the first card in Table 5A will always be one when the nonlinear option is equal to 1. The axis option may be either 1 or 2 since there are not any member spring supports. The output option is left blank so complete output will be printed for members with these stiffness types. Stiffness types 2, 3, 4, and 5 all have the same cross-sectional area so they are all assigned area number 2. Since the members with stiffness types 3, 4, and 5 have no lateral loads acting on them the output option is set equal to 1 to give only partial member output in Table 9.

Stiffness types 6 and 7 are input with their nonlinear option blank. Then since they are prismatic and do not have any member spring restraints, only one card is required to define their stiffness data. The check on the maximum stress will not be made on members with these stiffness types since their stress-strain curve is defined only by its modulus E .

Stiffness types 8, 9, and 10 are used to define the three sections of a typical haunched girder. Stiffness type 8 is input with area number 4 at its "From" joint and area number 5 at its "To" joint. Stiffness types 9 and 10 complete the defining of the stiffness types.

The five cross-sectional areas are each input as three rectangles in Table 5B and all are assigned stress-strain curve number 1, though several different stress-strain curves could have been used to define different grades of steel or different allowable stress conditions.

The stress-strain curve is input as two points in Table 5C for the reasons previously stated. The final stress and strain values used in the program are the product of the curve values and the stress and strain multipliers in Table 5B.

Member Load Data

The member load types are defined in Table 6. Load types 1 through 6 have only uniform loads over their full length and thus require only one data card. These load types are all given axis option 1. Thus, loads are oriented completely with respect to member axes, i.e., lateral loads are loads in the direction of the member's y'-axis and per unit of length along the member's x'-axis ($q_{y'x'}$).

Load types 7 and 8 have both distributed and uniform loads. The concentrated loads are input by having their "From" and "To" distances equal. Axis option 2 is used; hence, the concentrated loads are specified in the direction of the structure's y-axis (vertical), and the uniform load is input as a load acting in the direction of the structure's y-axis and per unit of length along the member's x'-axis ($q_{yx'}$). Distances are measured from the member's "From" joint along the member's x'-axis for axis option 2. An allowance for the weight of the girders is assumed to be included in the uniform loads given in Fig 14(a).

Load types 9, 10, and 11 are similar to 7 and 8 except that axis option 3 is used in order that the distributed loads may be input as parallel to the structure y-axis per unit of length along the structure's x-axis (q_{yx}).

Iteration Control (Input and Output)

The maximum number of consecutive iterations for both the frame and member solutions is set at 10 and monitor joints and members are selected in Table 7. The concentrated loads on the frame are probably only accurate to about 0.2 kip. Thus a reasonable joint force equilibrium error would be 0.02 kip and a reasonable joint moment equilibrium error would be the length of a typical member times the force, about 10 kip-inches. The member errors are set at one-tenth of the corresponding frame errors. Looking at the summary of frame iterations output at the end of Table 7 it appears the joint displacements have converged to four significant figures during the four frame iterations. The member solutions are seen to have all converged in two iterations or less.

Since the stress-strain curve was input as linear for all members, the only sources of nonlinearity are the geometric effects and the two nonlinear supports. The primary geometric effect was the $P\Delta$ moments, due to the relatively large joint displacements.

Results for Problem 501

Table 8 gives the displacements and reactions at all joints. The horizontal reactions and displacements of Joints 6 and 11 are seen to be compatible with the Q-W curve input for the joints. The horizontal displacements of the joints are rather high in general and might necessitate a redesign even if the stresses were at an acceptable level.

Scanning Table 9 one finds that member numbers 1, 14, and 15 have off-curve messages printed for them. This indicates that they have a stress higher in magnitude than the limit of their stress-strain curve, which was input as 24 ksi. Note that a stress check was not made for the upper girders, because of the way their stiffness data were defined. Lateral displacements in the girders seem reasonable.

The member output should, of course, be studied in more detail. Checking the many design requirements, such as shear, deflection, and lateral bracing, would be facilitated by the detailed member output. Based on such a study, the frame members could be revised and another analysis run. Several loading conditions would also need to be run. The designer might also want to investigate the redistribution of moments that occurs after initial yielding of the frame, by inputting the complete stress-strain curve for the steel. The effects of nonlinear material response are discussed in Chapters 6 through 10.

The number of elements per member was specified as 20 in Table 3. A check solution was run with 10 elements and the differences between the two solutions were small.

Problem 502 - Joint Effect

In Problem 501 the members were assumed to be rigidly connected at the theoretical joint locations. This is not always a valid assumption, as shown in the joint study reported in Chapter 7. For the frame shown in Fig 14 it is doubtful that any bending deformations would occur in the columns within the joint region. Thus, Problem 502 was run holding all the data from Problem 501 except Table 5A, in which the connections for the member stiffness types are given. The stiffness types of all the columns are to be changed; hence, the entire table was replaced. If only one or two stiffness types changed, it would be easier to assign new stiffness types to the members that changed (in Table 3) and then hold Table 5A and add on these new stiffness types. Note that if only the area of a stiffness type changes, all that is required is to redefine this area in Table 5B.

The length of stiffness type 1 is almost 30 feet, and the length of one of the 20 elements in it is approximately 18 inches. Thus, if one rigid element is specified at the top of stiffness type 1, one end of the element end will coincide with the edge of the connection. The length of stiffness types 2 through 5 is approximately 24 feet, and the length of one element is approximately 14-1/2 inches. Thus, one rigid element at the top of these stiffness types will be just outside the 27WF94 and one rigid element at the bottom will be just inside the built-up section. There is no need to try to exactly match the edge of the rigid element with the face of the connection since the behavior of the joint is not known that precisely. Using 20 to 40 elements per member, one can usually come close enough to model the effect that the joint stiffness has on a frame's behavior.

No elements are specified as remaining linear beyond these rigid elements, since the stress-strain curves are linear to start with. Note that an off-curve message will not be generated for any element that is specified as rigid or linear, regardless of the stress level.

Problem 502 is run as a type 2 problem, since the displacements are not expected to be too different from those of Problem 501. Problem 502 converges in only two frame iterations, two less than for Problem 501. The results of Problem 502 show that the lateral displacements of the joints are reduced by approximately 9 percent due to the joint effect. The moments in the laterally loaded exterior column are also reduced, but the off-curve messages are still generated for the same members as before.

CHAPTER 6. SOME ANALYTICAL VERIFICATIONS

In this chapter, comparisons are made with other nonlinear solutions of single members. The comparisons show that the proposed analysis is capable of considering both material and geometric nonlinearities. All discrete element solutions are for 40 elements unless otherwise indicated.

Cantilever with Large Displacements

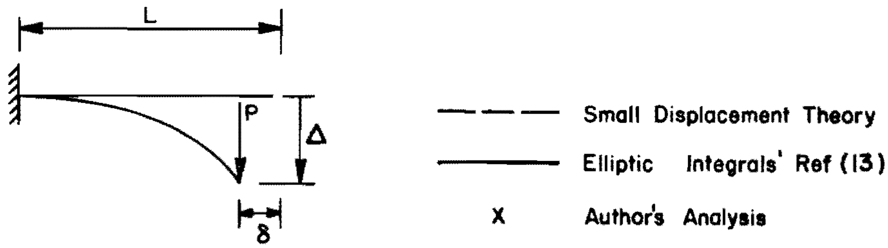
A cantilever with a point load as shown in Fig 15 was analyzed using the program developed herein. The actual cantilever used in the program was 100 inches long and had a modulus of elasticity E of 1000 psi, an area A of 1 square inch, and a moment of inertia I of 1 inch^4. The nondimensional load displacement curves of Fig 15 compare well with the large displacement solution by elliptic integrals made in Refs 21 and 13. Note that for a lateral displacement ratio Δ/L of less than 0.2, the differences between the lateral displacement ratios for large displacement and small displacement solutions are small. However, the axial displacement δ may be significant and this is not predicted by a small displacement solution.

The same cantilever was analyzed for a uniform load. The nondimensional load displacement curves are shown in Fig 16. The results are in good agreement with the series solution found in Ref 52. The nonlinearity for the uniform load is not as severe as for the concentrated load. This is because for a given lateral displacement, the center of gravity of the uniform load does not move toward the support as much as the end of the cantilever does.

It was assumed in the analyses that the material remained linearly elastic throughout. This assumption would be questionable in most civil engineering applications.

Post Buckling Analysis

Using large displacement theory, a column made of a linearly elastic material does not exhibit the indeterminacy of position indicated by small



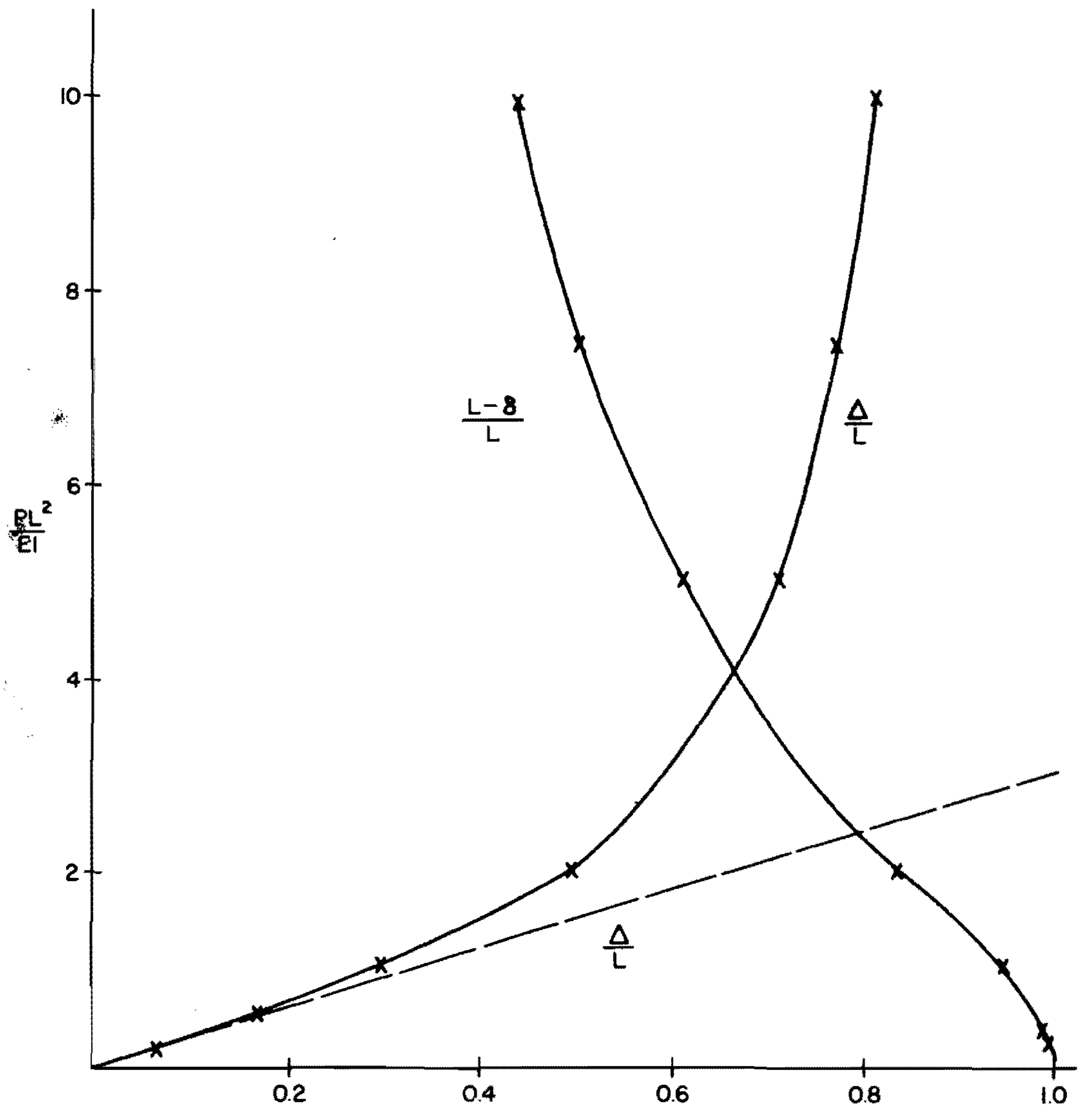


Fig 15. Large displacements of cantilever with concentrated load.

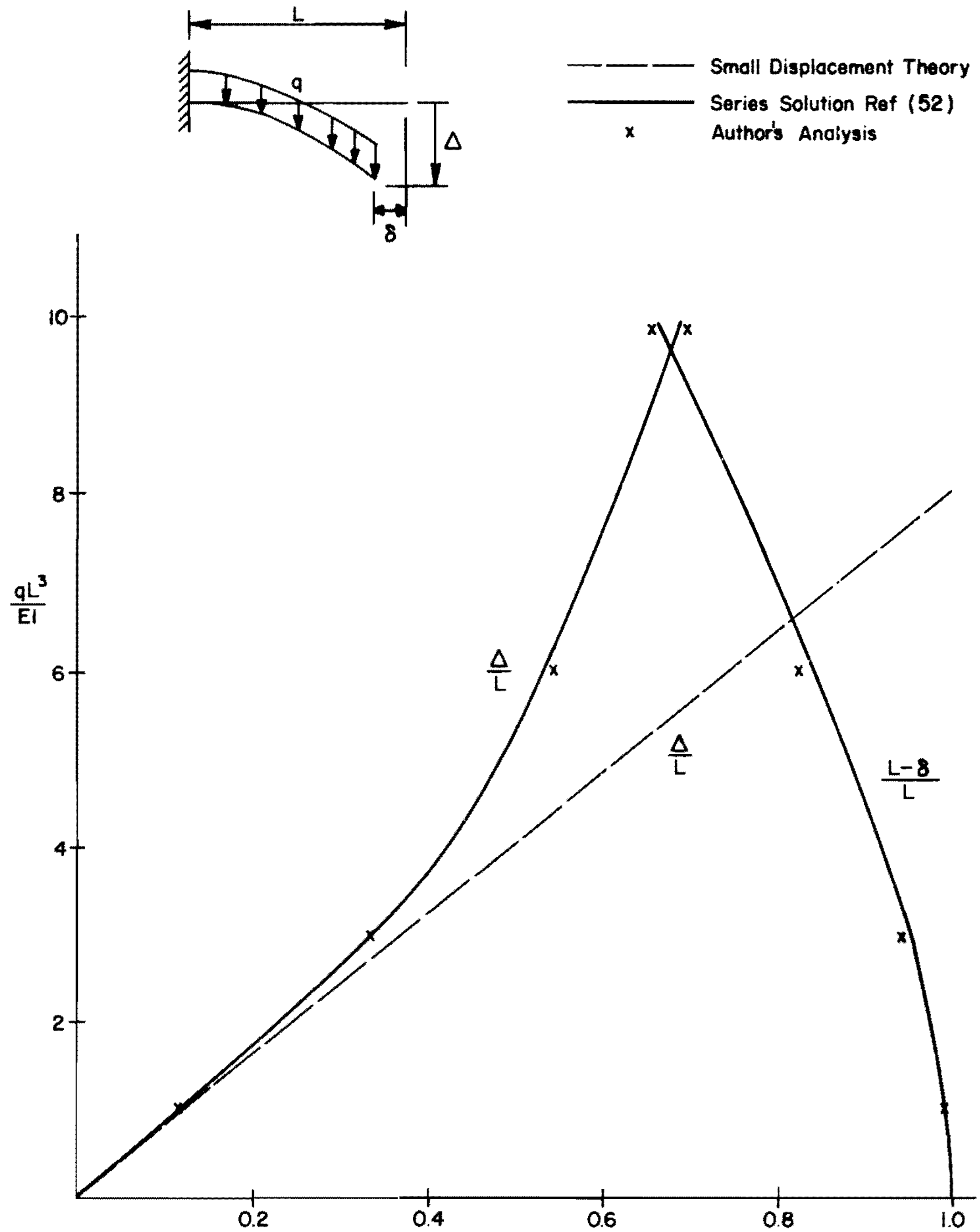


Fig 16. Large displacements of cantilever with uniform load.

displacement theory. Rather, as shown in Fig 17, at the Euler buckling load P_E the column will begin to deflect horizontally a large but finite amount under increasing axial load. Timoshenko (Ref 56) has solved the problem considering large displacements using elliptic integrals. The results of two solutions are compared with Timoshenko's large displacement solution in Fig 17. The two solutions made using the proposed method were for small lateral loads, $Q = 0.01P_E$ and $Q = 0.001P_E$. The small lateral loads were necessary to disturb the column from an unstable equilibrium position which the solution would find if no disturbing forces were present. Comparing the curves, it is seen that as Q approaches zero the discrete element solution approaches Timoshenko's post buckling solution. Thus, the discrete element solution can be used to approximate the post buckling behavior of slender columns and it can also be used to handle more realistic problems in which the lateral loads are not zero.

Membrane Forces

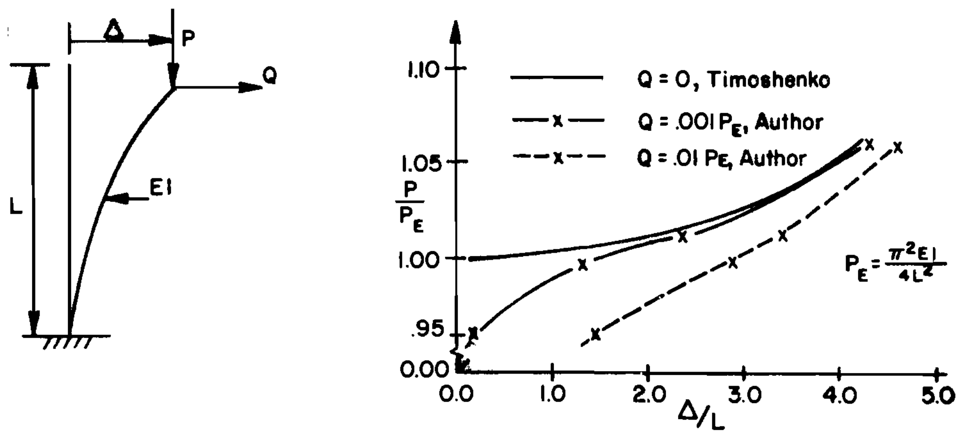
The stretching of the centroidal axis can produce large tensile axial forces which will greatly increase the stiffness of thin members composed of a linearly elastic material. Timoshenko (Ref 57) has a solution by elliptic integrals for a wide plate subject to a uniform load, as shown in Fig 17. The wide plate may be analyzed as a beam using an effective area and moment of inertia equal to their nominal values divided by $(1 - \mu^2)$, where μ is Poisson's ratio for the material. Murray presented a finite element solution of this problem in Ref 44. The solution developed herein compares favorably with both Murray's and Timoshenko's load displacement curves.

The maximum stress $(P/A + Mc/I)$ for a q of 5 ksi is 70.8 ksi and thus, the solution would be valid only if a high strength steel were used.

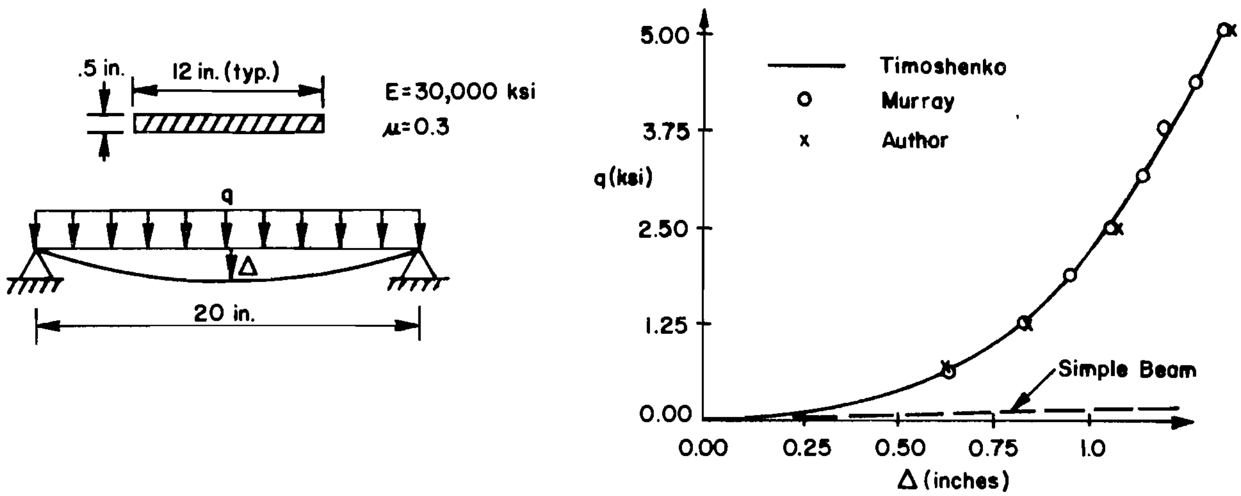
In the preceding solutions in this chapter nonlinear material properties were not considered. This was not due to their lack of possible importance, but because the solutions they were being compared with did not consider nonlinear materials properties.

Elastic-Plastic Analysis of Cantilever

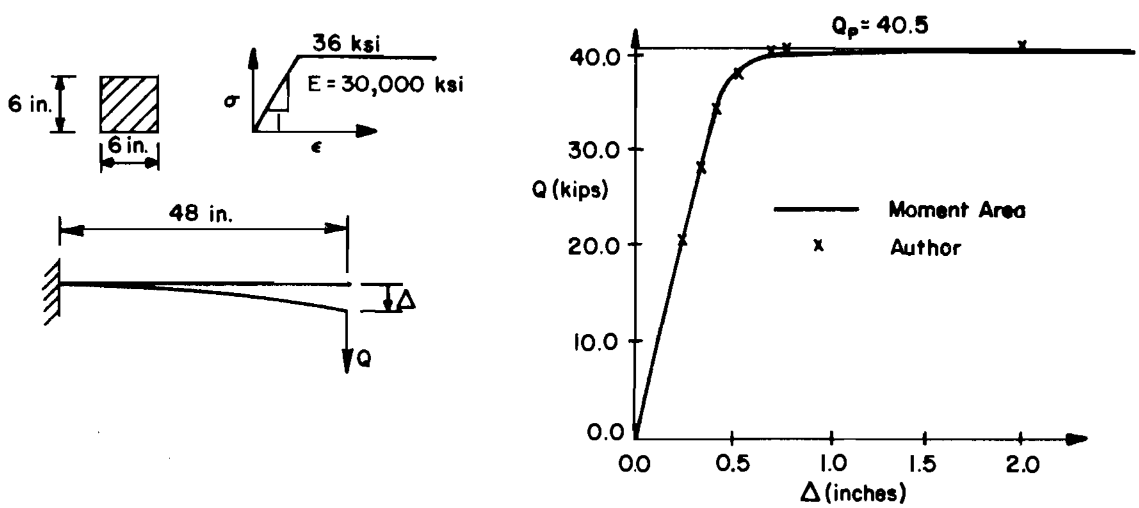
For a rectangular cross section and an elastic-plastic stress-strain curve as shown in Fig 17 the relationship between moment and curvature can be expressed in closed form (Ref 14).



(a) Post buckling analysis.



(b) Membrane forces in wide plate.



(c) Elastic-plastic analysis.

Fig 17. Example problems.

The displacement for the cantilever beam shown in Fig 17 can be obtained by using the moment-curvature relationship and the second moment area theorem. In using the moment area theorem the area of the curvature diagram is used rather than the normal M/EI diagram, since for moments above the yield moment the curvature is not equal to M/EI .

The load-displacement curve from a moment area analysis using the trapezoidal rule with 200 increments along the beam is shown in Fig 17 along with the 40 element discrete element solution. The results are in extremely good agreement. The moment area solution did not consider large displacements and hence it indicates that as the load Q approaches the mechanism load Q_p , the displacement becomes indefinitely large. The discrete element solution considers the effect of large displacements and thus, a load slightly in excess of Q_p was found ($Q = 40.9$ kips). The slightly higher load is also due to the fact that the maximum internal moment evaluated in the discrete-element is at the discrete rotational spring which is located a distance of $h/2 = 0.3$ inch from the theoretical end of the cantilever.

<u>Convergence Study for Cantilever Beam</u>

The cantilever beam examples were run using 4, 6, 8, 20, and 40 elements. The percent error in the lateral displacement-length ratio Δ/L is plotted versus the reciprocal of the number of elements ($1/m = 2h/L$) in Fig 18. The percent error is seen to approach zero as the number of elements increases, indicating the discrete element solution converges as the element length decreases.

The curves in Fig 18 for the large displacement analyses (cantilever with concentrated and uniform loads) show the convergence is extremely good. The four-element solution is in error by less than 1 percent. The curves appear parabolic, indicating second order or quadratic convergence.

Two curves are shown for the cantilever with nonlinear material properties. For the lower of the two curves ($Q = 0.95Q_p$) the error is only approximately 2 percent for a four-element solution and the convergence still appears quadratic. The upper curve ($Q = 0.99Q_p$) is essentially linear, indicating first order convergence. However, the 40-element solution is in error by less than one percent.

All problems reported herein used 40 elements per member, unless otherwise indicated, and many of these were compared with preliminary solutions

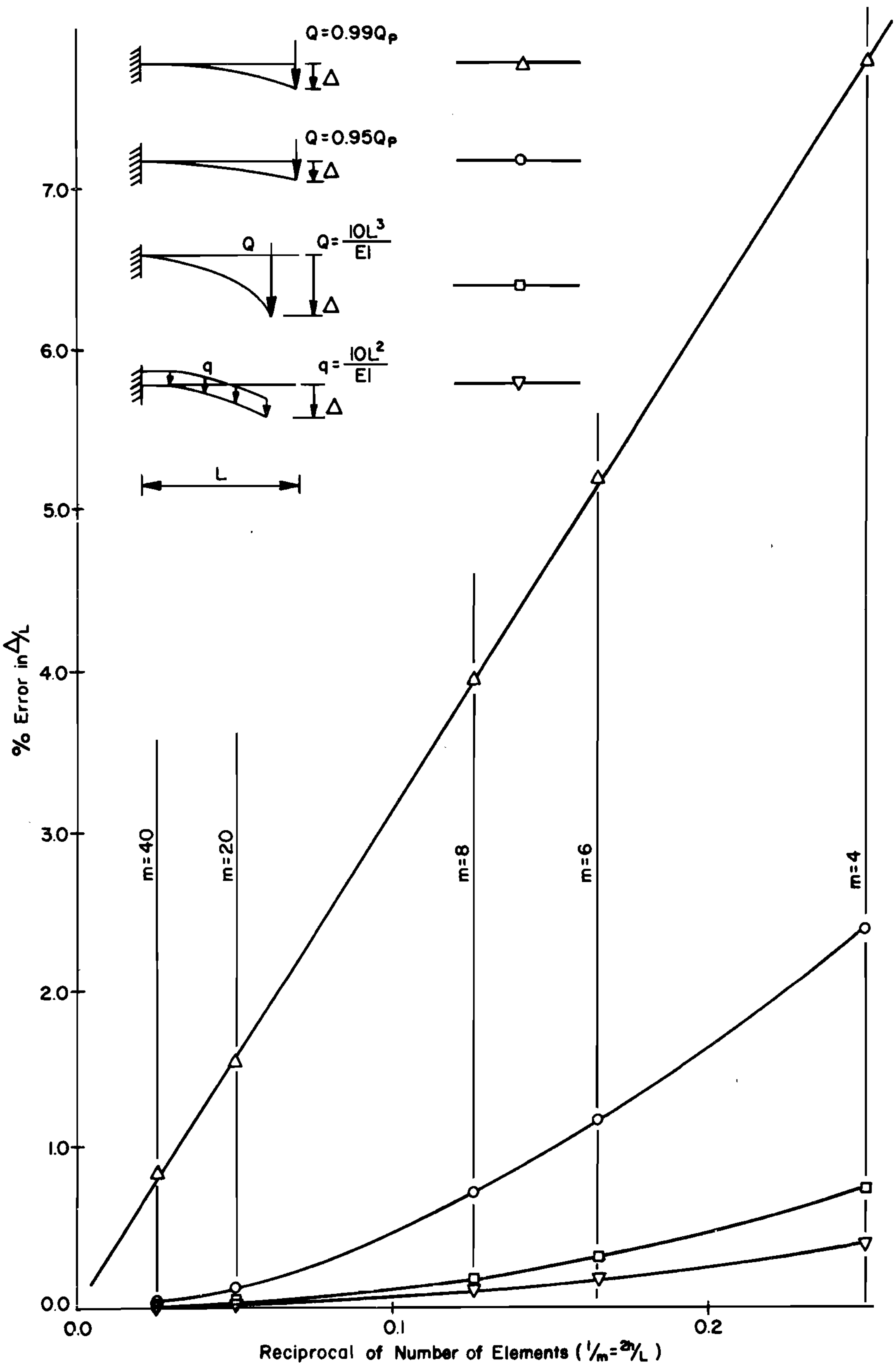


Fig 18. Convergence study for cantilever beams.

using fewer elements. The comparisons indicated that the 40-element solution was close to convergence in all cases, and most of the examples could be solved with good accuracy using fewer elements. Since the amount of computation time is a linear function of the number of elements per member, it may be wise to use fewer than 40 elements for applications where four-significant-figure accuracy is not required. The number of elements used could then be varied occasionally to get an idea of the discretizing error for particular types of problems.

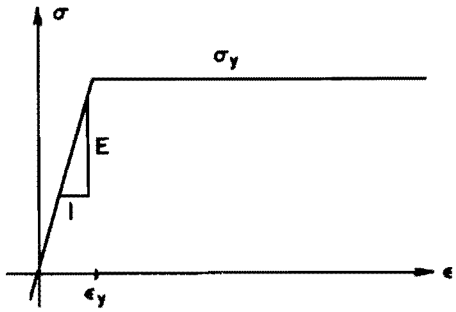
Moment-Curvature-Thrust (M-ϕ-T) Curves for Wide Flange Members

The relationships to describe the M-ϕ-T curves for a wide flange section have been developed at Lehigh and are reported in Ref 33. The elastic-plastic stress-strain curve shown in Fig 19 was assumed and the section was idealized as three rectangles, as shown in Fig 19. Nondimensional curves showing the M-ϕ-T relation for various values of axial thrust divided by the yield thrust T_y are shown in Fig 20.

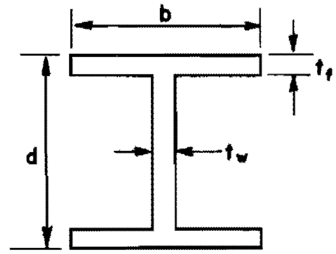
The solid curves do not consider the effect of residual stresses. The dashed curves consider the effect of residual stresses caused by the cooling of rolled shapes. During the cooling process the exterior portions of a cross section cool first and the inner portions cool last. The portions that cool first develop residual compressive stresses and the portions that cool last develop residual tensile stresses. Thus, the tips of the flanges tend to develop residual compressive stresses. This causes the tips of the flange to yield at an average compressive stress P/A below the yield stress, and hence, the bending stiffness of the section is reduced, as is evident from the M-ϕ-T curves in Fig 20.

The straightening or cold rolling processing produces other residual stresses which tend to offset the cooling residual stresses. Sections built up by welding plates together or to wide-flange shapes have residual stresses which may be appreciably higher than cooling residual stresses.

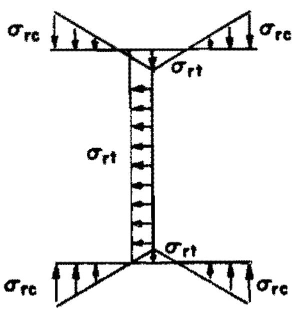
The exact distribution of cooling residual stresses can be found only by a costly testing procedure (Ref 31). The M-ϕ-T curves developed at Lehigh were based on the idealized cooling stress distribution shown in Fig 19. The residual compressive stress σ_{rc} is taken as some portion of the yield stress ($\sigma_{rc} = 0.3\sigma_y$ for the M-ϕ-T curves in Fig 20). The residual tension stress



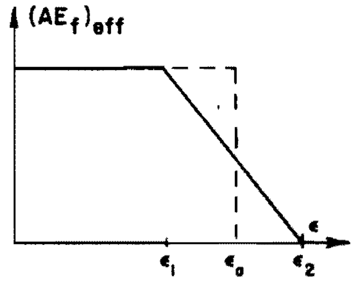
(a) Elastic-plastic stress-strain curve.



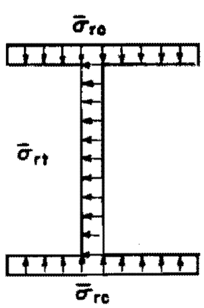
(b) Wide flange section.



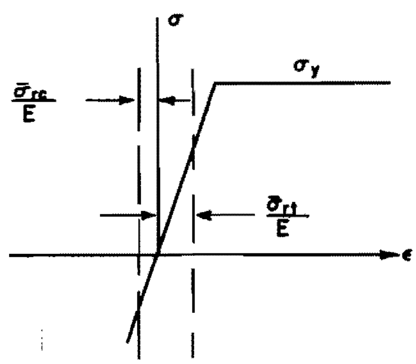
(c) Idealized cooling stresses.



(d) Effective EA of flange.



(e) Constant stress model of cooling stresses.



(f) Axis shift for flange and web.

Fig 19. Approximate solution for residual stresses in wide-flange section (strong axis bending).

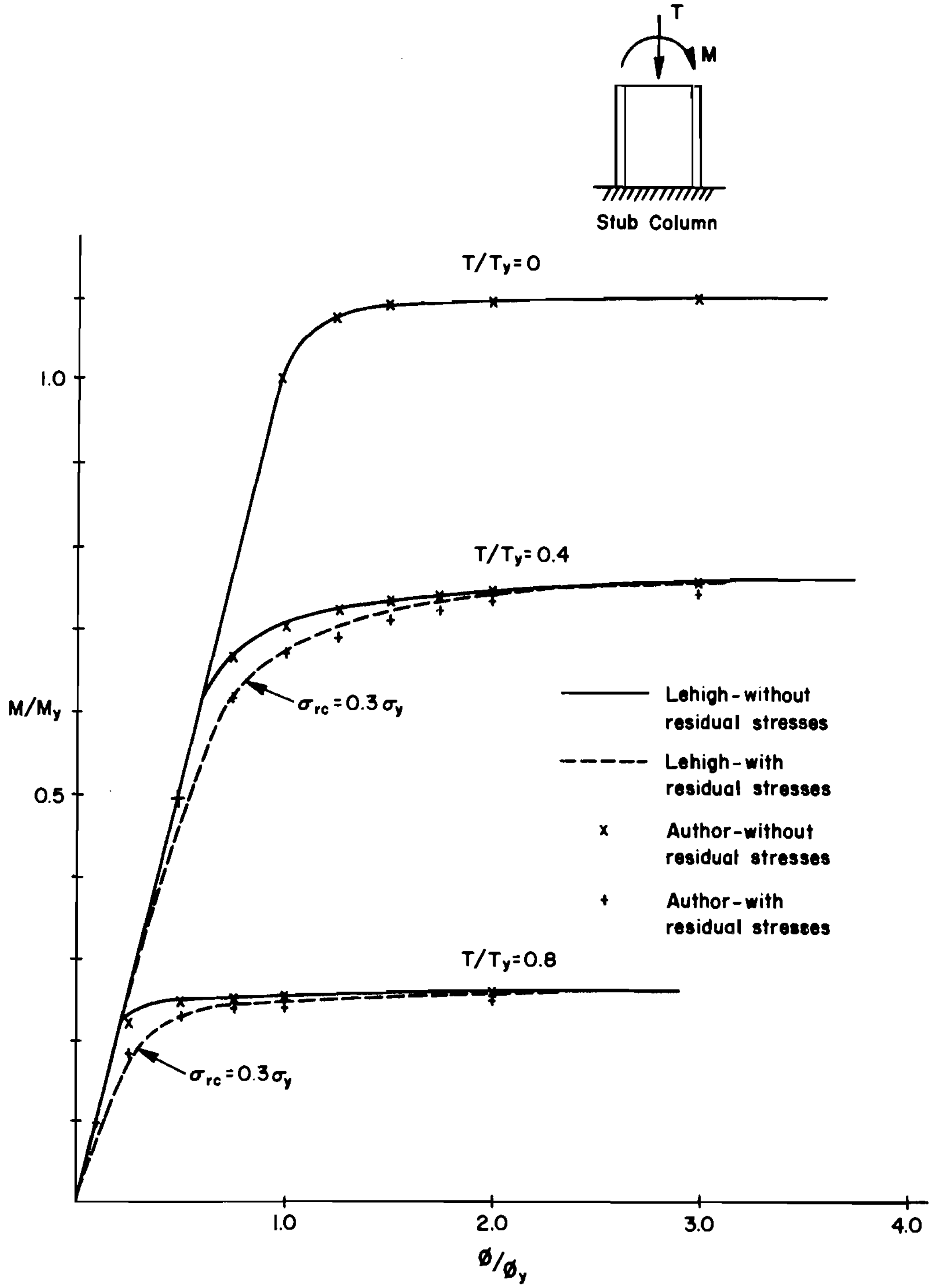


Fig 20. Nondimensional M-ϕ-T curves for 8 WF31 (strong axis bending).

σ_{rt} is computed by Eq 6.1 such that the residual stresses are self-equilibrating:

$$\sigma_{rt} = \frac{\sigma_{rc} bt_f}{bt_f + t_w(d - 2t_f)} \tag{6.1}$$

It was desired to incorporate the effects of cooling residual stresses in the proposed analysis and still maintain the basic input device of nonlinear stress-strain curves that are constant over a given rectangle. Therefore, the following approximate solution was developed. As the compression flange of a wide flange yields under gradually increasing compressive strain, the outer fibers yield first at a strain ϵ_1 where

$$\epsilon_1 = \frac{\sigma_y - \sigma_{rc}}{E} \tag{6.2}$$

Then the complete flange yields at a compressive strain of ϵ_2 where

$$\epsilon_2 = \frac{\sigma_y + \sigma_{rt}}{E} \tag{6.3}$$

The effective AE of the flange varies linearly with ϵ as shown in Fig 19. This gradual yielding of the flange could be approximated by a flange that remained linearly elastic until it reached a compressive strain of ϵ_a, where ϵ_a is the average of ϵ_1 and ϵ_2. This approximation is justifiable since the energy absorbed by the flange in reaching the fully yielded state is the same for both cases. Note that if there is any curvature the flange will not have a constant strain over its depth. Thus, the change in stiffness will not be as abrupt as indicated above. A constant stress model of the stresses is proposed for bending about the strong axis of a wide flange section, as shown in Fig 19. There, $\overline{\sigma}_{rc}$ is a constant residual compressive stress in the flange and it is selected such that the flange will yield at a compressive strain of ϵ_a:

$$\bar{\sigma}_{rc} = \frac{\sigma_{rc}}{2} \; \frac{t_w(d - 2t_f)}{bt_f + t_w(d - 2t_f)} \tag{6.4}$$

To maintain equilibrium, $\bar{\sigma}_{rt}$ is given by

$$\bar{\sigma}_{rt} = \frac{\sigma_{rc} bt_f}{bt_f + t_w(d - 2t_f)} \tag{6.5}$$

It is easy to incorporate $\bar{\sigma}_{rc}$ and $\bar{\sigma}_{rt}$ into the proposed analysis as residual stresses over the flanges and the web as shown in Fig 19. Obviously, a more accurate representation of the assumed residual stress distribution could be made by further subdividing the cross section and specifying different initial stresses for each one. This technique could also be used to study temperature effects.

Discrete-Element Solution for M-ϕ-T Curves

The results of the discrete-element solution for M-ϕ-T curves and the Lehigh solution are shown in Fig 20. The curves not considering residual stresses are almost identical. The curves which consider cooling residual stresses are seen to be in essential agreement. The constant stress model, as expected, is initially stiffer than the Lehigh solution and then less stiff.

The computer program developed does not specifically develop M-ϕ-T curves as a part of the analysis. The thrust, axial force, and stiffness terms are generated by the integration process as needed in the frame iterative process. However, it was a simple matter to run a series of problems for a stub (short) column subject to various axial loads. The curvature was varied for each axial load to generate the curves.

Summary of Chapter 6

Several examples were discussed in the chapters which demonstrate that the proposed solution is capable of predicting the nonlinear response of members subject to either geometric or material nonlinearity. A brief error study indicated the good convergence properties of the discrete element solution. In succeeding chapters the method is applied to more realistic problems that combine both geometric and material nonlinearities, and the results are compared with other iterative solutions, where available, and with experimental results.

CHAPTER 7. STEEL FRAMES

In this chapter, the discrete element frame solution is used to model two steel frames. The results compare well with experimental data and other analytical solutions. The effects of joint rigidity and prestressed tie rods on the load-displacement response of the frame are demonstrated.

Hybrid Steel Frame

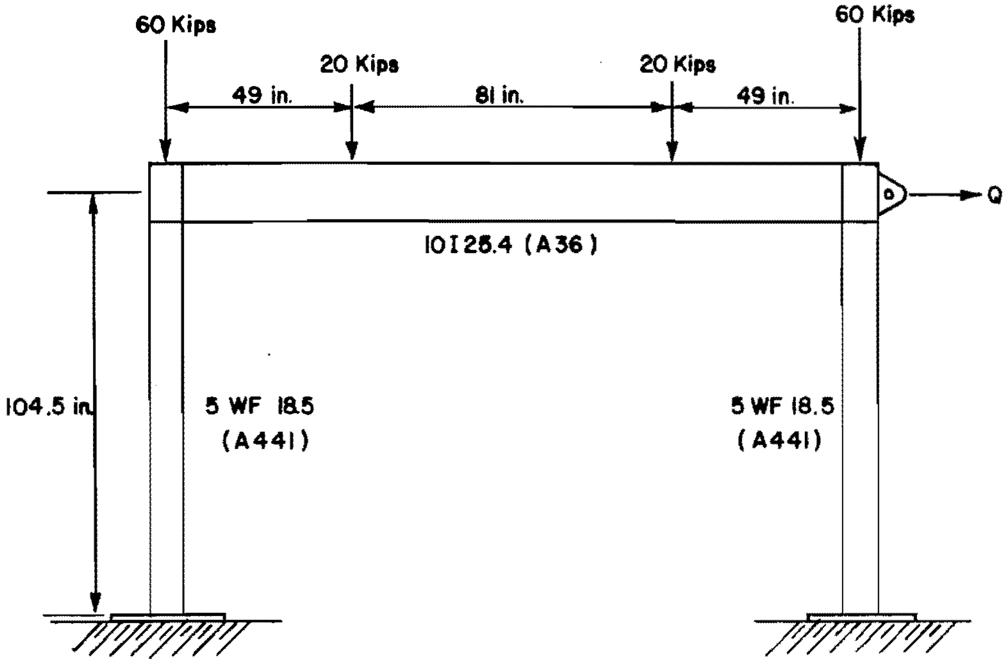
The hybrid steel frame shown in Fig 21 was tested at Lehigh University and is reported in Ref 9. The girder was composed of A-36 steel and the columns were made of A-441 steel. Average stress-strain curves obtained by averaging the results from several coupon tests are shown in Fig 21. Cross section properties were measured and found to be very close to handbook properties.

Base Restraint

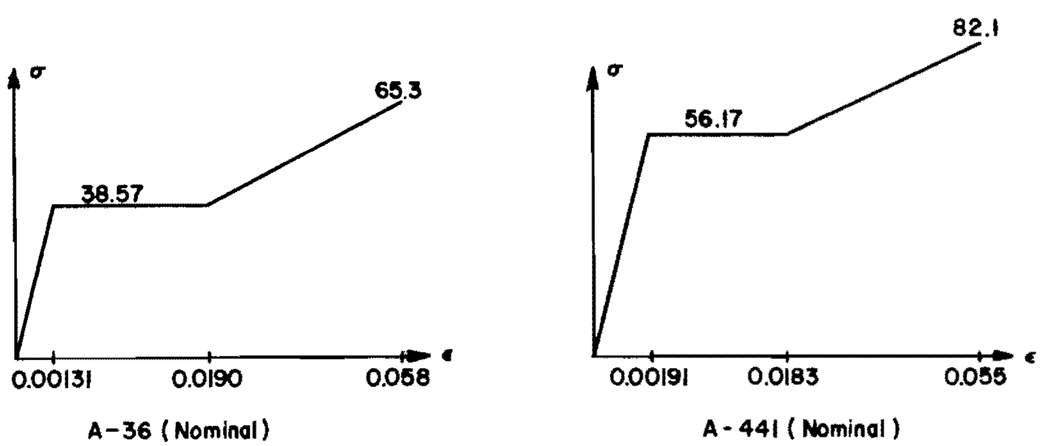
The bases were nominally fixed; however, some rotations did occur in the test and they were measured. In the present analysis, a rotational restraint of 200,000 lb-in/rad was used to simulate the partial base fixity. This value was also used by Gunnin (Ref 25). The present program is capable of considering nonlinear joint restraints; however, the experimental moment-rotation curves were essentially linear. Thus, a single spring constant was used.

Load-Displacement Curves

Load-displacement curves obtained from the test and from analyses by Arnold (Ref 31) and Gunnin (Ref 25) are shown with the discrete element solution in Fig 22. Arnold's analysis considered finite joint displacements, the beam column effect (P-y moments), and the effect of nonlinear material properties in the form of plastic hinges. Gunnin's analysis considered finite joint displacements and nonlinear material properties in the form of Ramberg-Osgood M-ϕ-T curves. The discrete element solution considers all large



(a) Frame dimensions and loads.



(b) Stress-strain curves for hybrid steel frame.

Fig 21. Hybrid steel frame tested at Lehigh University.

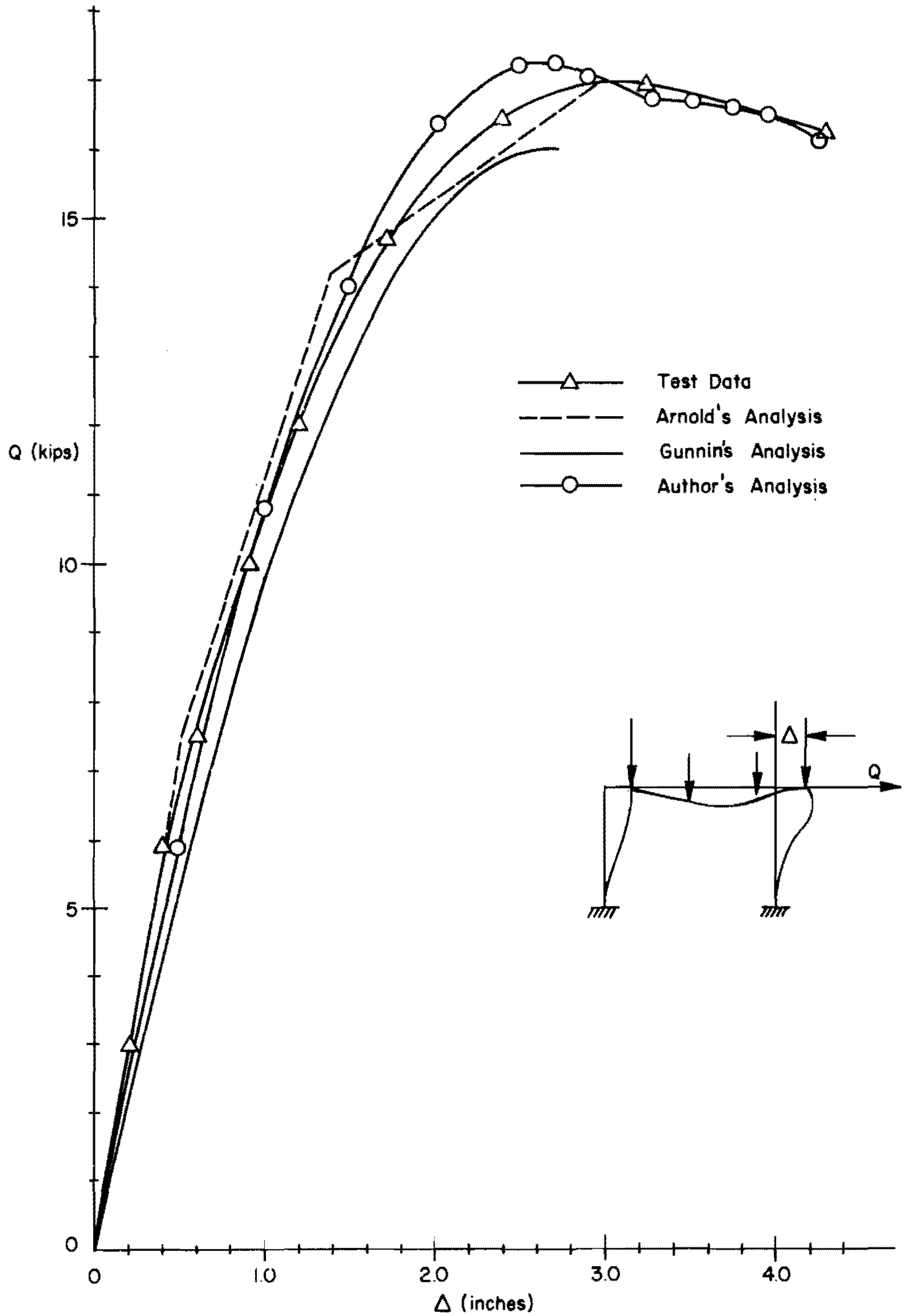


Fig 22. Analytical and experimental load-displacement curves for hybrid steel frame.

displacement effects and nonlinear material properties using the experimentally obtained stress-strain curves.

Residual Stresses

The residual stresses were also determined experimentally and were found to be low. The average value of compressive residual stress in the outer flange of the columns was 8 ksi. The discrete element solution was run once including these stresses in the manner developed in Chapter 6 and no plotable differences in moments or displacements occurred. Arnold did not include the effects of residual stresses in his analysis. Gunnin's analysis includes them indirectly in that he uses different coefficients for the M-ϕ-T curves for columns to account for the effects of residual stresses.

Stiffening Effect of Joints

All of the analyses shown in Fig 22 considered the fact that due to the stiffening effect of the joint the plastic hinge formed away from the face of the connection at a distance equal to the depth of the member d in which the hinge formed. However, Yura stated (Ref 62), based on experiments reported in Ref 63, that the plastic hinge tends to form at a distance of only $d/2$ from the face of the connection in larger members. The location at which the hinge forms as well as the deformation in that region can have a marked effect upon the frame's load-displacement response, as demonstrated later in this chapter.

Comparison of Load-Displacement Curves

All of the analytical curves are in good agreement with the experimental data, although Gunnin's analysis is consistently less stiff than the other solutions and the experimental data. This is possibly due to the Ramberg-Osgood M-ϕ-T curves used by Gunnin, which do not exhibit linear behavior initially. The maximum horizontal load observed experimentally was 16.9 kips, which Arnold predicted. Gunnin's maximum load was 16.0 kips and the maximum load the author found was 17.25 kips.

Specified Displacement Solution

The load of 17.25 kips was obtained by a controlled displacement solution. The horizontal displacement of the frame was varied by specifying a large spring and correspondingly large forces to enforce the desired displacement. This allowed the maximum load to be well defined and also allowed points on the descending or unstable portion of the curve to be obtained.

Another solution was run in which the horizontal load was applied in increments and the solution converged up to a load of 17.2 kips. This indicates that an applied load solution will converge reasonably close to the maximum load. However, fairly small increments are required because the frame's tangent stiffness is approaching zero.

In the unloading portion of the curve a definite change in stiffness at a displacement of 3.25 inches is observed. This is due to the fact that strain hardening in the beam starts at this time. Strain hardening has already occurred at several points in the columns.

Comparison with Experimental Moments

The discrete element solution for moments at the theoretical joint centerlines are shown with the experimentally observed values in Fig 23. The results compare quite well except for the moment M_D at the base of the loading column. Arnold's and Gunnin's analyses show a similar trend.

The high value reported for M_D does not seem plausible for two reasons. First, it is not in equilibrium with the other three observed moments, and second, it is over 50 percent above the plastic capacity of the section, considering axial force.

The moments at A and at B decrease as the horizontal load is initially applied. However, the unloading occurs at a stress below the yield stress and hence the assumption of no inelastic unloading is satisfied.

Joint Study

The high concentration of material around a "rigid" joint in a steel frame has two effects; first, it tends to cause the primary zone of yielding (plastic hinge) to occur away from the face of the connection, and second, it causes the bending deformations in the connection to be very small.

The computer program developed for the discrete element solution allows the user to vary the stiffness and strength of the joint as discussed in Chapter 6. This feature was used to study the effect of various assumptions of joint behavior. The load-displacement curves for four different assumptions of joint behavior are shown in Fig 24.

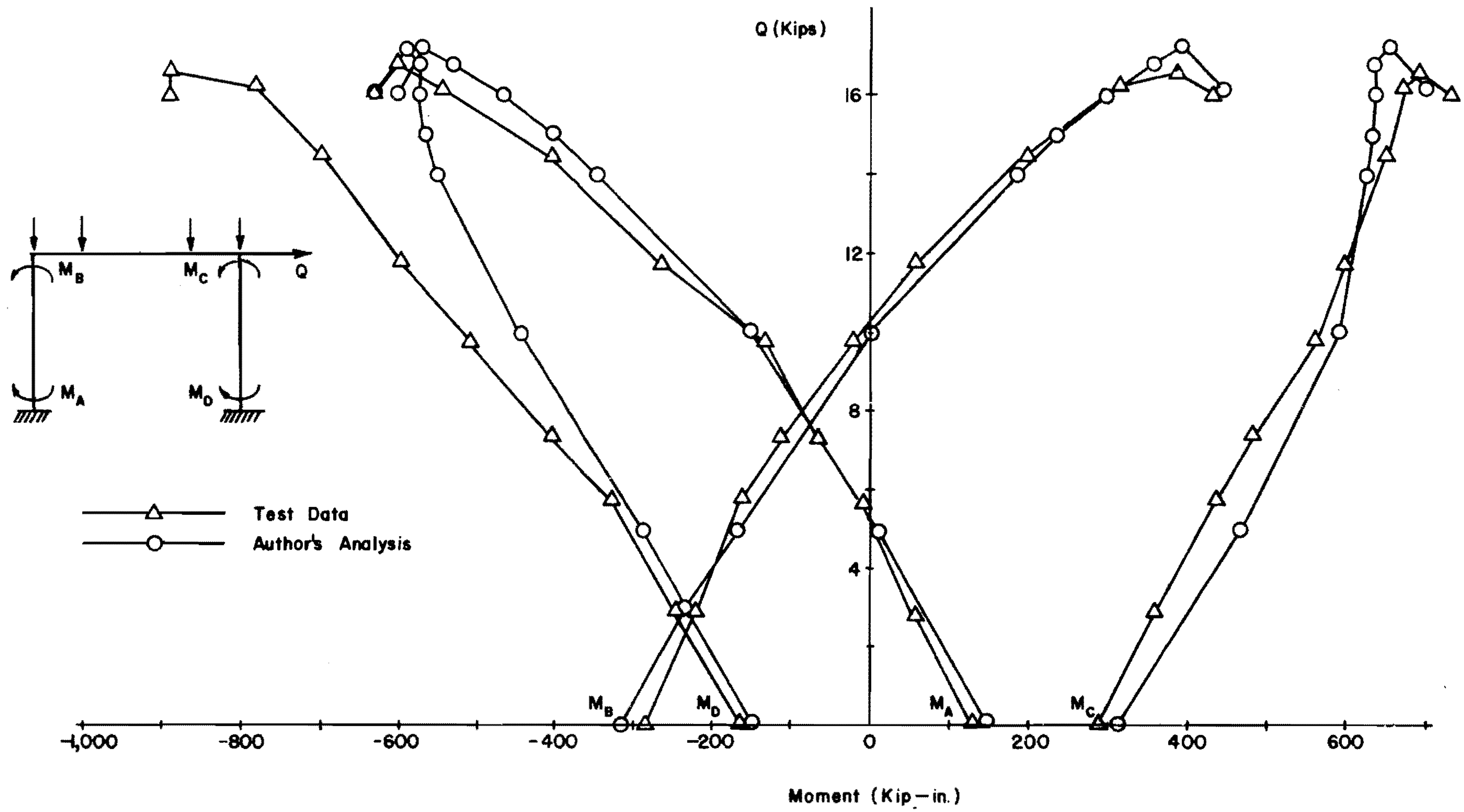


Fig 23. Load-moment variation in hybrid steel frame.

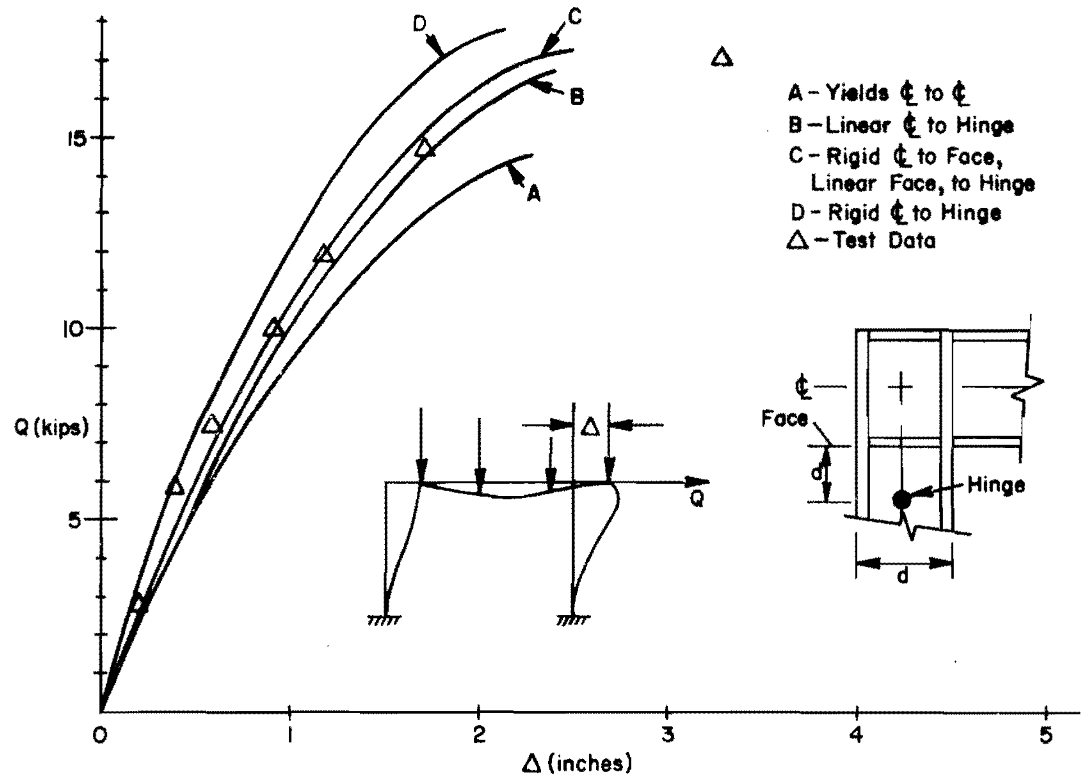


Fig 24. Effect of joint assumption on load-displacement curve for hybrid steel frame.

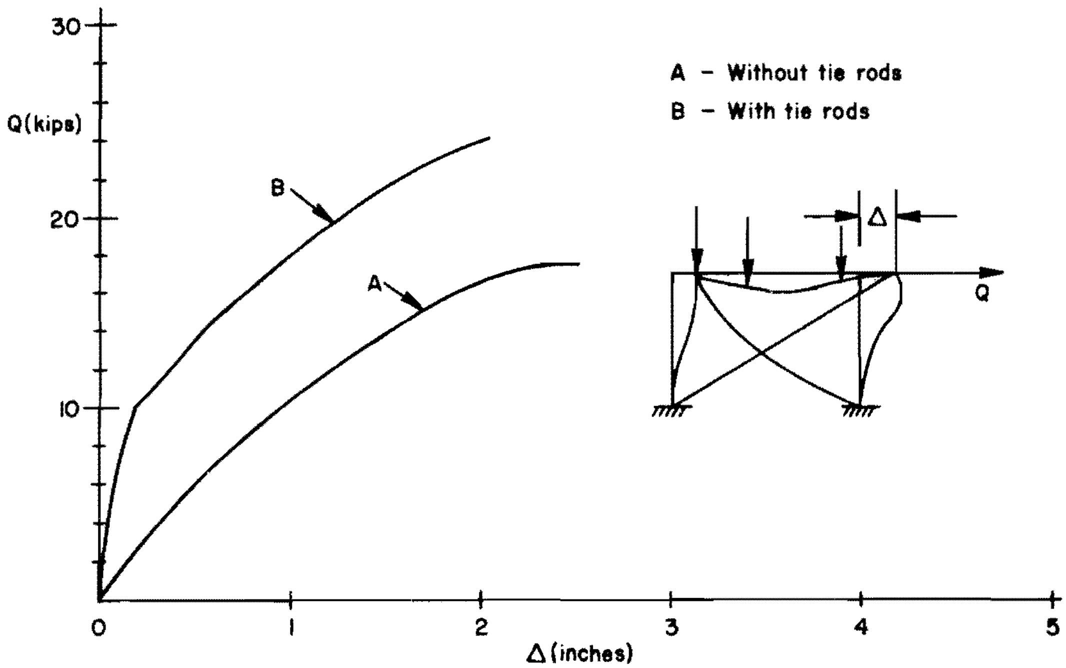


Fig 25. Effect of tie rods on load displacement curve for hybrid steel frame.

Curve A shows the results for the conservative assumption that the material yields throughout. The maximum load is only 14.5 kips, which is well below the maximum observed load of 16.9 kips, and the displacements predicted by curve A are poor at all load levels.

Curve B was obtained assuming the material does not yield from the joint centerline to the location of the plastic hinge. The hinge is assumed in this and the remainder of the curves to occur a distance d from the face of the connection. Curve B comes closest to predicting the experimental load displacement response of the frame at the higher load levels. The maximum load obtained for curve B was 16.7 kips.

Curve C assumes the material is rigid from the joint centerline to the face and the material remains linear to the hinge. Curve C gives the best fit of the experimental curve throughout the complete load range. The maximum load obtained was 17.25 kips, which is only 2 percent above the observed load. Curve C was shown in Fig 22 since it seems to fit the experimental data best and is based on the most reasonable assumptions.

Curve D is based on the assumption that the material is rigid from the joint centerline to the hinge. Curve D is obviously too stiff once yielding begins and its maximum load is 18 kips.

While no broad conclusions can be made from this short study, the joint effect is seen to be significant and the present program is seen to be capable of approximating this effect in a reasonable manner.

Prestressed Tie Rods

The end frames in single story structures often have tie rods used as x-bracing, as shown in Fig 25. The frame previously analyzed was rerun assuming that tie rods $1/2 \times 1/2$-inch were installed prestressed to a stress of 1/2 the yield stress, which was assumed to be 36 ksi. The load displacement curves in Fig 25 show that the frame is initially stiffer than the frame without tie rods and that it carries considerably more load.

The inclusion of the tie rods in the general frame analysis required some special consideration, since both of the members reach a state of zero stiffness long before the maximum load of the frame is reached.

The variation in axial thrust with horizontal load is shown in Fig 26. Both rods are initially stressed to a force of 4.43 kips. The initial stress of 18 ksi would give a force of 4.5 kips but shortening of the columns causes

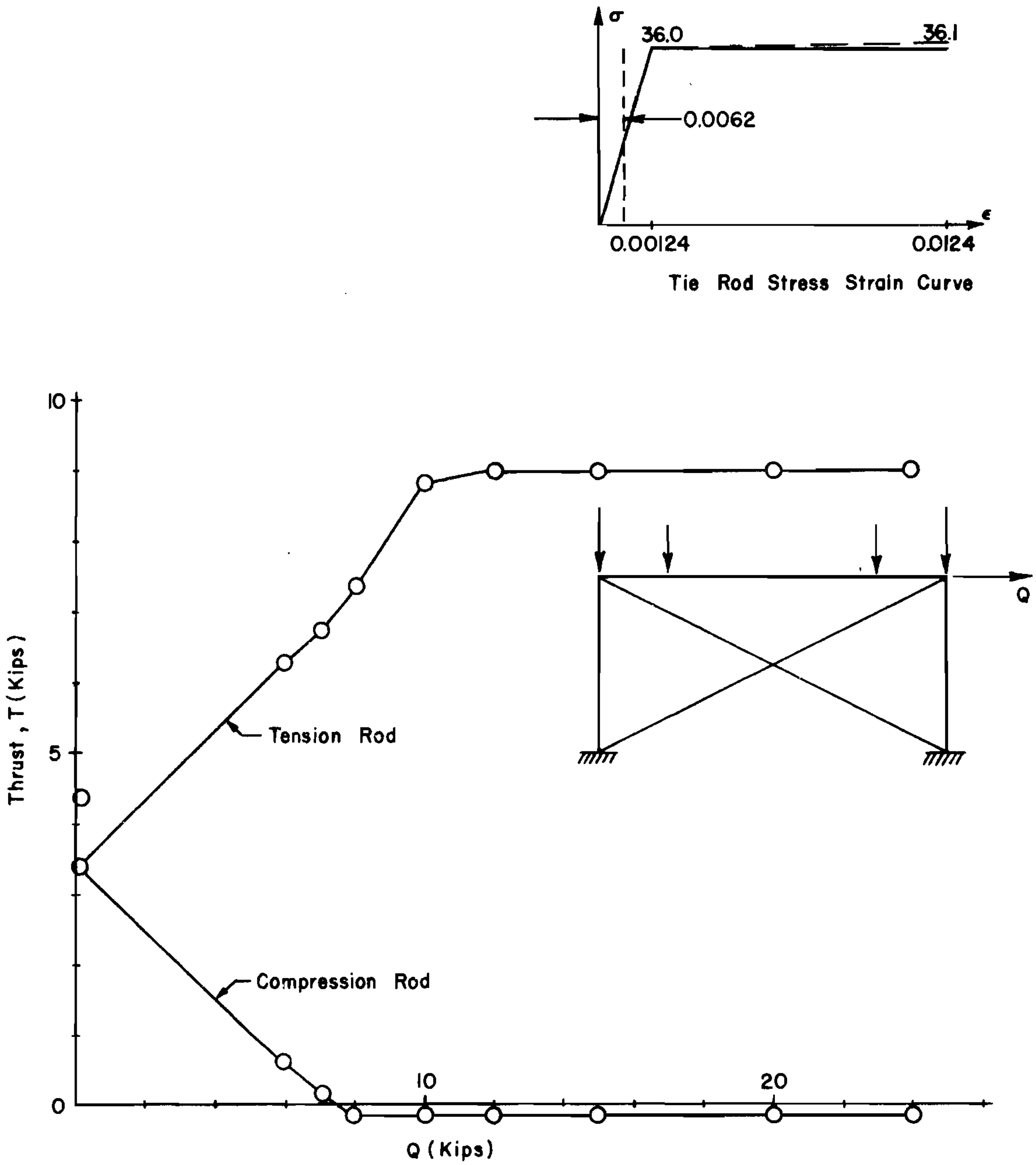


Fig 26. Axial thrusts in tie rods for hybrid steel frame.

the slight reduction. When the vertical loads are applied the tension in the rods is reduced to 3.40 kips.

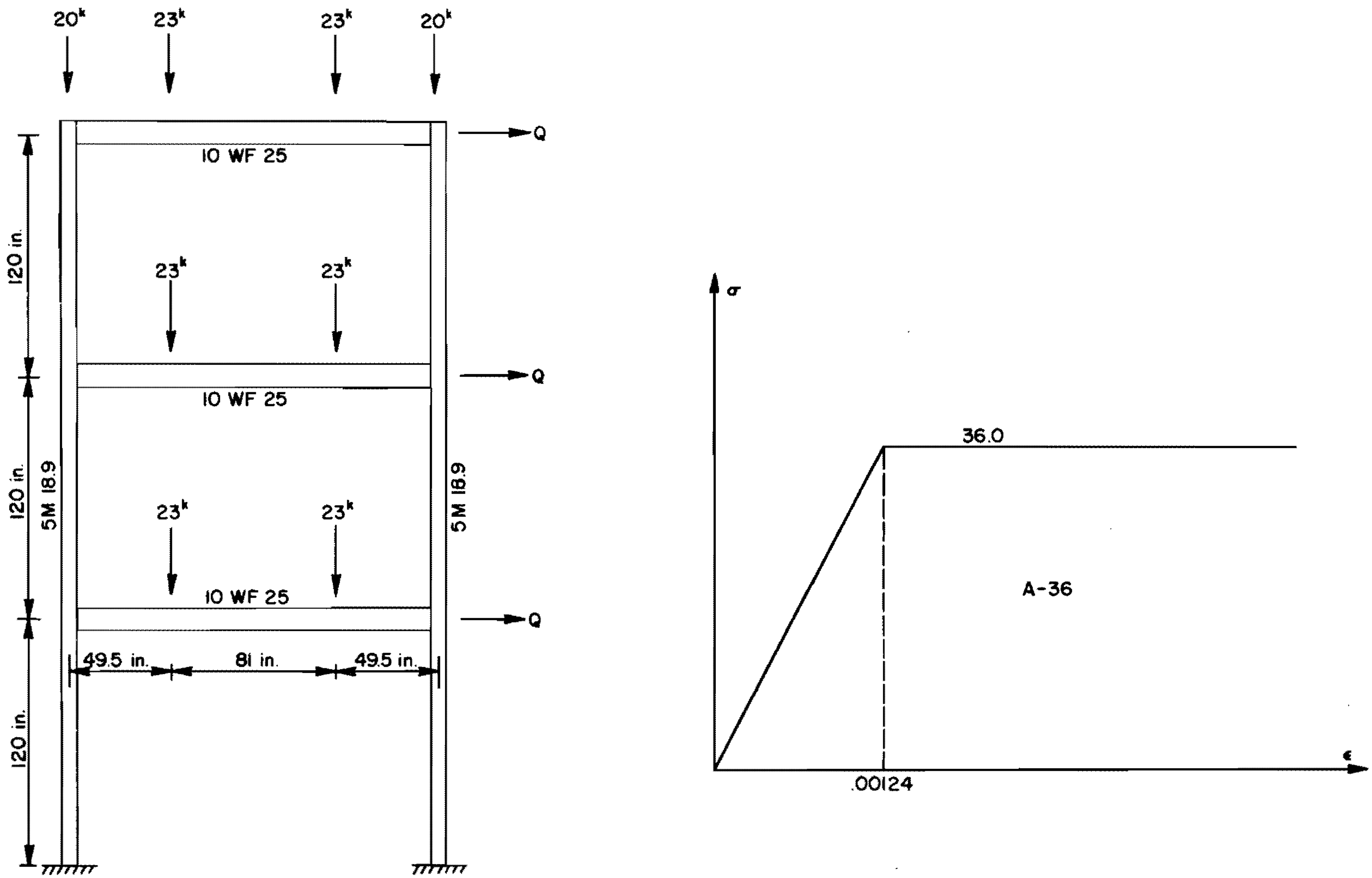
The horizontal force is then applied, and one rod increases in tension while the other rod goes into compression. At a horizontal load of approximately 7.5 kips the force in the compression rod has reached zero and at a slightly higher load it "buckles," carrying a maximum load of only about one-tenth kip. However, due to the large displacement capabilities of the program, the solution is able to converge, provided fairly small increments of load are taken around the point where the rod goes into compression.

The solution for the tie rod in compression was made in an initial run with the tie rod assumed weightless and pinned to the joints. This solution did not exhibit any lateral effects of axial compression in the rod since the rod at all times remained straight and did not buckle. However, buckling of the rod can be initiated in the computer solution either by making the connections to the joints rigid or by including a small member load, such as its own weight.

At a horizontal load of approximately 10 kips the tension rod yields and causes the computer solution for the member to blow up if the stress-strain is assumed to have a horizontal branch, as shown by the solid curve in Fig 26. However, by specifying a very small increase in stress at a much higher strain, as shown in the dashed curve, the member solution was stabilized and the frame solution could continue.

Three-Story Steel Frame

The three-story steel frame of Fig 27 was tested by Yarimci (Ref 61). Yarimci developed an incremental method of analysis based on variational principles that considers inelastic material unloading and the reduction of stiffness in the columns due to axial load. However, all yielding is concentrated at plastic hinges and for this frame the spread of yielding away from the hinges causes a significant additional reduction in stiffness. The axial load at the start of the application of the horizontal load is 45 percent of the yield axial load and the horizontal loading causes the axial force in the loading column to be increased to 48 percent of the yield load. Thus, Yarimci predicts a maximum load of 1.9 kips while the maximum observed load was only 1.62 kips.



(a) Frame geometry and loading.

(b) Stress-strain curve.

Fig 27. Three-story steel frame tested at Lehigh.

Gaylord and Wright (Ref 60) considered the spread of yielding by using M-ϕ-T curves and a form of finite element analysis in which the elements have a reduced moment of inertia in order to account for the reduced flexural stiffness as indicated by the curves. They report a maximum load of 1.62 kips; however, their M-ϕ-T curves as shown in Ref 60 indicate yielding at an extremely low stress level.

Gunnin (Ref 25) chose to neglect the joint effect in his analysis and underestimated the strength and stiffness of the frame, as shown in Fig 28.

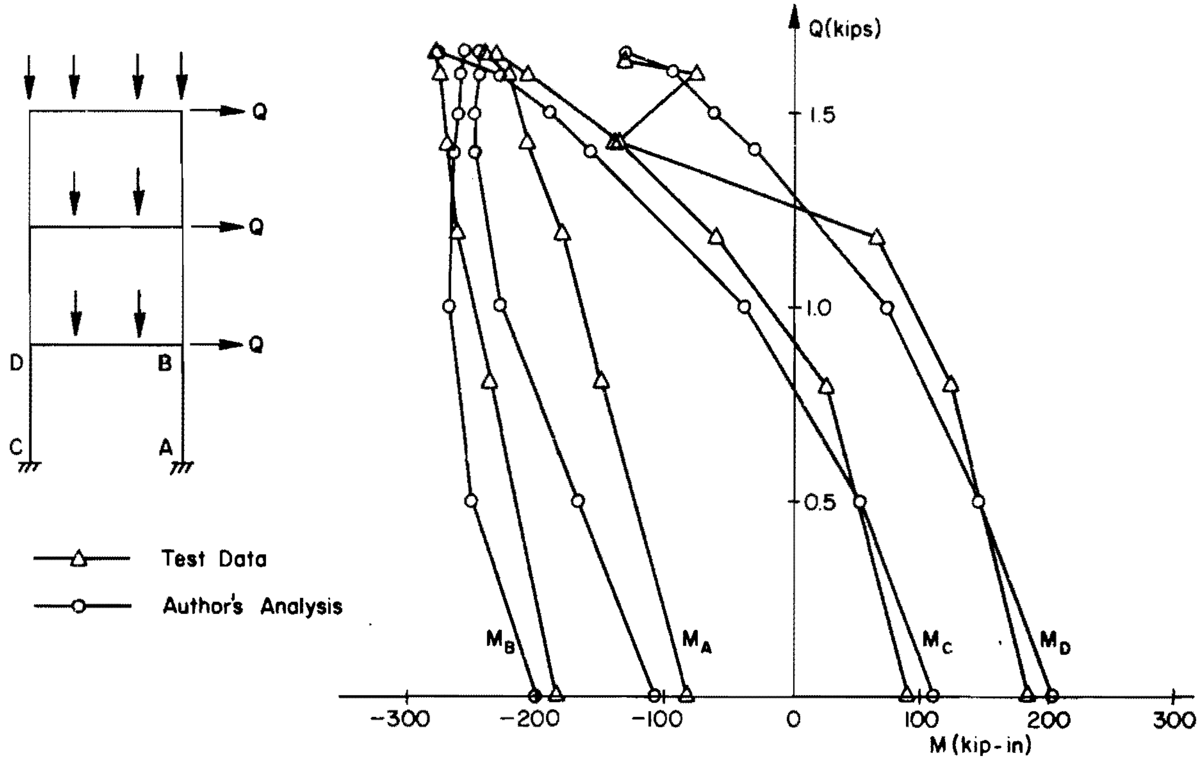
The discrete element solution shown in Fig 28 is very close to the experimental load-displacement curve. A maximum load of 1.65 kips was found in the analysis, which assumed the joints rigid from the centerline to the face of the connection and then nonyielding to the location of the plastic hinges.

The column moments at the theoretical joint centerlines obtained from the discrete element solution are seen in Fig 28 to be in general agreement with the experimental values. One experimental value for M_D seems to be a data reduction error.

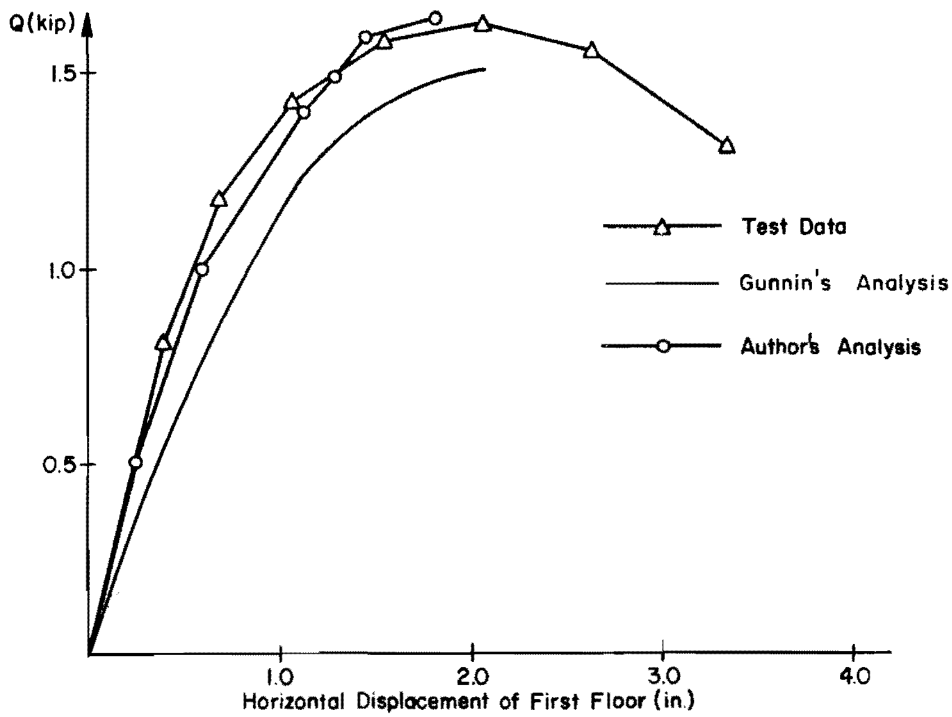
No data were given by Yarimci for residual stresses or strain hardening, and thus these effects were not included in the discrete element analysis. The base was designed as fixed and Yarimci states that the rotations which occurred were negligible. Handbook values of section properties were used and Yarimci reports that test values of flexural stiffness and plastic moment capacity were very close to handbook values.

Yarimci's analysis indicated that a sway mechanism formed in the lower floors. However, the experimental moment values and the discrete element solution indicate a stability failure with a combination mechanism very close to forming. At a horizontal load of 1.65 kips, which was the last load for which a solution was found, the moment under the left load on the lower girder was over 90 percent of the plastic moment capacity. The discrete element solution failed to converge on a load of 1.70 kips and from the extreme flatness of the load displacement curve a stability failure seems plausible.

The discrete element analysis indicated that the stress near the joints in all the columns was at the yield stress before the horizontal loading was applied. Therefore some inelastic unloading did occur in the columns. Evidently, the effect of this unloading, which was not considered in the discrete element analysis, did not significantly affect the behavior of the frame.



(a) Load-moment variation.



(b) Load-displacement curves.

Fig 28. Comparison of test results and theory for three-story frame.

Summary of Chapter 7

The discrete element analysis was used to model two steel frames that had been tested previously by others. The tests indicated a high degree of geometric and material nonlinearity. The discrete element solutions for displacements and moments were in very good agreement with the experimental observations.

The ability of the analysis to model the stiffening effect that occurs at joints and the existence of prestress forces in frame members were demonstrated. The ability of the method to approach a structure's maximum load by applying increments of loads was demonstrated by doing a controlled displacement solution for comparison.

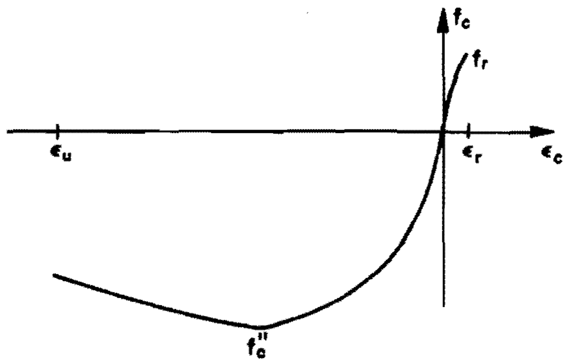
CHAPTER 8. CONCRETE FRAMES

In this chapter, the assumptions of the proposed method of analysis are examined with regard to reinforced concrete frames. It is shown that the method is capable of predicting the general response to short-time static loads of reinforced concrete members, continuously prestressed beams, and reinforced concrete frames.

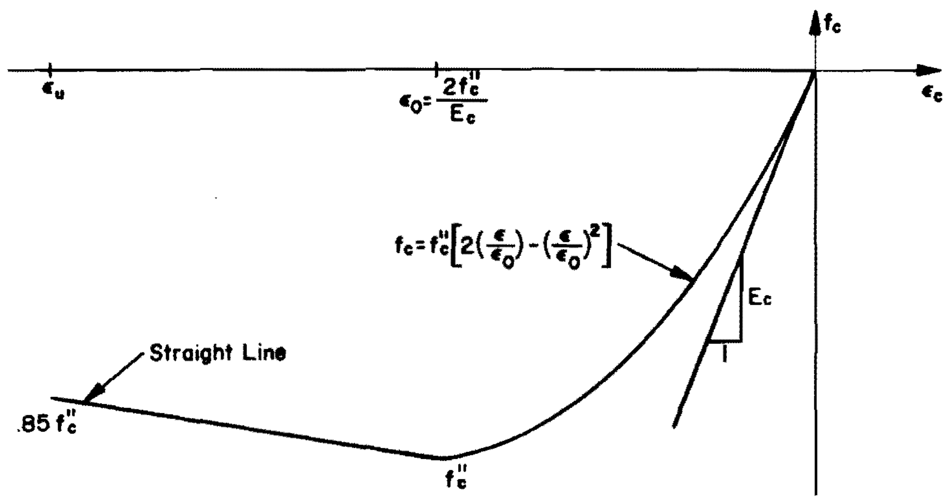
Assumptions for Reinforced and Prestressed Concrete Members

Reinforced concrete members crack under loads well below their maximum, and the assumption of a linear variation of strain over the depth (plane sections remain plane) is open to question. However, Hognestad (Ref 30) and others have shown that this assumption is valid on an average basis over a finite length of member. A typical stress-strain curve for concrete at a flexural crack is shown in Fig 29(a). The stress-strain relation in tension is somewhat linear and rupture occurs at a fairly small stress f_r. The concrete is very nonlinear in compression and has a maximum compressive stress f''_c which is related to but not always equal to the compressive strength of a standard test cylinder, f'_c. However, for laboratory conditions, the two values are often taken as equal (Ref 23). The concrete crushes at a strain ϵ_u which can vary (Ref 42).

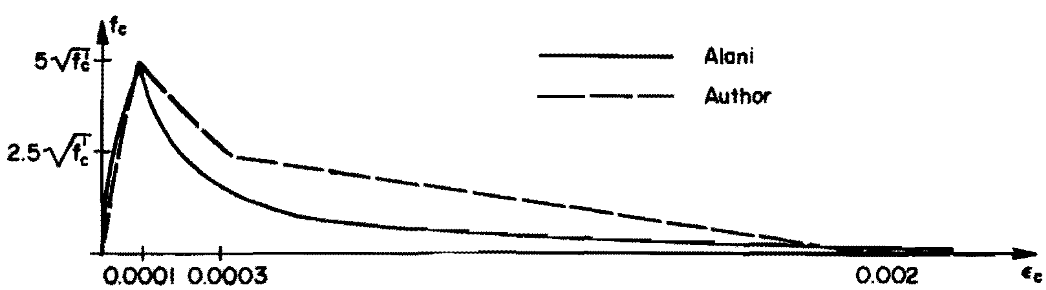
Hognestad's stress-strain curve (Ref 29) for the concrete in compression has been used by numerous researchers. Hognestad's curve consists of a parabola and a straight line, as shown in Fig 29(b). The ultimate strain has often been used as around 0.004 (Refs 23 and 26). The attainment of the maximum moment at a given section often occurs before the limiting strain is reached. Thus, the exact value of this limiting strain is only of primary importance when the section must continue to deform upon reaching its maximum moment, as is required in limit design. Some researchers, such as Barnard (Ref 12), have maintained that the ultimate strain is actually of little consequence since, even though the concrete starts to crush at this value, the



(a) Stress-strain curve for concrete at crack.



(b) Hognestad's compressive stress-strain curve.



(c) Average stress-strain curves for concrete in tension.

Fig 29. Stress-strain characteristics of concrete.

concrete still deforms under a decreasing moment. The ultimate strain was assumed as 0.004 for the problems worked herein.

Using Hognestad's stress-strain curve for the concrete in compression, a linear stress-strain relation for the concrete in tension up to the cracking stress, and the assumptions of a linear distribution of strain, moment-curvature curves can be developed using established procedures (Ref 15 and 16). However, Alani (Ref 3) shows that curves developed in such a manner do not compare well with experimental results for beams with small percentages of steel. Alani points out that for lightly reinforced beams, the steel stress varies considerably between cracks. The steel stress is high at the crack but drops off between the cracks, where the concrete carries a major portion of the tensile force. Thus, development of moment-curvature relations should be based on average stress-strain relations in a finite length of beam.

Alani shows that by using "average" stress-strain curves for the steel (Refs 3 and 50), Hognestad's stress-strain curve for the concrete in compression, and the solid curves shown in Fig 29(c) for the concrete in tension, he is able to keep the assumption of a linear strain distribution and predict the observed moment-curvature behavior of beams with small reinforcement ratios p ($p = \frac{A_s}{bd}$ where A_s is the area of the tension steel, b is the width of the compression force, and d is the distance from the tension steel to the compression face). The present method of analysis would permit the use of both the average steel stress-strain curves and Alani's curve for the concrete in tension. However, it was decided to try and account for the cracking effect by simply over-modifying the tension curve for the concrete. The stress-strain curve shown dashed in Fig 29(c) was used, along with Hognestad's stress-strain curve, for the concrete in compression and the normal stress-strain curve for the steel. Several examples now presented show that the general behavior of lightly reinforced beams can be predicted using this technique. Even more accurate predictions could probably be made by using Alani's complete recommendations. Beams that are heavily reinforced, and columns, are little affected by the assumption of how the tension stresses are distributed.

Alani's Test Beams

Two of Alani's test beams are shown in Figs 30 and 31. They represent the minimum and maximum reinforcement ratios in his tests, $p = 0.0032$ and

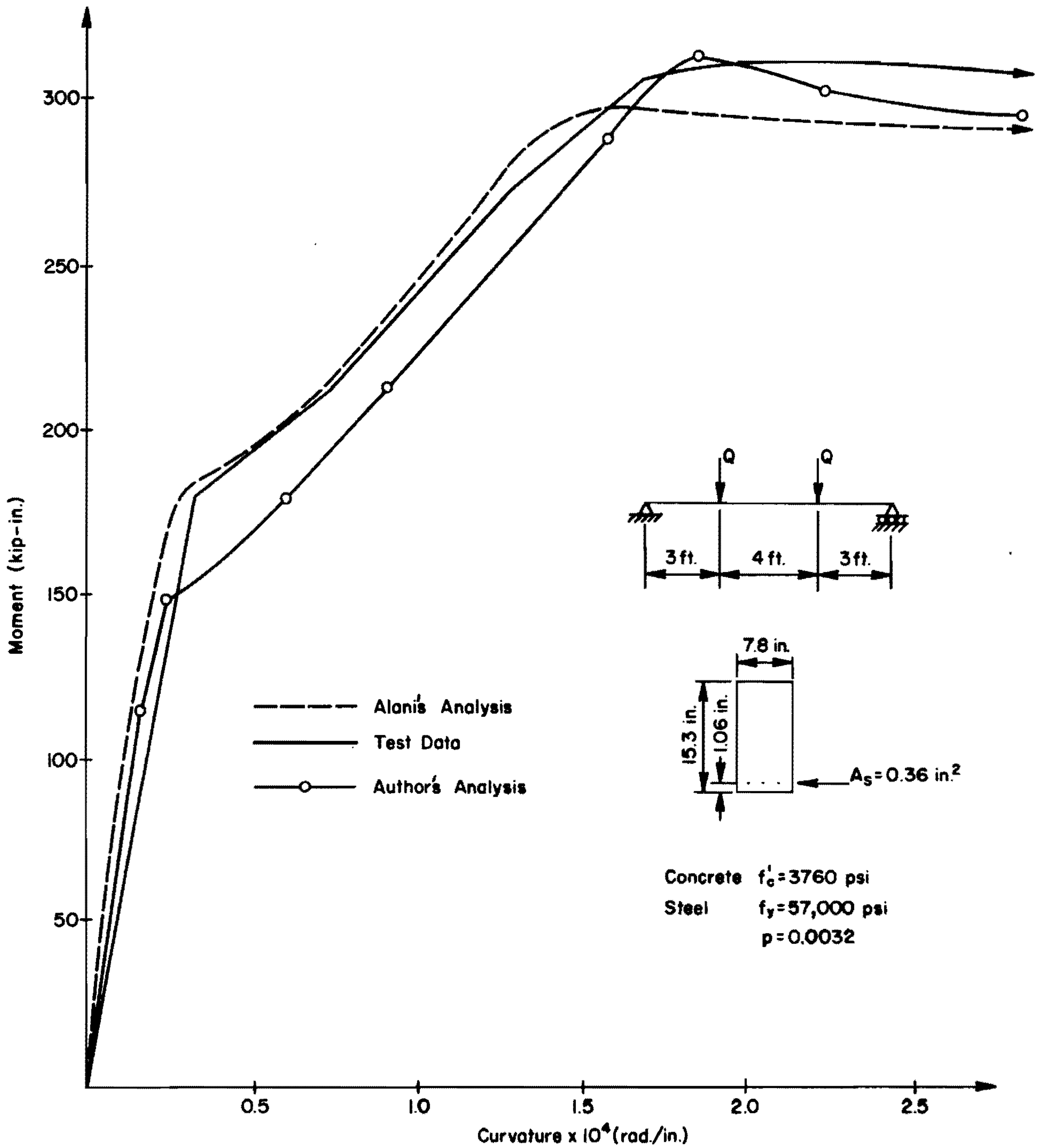


Fig 30. Moment-curvature relation for beam with low percentage of steel.

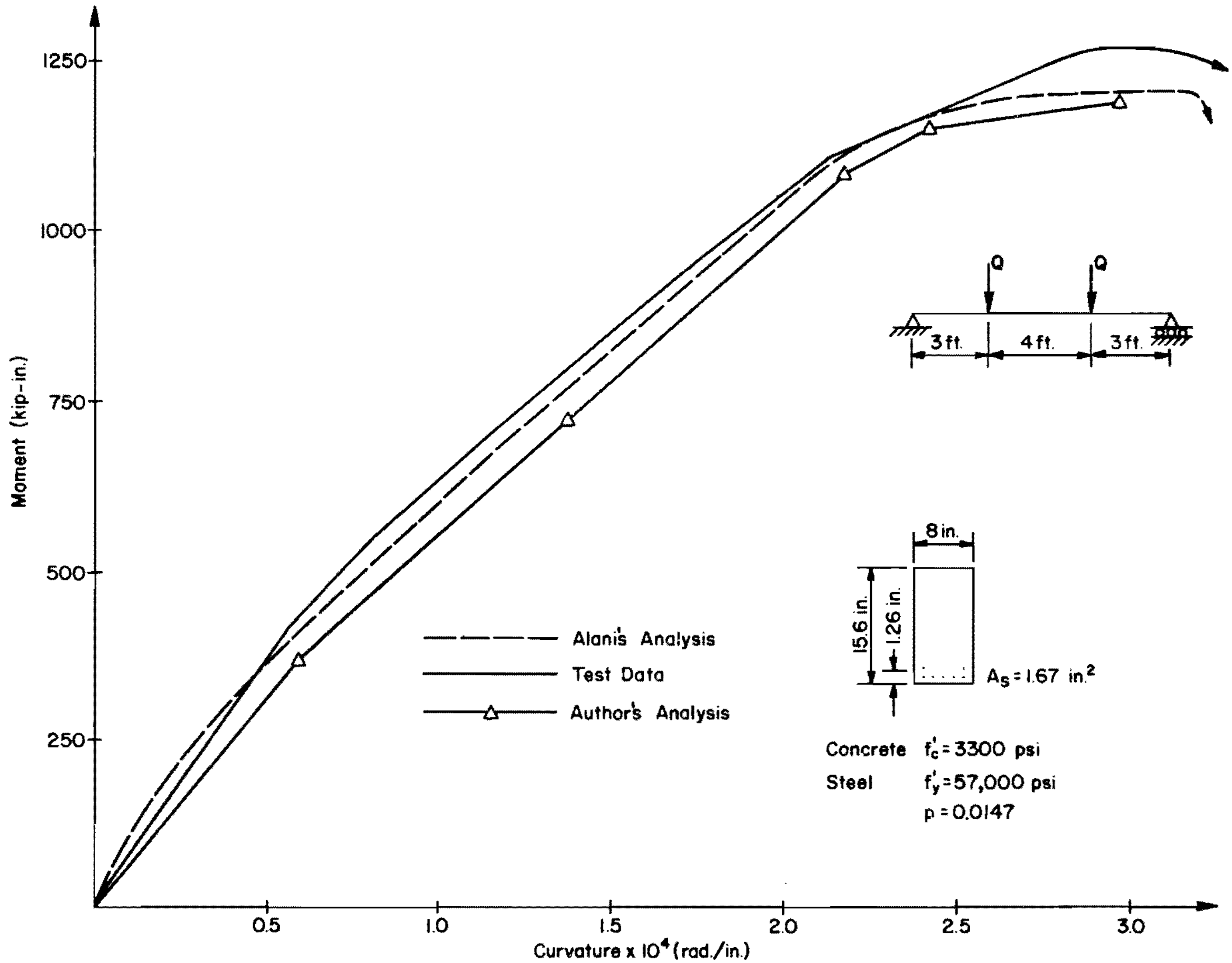


Fig 31. Moment-curvature relation for beam with normal percentage of steel.

0.0147, respectively. The moment-curvature curves obtained from the tests, Alani's analysis, and the discrete element solution using the over-modified tension curves for the concrete are shown in the two figures. Good agreement is found between all the curves except that the author's curve for the small percentage of steel shows a decrease in stiffness at a smaller curvature than do Alani's analysis and the test result.

The discrete element solutions were generated by modeling Alani's test beam as a member with two concentrated loads. The stress-strain curves were input as a series of points. Note, however, that the M-ϕ curve for the beam with the smaller percentage of steel shows a descending portion. It was necessary to use a controlled-displacement solution to generate this descending branch. Thus, the member was divided into three members with joints at the two load points, and the displacements of these two loads were enforced by large joint springs and correspondingly large forces. The maximum moment from the discrete element solution is 5 percent higher than Alani's analysis and approximately equal to the maximum observed value.

Continuously Prestressed Beam

The ability of the discrete element solution to input nonlinear stress-strain curves that do not have to pass through the origin allows one to study a variety of prestressing effects; one such application is the study of pretensioned or bonded, post-tensioned beams. The two-span pretensioned beam shown in Fig 32 was tested at the University of Illinois and reported in Ref 26. The cross section and other pertinent data are also shown in Fig 32. The stress-strain curve for the steel is shown in Fig 33. The stress axis is shifted to the right the amount of the initial prestressing strain, 0.0042.

The discrete element solution considers the elastic shortening and bending of the concrete. Thus, the input strain corresponds to the strain one would obtain by dividing the change in length of the wires by the length of the unstretched wires. This means that a given cross section would not be in equilibrium in a zero-strain condition. Thus, the discrete element solution finds the new position after prestressing, which indicates the stretching and bending of the section due to the prestressing.

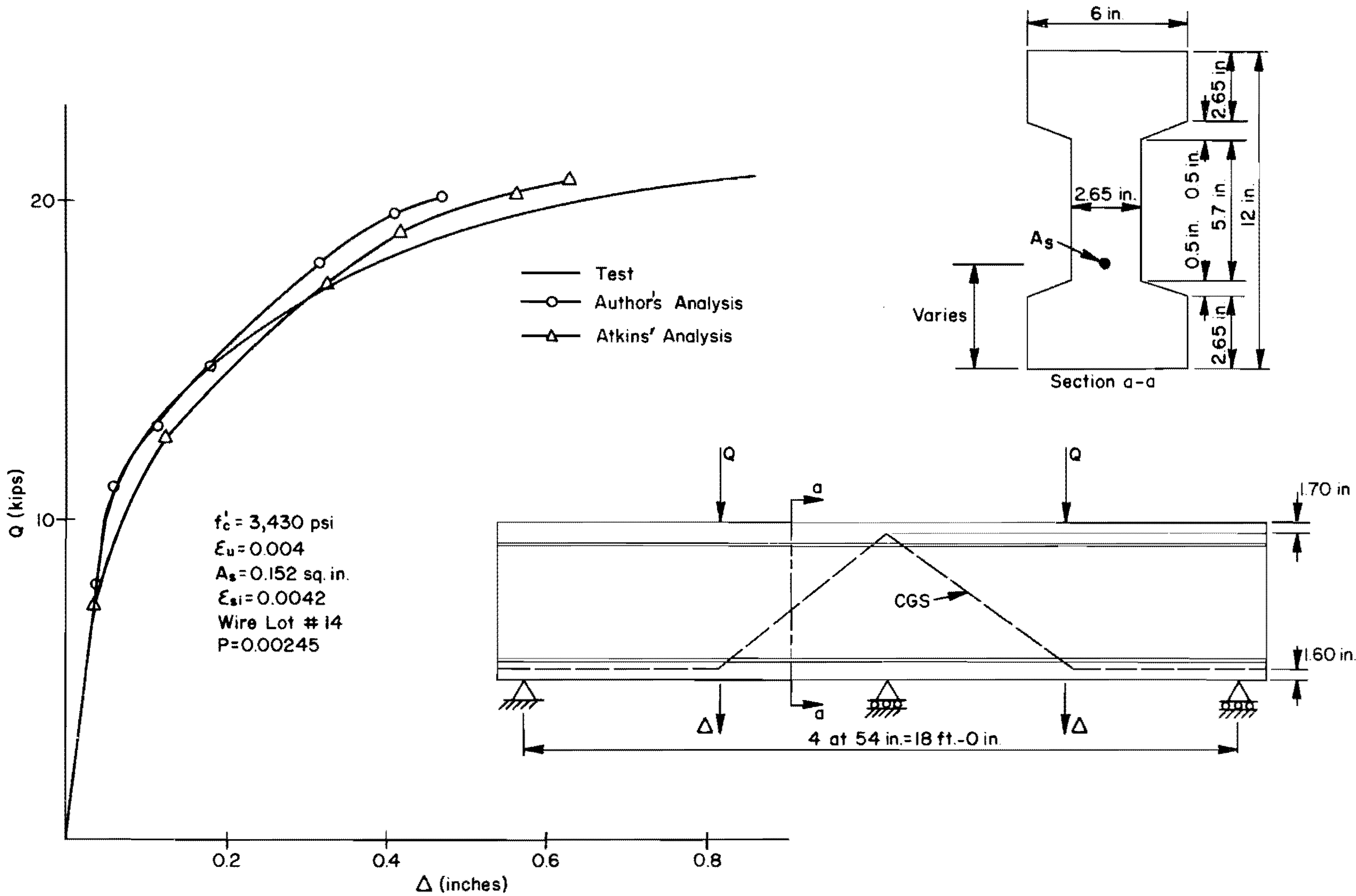


Fig 32. Two span prestress beam tested at Illinois.

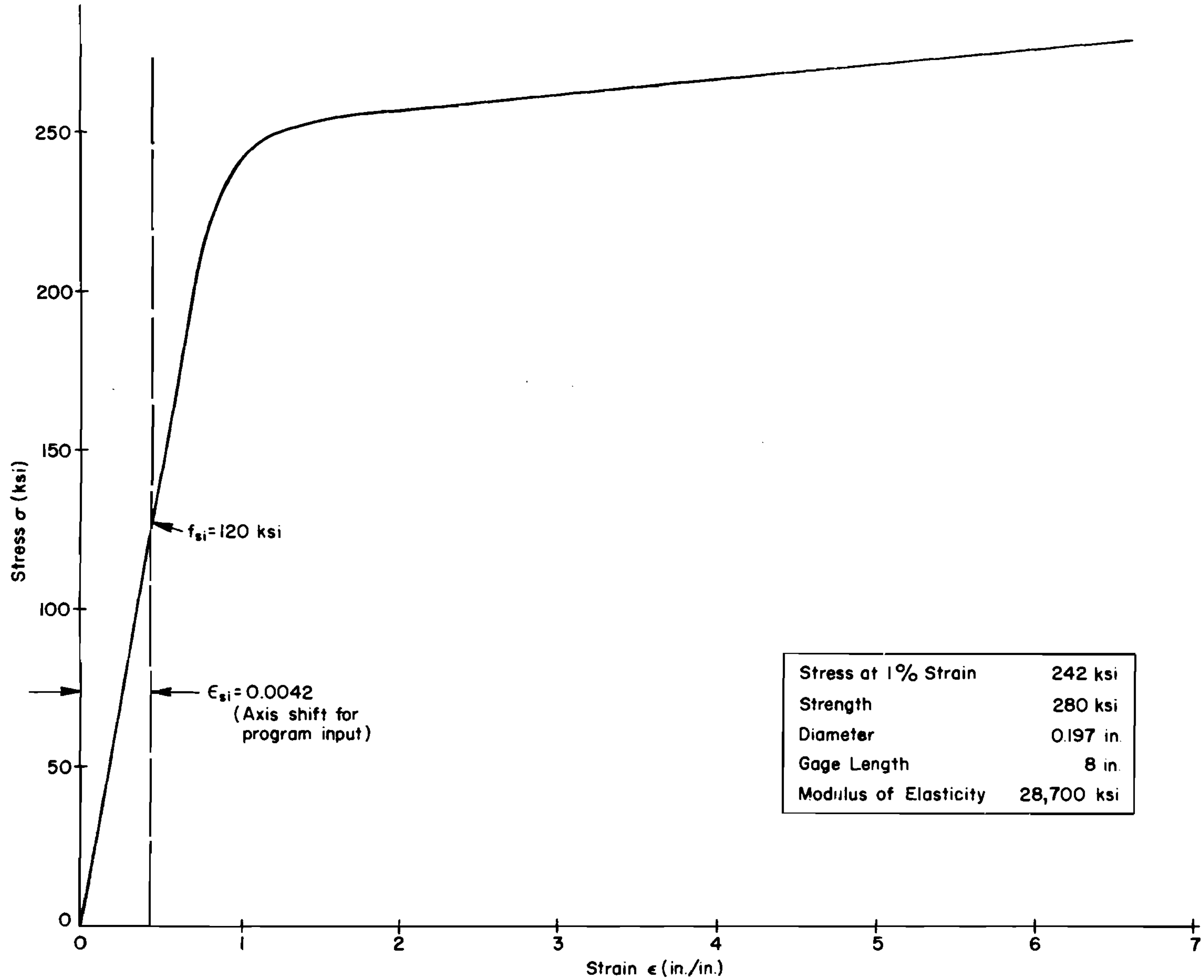


Fig 33. Stress-strain relation for Lot 14 wire.

Losses of Prestress

In addition to the so-called elastic losses of prestress due to the aforementioned prestressing deformations, there are several other sources of prestress loss (Ref 35). The primary sources are creep and shrinkage in the concrete and stress relaxation in the steel. The stresses were measured at the time of prestress and at the time of the test for the two-span beam. The difference in these two stresses was the loss due to all effects. Since the discrete element solution considers only elastic losses, the other losses should be subtracted from the initial stress applied to the member to simulate test conditions. This was done for the test beam, and a preliminary run considering only elastic losses indicated the reported initial stress of 125 ksi should be reduced to 120 ksi. For normal applications, the prestress losses due to other than elastic shortening could be estimated with sufficient accuracy without making a preliminary solution.

Load-Displacement Curve

The load-displacement curves obtained from the test are compared with the author's discrete element solution and a discrete-element solution by Atkins (Ref 11). Atkins' analysis does not consider the effect of the stress variation in the steel between cracks and at the start of cracking his solution underestimates the stiffness of the beam. However, near the maximum load, his analysis is closer to the reported test values.

Discrete Element Solution

Taking advantage of symmetry, the problem was coded for only one of the spans. A large rotational restraint was placed at the center support to achieve the desired "zero" rotation. A joint was placed at the point of the tendon hold-down, and the linear variation of cross-sectional properties allowed in the program permitted the tendon to be located simply by specifying its locations at the ends of the members. (The computer model of one span consisted of three joints and two members.) Atkins' prestressed-beam program required that cross section data be specified at a large number of points in the region between the hold-down and the center support (Ref 11).

Two solutions were run for the beam; in the first, 20 elements were used per member and in the second, 40 elements were used per member. This corresponds to 80 and 160 elements for the full two-span beam. The displacement under the load for Q = 20 kips was -0.434-inch for the 20-element solution and -0.445-inch for the 40-increment solution. The difference of 2.5 percent is due to the high moment gradients and the even higher curvature gradients near the center support and under the load.

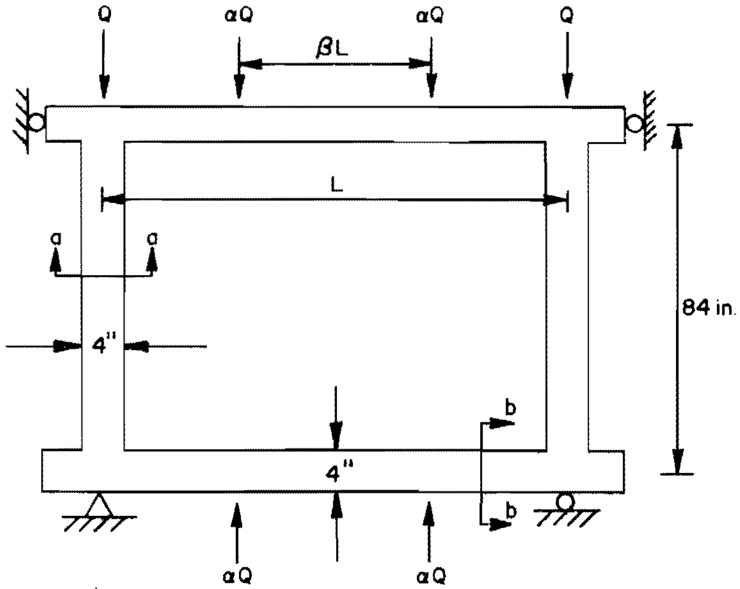
The 20-element solution converged at a load of Q = 20.25 kips and failed to converge at a load of Q = 20.5 kips. The 40-element solution failed to converge at Q = 20.25 kips after converging for Q = 20.00 kips. In both cases, for the last solution which converged the moments under the load and at the support were approximately equal and the strain was less than the maximum concrete strain. This indicated that the maximum load had been achieved before the concrete reached its maximum strain. Atkins' analysis, which is noticeably less stiff, indicated that the limiting strain was reached slightly before the maximum load would have otherwise been reached.

Concrete Frames

A series of single-story, single-bay reinforced concrete frames was tested by Furlong (Ref 23). The frames were loaded, as shown in Fig 34, to produce single curvature in the columns. The frame and loads were nominally symmetric; however, external restraints were provided to brace the frame against sway. The results of the test are compared with the discrete element solution and Furlong's and Gunnin's analyses for frames F2 and F4. The dimensions and physical properties of these two frames are shown in Fig 34.

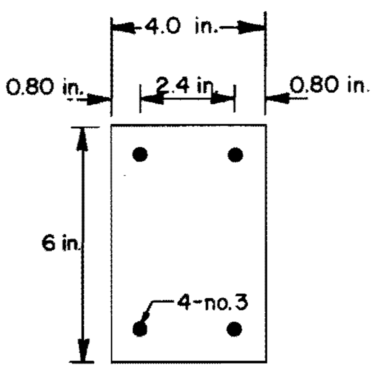
Load-Displacement Curves

The load-displacement curves of Fig 35 show the variation in the lateral displacement at the mid-height of the columns as the column thrusts increase. Even though the frames were nominally symmetric, the displacements were observed to be different in the two columns of both frames. Thus, some eccentricities were present. The author and Furlong both predicted the general load-displacement response of the frames. Gunnin's analysis is generally less stiff than the observed behavior.



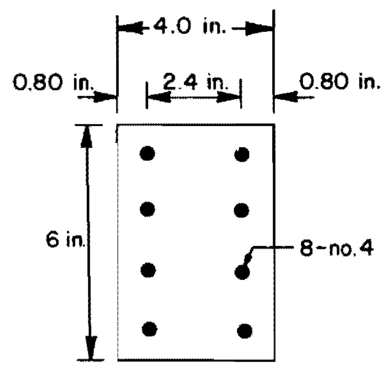
Frame	L	α	βL
F2	124 in.	0.0256	40 in.
F4	68 in.	0.1500	32 in.

Frame Dimensions and Loading



Section a-a

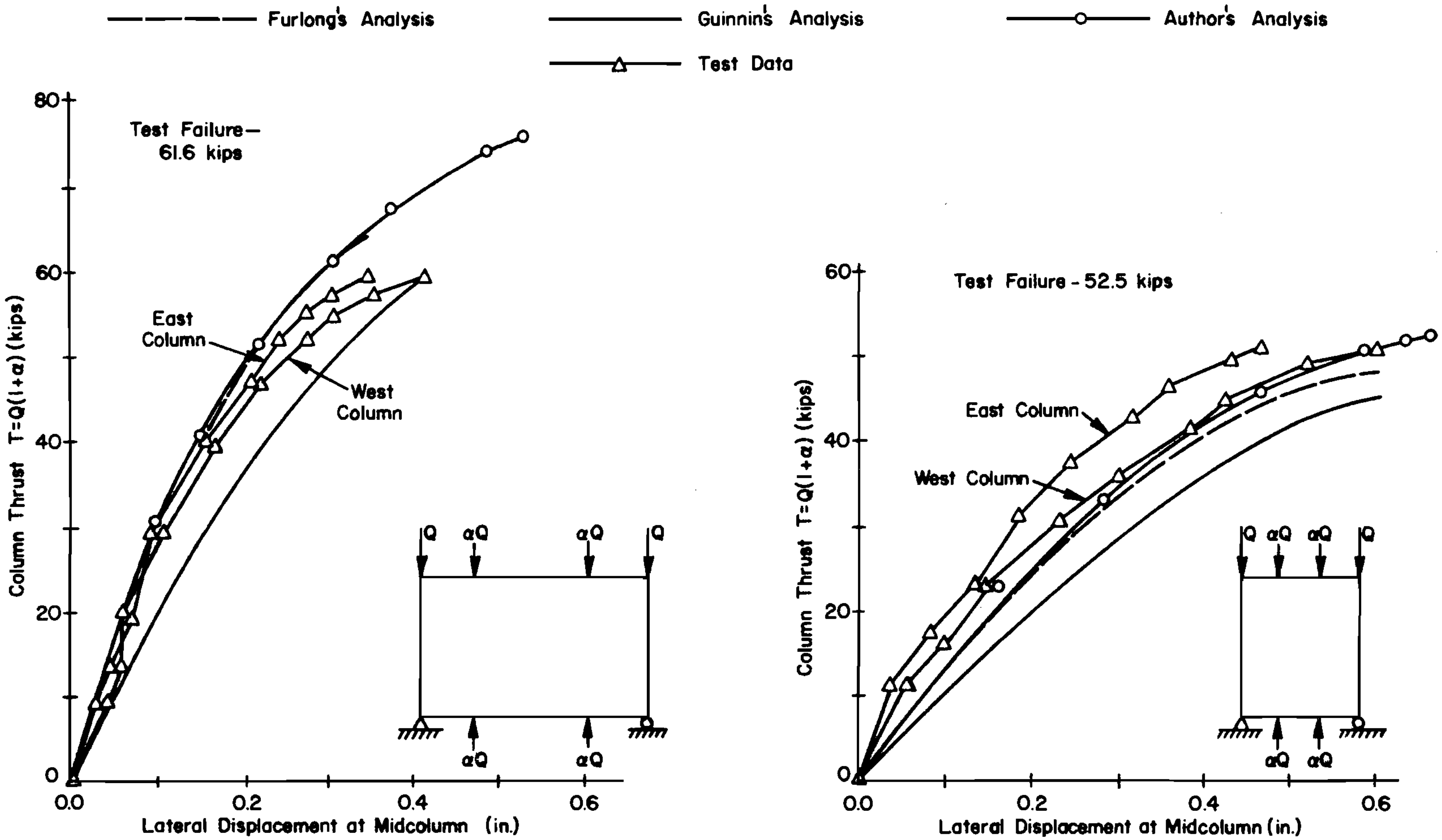
Frame	f'_c (ksi)	f_y (ksi)	E_s (ksi)
F2	4.30	54.9	28,500
F4	3.24	59.0	28,500



Section b-b

Frame	f'_c (ksi)	f_y (ksi)	E_s (ksi)
F2	4.30	54.9	28,500
F4	3.24	59.0	28,500

Fig 34. Concrete frames in single curvature.



(a) Frame F2.

(b) Frame F4.

Fig 35. Load-displacement curves for concrete frames.

Frame F2

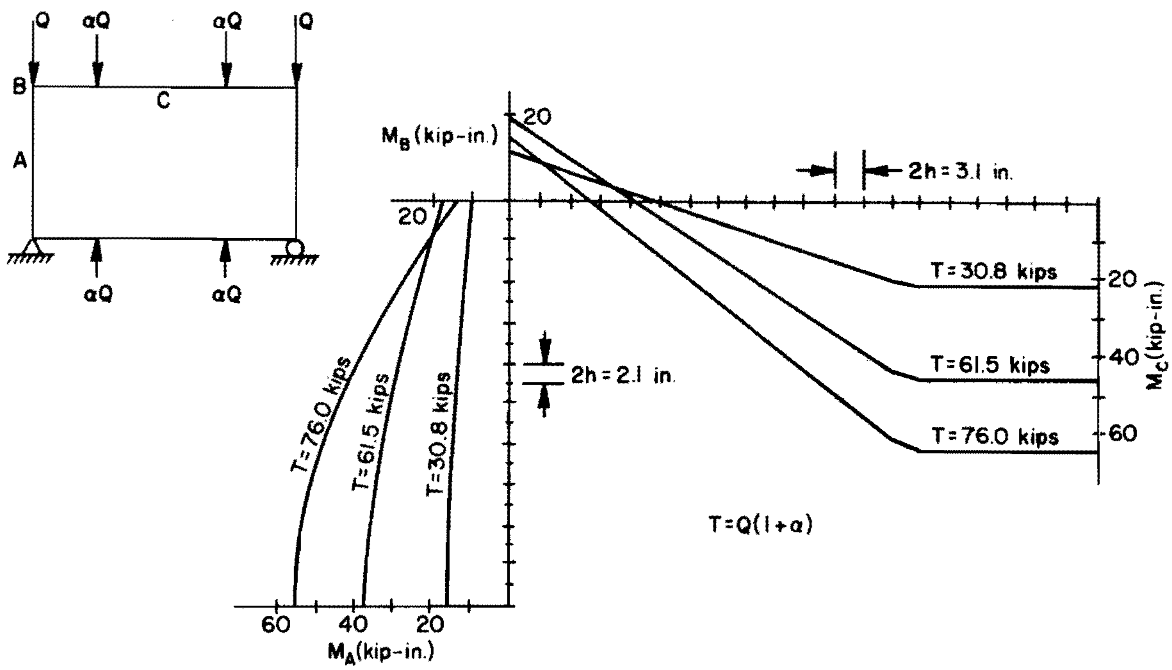
Failure occured in frame F2 at a thrust of 61.2 kips. This was below the load of 71.5 kips predicted by Furlong and the load of 76.8 kips predicted by the author. The maximum load at which Gunnin's analysis converged was approximately the observed failure load; however, he stated that this was due to a lack of mathematical convergence as no failure condition was indicated by his solution.

The load-moment plots from the discrete element analysis and the test data are shown in Fig 36(b) for frame F2. The maximum moment at the middle of the column found in the discrete element solution is seen to be slightly above the column interaction diagram. This indicates that the maximum moment is reached before the strain used to compute the interaction diagram is reached. The moments are generally in qualitative agreement with the test data but are consistently lower than the test data.

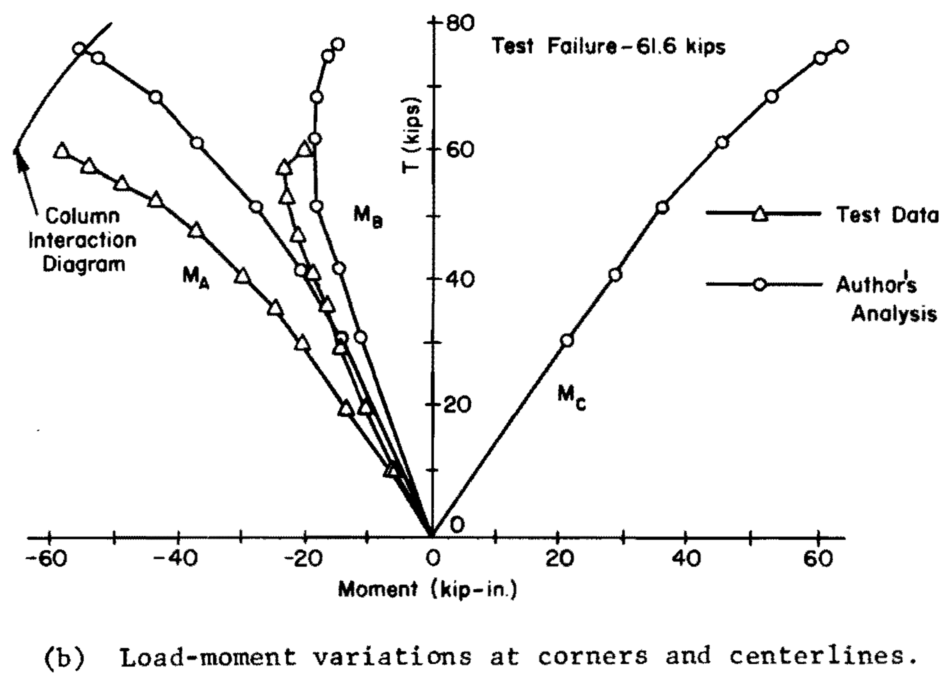
The moment diagram for one-quarter of the frames is plotted on the tension side for three different load levels in Fig 36(a). Two different trends are observed. First, as the axial thrust increases, the moment magnification in the column increases: at a column thrust of 30.8 kips the ratio of the column centerline-moment to the column end-moment is 1.3, and at a thrust of 76.0 kips this ratio has increased to 3.6. Second, due to the decreasing stiffness of the column caused by increasing axial thrust, the column end-moment does not increase linearly with applied load; in fact, it actually decreases prior to the attainment of the maximum load. This second trend causes the inflection point in the beam to move closer to the column, as seen in the moment diagrams. This beneficial shifting of the inflection point could not occur if the beam stiffness decreased sharply due to yielding of the beam steel. The beams were designed to insure that failure would occur in the columns.

Frame F4

The observed failure load for frame F4 of 52.5 kips is very close to the failure load of 52.4 kips predicted by the discrete element solution. Furlong's and Gunnin's analyses gave maximum loads of 48.0 and 45.1 kips, respectively. The load-displacement (Fig 35) and load-moment (Fig 37(b)) response predicted for frame F4 by the discrete element solution are in excellent agreement with

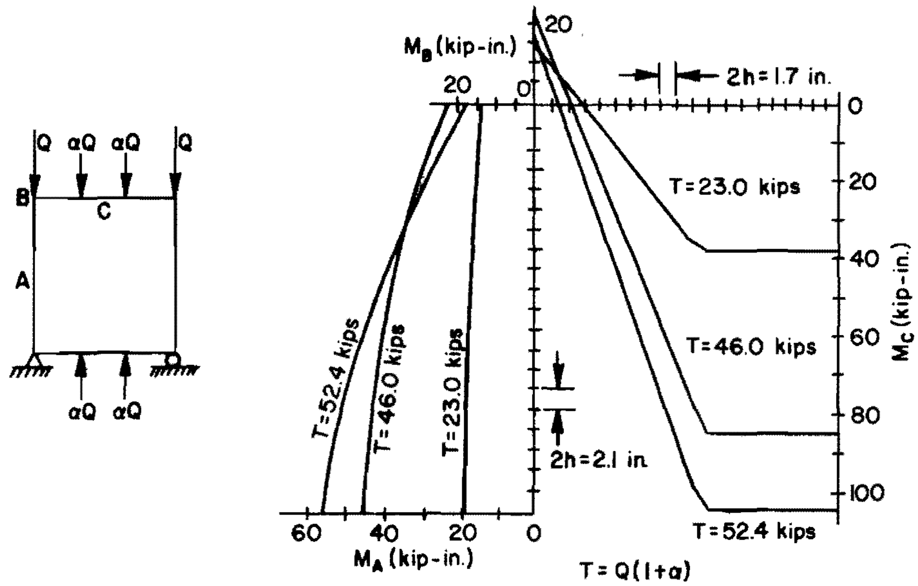


(a) Moment diagram for quarter frame at various load levels.

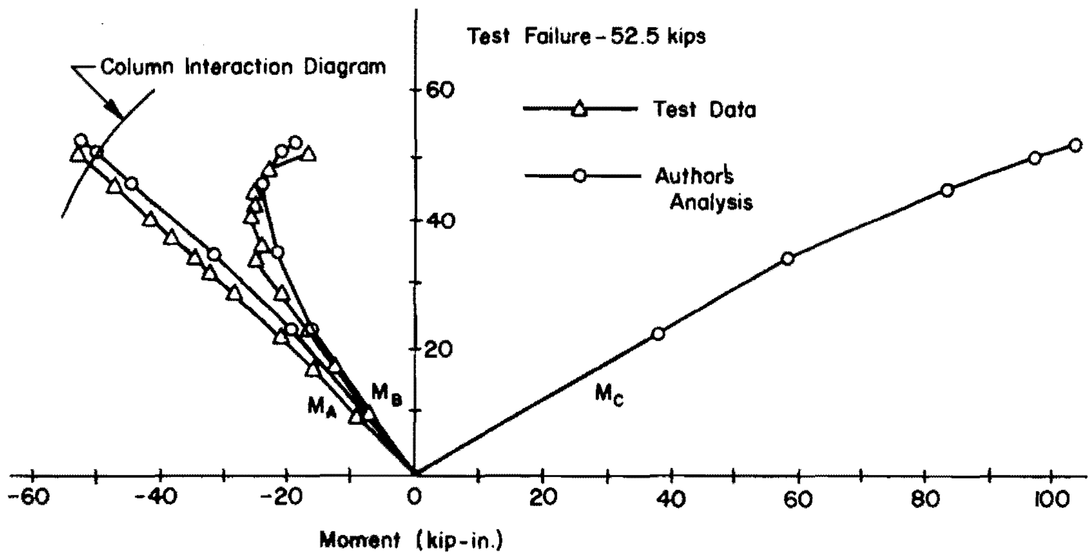


(b) Load-moment variations at corners and centerlines.

Fig 36. Moment study for Frame F2.



(a) Moment diagram for quarter frame at various load levels.



(b) Load-moment variations at corners and centerlines.

Fig 37. Moment study for Frame F4.

the observations. The moment diagram for one-quarter of the frame (Fig 37(a)) shows the same trends that were observed for frame F2. However, these trends were not as pronounced since the beams were shorter and thus stiffer. An analysis of frame F4 was run using 20 elements per member in addition to the 40-element solution and the results were almost identical. For instance, for a column thrust of 52.4 kips, the maximum column moments were 53.9 and 53.8 kip-inches for the 40 and 20-element solutions, respectively.

Sway Failure of Symmetrical Frames

Symmetrical frames which are nominally loaded symmetrically but not braced against sway will often fail by sway instability (Ref 64). This failure might be viewed as buckling; however, in practice, some horizontal loads will always be present to trigger the sway instability. For instance, frame F2 was analyzed for a constant 100-pound force applied at one of the column tops and the other loading increased as in the previous analysis. A sway instability failure occured at a nominal column thrust of only 64.6 kips. This is well below the failure load of 76.0 kips predicted without the unsymmetrical load. This points out that where sway is not positively restrained, the effects of unsymmetrical loads should be investigated.

However, the bracing system does not have to and could not completely prevent sway. Another analysis was run where a constant displacement of 1/8-inch, rather than the 100-pound load, was introduced at the top of one of the columns. This small displacement did not have any appreciable effect on the frame's behavior. If the force-displacement characteristics of the bracing system are known, they can be included in the discrete element analysis, either as joint springs or as members of the frame.

Summary of Chapter 8

The discrete element analysis was used to model two lightly reinforced beams, a two-span continuous prestressed beam that had a small percentage of steel, and two reinforced concrete frames. All of these examples had been previously tested by others. Even though not all the assumptions of the proposed method of analysis are rigorously satisfied, the method predicted the general response of all of these diverse examples.

CHAPTER 9. SOIL-STRUCTURE INTERACTION

Because of poor soil strata near the ground surface, many framed structures are supported by pile foundations. The piles may be attached to the super-structure either through a pile cap or directly to one of the columns. Both methods are illustrated in Fig 38. Lateral and axial forces are developed along the length of the pile due to the soil displacements which occur when loads are applied to the frame.

The distributed load-displacement response of the soil may be represented by nonlinear Winkler-type springs (q-w curves). Matlock (Ref 38) gives criteria for determining lateral q-w curves which describe the distributed load-displacement properties of clay soils. Coyle and Reese (Ref 17) give criteria for determining axial q-w curves for clay soils. Parker and Reese (Ref 48) have developed techniques for finding both lateral and axial q-w curves for sandy soils.

In the past (Refs 51 and 2), pile-supported structures were analyzed by separating the supporting piles from the super-structure and solving the piles and frame separately. Then, through an iterative process, the displacements and forces were matched up at the common boundaries. Sometimes, the structure was assumed as rigid in these analyses, thus neglecting a significant portion of the soil-structure interaction. The analysis developed herein is capable of solving an entire frame-pile structure in one solution.

The ability of the present program to handle soil-structure interaction problems is demonstrated by comparing the results of the discrete element frame solution with other analytical and experimental results in this chapter.

Jacket-Leg and Pile Problem

Offshore structures often have their piles driven through jacket-legs, which are the columns on the frame. The piles are then usually grouted to the jacket-legs to insure that they act as a unit.

The line-member representation of a jacket-leg and pile problem, shown in Fig 39, was analyzed by Matlock and Haliburton (Ref 41). They considered the

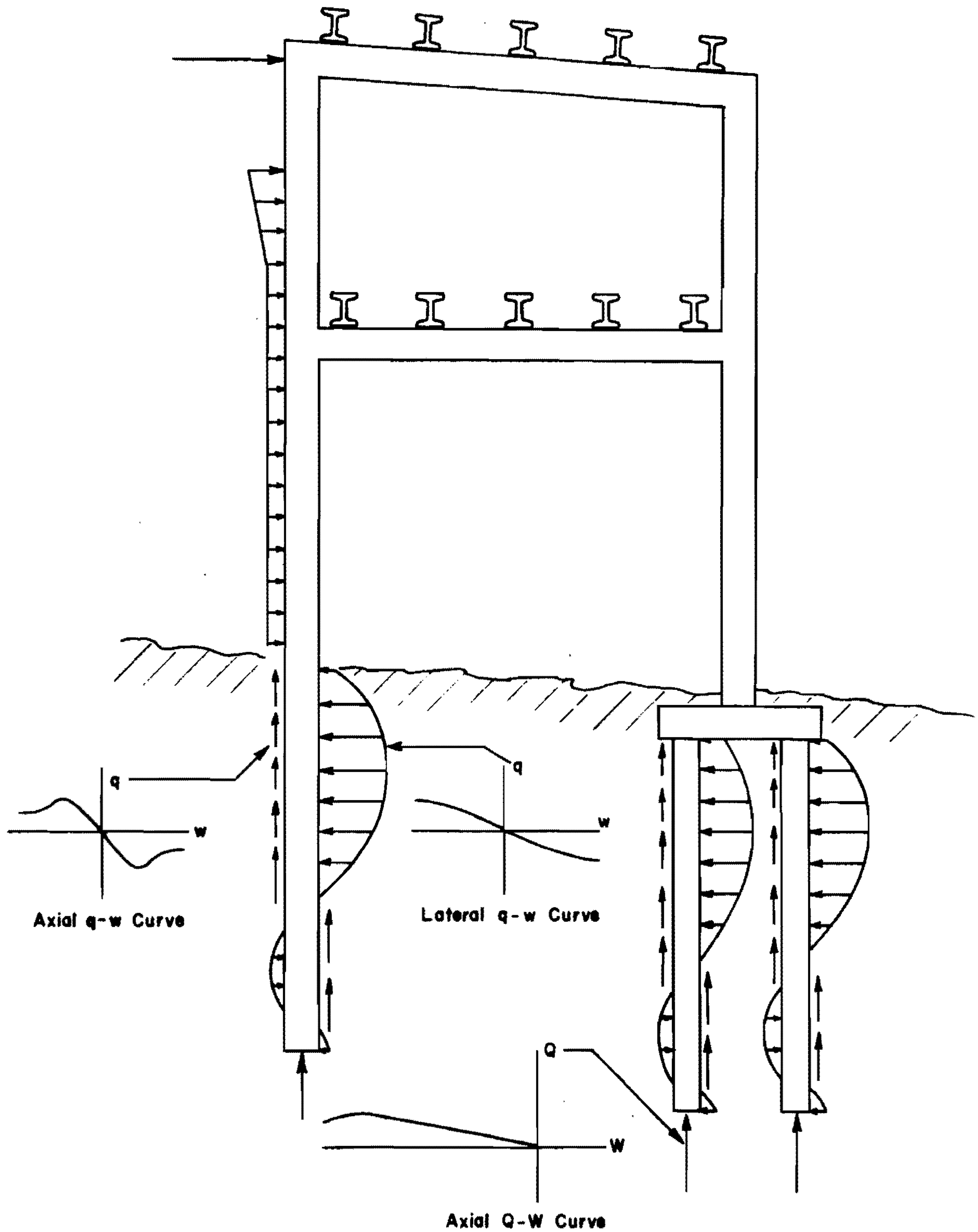
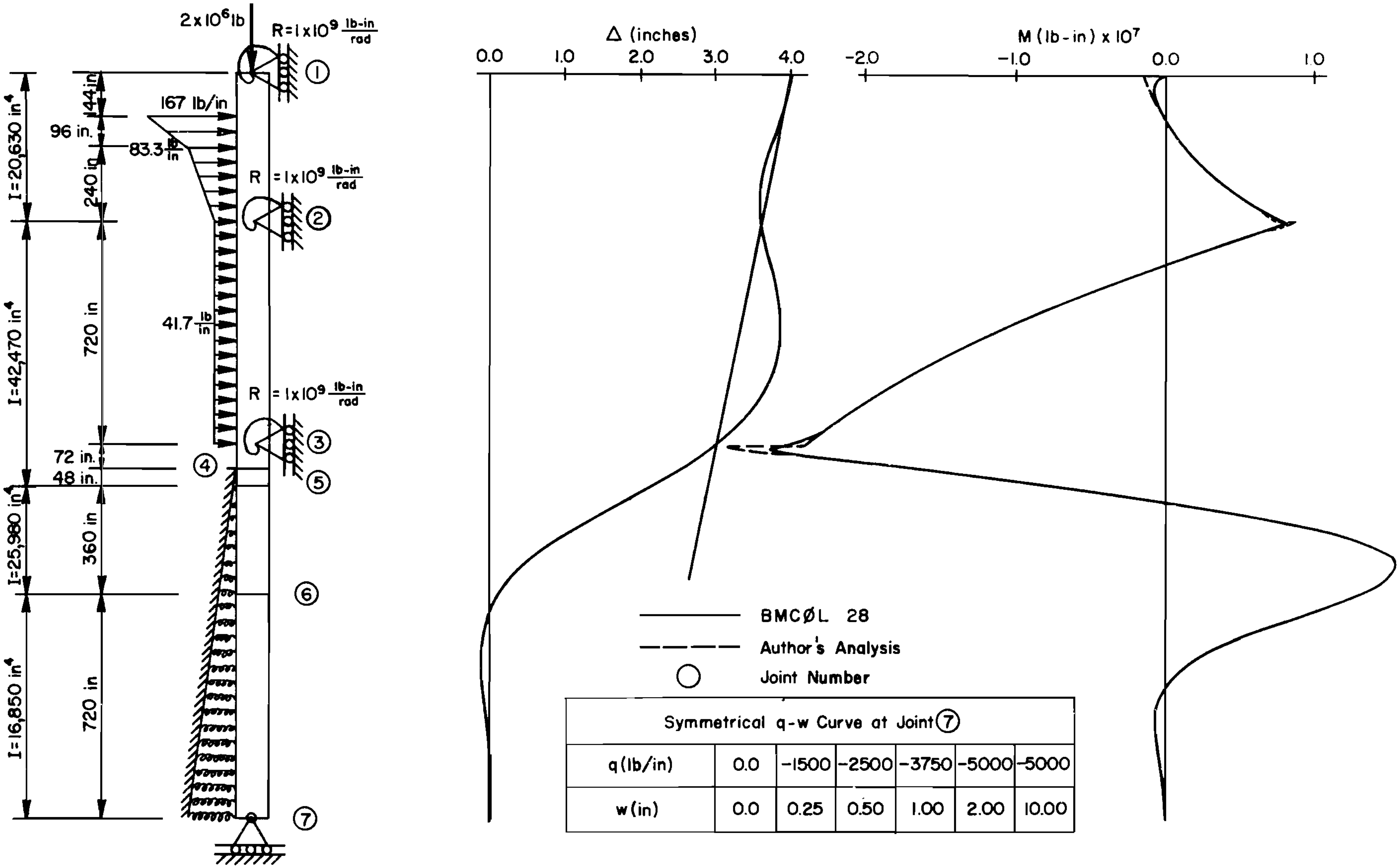


Fig 38. Pile-supported structure.



Symmetrical q-w Curve at Joint ⑦						
q (lb/in)	0.0	-1500	-2500	-3750	-5000	-5000
w (in)	0.0	0.25	0.50	1.00	2.00	10.00

(a) Jacket and pile. (b) Lateral displacement curve. (c) Bending moment diagram.

Fig 39. Solution of jacket leg and pile with nonlinear lateral soil supports.

effect of the axial load on the lateral displacements using a beam-column solution. The nonlinear lateral soil supports were represented by the nonlinear q-w curve given in Fig 39, which was assumed to be acting at the base, and the zero-resistance curve, which was assumed to be acting at the mud line (joint 4 in the discrete element frame solution). The effects of frame action were simulated by specifying rotational restraints R as shown in Fig 38(a). Specified lateral displacements of 4, 3, and 2 inches were enforced at joints 1, 2, and 3, respectively.

The lateral deflected shape and bending moment diagrams obtained by the beam-column solution (program BMCOL 28) and the author's discrete element frame solution are seen to be almost identical (Fig 39). The frame solution has a joint at the rotational spring restraints and gives a value of moment on both sides of the theoretical joint location.

The beam-column solution was for 100 increments, which contained 100 discrete angle changes. The frame solution was for 10 elements per member, or a total of 60 elements, which had 120 discrete angle changes. An additional frame solution was run using 20 elements per member and the difference in maximum moment between the two frame solutions was in the fourth significant figure.

Soil-Supported Bent Test from Galati, Rumania

Recently, a series of reinforced concrete bents with battered piles were tested in Galati, Rumania, by Iacint Manoliu, at a test site near the Danube River. The upper layer of soil in the area was a silty highly compressible clay about 15 feet thick. Under this layer were intermixed layers of fine sand and clay of medium consistency. One of the bents tested is shown in Fig 40. It consists of three battered piles driven into the soil and a fairly rigid beam which connects them. The lateral and axial q-w curves needed to define the response of the soil which supported the bents were furnished by Welch (Ref 58). Welch used Matlock's criteria for establishing the lateral q-w curves and Coyle's and Reese's criteria for developing the axial q-w curves. Welch did not have a complete shear-strength profile available; therefore, estimates of the shear strength at several levels were made, based on the points available and correlated to the observed response of single-pile tests for axial and lateral loads.

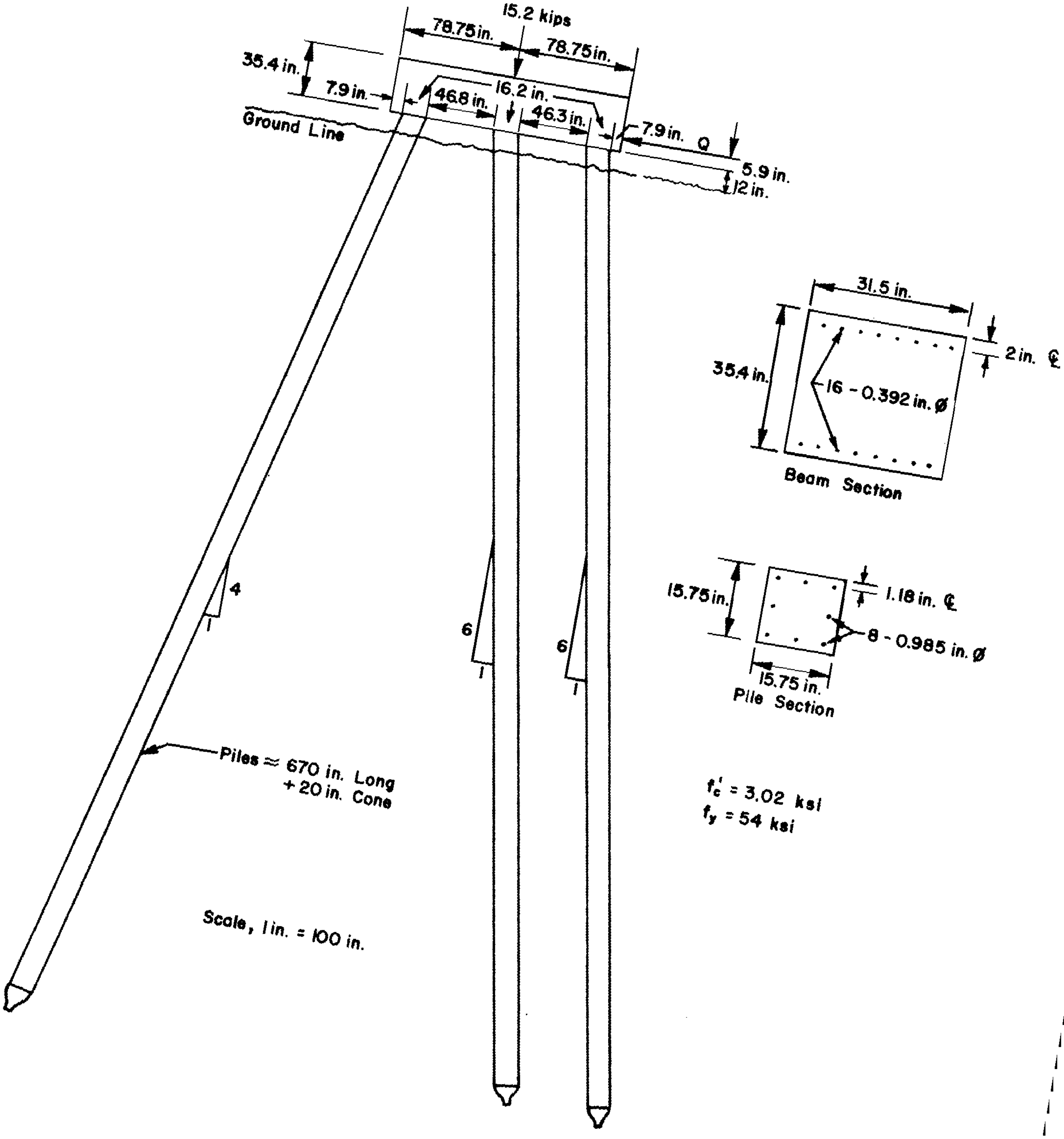


Fig 40. Soil-supported bent tested at Galati, Rumania.

Axially Loaded Pile Tests

The results of the two axial load tests on vertical piles and the author's solution are shown in Fig 41. The applied load versus the top displacement curves observed for the two piles and the curve from the analysis have the same general shape but different magnitudes of maximum load, as one would expect for such a variable material as soil. An end-bearing force-displacement (Q-W) curve could have been generated using criteria developed by Skempton (Ref 55); however, it would have little effect on the response of the pile until displacements near the maximum were reached. Since the primary purpose of this analysis was to verify that the axial q-w curves were satisfactory under the level of axial loadings experienced by the piles in the bent test, end-bearing curves were not developed.

The axial q-w curves used for the single-pile analysis are the same as the ones used in the bent analysis. The pile lengths, section properties, and concrete and steel strengths were also the same as for the bent problem.

Laterally Loaded Pile Tests

The lateral-load versus lateral-displacement curves and lateral-load versus rotation curves are shown in Figs 42 and 43 for tests on two vertical piles. The analytical curves have the same shape as the observed curves except for an unexplained jump in the observed curves at an applied load of approximately 15 kips. The analysis did not indicate that the maximum load had been reached when it was stopped at a displacement of 2.5 inches. However, the slope of the analytical load-displacement curve is very small, as is the slope of observed load-displacement curve. The lateral q-w curves and other pile data are the same as for the bent test, which is described below.

Computer Model of Three-Pile Bent

The computer model of the three-pile bent previously discussed is shown in Fig 44. Input and output for two problems that were run on this bent are given in the appropriate appendices (Problems 901 and 902). Problem 901 is for the vertical loads only. Problem 902 is for these loads plus a horizontal load of 80 kips. Several intermediate values of horizontal loading were also run, to completely define the load-displacement response of the frame; however, these inputs and outputs are not included, for brevity.

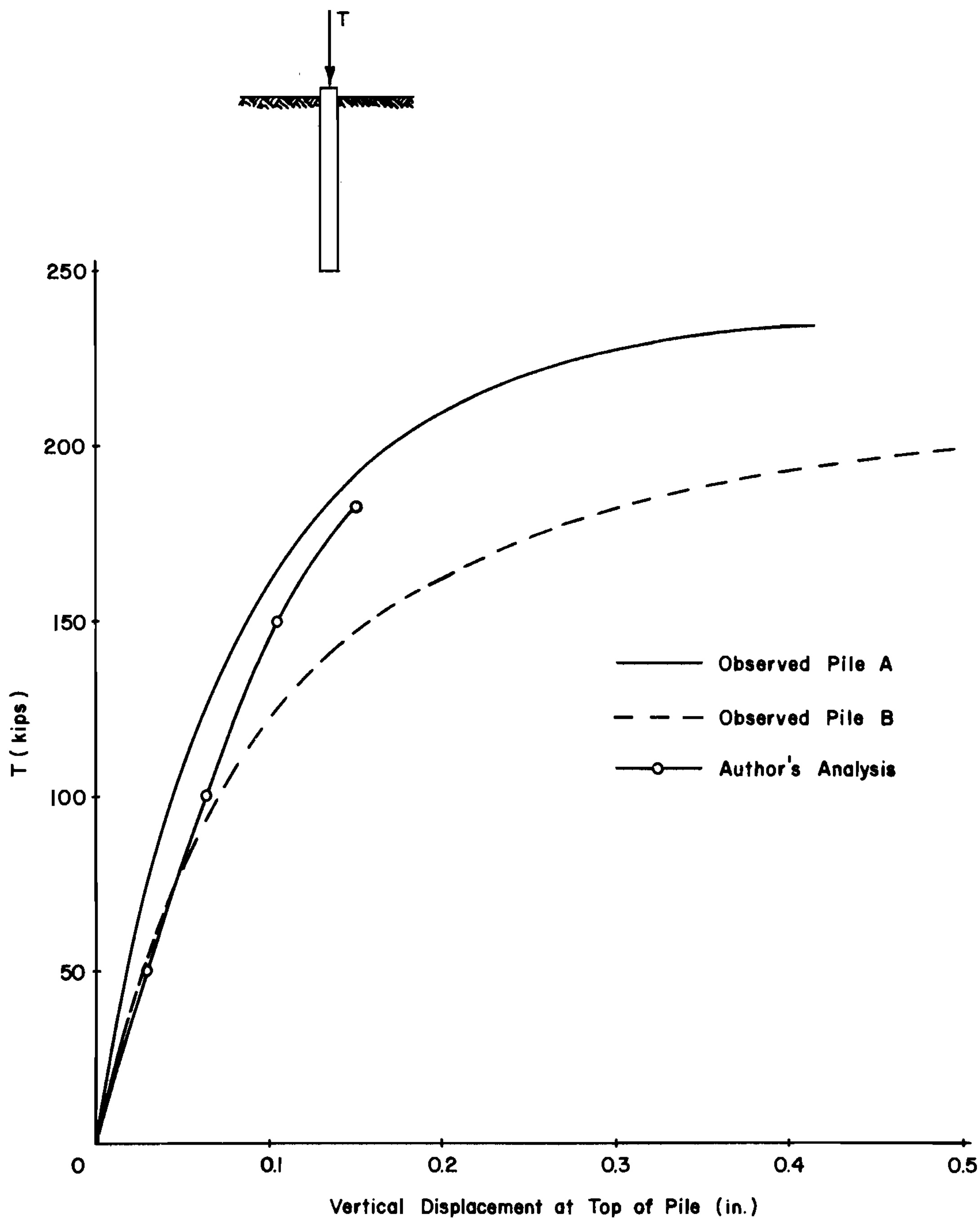


Fig 41. Load-displacement curves for axially loaded piles.

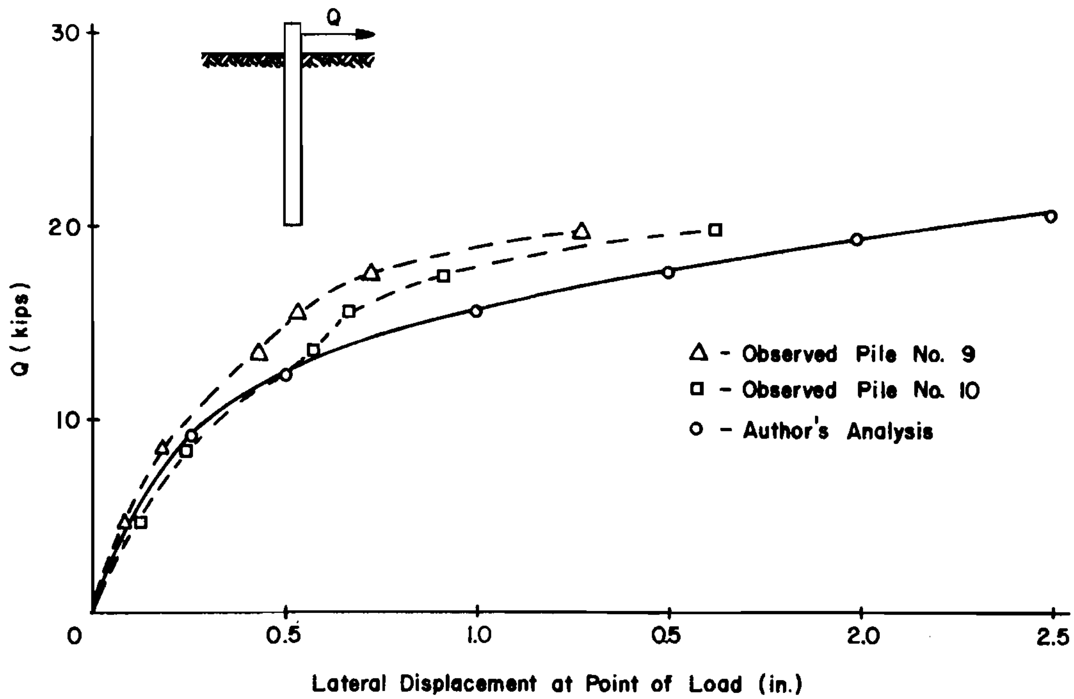


Fig 42. Load-displacement curves for laterally loaded piles.

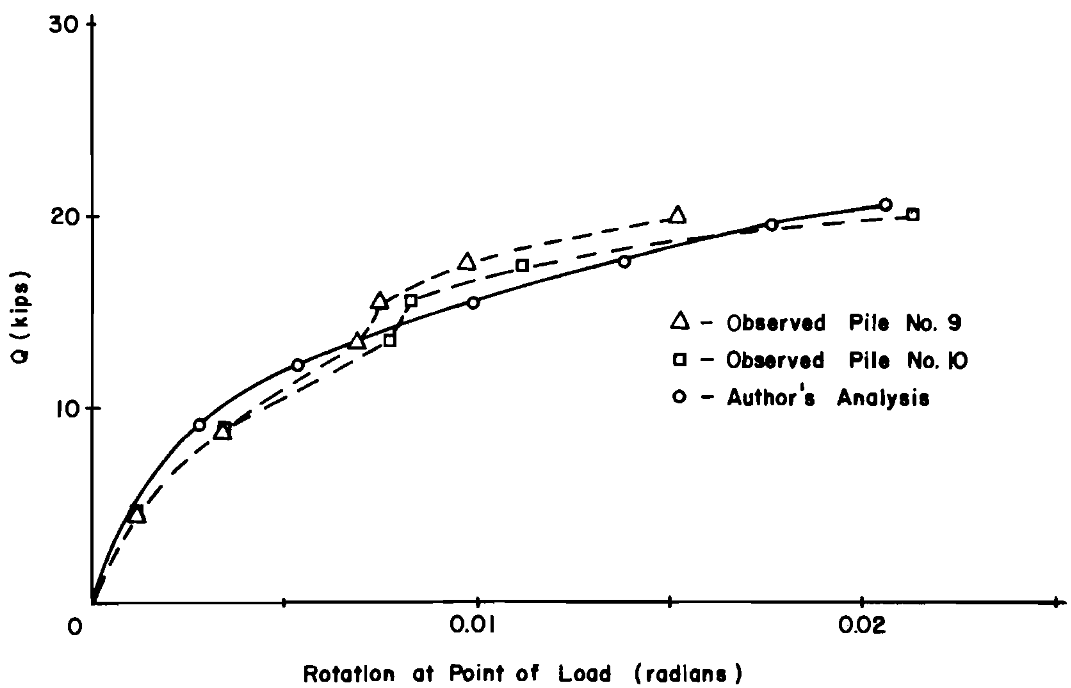
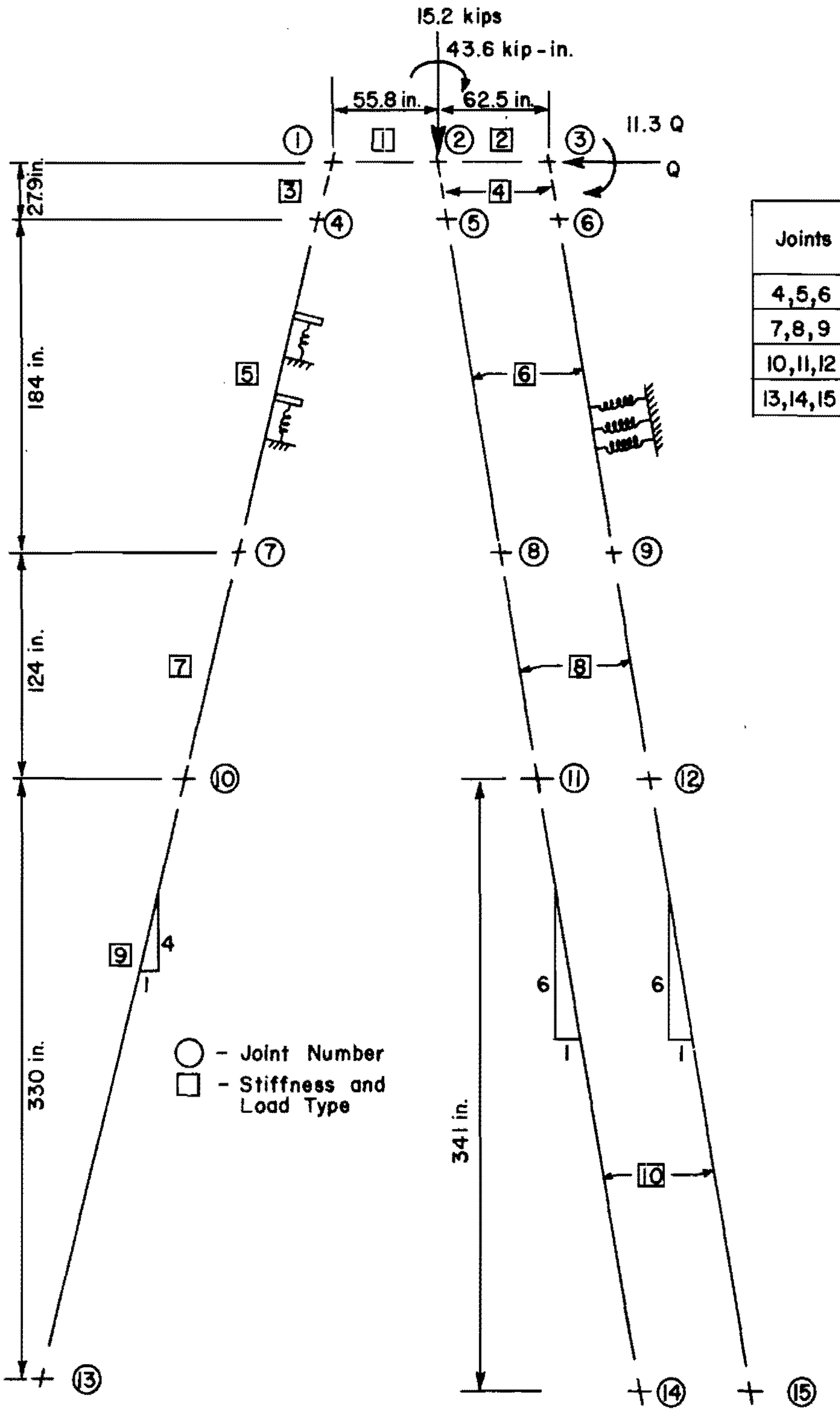


Fig 43. Load-rotation curves for laterally loaded piles.



Joints	Axial q-w Curve #	Lateral q-w Curve #
4,5,6	1	4
7,8,9	2	5
10,11,12	3	6
13,14,15	3	6

Fig 44. Computer model of three-pile bent tested at Galati, Rumania.

Joints 1, 2, and 3 are located at the intersection of the pile centerlines and the centerline of the horizontal beam in Problem 901. Joints 4, 5, and 6 are located at the groundline. The remaining joints, 7 through 15, are located to facilitate the description of the soil properties by q-w curves with a linear variation between these joints. The ability of the program to input joint offsets rather than joint coordinates is an obvious asset for this type of problem. Stiffness types and load types are assigned in the manner described in Chapter 5. Ten elements per member were used, based on the accuracy obtained in the jacket-leg and pile problem. This gives a total of thirty elements per pile, below the ground line.

It is doubtful if any bending deformation would occur in the pile within the region of the supporting beam, particularly if the steel in the pile is properly connected to the beam. Therefore, four rigid elements were specified at the ends of stiffness types 3 and 4 adjacent to the beam.

The reinforcing steel used in the pile and the beam were plain bars with a yield stress of 54 ksi. Concrete samples were tested on cubes 20 centimeters on an edge. The reported strength was reduced by 85 percent to obtain an f'_c value of 3020 psi. The depth of the beam was such that neglecting shearing deformation would cause some errors. However, due to its extreme stiffness compared to the other members, its exact value would have little effect on the overall response of the frame. To verify this, another solution was run in which the beam stiffness was reduced by reducing the width of the beam by 25 percent. The resulting displacements at a load of 80 kips differed by less than one percent from the stiffer solution.

In Problem 901, the dead weight of all members was included, plus the applied vertical load of 15.2 kips. Since this load was offset a slight distance from the joint centerline, a moment was applied at the joint to preserve statics. Note that there are no joint supports for this frame. The frame receives all of its support from the axial and lateral soil restraints which are input as member properties with the member stiffness types in Table 5. Actually, the frame will develop some end-bearing on the ends of the piles, and q-w curves to represent this could be included in Table 4. However, as discussed previously, these would have little effect under the range of loading studied in this problem series.

Problem 902 was worked by holding all tables from Problem 901 and simply adding on the new load and moment in Table 4(a). The moment was again due to the eccentricity of the applied load from the theoretical joint centerline.

The results of problems 901 and 902 are not sufficient to plot load-displacement and load-rotation curves. However, they may be all that is required if only the response of the structure under a given level of loading is desired. It is worth noting that the computer time required for six values of loading was approximately three minutes, while the time for these two problems was slightly in excess of one minute.

Analytical and Experimental Response of Frame

The load-displacement and load-rotation curves for the three-pile bent are shown in Figs 45 and 46, respectively. The agreement between the observed and calculated curves is rather good up to a load level of approximately 60 kips, particularly considering the possible variation in soil and structural properties. However, at a load level of about 60 kips, the observed curves show a marked decrease in stiffness. The analytical curves do not show such a response.

The deflected shape of the soil-supported bent for a load level of 80 kips is shown in Fig 47. The rigidity of the beam is obvious from the sketch. Because of this beam rigidity, the right column rotated down; therefore, the primary axial tension is carried by the center pile, rather than the pile on the right. Most of the flexural effects have died out at less than half the depth of the pile, a common occurrence when piles are subjected to both lateral and axial effects.

The axial thrust, shear, and bending moment diagrams for the center pile are shown in Fig 48. Note that the center pile is in tension. The variation of the axial forces in the three piles with the applied horizontal loading is plotted in Fig 49. Initially, all of the piles carry approximately equal loads in compression. Then, as the horizontal load is applied, the left pile increases in compression. The right pile initially starts to go into tension; however, as the rotation of the bent increases, the axial displacement of this pile is virtually eliminated and thus no significant axial force is developed therein. The center pile gradually increases in tension as the load is applied.

A detailed study of the output for a level of 80 kips does not indicate that any structural failure is imminent from excessive bending in the plane of

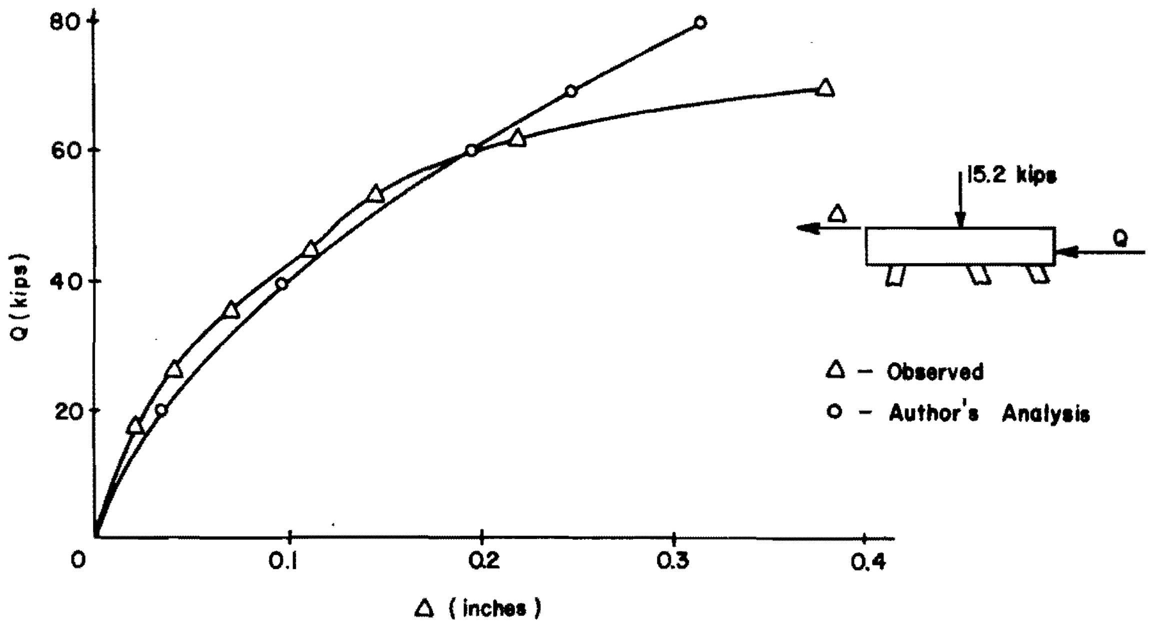


Fig 45. Load-displacement curves for three-pile bent.

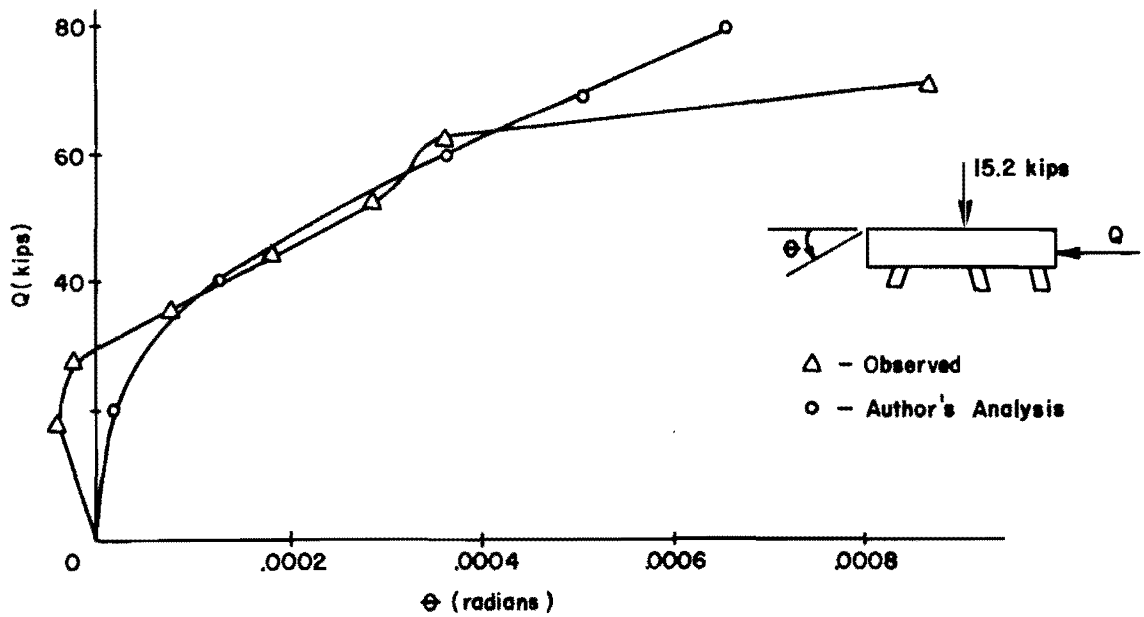


Fig 46. Load-rotation curves for three-pile bent.

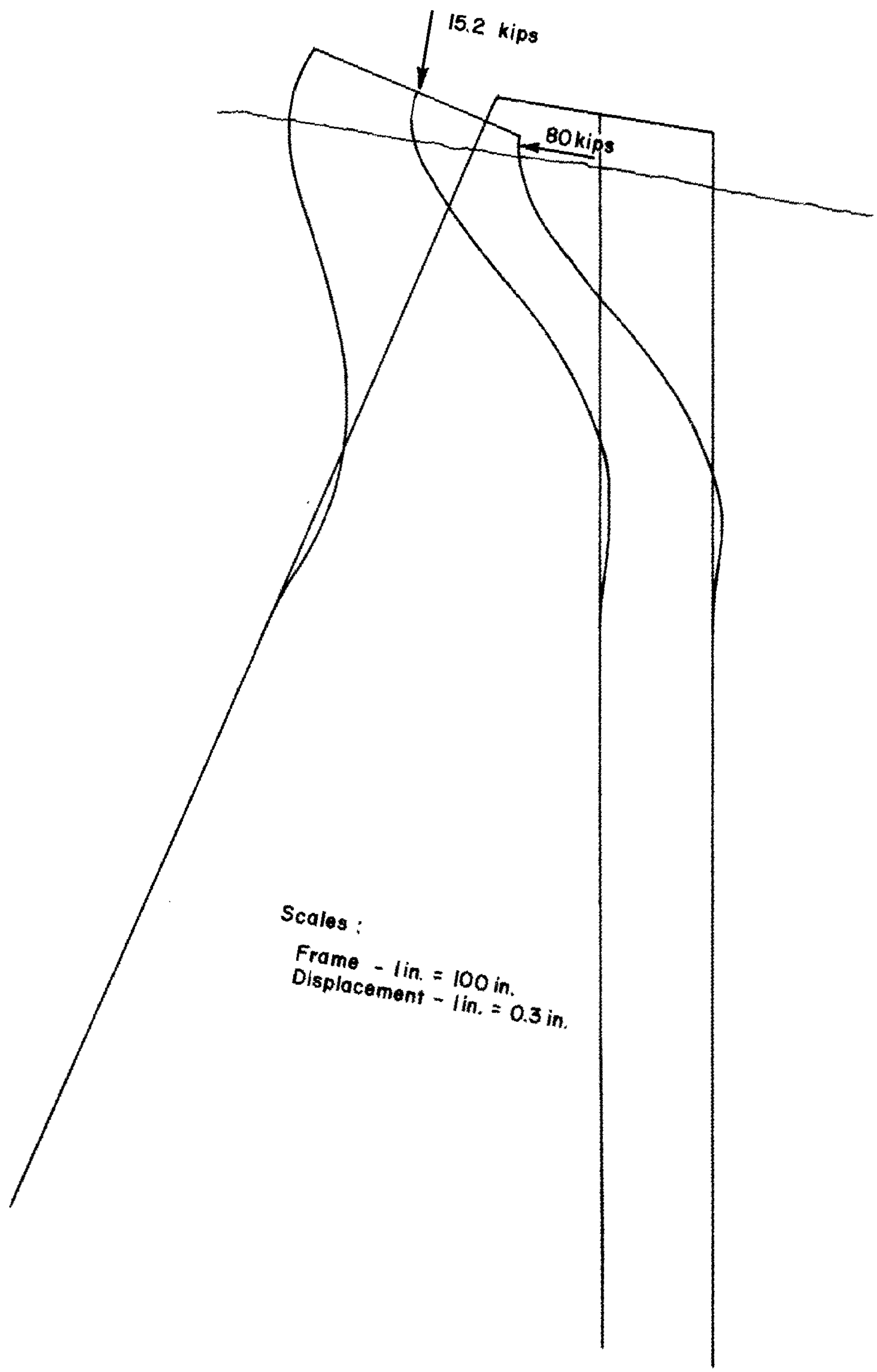


Fig 47. Deflected shape of soil-supported bent.

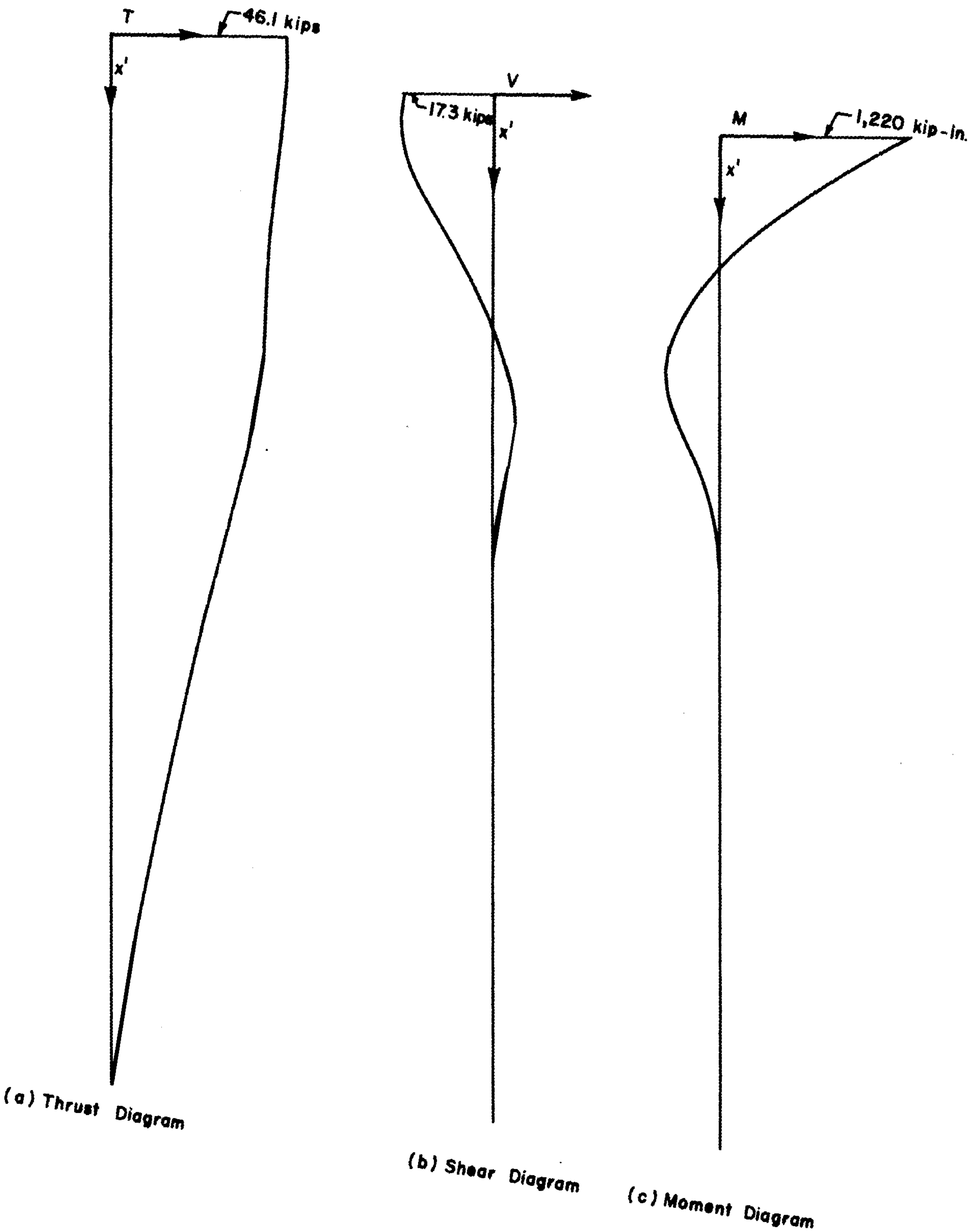


Fig 48. Variation in thrust, shear, and moment along the length of the center pile for lateral load of 80 kips.

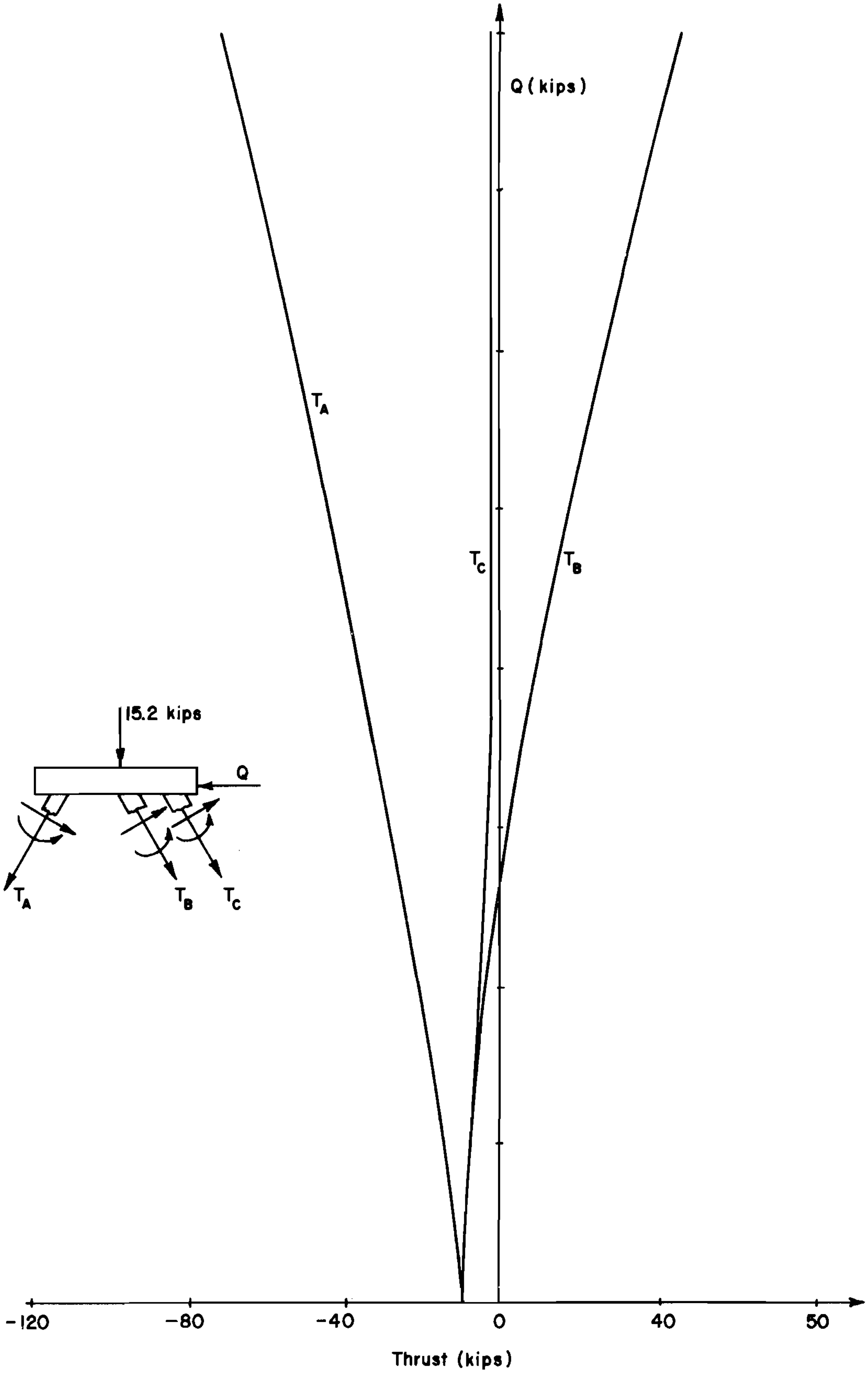


Fig 49. Pile thrust variations.

the structure. However, the observed load-displacement and load rotation curves indicate some sort of distress in the frame. There are several possible sources of this discrepancy. The nominal shear stress in the center column is 91 psi. This rather high shear stress, in conjunction with the axial tension in this column, could be one possible source of distress. No details of stirrups were given for the piles. Another possible source of loss of strength would be at the connection from the pile to the beam. No details of the imbedment length of the bars at this point are given. The combination of axial tension, bending moment, and high shear force could well have caused a pullout problem, particularly since plane bars were used.

Summary of Chapter 9

The discrete element frame solution was compared with a previous discrete element solution of line members for long laterally supported piles. The agreement was excellent. The results of the test of a laterally and axially loaded pile-supported structure were compared with the discrete element frame solution. Agreement was extremely good until the load level just prior to the loading on the test frame was stopped.

CHAPTER 10. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The principal result of this research has been the development of a method of analysis for predicting the static load-displacement response of plane frames which have significant material, geometric, and support nonlinearities. The analysis has been put into a useful form by developing computer program FRAME 51, which has sufficient generality to work real frame problems. The analysis and the program have been verified by working a number of problems and comparing the computer analyses with existing analytical and experimental results.

Summary of Presentation

In Chapter 1, the sources of nonlinear frame behavior were discussed. The tangent stiffness method as an extension of the direct stiffness method was reviewed in Chapter 2, and a general flow chart for a nonlinear frame solution using a nonlinear discrete element model of the frame members was presented. The details of the frame solution and the assumptions of the analysis were given in Chapter 3.

The nonlinear force-displacement equations for the discrete element were developed in Chapter 4, and Castigliano's first theorem was applied to develop a general discrete element stiffness matrix. Then the member solutions needed to define the force-displacement response of the member were discussed. The numerical integration of nonlinear stress-strain curves to define the force-deformation response at a cross section is given in Appendix B. The matrices needed to generate the stiffness matrix for the discrete element used in the member solutions are listed in Appendix C.

Chapter 5 presented a description of the computer program and an example problem to illustrate the use of the program.

Several members with a high degree of geometric nonlinearity were worked in Chapter 6 and the results were in good agreement with existing analytical solutions. The effects of nonlinear stress-strain curves and residual stresses on the force deformation response of a steel cross section were demonstrated and the computer analysis gave a good correlation with existing analytical procedures.

In Chapter 7, two steel frames which had been previously tested were analyzed. The observed behavior, throughout the complete load-displacement range, was predicted by the discrete element solution, within the bounds of experimental error. The ability of the program to handle axially prestressed members and the joint effect was also demonstrated. In Chapter 8, a variety of concrete problems were worked: lightly reinforced members, a prestressed beam with a small percentage of reinforcement, and two concrete frames. The response of all of these was predicted well qualitatively, and the quantitative answers were adequate for design applications.

The method of analysis was used in Chapter 9 to predict the general load-displacement response of a bent containing laterally and axially loaded piles. The problem had nonlinear material, geometric, and support characteristics.

Conclusions and Recommendations

Based on the demonstrated ability of the program to predict the response of a wide range of nonlinear frames, the method of analysis is felt to be valid within the scope of the stated assumptions. Due to the broad analytical scope of the work, conclusions about nonlinear behavior for specific types of structures will not be drawn at this time. Before such conclusions are drawn, more detailed studies should be made using the computer program in conjunction with existing experimental data and as an aid to planned experimental programs.

The program was intended to be capable of working real structures subjected to complex systems of loads and support conditions. This capability has been demonstrated in the example problems. There are, however, some modifications that could be made in order to make the program more convenient to the user. Several possible modifications are

(1) Extend the input formats to include automatic generation of stress-strain curves and cross section data for standard construction practices.

(2) Extend the input formats to automatically subdivide pile-type members into submembers and generate the soil-support curves from a limited amount of input of soil shear strength and deformation characteristics.

(3) Modify the program to allow the same general variations in nonlinear stiffness properties throughout the length of the member as permitted for loads and linear stiffness properties.

Because of the wide range of application, the program may not be extremely efficient for a particular type of problem that does not need the full generality of the program. For instance, most civil engineering structures attain their maximum load before really large displacements occur, as borne out in the example problems. Therefore, some saving in computer time could be made by using a less rigorous model of the large displacement effects; i.e., the first one or two terms of the series expansions of the trigonometric functions could be used in the element force-displacement equations and stiffness matrices. Options could be provided in the program to allow the user to make such simplifications in the analysis.

Finally, the scope of this work was limited to the short-term static, nonlinear but elastic response of two-dimensional frames; however, many framed structures have important time-dependent dynamic, inelastic, and three-dimensional characteristics. The work done in this research could serve as a guide for efforts to extend the nonlinear analysis technique to include these effects. For instance, the general derivation of the discrete element stiffness matrix which was used in Chapter 4 for plane frame members is valid for any discrete element with m discrete energy absorbing springs and n element end-displacements. This should prove helpful in developing or checking the stiffness matrix for a three-dimensional discrete element model of a line member.

REFERENCES

1. Adams, Peter F., "Load-Deflection Relations for Simple Frames," Fritz Engineering Laboratory Report No. 273.21, Lehigh University, Bethlehem, Pennsylvania, December 1964.

2. Agaskar, Vishnu L., and Michael F. Metcalf, "Interaction Between Structure and Pile Foundation of Offshore Platforms," Offshore Technology Conference, OTC 1484, 1971.

3. Alani, Adnan F., "Correlation of Physical Tests with Computer Simulation Models for Slab and Girder Bridge System," Ph.D. Dissertation, The University of Texas at Austin, May 1971.

4. Alvarez, Ronald J., and Charles M. Birnstiel, "Inelastic Analysis of Multistory, Multibay Frames," Proceedings of the American Society of Civil Engineers, Journal of the Structural Division, Vol. 94, No. ST5, May 1968.

5. American Concrete Institute Committee 318, Building Code Requirements for Reinforced Concrete (ACI 318-71), American Concrete Institute, Detroit, 1971.

6. American Institute of Steel Construction, Manual of Steel Construction, 7th. Ed., New York, 1970.

7. "American Standard FORTRAN," American Standards Association, New York, 1966.

8. Argysis, J. H., "Continua and Discontinua," Conference on Matrix Methods in Structural Mechanics, Wright Patterson Air Force Base, Dayton, Ohio, 1965.

9. Arnold, Peter, and others, "Experimental and Analytical Behavior of a Hybrid Frame," Fritz Engineering Laboratory Report No. 297.18, Lehigh University, Bethlehem, Pennsylvania, May 1966.

10. Austin, Walter J., Lecture Notes in "Numerical Methods in Structural Mechanics," given at the National Science Foundation Summer Institute in Structural Mechanics, University of Colorado, Boulder, Colorado, June 1968.

11. Atkins, W. D., "A Generalized Numerical Solution for Prestressed Concrete Beams," Masters Thesis, The University of Texas at Austin, August 1965.

12. Barnard, Peter R., "The Collapse of Reinforced Concrete Beams," Proceedings, Symposium on Flexural Mechanics of Reinforced Concrete (SP-12), American Society of Civil Engineers, 1964.

13. Bisshopp, K. E., and D. C. Drucker, "Large Deflections of Cantilever Beams," Quarterly Applied Mathematics 3, (1945).

14. Bleich, F., The Buckling Strength of Metal Structures, (Engineering Societies Monograph) 1st. Ed., McGraw-Hill Book Company, New York, 1951.

15. Burns, Ned H., "Moment Curvature Relations for Partially Prestressed Concrete Beams," Proceedings, Prestressed Concrete Institute, Vol. 9, No. 1, February 1964.

16. Chang, W. F., and Phil M. Ferguson, "Long Hinged Concrete Columns," Journal of the American Concrete Institute, Vol. 60, No. 1, January 1963.

17. Coyle, Harry M., and Lymon C. Reese, "Load Transfer for Axially Loaded Piles in Clay," Proceedings of the American Society of Civil Engineers, Journal of the Soil Mechanics and Foundations Division, Vol. 92, No. SM2, March 1966.

18. Endres, Frank L., and Hudson Matlock, "An Algebraic Equation Solution Process Formulated in Anticipation of Banded Linear Equations," Research Report No. 56-19, Center for Highway Research, The University of Texas at Austin, January 1971.

19. Felippa, C. A., "Refined Finite Element Analysis of Linear and Nonlinear Two-Dimensional Structures," SEL Report No. 66-22, University of California, Berkeley, 1966.

20. Fisher, J. W., et al, "Plastic Analysis and Tests of Haunched Corner Connections," Welding Research Council, Bulletin No. 91, October 1963.

21. Frisch-Fay, R., Flexible Bars, Butterworth, London, 1962.

22. Furlong, Richard W., "Long Columns in Single Curvature as a Part of Concrete Frames," Ph.D. Dissertation, The University of Texas, Austin, June 1963.

23. Furlong, R. W., and P. M. Ferguson, "Tests of Frames with Columns in Single Curvature," Proceedings, Symposium on Reinforced Concrete Columns (SP-13), American Society of Civil Engineers, 1966.

24. Goldberg, J. E., and R. M. Richard, "Analysis of Nonlinear Structures," Proceedings of the American Society of Civil Engineers, Journal of the Structural Division, Vol. 89, No. ST4, August 1963.

25. Gunnin, Bill Lee, "Nonlinear Analysis of Plane Frames," Ph.D. Dissertation, The University of Texas at Austin, January 1970.

26. Hawkins, N. M., et al, "Strength and Behavior of Two-Span Continuous Prestressed Concrete Beams," University of Illinois Engineering Experimental Station, Structural Research Series No. 225, September 1961.

27. Hays, Clifford O., and Hudson Matlock, "Linearly Elastic Analysis of Plane Frames Subjected to Complex Loading Conditions," Research Report No. 56-21, Center for Highway Research, The University of Texas at Austin, June 1971.

28. Hilderbrand, F. B., Introduction to Numerical Analysis, McGraw-Hill, New York, 1956.

29. Hognestad, Elvind, "A Study of Combined Bending and Axial Load in Reinforced Concrete Members," University of Illinois Engineering Experiment Station, Bulletin Series No. 399, November 1951.

30. Hognestad, Elvind, and others, "Ultimate Flexural Strength of Prestressed and Conventionally Reinforced Concrete Beams," Proceedings, Journal of the American Concrete Institute, Vol. 52, January 1956.

31. Huber, A. W., and L. S. Beedle, "Residual Stress and the Compressive Strength of Steel," Welding Journal, December 1954.

32. Jennings, A., "Frame Analysis Including Change of Geometry," Proceedings of the American Society of Civil Engineers, Journal of the Structural Division, Vol. 94, No. ST3, March 1960.

33. Ketter, Robert L., and others, "Plastic Deformation of Wide-Flange Beam-Columns," Transactions, American Society of Civil Engineers, Vol. 120, 1955.

34. Lee, Seng-Lip, and others, "Large Deflections and Stability of Elastic Frames," Proceedings of the American Society of Civil Engineers, Journal of the Engineering Mechanics Division, Vol. 94, No. EM2, April 1968.

35. Lin, T. Y., Design of Prestressed Concrete Structures, 2nd. Ed., John Wiley and Sons, New York, 1963.

36. Martin, Harold C., Introduction to Matrix Methods of Structural Analysis, McGraw-Hill, New York, 1966.

37. Martin, H. C., "On the Derivation of Stiffness Matrices for the Analysis of Large Deflection and Stability Problems," Proceedings, Conference on Matrix Methods in Structural Mechanics, Wright Patterson Air Force Base, Dayton, Ohio, 1965.

38. Matlock, Hudson, "Correlations for Design of Laterally Loaded Piles in Soft Clay," Offshore Technology Conference, OTC 1204, 1970.

39. Matlock, Hudson, and others, A report on nonlinear beam-column analysis considering geometric, material, and support nonlinearities for line members being prepared for the Center for Highway Research, The University of Texas at Austin, Texas.

40. Matlock, Hudson, and T. Allan Haliburton, "A Finite-Element Method of Solution for Linearly Elastic Beam-Columns," Research Report No. 56-1, Center for Highway Research, The University of Texas, Austin, September 1966.

41. Matlock, Hudson, and T. Allan Haliburton, "A Program for Finite-Element Solution of Beam-Columns on Nonlinear Supports," Hudson Matlock, 1335 Bonham Terrace, Austin, Texas, June 1964.

42. Mattock, Alan H., "Rotational Capacity of Hinging Regions in Reinforced Concrete Beams," Proceedings, Symposium on Flexural Mechanics of Reinforced Concrete, (SP-12), American Society of Civil Engineers, 1964.

43. Mises, R. V., "On Saint Venants Principle," Bulletin of the American Mathematical Society, Vol. 51, 1945, p. 555.

44. Murray, D. W., "Large Deflection Analysis of Plates," Report No. 67.24, Structural Engineering Laboratory, University of California, Berkeley, September 1967.

45. Newmark, N. M., "Numerical Procedure for Computing Deflections, Moments, and Buckling Loads," Proceedings, American Society of Civil Engineers, Vol. 108, 1943, p. 1161.

46. Osgood, W. R., "A Theory of Flexure for Beams with Non-Parallel Extreme Fibers," Journal of Applied Mechanics, American Society of Mechanical Engineers, Vol. 6, 1939, pp. 122-127.

47. Parikh, Balmukund P., "Elastic-Plastic Analysis and Design of Unbraced Multi-Story Steel Frames," Fritz Engineering Laboratory Report No. 273.44, Lehigh University, Bethlehem, Pennsylvania, May 1966.

48. Parker, Frazier, Jr., and Lymon C. Reese, "Experimental and Analytical Studies of Behavior of Single Piles in Sand Under Lateral and Axial Loads," Research Report No. 117-2, Center for Highway Research, The University of Texas at Austin, November 1970.

49. Przemieniecki, J. S., Theory of Matrix Structural Analysis, McGraw-Hill, New York, New York, 1968.

50. Rao, P. S., "Die Grundlagen Zur Berechnung Der Bei Statisch Unbestimmten Stahlbeton Konstruktionen Im Plastischen Bereich Auftertenden Umlageunge Der Schnittkrafte," Deutscher Ausschus Fur Stahlbeton, Heft 177, Berlin, 1966.

51. Reese, Lymon C., and Hudson Matlock, "Behavior of a Two-Dimensional Pile Group Under Inclined and Eccentric Loading," Proceedings of Offshore Exploration Conference, 1966.

52. Rhode, F. V., "Large Deflections of a Cantilever Beam with a Uniformly Distributed Load," Quarter Applied Mathematics, 11 (1953).

53. Saafan, S. A., and D. M. Brotton, "Elastic Finite Deflection Analysis of Rigid Frameworks by Digital Computer," Symposium on the Use of Computers in Civil Engineering, 1962.

54. Shanley, F. R., "Inelastic Column Theory," Journal of Aeronautical Science, Vol. 13, No. 12, December 1946.

55. Skempton, A. W., "The Bearing Capacity of Clays," Building Research Congress, Division I, Part III, 1951, pp. 180-189.

56. Timoshenko, S., and James M. Gere, Theory of Elastic Stability, (Engineering Societies Monograph), 2nd. Ed., McGraw-Hill, New York, 1961.

57. Timoshenko, S., and S. Woinowsky-Krieger, Theory of Plates and Shells, (Engineering Societies Monograph), 2nd. Ed., McGraw-Hill, New York, 1959.

58. Welch, Robert C., Dissertation in progress on nonlinear response of laterally and axially loaded piles, under the direction of Lymon C. Reese, The University of Texas at Austin.

59. Wilson, E. L., "Matrix Analysis of Nonlinear Structures," American Society of Civil Engineers, Second Conference on Electronic Computation, 1963.

60. Wright, E. W., and E. H. Gaylord, "Analysis of Unbraced Multi-Story Steel Rigid Frames," Proceedings of the American Society of Civil Engineers, Journal of the Structural Division, Vol. 94, No. ST5, May 1968.

61. Yarimci, Erol, "Incremental Inelastic Analysis of Framed Structures and Some Experimental Verifications," Fritz Engineering Laboratory Report No. 273.45, Lehigh University, Bethlehem, Pennsylvania, May 1965.

62. Yura, J. A., Personal conversation, January 28, 1971.

63. Yura, J. A., "The Strength of Braced Multi-Story Steel Frames," Ph.D. Dissertation, Lehigh University, Bethlehem, Pennsylvania, 1965.

64. Yura, Joseph A., "Strength of Single-Story Steel Frames," Proceedings of the American Society of Civil Engineers, Journal of the Structural Division, Vol. 91, No. ST5, October 1965.

65. Zarghamee, Mehdi S., and Jayant M. Shah, "Stability of Spaceframes," Proceedings of the American Society of Civil Engineers, Journal of the Engineering Mechanics Division, Vol. 94, No. EM2, April 1968.

66. Zienkiewicz, O. C., The Finite Element Method in Structural and Continuum Mechanics, McGraw-Hill, Maidenhead, Berkshire, England, 1967.

APPENDIX A

PRISMATIC MEMBER LINEAR STIFFNESS MATRIX [K]
AND TRANSFORMATION MATRIX [T]

APPENDIX A. PRISMATIC MEMBER LINEAR STIFFNESS MATRIX [K] AND TRANSFORMATION MATRIX [T]

$$[K] = \left[\begin{array}{ccc|ccc} \frac{AE}{L} & 0 & 0 & -\frac{AE}{L} & 0 & 0 \\ 0 & \frac{12EI}{L^3} & \frac{6EI}{L^2} & 0 & -\frac{12EI}{L^3} & \frac{6EI}{L^2} \\ 0 & \frac{6EI}{L^2} & \frac{4EI}{L} & 0 & -\frac{6EI}{L^2} & \frac{2EI}{L} \\ \hline -\frac{AE}{L} & 0 & 0 & \frac{AE}{L} & 0 & 0 \\ 0 & -\frac{12EI}{L^3} & -\frac{6EI}{L^2} & 0 & \frac{12EI}{L^3} & -\frac{6EI}{L^2} \\ 0 & \frac{6EI}{L^2} & \frac{2EI}{L} & 0 & -\frac{6EI}{L^2} & \frac{4EI}{L} \end{array}\right]$$

$$[T] = \begin{bmatrix} \alpha & \beta & 0 \\ -\beta & \alpha & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

A = Cross sectional area (in^2)

E = Modulus of elasticity (kip/in^2)

I = moment on inertia (in^4)

L = length of member (in)

α = Cosine of angle between the member and the structure x-axis

β = Cosine of angle between the member and the structure y-axis

APPENDIX B

NUMERICAL INTEGRATION OF NONLINEAR STRESS-STRAIN CURVES

APPENDIX B. NUMERICAL INTEGRATION OF NONLINEAR STRESS-STRAIN CURVES

A cross-section can be specified by a series of rectangles. A section composed of nonrectangular pieces will of course be only approximately represented. Similarly, a nonlinear stress-strain curve may be represented by a series of straight line segments. The more nonlinear the curve, the more points required to accurately define the curve. The procedure developed herein is exact for a section actually composed of all rectangular pieces and whose stress-strain curves consist of a finite number of straight line segments. The program also permits input of thin wall tubular pieces as discussed at the end of this appendix.

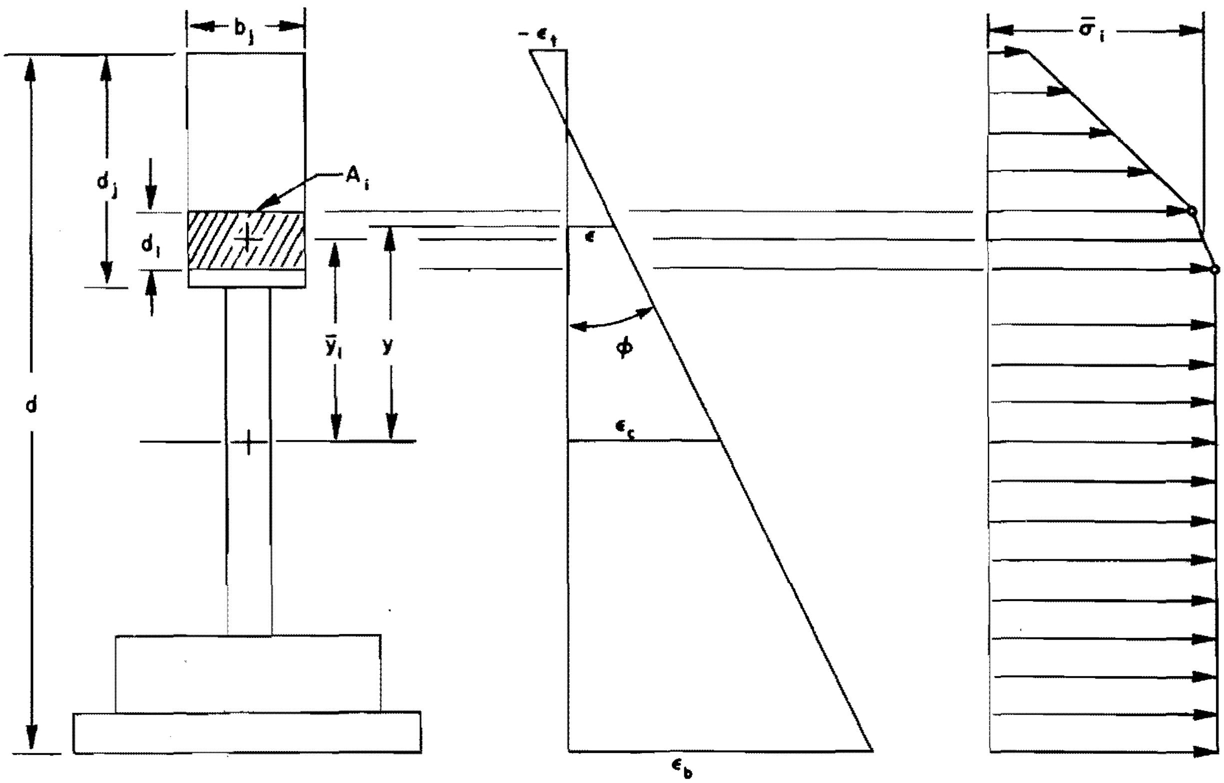
Consider the cross-section shown in Fig 50(a). The section is composed of m rectangles ($j = 1, m$). The stress-strain curve for the rectangle is defined by the stress-strain curve of Fig 50(d). The curve is specified by giving a number of points on the curve. Different rectangles of the section may have different stress-strain curves.

A linear variation of strain is assumed over the depth of the section as shown in Fig 50(b). Thus, the strain distribution is defined by specifying the strains at the top and bottom ϵ_t and ϵ_b . For small strains, the curvature ϕ is given by

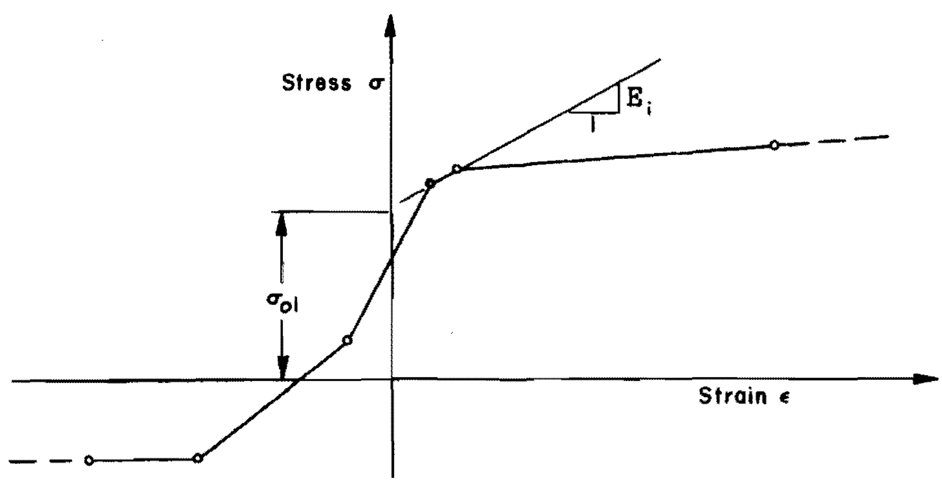
$$\phi = \frac{(\epsilon_t - \epsilon_b)}{d} \tag{B.1}$$

Positive strain is tension and positive curvature indicates more tension on the bottom fiber of the member than on the top. The strain distribution is also defined if the curvature ϕ and the strain ϵ_c at the member's x'-axis* are known. The strain at any point y is given by

*The geometric centroid is used as the member axis for sections of one material; however, for beams of more than one material, the plastic centroid has been recommended (Ref 5).



(a) Cross section. (b) Strain distribution. (c) Stress distribution.



(d) Stress-strain curve.

Fig 50. Cross-section and stress-strain assumptions.

$$\epsilon = \epsilon_c - \phi y \tag{B.2}$$

With the strain distribution so defined, the stress distribution is then found by using the stress-strain curves for each of the m rectangles. The j^{th} rectangle, as shown in Fig 50(a), does not have a linear variation in stress over its depth. However, it may be subdivided into n sub-rectangles ($i = 1, n$) such that each sub-rectangle will have a linear variation in stress over its depth d_i. The slope of the stress-strain curve over the i^{th} sub-rectangle is E_i and the intercept of the straight line segment and the stress axis is σ_{oi}. The stress at any point in the sub-rectangle is

$$\sigma = \sigma_{oi} + E_i \epsilon \tag{B.3}$$

Combining Eqs B.2 and B.3,

$$\sigma = \sigma_{oi} + E_i(\epsilon_c - \phi y) \tag{B.4}$$

The thrust T_i acting on the sub-rectangular area A_i is found by integrating the stress over the area.

$$T_i = \iint_{A_i} \sigma \, dA_i \tag{B.5}$$

$$T_i = \iint_{A_i} [\sigma_{oi} + E_i(\epsilon_c - \phi y)] \, dA_i \tag{B.6}$$

$$T_i = \sigma_{oi} \iint_{A_i} dA_i + E_i \epsilon_c \iint_{A_i} dA_i - E_i \phi \iint_{A_i} y \, dA_i \tag{B.7}$$

And since

$$\bar{y}_i A_i = \iint_{A_i} y \, dA_i \tag{B.8}$$

where $\bar{y}_i$ is the distance from the section centroid to the centroid of A_i, as shown in Fig 50(a).

$$T_i = \sigma_{oi}A_i + E_i\epsilon_c A_i - E\phi\bar{y}_i A_i \tag{B.9}$$

The thrust T over the entire cross-section is found by summing up T_i for all the sub-rectangles. Thus,

$$T = \sum_{j=1}^{m} \sum_{i=1}^{n} (\sigma_{oi} + E_i\epsilon_c - E\phi\bar{y}_i)A_i \tag{B.10}$$

The multiple of A_i in Eq B.10 is seen (from Eq B.4) to be the stress $\bar{\sigma}_i$ which is the stress at the centroid of the sub-rectangle. Thus,

$$T = \sum_{j=1}^{m} \sum_{i=1}^{n} \bar{\sigma}_i A_i \tag{B.11}$$

The moment of T_i about the centroid of the section, M_i, is found by integrating Eq B.12

$$M_i = -\iint_{A_i} \sigma y \, dA_i \tag{B.12}$$

Combining Eqs and B.4 and B.12,

$$M_i = E_i\phi\iint_{A_i} y^2 dA_i - (\sigma_{oi} + E_i\epsilon_c)\iint_{A_i} y dA_i \tag{B.13}$$

The moment of inertia of sub-rectangle i about the centroid of the section, I_i, is given by

$$I_i = \iint_{A_i} y^2 dA_i \tag{B.14}$$

Combining Eqs B.8, B.13, and B.14 gives

$$M_i = E_i I_i \phi - (\sigma_{oi} + E_i \epsilon_c)\overline{y}_i A_i \tag{B.15}$$

Thus, the total moment on the cross section is found to be

$$M = \sum_{j=1}^{m} \sum_{i=1}^{n} E_i I_i \phi - (\sigma_{oi} + E_i \epsilon_c)\overline{y}_i A_i \tag{B.16}$$

From Eq B.4,

$$\overline{\sigma}_i = \sigma_{oi} + E_i(\epsilon_c - \phi\overline{y}_i) \tag{B.17}$$

Combining Eqs B.16 and B.17,

$$M = \sum_{j=1}^{m} \sum_{i=1}^{m} E_i I_i \phi - (\overline{\sigma}_i + E_i \phi\overline{y}_i)\overline{y}_i A_i \tag{B.18}$$

By the parallel axis theorem,

$$I_i = \overline{I}_i + A_i(\overline{y}_i)^2 \tag{B.19}$$

where $\overline{I}_i$ is the moment of inertia of the i^{th} sub-rectangle about its own centroid. Thus, combining Eqs B.11, B.18, and B.19 gives

$$M = \sum_{j=1}^{m} \sum_{i=1}^{n} E\overline{I}_i \phi - T_i \overline{y}_i \tag{B.20}$$

For any distribution of strain over the cross-section, i.e., given ϵ_c and ϕ from a geometric analysis of the model, the process to determine T and M is a straightforward process which does not require any iterations. First, subdivide the rectangles of the cross-section into sub-rectangles. Each sub-rectangle is obtained such that it has a linear stress distribution over it. The technique to do this is a direct process and is illustrated in the flow chart for subroutine FAEJR. Then, by interpolations along the stress-strain curve, the stress $\bar{\sigma}_i$ can be found. Then Eq B.11 may be used to find the thrust. Similarly E_i may be found by interpolation and $\bar{I}_i$ computed for the sub-rectangle and Eq B.20 used to find the moment.

The above procedure completely defines the thrust and moment on a given section given the strain distribution. It is also desired to have the stiffness of the cross-section. In Appendix C, the discrete-element force deformation matrix is given in terms of the partial derivatives of thrust and moment with respect to axial strain and curvature. The following derivatives are thus needed:

Differentiating Eq B.10,

$$\frac{\partial T}{\partial \epsilon_c} = \sum_{j=1}^{m} \sum_{i=1}^{n} A_i E_i \tag{B.21}$$

This is the sum of AE for all sub-rectangles and is thus equal to AE for a cross-section with a single linear stress-strain curve. Thus, it can be interpreted as the effective AE of the section.

Differentiating Eq B.16,

$$\frac{\partial M}{\partial \phi} = \sum_{j=1}^{m} \sum_{i=1}^{n} E_i I_i \tag{B.22}$$

For a cross-section with a constant value of E , this becomes simply EI at the geometric centroid, and $\frac{\partial M}{\partial \phi}$ may be interpreted on the effective EI of the section. Taking the derivative of Eq B.10 with respect to ϕ and Eq B.16 with respect to ϵ_c gives

$$\frac{\partial T}{\partial \phi} = \frac{\partial M}{\partial \varepsilon_c} = \sum_{j=1}^{m} \sum_{i=1}^{n} - A_i E_i \bar{y}_i \qquad (B.23)$$

For a section with a constant E , the partial derivatives of Eq B.23 become zero. They are an indication of the increment in thrust due to an increment in curvature and the increment in moment due to an increment in axial strain. This property of the section will be referred to as AEY .

Thin Wall Tubular Sections

The program also allows input of a piece of a section having the properties of a thin wall tube. Each tubular piece is subdivided by the program into 20 equal radial segments and equivalent rectangular properties for each segment are calculated. Then the equivalent rectangles are used in the numerical integration procedure just developed. Using 20 segments, it was found that the moment of inertia of the equivalent rectangles was different from the moment of inertia of a typical thin tubular section by less than 1 percent.

APPENDIX C

DISCRETE ELEMENT MATRICES

APPENDIX C. DISCRETE ELEMENT MATRICES

Initial Stress Stiffness Matrices $[k]_{ST}$ and $[k]_{SV}$

The initial stress stiffness matrices $[k]_{ST}$ and $[k]_{SV}$ were obtained by taking the second partial derivatives indicated in Eq 4.36 and then separating the terms containing the thrust T and the shear V . To illustrate:

From Eq 4.36

$$kst_{11} + ksv_{11} = \sum_{k=1}^{3} S_k \frac{\partial^2 \delta_k}{\partial w_1 \partial w_1} \tag{C.1}$$

kst_{11} and ksv_{11} are the terms on the first row and the first column of $[k]_{ST}$ and $[k]_{SV}$.

The summation of k from 1 to 3 is over the three energy absorbing elements of the bar; the axial deformable bar with its internal force T and its deformation δ , the rotational springs at points 1 and 2 on the element with their internal moments M_1 and M_2 and their corresponding deformations Ψ_1 and Ψ_2 . Thus

$$kst_{11} + ksv_{11} = T \frac{\partial^2 \delta}{\partial w_1 \partial w_1} + \frac{M_1 \partial^2 \Psi 1}{\partial w_1 \partial w_1} + \frac{M_2 \partial^2 \Psi 2}{\partial w_1 \partial w_1} \tag{C.2}$$

The partials in Eq C.2 are found by differentiating Eqs 4.1 through 4.6.

$$\frac{\partial^2 \delta}{\partial w_1 \partial w_1} = \frac{s^2}{(h + \delta)^3} \tag{C.3}$$

$$\frac{\partial^2 \psi 1}{\partial w_1 \partial w_1} = \frac{2s(h + r)}{(h + \delta)^4} \tag{C.4}$$

$$\frac{\partial^2 \Psi 2}{\partial w_1 \partial w_1} = \frac{-2s(h + r)}{(h + \delta)^4} \tag{C.5}$$

Thus

$$kst_{11} + ksv_{11} = \frac{Ts^2}{(h + \delta)^3} + \frac{M_1 2s(h + r)}{(h + \delta)^4} - \frac{M_2 2s(h + r)}{(h + \delta)^4} \tag{C.6}$$

Noting the shear V as given by Eq 4.13

$$kst_{11} + ksv_{11} = \frac{Ts^2}{(h + \delta)^3} \quad \frac{-2Vs(h + r)}{(h + \delta)^3} \tag{C.7}$$

Then

$$kst_{11} = \frac{Ts^2}{(h + \delta)^3} \tag{C.8}$$

and

$$ksv_{11} = \frac{-2Vs(h + r)}{(h + \delta)^3} \tag{C.9}$$

The remainder of the terms were similarly computed. The algebra involved in getting $[k]_{ST}$ and $[k]_{SV}$ was quite extensive as was the algebra involved in getting the incremental deformation displacement [B] (shown later in this Appendix). All three of these matrices are used to evaluate the element's stiffness matrix [k] and it was desired to check the algebra in some way. A numerical differentiation using 30 significant figures was performed on the element's force displacement equations and these results were found to compare to 14 significant figures with the results obtained using the closed form procedure developed herein on several test cases. The test cases were chosen over a fairly wide range of element displacements, hence a fair degree of confidence can be placed in the results.

$$[k]_{ST} = \frac{T}{(h+\delta)^3}\begin{bmatrix} s^2 & -s(h+r) & kst_{13} & -s^2 & s(h+r) & kst_{16} \\ & (h+r)^2 & kst_{23} & s(h+r) & -(h+r)^2 & kst_{26} \\ & \text{Symmetric} & kst_{33} & -kst_{13} & -kst_{23} & kst_{36} \\ & & & s^2 & -s(h+r) & -kst_{16} \\ & & & & (h+r)^2 & -kst_{26} \\ & & & & & kst_{66} \end{bmatrix}$$

$$kst_{13} = \frac{-hs}{2}[s \cdot \sin(w_3) + (h+r)\cos(w_3)]$$

$$kst_{16} = \frac{-hs}{2}[s \cdot \sin(w_6) + (h+r)\cos(w_6)]$$

$$kst_{23} = \frac{h}{2}(h+r)[s \cdot \sin(w_3) + (h+r)\cos(w_3)]$$

$$kst_{26} = \frac{h}{2}(h+r)[s \cdot \sin(w_6) + (h+r)\cos(w_6)]$$

$$kst_{33} = \frac{h^2}{4}[s \cdot \sin(w_3) + (h+r)\cos(w_3)]^2 + \frac{h}{2}(h+\delta)^2[s.\sin(w_3) + (h+r)\cos(w_3)]$$

$$kst_{36} = \frac{h^2}{4}[s \cdot \sin(w_3) + (h+r)\cos(w_3)][s \cdot \sin(w_6) + (h+r)\cos(w_6)]$$

$$kst_{66} = \frac{h^2}{4}[s \cdot \sin(w_6) + (h+r)\cos(w_6)]^2 + \frac{h}{2}(h+\delta)^2[\sin(w_6) + (h+r)\cos(w_6)]$$

$$[k]_{SV} = \frac{-V}{(h+\delta)^3}\begin{bmatrix} 2s(h+r) & z^{*} & ksv_{13} & -2s(h+r) & -z^{*} & ksv_{16} \\ & -2s(h+r) & ksv_{23} & -z^{*} & 2s(h+r) & ksv_{26} \\ & \text{Symmetric} & ksv_{33} & -ksv_{13} & -ksv_{23} & ksv_{36} \\ & & & 2s(h+r) & z^{*} & -ksv_{16} \\ & & & & -2s(h+r) & -ksv_{26} \\ & & & & & ksv_{66} \end{bmatrix}$$

$$z = s^2 - (h+r)^2 {}^{*}$$

$$ksv_{13} = \frac{hz\cos(w_3)}{2} - hs(h+r)\sin(w_3)$$

$$ksv_{16} = \frac{hz\cos(w_6)}{2} - hs(h+r)\sin(w_6)$$

$$ksv_{23} = \frac{-hz\sin(w_3)}{2} - hs(h+r)\cos(w_3)$$

$$ksv_{26} = \frac{-hz}{2}\sin(w_6) - hs(h+r)\cos(w_6)$$

$$ksv_{33} = \frac{h^2}{2}s(h+r)[\sin^2(w_3) - \cos^2(w_3)] - \frac{h^2}{2}z\sin(w_3)\cos(w_3)$$
$$+ \frac{h}{2}(h+\delta)^2[(h+r)\sin(w_3) - s\cos(w_3)]$$

$$ksv_{36} = \frac{h^2}{2}s(h+r)[\sin(w_3)\sin(w_6) - \cos(w_3)\cos(w_6)]$$
$$- \frac{h^2}{4}z[\sin(w_3)\cos(w_6) + \cos(w_3)\sin(w_6)]$$

$$ksv_{66} = \frac{h^2}{2}s(h+r)[\sin^2(w_6) - \cos^2(w_6)] - \frac{h^2}{2}z\sin(w_6)\cos(w_6)$$
$$+ \frac{h}{2}(h+\delta)^2[(h+r)\sin(w_6) - s\cos(w_6)]$$

Incremental Deformation-Displacement Matrix [B]

$$[B] = \frac{1}{(h+\delta)^2}\begin{array}{c} \begin{array}{cccccc} \partial w_1 & \partial w_2 & \partial w_3 & \partial w_4 & \partial w_5 & \partial w_6 \end{array} \\ \left[\begin{array}{c|c|c|c|c|c} b_{11} & b_{12} & b_{13} & -b_{11} & -b_{12} & b_{16} \\ \hline b_{21} & b_{22} & b_{23} & -b_{21} & -b_{22} & b_{26} \\ \hline -b_{21} & -b_{22} & b_{33} & b_{21} & b_{22} & b_{36} \end{array}\right] \end{array} \begin{array}{c} \\ \partial_\delta \\ \partial\Psi_1 \\ \partial\Psi_2 \end{array}$$

$$b_{11} = -(h+r)(h+\delta)$$
$$b_{12} = -s(h+\delta)$$
$$b_{21} = s$$
$$b_{22} = -(h+r)$$

$$b_{13} = \frac{h}{2}(h+\delta)[(h+r)\sin(w_3) - s\cos(w_3)]$$

$$b_{16} = \frac{h}{2}(h+\delta)[(h+r)\sin(w_6) - s.\cos(w_6)]$$

$$b_{23} = -1 - \frac{h}{2}[(h+r)\cos(w_3) + s.\sin(w_3)]$$

$$b_{26} = -\frac{h}{2}[(h+r)\cos(w_6) + s.\sin(w_6)]$$

$$b_{33} = \frac{h}{2}[(h+r)\cos(w_3) + s\cdot\sin(w_3)]$$

$$b_{36} = 1 + \frac{h}{2}[(h+r)\cos(w_6) + s\cdot\sin(w_6)]$$

Incremental Force-Deformation Matrix [D]

The incremental force-deformation matrix [D] is found from Eq 4.25 where the forces are the thrust T , the moments M_1 and M_2 , and where the corresponding deformations are the discrete change in length δ , and the discrete angle changes Ψ_1 and Ψ_2 .

Thus

$$[D] = \begin{bmatrix} \frac{\partial T}{\partial \delta} & \frac{\partial T}{\partial \Psi_1} & \frac{\partial T}{\partial \Psi_2} \\ \frac{\partial M_1}{\partial \delta} & \frac{\partial M_1}{\partial \Psi_1} & 0 \\ \frac{\partial M_2}{\partial \delta} & 0 & \frac{\partial M_2}{\partial \Psi_2} \end{bmatrix} \qquad \text{(C.10)}$$

The evaluation of the partial derivative in Eq C.10 is made in terms of the derivative cross-section stiffnesses (EI , AE , AEY) developed in Appendix B. The relationships between the discrete model deformations and the member section deformations for small strains and curvature are:

$$\epsilon_c = \delta/2h \qquad \text{(C.11)}$$

$$\phi_1 = \Psi_1/h \qquad \text{(C.12)}$$

$$\phi_2 = \Psi_2/h \qquad \text{(C.13)}$$

Thus [D] may be written as

$$[D] = \begin{bmatrix} \frac{\partial T}{\partial \varepsilon_c} \cdot \frac{1}{2h} & \frac{\partial T}{\partial \phi_1} \cdot \frac{1}{2h} & \frac{\partial T}{\partial \varphi_2} \cdot \frac{1}{2h} \\ \frac{\partial M_1}{\partial \varepsilon_c} \cdot \frac{1}{2h} & \frac{\partial M_1}{\partial \phi_1} \cdot \frac{1}{h} & 0 \\ \frac{\partial M_2}{\partial \varepsilon_c} \cdot \frac{1}{2h} & 0 & \frac{\partial M_2}{\partial \varphi_2} \cdot \frac{1}{h} \end{bmatrix} \tag{C.14}$$

All the derivatives in Eq C.14 are seen to be the stiffness terms of Appendix B evaluated at points 1 and 2 in the element. Thus

$$D = \begin{bmatrix} \frac{AE_1 + AE_2}{4h} & \frac{AEY_1}{2h} & \frac{AEY_2}{2h} \\ \frac{AEY_1}{2h} & \frac{EI_1}{h} & 0 \\ \frac{AEY_2}{2h} & 0 & \frac{EI_2}{h} \end{bmatrix} \tag{C.15}$$

for the special case of a linear material (constant E). And assuming the average value of A and I are used, [D] becomes

$$[D] = \begin{bmatrix} \frac{AE}{2h} & 0 & 0 \\ 0 & \frac{EI}{h} & 0 \\ 0 & 0 & \frac{EI}{h} \end{bmatrix} \tag{C.16}$$

APPENDIX D

TRANSFORMATION OF SPRINGS BETWEEN MEMBER AND STRUCTURE COORDINATES

APPENDIX D. TRANSFORMATION OF SPRINGS BETWEEN MEMBER AND STRUCTURE COORDINATES

Case A - Structure Joint Springs in Direction of Member Coordinates

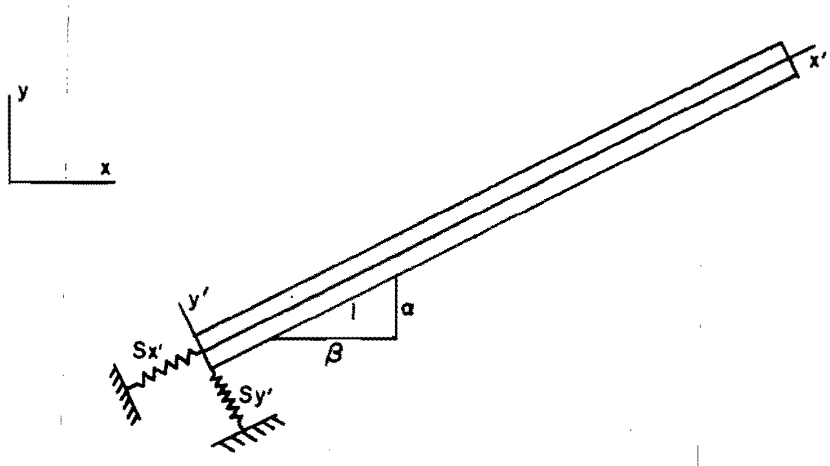


Fig 51. Structure springs in member coordinates.

From the figure above it is seen that a unit displacement along x produces a force in both the x and y-directions. The effect of $S_{x'}$ and $S_{y'}$ on the structure stiffness matrix is the addition of the 2 X 2 stiffness matrix $[K]_{SM}$

$$[K]_{SM} = \left[\begin{array}{c|c} \alpha^2 S_{x'} + \beta^2 S_{y'} & \alpha\beta(S_{x'} - S_{y'}) \\ \hline \alpha\beta(S_{x'} - S_{y'}) & \beta^2 S_{x'} + \alpha^2 S_{y'} \end{array}\right] \tag{D.1}$$

The terms in $[K]_{SM}$ may be easily verified. The first term ksm_{11} is the force directed along the x axis due to a unit displacement along the x axis.

The evaluation of forces in structure directions due to springs in member x' and y'-directions is accomplished by transforming structure displacements to member coordinates and then evaluating the spring forces. Then the forces are transformed back to structure coordinates.

Case B - Member Springs in Direction of Structure Coordinates

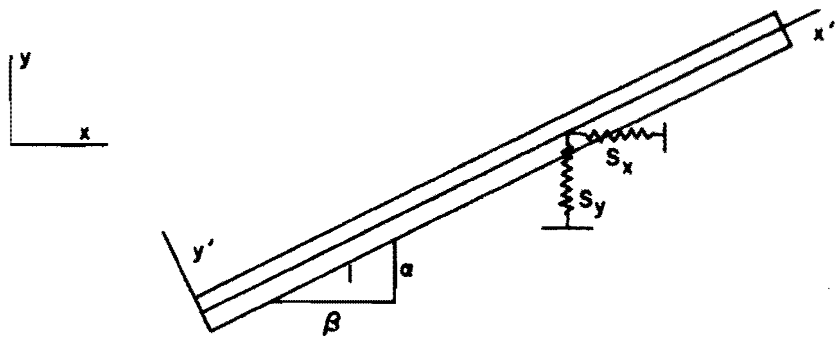


Fig 52. Member springs in structure coordinates.

From the figure above it is seen that a unit displacement along x' produces a force in both the x' and y' directions. The effect of S_x and S_y on the member stiffness matrix is the addition of the 2 x 2 stiffness matrix $[K]_{MS}$

$$[K]_{MS} = \left[\begin{array}{c|c} \alpha^2 S_x + \beta^2 S_y & \alpha\beta(S_y - S_x) \\ \hline \alpha\beta(S_y - S_x) & \beta^2 S_x + \alpha^2 S_y \end{array}\right] \qquad (D.2)$$

The terms in $[K]_{MS}$ may be easily verified. The first term kms_{11} is the force directed along the x' axis due to a unit displacement along the x' axis.

The evaluation of forces in member directions due to springs in structure x and y-directions is accomplished by transforming member displacements to structure coordinates and then evaluating the spring forces. Then the forces are transformed back to member coordinates.

APPENDIX E

GUIDE FOR DATA INPUT

Units of force (f) and distance (d) are indicated below all dimensional input.

IDENTIFICATION OF RUN (2 alphanumeric cards per run)

1 – 80

1 – 80

IDENTIFICATION OF PROBLEM (one card for each problem; program stops if problem number = CEASE)

Problem Number (alphanumeric) (1 – 5)	(11 – 80)
	Description of problem (alphanumeric)

TABLE 1. PROGRAM CONTROL DATA (2 cards per problem)

Hold Option for Tables 2 Through 7
Enter 1 to Hold Prior Data (only if data was input or held for Table in preceding problem)

Output Options for Table 8 Through 10
Enter 1 to Suppress Output

PROB TYPE	TABLE 2	3	4A	4B	4C	5A	5B	5C	5D	6	7	8	9	10
6 – 10	15	20	25	30	35	40	45	50	55	60	65	70	75	80

(1st card)

Number of Cards in Tables 2 Through 7 for this problem

TABLE 2	3	4A	4B	4C	5A	5B	5C	5D	6	7
11 – 15	20	25	30	35	40	45	50	55	60	65

(2nd card)

PROB TYPE 1 - Displacements not held from preceding problem.

PROB TYPE 2 - Displacements held from preceding problem.

TABLE 2. FRAME GEOMETRY DATA (number of cards per Table 1)

(1st card)

Num of Joints	Ref Joint	x-Coordinate	y-Coordinate	Joint Location Tolerance
11 15	21 25	31 (d) 40	d 50	61 (d) 70

From Joint	x-Offset	y-Offset	To Joint	To Joint	To Joint	To Joint	To Joint	To Joint	To Joint
11 15	21 (d) 30	(d) 40	50	55	60	65	70	75	80

(2nd and succeeding cards)

TABLE 3. MEMBER TYPE LOCATION (number of cards per Table 1)

(1st card)

Num of Stiffness Types	Num of Load Types	Num of Elements per Member
11 15	21 25	31 35 *

From Joint	Stiffness Type	Load Type	To Joint	To Joint	To Joint	To Joint	To Joint	To Joint	To Joint	To Joint	To Joint	To Joint
6 10	16 20	25	31 35	40	45	50	55	60	65	70	75	80

(2nd and succeeding cards)

* An even number of elements between 4 and 40 may be used. If blank, 40 elements are used for the solution.

TABLE 4A. JOINT LOADS AND SUPPORTS (LINEAR RESTRAINTS) IN STRUCTURE x,y,z-AXES (number of cards per Table 1)

Joint	Load // to x-Axis	Load // to y-Axis	Moment about z-Axis	Restraint // to x-Axis	Restraint // to y-Axis	Rotational Restraint about z-Axis	
6–10	(f) 20	(f) 30	(fd) 40	(f/d) 50	(f/d) 60	(fd) 70	(All cards)

TABLE 4B. NONLINEAR JOINT SUPPORTS (number of cards per Table 1)

Joint	Q-Mult	W-Mult	Joint Support Curve Numbers: // to x-Axis	// to y-Axis	about z-Axis	// to x′-Axis	// to y′-Axis	Stiff Type
6–10	(f), (fd) 20	(d), (d/d) 30	41–45	50	55	60	65	76–80

TABLE 4C. NONLINEAR SUPPORT CURVES (number of cards per Table 1, 2 cards per curve)

Curve Number	Number of Points	Symmetry Option
6–10	15	20 *

Q-Values

26–30	35	40	45	50	55	60	65	70	75	80

W-Values

26–30	35	40	45	50	55	60	65	70	75	80

* If equal to 1 a symmetrical branch is provided internally. The first Q and W values must be 0 if the symmetry option is used.

TABLE 5A. MEMBER STIFFNESS TYPES (number of cards as per Table 1; number of sets of cards equal to the number of stiffness types defined in this problem)

(1st card of set)

	Stiffness Type	Modulus of Elasticity (Blank if nonlinear option =1)		Prismatic Moment of Inertia (Blank, if 2nd Card Used)	Prismatic Area (Blank, if 2nd Card Used)	Nonlinear Option *	Num Cards Follow	Axis Option +	Output Option ‡	Joint Options "From" Joint ǂ	Joint Options "To" Joint ǂ
Columns	6–10	10–20		31–40	40–50	50–55	55–60	60–65	65–70	70–75	75–80
Units		(f/d^2)		(d^4)	(d^2)						

*(2nd and succeeding cards of set if nonlinear option is blank)

	From (Distance)	To (Distance)	Moment of Inertia	Area	Restraint // to x′,x-Axis	Restraint // to y′,y-Axis	Rotational Restraint about z′-Axis
Columns	11–20	20–30	30–40	40–50	50–60	60–70	70–80
Units	(d)	(d)	(d^4)	(d^2)	(f/d^2)	(f/d^2)	(f)

*(2nd card of set if nonlinear option=1)

	At "From" Joint: Cross Section Numb	At "From" Joint: q-w Curve Number x′,x	At "From" Joint: q-w Curve Number y′,y	At "From" Joint: q-w Curve Number z′	At "To" Joint: Cross Section Numb	At "To" Joint: q-w Curve Number x′,x	At "To" Joint: q-w Curve Number y′,y	At "To" Joint: q-w Curve Number z′	q-Mult	w-Mult
Columns	11–15	15–20	20–25	25–30	36–40	40–45	45–50	50–55	61–70	70–80
Units									$(f/d),(f)$	$(d),(d/d)$

+ If equal to 1, restraints are in direction of member axes. If equal to 2, restraints are in direction of structure axes. In both cases, they are per unit of length along the member x′-axis, and distances are along the member x′-axis.

‡ If blank, complete beam-column output is given; if equal to 1, only member end forces are given.

ǂ If equal to 1, the member is assumed pinned to joint at "From" end. If blank, the member is assumed rigidly connected to joint at "From" end. If equal to -ij the member is assumed to be rigidly connected to the joint at "From" end and it is assumed to have i rigid discrete elements followed by j discrete elements that remain linear regardless of stress level.

ǂ If equal to 1, the member is assumed pinned to joint at "To" end. If blank, the member is assumed rigidly connected to joint at "To" end. If equal to -ij the member is assumed to be rigidly connected to the joint at "To" end and it is assumed to have i rigid discrete elements followed by j discrete elements that remain linear regardless of stress level.

TABLE 5B. CROSS-SECTION PROPERTIES (number of cards as per Table 1; number of sets of cards equal to number of cross-sections defined in this problem.)

	Cross Section Number	Number Cards Follow	
	6–10	10–15	(first card of set)

Rectangle or Thin Wall Tube

	Width or Outside Diameter	Depth or Thickness	Centroidal Distance	Area Option	Curve Number	Stress-Strain Data: Stress-Mult	Stress-Strain Data: Strain-Mult
Second and succeeding cards of set				*			
	11 (d) 20	(d) 30	(d) 40	45	50	(f/d^2) 60	(d/d) 70

* If blank, input properties of rectangle. If equal to 1, input properties of thin wall tube.

TABLE 5C. STRESS-STRAIN CURVES (number of cards as per Table 1: 2 per curve)

Curve Number	Number of Points	Symmetry Option	Stress - Values										
		*											
6–10	10–15	15–20	26–30	35	40	45	50	55	60	65	70	75	80

Strain - Values										
26–30	35	40	45	50	55	60	65	70	75	80

* If equal to 1 a symmetrical branch is provided internally. The first SIG and EP values must be 0 if the symmetry option is used.

TABLE 5D. NONLINEAR MEMBER SUPPORT CURVES (number of cards as per Table 1: 2 per curve)

Curve Number	Number of Points	Symmetry Option		q-Values										
		*												
6–10	10–15	15–20		26–30	30–35	35–40	40–45	45–50	50–55	55–60	60–65	65–70	70–75	75–80

w-Values										
26–30	30–35	35–40	40–45	45–50	50–55	55–60	60–65	65–70	70–75	75–80

* If equal to 1 a symmetrical branch is provided internally. The first q and w values must be 0 if the symmetry option is used.

TABLE 6. MEMBER LOAD DATA (number of cards per Table 1; number of sets of cards equal to the number of load types defined in this problem)

Member loads may be input by any one of the four axis options outlined below. Q_a is the concentrated load in the direction of the a-axis. q_{ab} is the distributed load in the direction of the a-axis and has its intensity per unit of length along the b-axis.

Note: Concentrated loads may not be input at a distance of 0.0.

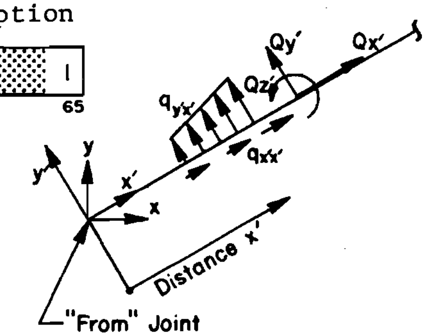
AXIS OPTION 1

(1st card of set)

Columns	6–10	10–20	31–40	40–50	56–60	60–65
Field	Load Type	Blank Unless Hold Option = 2: % Increase in Load	Blank, if 2nd card used: Uniform Load // to x′-Axis	Blank, if 2nd card used: Uniform Load // to y′-Axis	Num Cards Follow	Axis Option
Entry			$q_{x'x'}$ (f/d)	$q_{y'x'}$ (f/d)		1

(2nd and succeeding cards of set)

Columns	11–20	20–30	30–40	40–50	50–60
Field	From (Distance along Member)	To (Distance along Member)	Load // to x′-Axis	Load // to y′-Axis	Moment about z′-Axis
Entry	x' (d)	x' (d)	$Q_{x'}$, $q_{x'x'}$ (f), (f/d)	$Q_{y'}$, $q_{y'x'}$ (f), (f/d)	$Q_{z'}$, $q_{z'x'}$ (fd), (f)



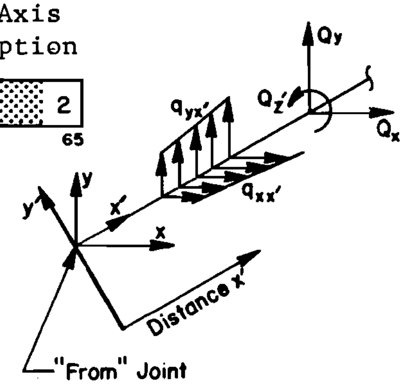
AXIS OPTION 2

(1st card of set)

Columns	6–10	10–20	31–40	40–50	56–60	60–65
Field	Load Type	Blank Unless Hold Option = 2: % Increase in Load	Blank, if 2nd Card used: Uniform Load // to x-Axis	Blank, if 2nd Card used: Uniform Load // to y-Axis	Num Cards Follow	Axis Option
Entry			$q_{xx'}$ (f/d)	$q_{yx'}$ (f/d)		2

(2nd and succeeding cards of set

Columns	11–20	20–30	30–40	40–50	50–60
Field	From (Distance along Member)	To (Distance along Member)	Load // to x-Axis	Load // to y-Axis	Moment about z′-Axis
Entry	x' (d)	x' (d)	Q_x , $q_{xx'}$ (f), (f/d)	Q_y , $q_{yx'}$ (f), (f/d)	$Q_{z'}$, $q_{z'x'}$ (fd), (f)



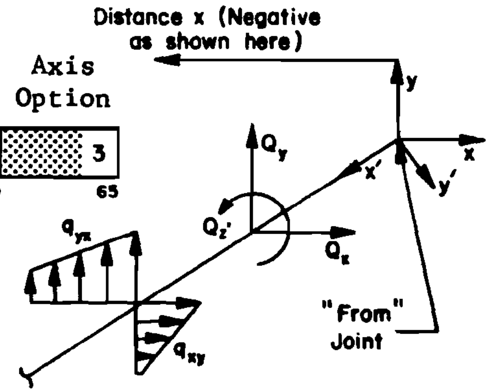
AXIS OPTION 3

(1st card of set)

Field	Columns	Entry
Load Type	6–10	
% Increase in Load (Blank Unless Hold Option = 2)	11–20	
Uniform Load // to x-Axis (Blank, if 2nd Card Used)	31–40 (f/d)	q_{xy}
Uniform Load // to y-Axis (Blank, if 2nd Card Used)	41–50 (f/d)	q_{yx}
Num Cards Follow	56–60	
Axis Option	61–65	3

(2nd and succeeding cards of set)

Field	Columns	Entry
From (Distance along Structure Axis)	11–20 (d)	x
To (Distance along Structure Axis)	21–30 (d)	x
Load // to x-Axis	31–40 (f) (f/d)	Q_x , q_{xy}
Load // to y-Axis	41–50 (f) (f/d)	Q_y , q_{yx}
Moment about z′-Axis	51–60 (fd) (f)	$Q_{z'}$, $q_{z'x'}$



Axis Option 4 is identical to Axis Option 3 except distances are in structure y-axis and 4 is input in column 65 of first card.

See page 11 of this appendix for an example using the various axis options.

The member x′-axis goes from the "From" joint to the "To" joint. The "From" and "To" joints are determined by input of Table 3.

TABLE 7. ITERATION CONTROL (two cards unless held from previous problem)

(Frame Solutions 1st Card)

Field	Columns
Max Num Iter	11–15
Force Error	21–30
Moment Error	31–40
Monitor Joint Numbers	51–55, 56–60, 61–65, 66–70, 71–75

(Member Solutions 2nd Card)

Field	Columns
Max Num Iter	11–15
Force Error	21–30
Moment Error	31–40
Monitor Member Numbers	51–55, 56–60, 61–65, 66–70, 71–75

GENERAL PROGRAM NOTES

The data cards must be stacked in proper order for the program to run.

A consistent system of units of force (f) and distance (d) must be used for all input data, e.g., pounds and inches.

All 5-space words are understood to be integers . . . . + 4 3 2 1

All 10-space words are floating-point decimal numbers . . . . - 4 . 3 2 1 E + 0 3

All numbers must be right justified.

The problem number may contain alphanumeric characters.

Blank fields on data cards, except the first five columns, may be used as desired to aid in coding problems. Information in these fields is ignored by the program.

TABLE 1. PROGRAM CONTROL DATA

Two cards are required in Table 1 for all problems.

Data are accumulated in Tables 2 through 7 until the corresponding Hold Option is left blank in Table 1.

The maximum number of cards accumulated in Table 5A is 50 plus the number of stiffness types.

The maximum number of cards accumulated in Table 6A is 75 plus the number of load types.

Type 1 problems start the iterative solution with zero displacements.

Type 2 problems use the displacements from the previous problem in the first iteration.

TABLE 2. FRAME GEOMETRY DATA

The first card gives the <u>total</u> number of joints in the frame, which must not exceed 20.

The reference joint, its coordinates, and the joint location tolerance are given only if the Hold Option for Table 2 is not exercised.

Joints are numbered from 1 to the total number of joints. A joint number may not be deleted in a series until the Hold Option is not used. However, the joint may be structurally deleted by removing all members intersecting at the joint.

The reference joint may be any joint and it may have any coordinates, except that it and all other joints must have coordinates less than 1.0E50.

The maximum difference in joint numbers, for joints that are connected by members, is 5.

The second and succeeding cards in Table 2 specify the location of all additional joints in the frame at least once. If the Hold Option is used, only the new joints must be specified.

All offsets must be "From" a previously located joint "To" another joint. The "To" joint may be a previously defined joint. This allows the user to check the locations of the joints. If the error in the location of the joint is within the joint location tolerance, then the solution continues; otherwise, the solution terminates with an appropriate diagnostic.

The joint location tolerance should allow for normal round-off error. If offsets are input to the nearest 0.1-inch, then a joint location tolerance of 0.3-inch usually will be sufficient for a moderate-sized frame.

The repetition of the "To" joint allows the user to locate up to seven joints with one card, if the offsets between each new "To" joint are the same as between the "From" joint and the first "To" joint.

It is not necessary for offsets to be given at locations where members are. However, the location of all joints must be specified at least once.

TABLE 3. MEMBER TYPE LOCATION

The first card in Table 3 gives the <u>total</u> number of stiffness types and the <u>total</u> number of load types.

Stiffness and load types (other than zero) are numbered from one to their total number. The total number of stiffness types must not exceed 25. The total number of load types must not exceed 25.

The total number of members in the frame must not exceed 40.

Type zero stiffness is used to delete a previously defined stiffness. Type zero load is used to indicate no load on a member. The restrictions on length, orientation, etc., outlined below, do not apply to members with type zero stiffness and type zero load.

In order for two members to have the same stiffness type, they must have the same length, the same angular orientation in the frame, and the same stiffness properties with respect to their "From" and "To" joints.

In order for two members to have the same load type, they must have the same length, the same angular orientation in the frame, and the same loading with respect to their "From" and "To" joints.

The member coordinate axes are defined by the "From" and "To" joints specified. The member x'-axis starts at the "From" joint and goes to the "To" joint. The member y'-axis and z'-axis are located from the member x'-axis by the right-hand rule.

All members in the frame must be assigned a stiffness type and a load type. This assignment is not accumulative for a member in the frame, i.e., the last values of stiffness type and load type specified replace the previous values. Thus, stiffness and load types for a member must be specified on the same card.

Up to ten members with the same stiffness and load type may be located with a single card if the "From" joint of each new member is the "To" joint of the previous one.

TABLE 4A. JOINT LOADS AND SUPPORTS (LINEAR RESTRAINTS)

All joint loads and linear supports (restraints) are specified with respect to the structure axes.

Joint loads and restraints are accumulated in Table 4A.

Structure supports may be input as joint restraints (linearly elastic springs). Complete fixity of a joint may be achieved by putting in very large spring values. No round-off errors are encountered when extremely large values are used unless large values are input and then subtracted away.

Complete freedom of joint movements is obtained by not specifying any restraints at a joint.

A displacement may be enforced by specifying a very large restraint and a corresponding force equal to the desired displacement times the large restraint.

TABLE 4B. NONLINEAR JOINT SUPPORTS

The latest curve numbers, including zero (which deletes any old curve number), replace the old curve numbers at a joint. Curves may have any number from 1 to 20.

A joint may have both linear supports (Table 4A) and nonlinear supports (Table 4B).

Curves may be specified in both structure and member directions. If curves are specified in member directions, then the stiffness type of the member which the curves are referenced to must be given.

The Q and W multipliers input in Table 4B are multiplied times the Q-W curves input in Table 4C to obtain the final Q-W values at a joint.

The ratio of the final Q values to the final W values should not be many orders of magnitude larger than the stiffness data for the members of the frame, if the supports are specified in member directions.

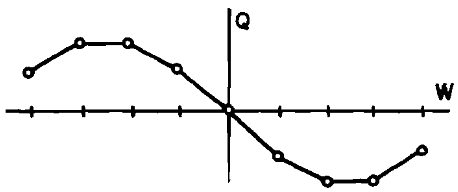
TABLE 4C. NONLINEAR SUPPORT CURVES

The Q-W curves do not have to be input in the order of the curve numbers.

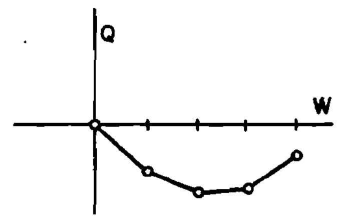
The Q-W curves must be input such that the final W values will be in ascending algebraic order.

Normal Q-W curves will have opposite signs for displacement and force.

Symmetrical (*Anti-Symmetrical*) curves may be input by specifying only the positive displacement branch including the 0,0 point.



Anti-Symmetrical Curve



Input Curve

TABLE 5A. MEMBER STIFFNESS TYPES

Stiffness types must be input in ascending order. If Table 5 is held from the previous problem, then the first new stiffness type in Table 5 (if any) must equal the number of stiffness types in the last problem plus one.

Prismatic members with a single modulus of elasticity which do not have any elastic restraints may be input with one card. Other members require two or more cards.

If more than one card is used to describe a member stiffness type, the prismatic stiffness properties must be left blank.

If the nonlinear option is left blank, then the second and succeeding cards describe the variation in the linear stiffness properties of the members. This type of input is illustrated on page 15 of this appendix.

If any of the member stiffness properties are nonlinear, the nonlinear option is set equal to 1 and the second card gives the cross-section numbers, q-w curve numbers, and q and w multipliers at the member's "From" and "To" joint. Then the cross-section properties, stress-strain curves, and q-w curves are defined in Tables 5B, 5C, and 5D.

The final q-w values used are the product of the q and w multipliers and the q-w curves input in Table 5D.

The latest multipliers, cross-section numbers, and curve numbers replace the old data, if any, at a joint.

Cross-sections may have any number from 1 to 20, and q-w curves may have any number from 1 to 20.

TABLE 5B. CROSS-SECTION PROPERTIES

Cross-sections do not have to be input in the order of their numbers.

Cross-sections are defined as a series of up to 10 pieces. Each piece may be either a rectangle or a thin wall tube and have a unique stress-strain curve number up to 8. The final stress-strain values are the product of the stress and strain multipliers and the stress-strain curves input in Table 5C.

The centroidal distance input for the tube and the rectangle is the distance from the member x'-axis to the centroid of the pipe or rectangle. This distance is positive if in the direction of the member y'-axis. Linear interpolation along the length of the member between corresponding pieces is provided in the program; thus, the cross-section input at the two joints should have the same number of pieces and the pieces should be input in the same order. Interpolation between a rectangular piece and tubular piece is not allowed.

All data input for a cross-section number replaces the previous data, if any, for that cross-section number.

TABLE 5C. STRESS-STRAIN CURVES

Stress-strain curves are input similar to the Q-W curves of Table 4C. However, normally stress and strain values will have the same sign.

Corresponding pieces in a cross-section at the two joints must have the same number of points on their stress-strain curves. This allows linear interpolation along the length of the member.

TABLE 5D. NONLINEAR MEMBER SUPPORT CURVES

Member support curves (q-w) are input similar to the Q-W curves of Table 4C. However, the final q values have the units of force per unit of distance.

The q-w curves at both joints on a member must have the same number of points. This allows linear interpolation along the length of the member.

TABLE 6. MEMBER LOAD DATA

Load types must be input in ascending order. If Table 6 is held from the previous problem, then the first new load type in Table 6 (if any) must equal the number of load types in the last problem plus one.

If the Hold Option for Table 6 is set equal to 2 in Table 1, then Table 6 must have one card for each old load type, which has the load type and the percent (25 percent = 25.0) increase in absolute value of all loads described in that load type, plus whatever cards are needed to define any new load types.

Load types with only uniform loads over their full length may be input with only one card. Other loadings require two or more cards.

If more than one card is used to describe a member load type, the uniform loads on the first card must be left blank.

Variable, concentrated, and partial uniform loadings must be input in sections but need not be input consecutively, and sections may overlap. This format is illustrated on page 16 of this appendix.

All sections, except concentrated loads, must have their "To" distance larger in absolute value than their "From" distance by more than the length of one discrete element.

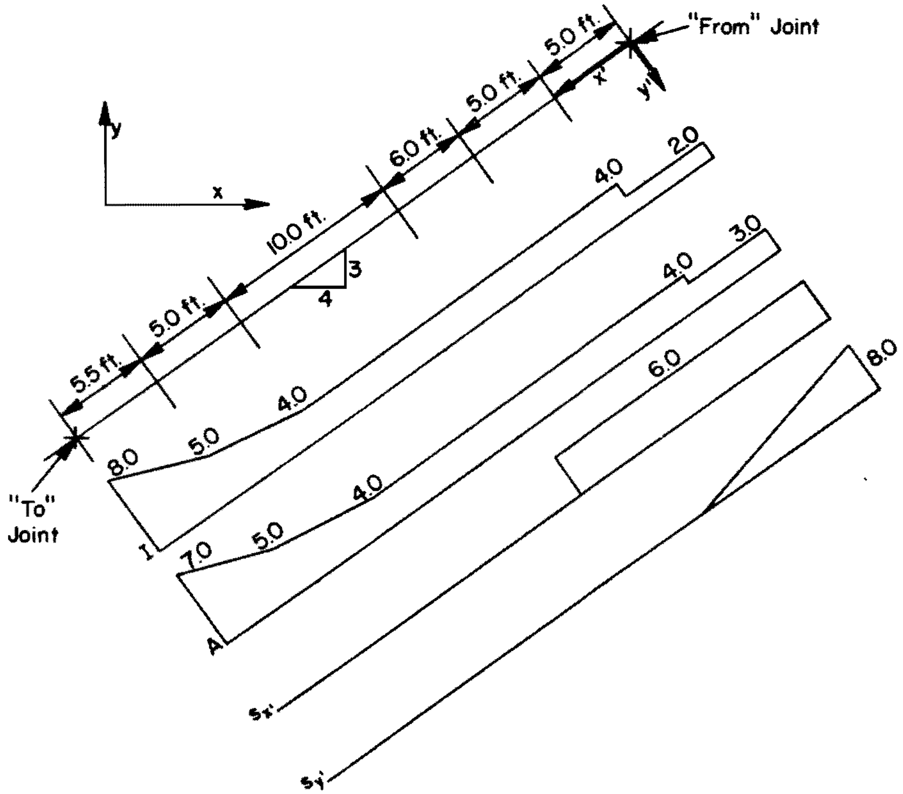
Concentrated loads may not be specified at a distance of 0.0.

TABLE 7. ITERATION CONTROL

The maximum number of iterations for the frame and member solutions should be specified to save computer time. Normally, convergence will have been reached in five or ten iterations. An upper limit of 20 is set in the program.

The allowable equilibrium errors may be set by the following procedure until the user develops his own special requirements. Select as a force and a moment that would have a negligible effect on the frame if applied at any point in the frame. These may be used as the joint equilibrium errors. (For example, the designer may know the value of his loads to the nearest 0.1-kip. Then a reasonable joint force error would be 0.01-kip, and a reasonable moment error would be 0.01-kip times the length of a typical member.) The errors permitted in the member solution should be 0.1 times the corresponding joint errors to allow for round-off.

Monitor joints and members should be specified to study the iteration process, particularly if the solution fails to converge. The numbers of the monitor members are the ones assigned by the program in the order in which the members are input in Table 3.



Variable Linear Member Stiffness Properties

	From	To	I	A	$s_{x'}$	$s_{y'}$	$s_{z'}$
*	0.0		2.0	3.0	6.0	8.0	
		5.0	2.0	3.0	6.0	4.0	
*	5.0		4.0	4.0	6.0	4.0	
		10.0	4.0	4.0	6.0	0.0	
•	10.0	16.0	4.0	4.0	6.0		
•	16.0	26.0	4.0	4.0			
*	26.0		4.0	4.0			
		31.0	5.0	5.0			
*	31.0		5.0	5.0			
		36.5	8.0	7.0			

Axis Option I

* – Two Cards for Sections with Linearly Varying Stiffness

• – One Card for Sections with Constant Stiffness

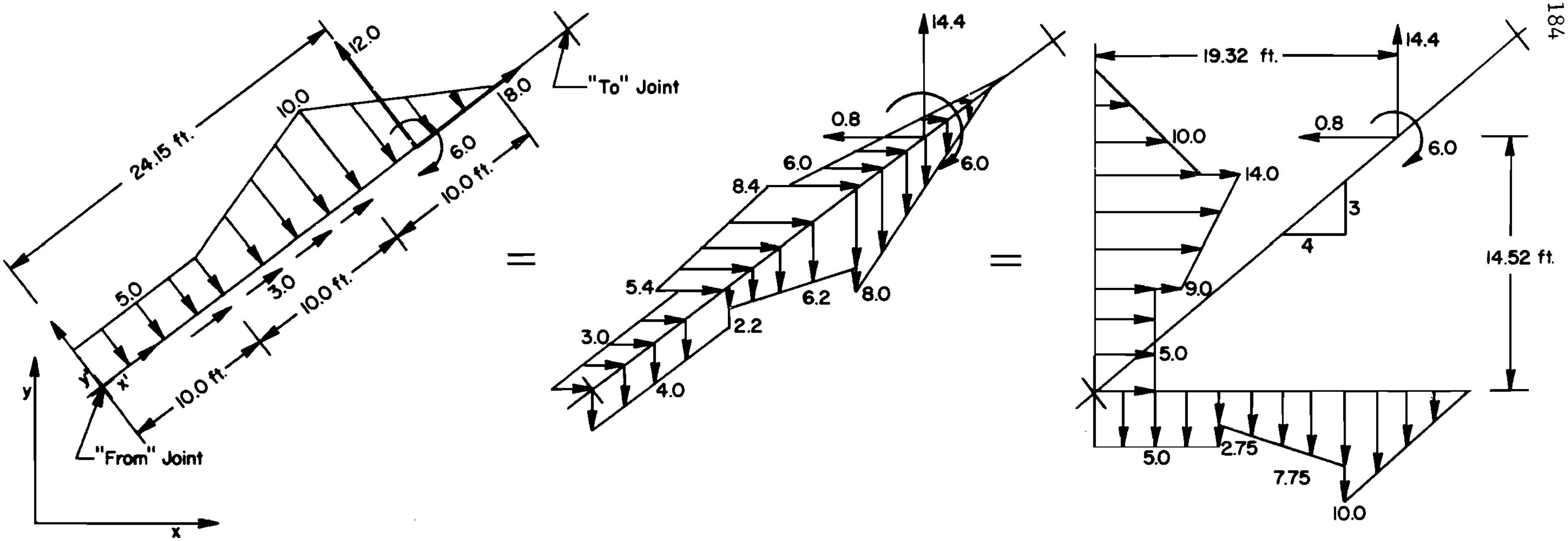
Notes: Sections must be input in order.

A new section must be started when a change in the variation of any of the stiffness properties occurs.

There is no restriction on the length of a section except it must exceed the length of one of the discrete elements.

"From" and "To" joints are set by input in Table 3.

Axis Option 2 is used for the rare case where the member restraints act parallel to tha structure axes rather than the member axes.



	Axis Option 1				
	From	To	$Q_{x'},q_{x'x'}$	$Q_{y'},q_{y'x'}$	$Q_{z'},q_{z'x'}$
●	0.0	10.0		-5.0	
*	10.0		3.0	-5.0	
		20.0	3.0	-10.0	
o	24.15	24.15	8.0	12.0	-6.0
*	20.0			-10.0	
		30.0		0.0	

	Axis Option 2				
	From	To	$Q_x,q_{xx'}$	$Q_y,q_{yx'}$	$Q_{z'},q_{z'x'}$
●	0.0	10.0	3.0	-4.0	
*	10.0		5.4	-2.2	
		20.0	8.4	-6.2	
o	24.15	24.15	-0.8	14.4	-6.0
*	20.0		6.0	-8.0	
		30.0	0.0	0.0	

	Axis Option 3				
	From	To	Q_x,q_{xy}	Q_y,q_{yx}	$Q_z,q_{z'x'}$
●	0.0	8.0	5.0	-5.0	
*	8.0		9.0	-2.75	
		16.0	14.0	-7.75	
o	19.32	19.32	-0.8	14.4	-6.0
*	16.0		10.0	-10.0	
		24.0	0.0	0.0	

	Axis Option 4				
	From	To	Q_x,q_{xy}	Q_y,q_{yx}	$Q_z,q_{z'x'}$
●	0.0	6.0	5.0	-5.0	
*	6.0		9.0	-2.75	
		12.0	14.0	-7.75	
o	14.52	14.52	-0.8	14.4	-6.0
*	12.0		10.0	-10.0	
		18.0	0.0	0.0	

o - One Card for Concentrated Loads

● - One Card for Sections with Uniform Loads

* - Two Cards for Sections with Linearly Varying Loads

Notes:

There is No Restriction on the Length of a Section Except that it Must Exceed the Length of One of the Discrete Elements.

"From" and "To" Joints Set by Input in Table 3.

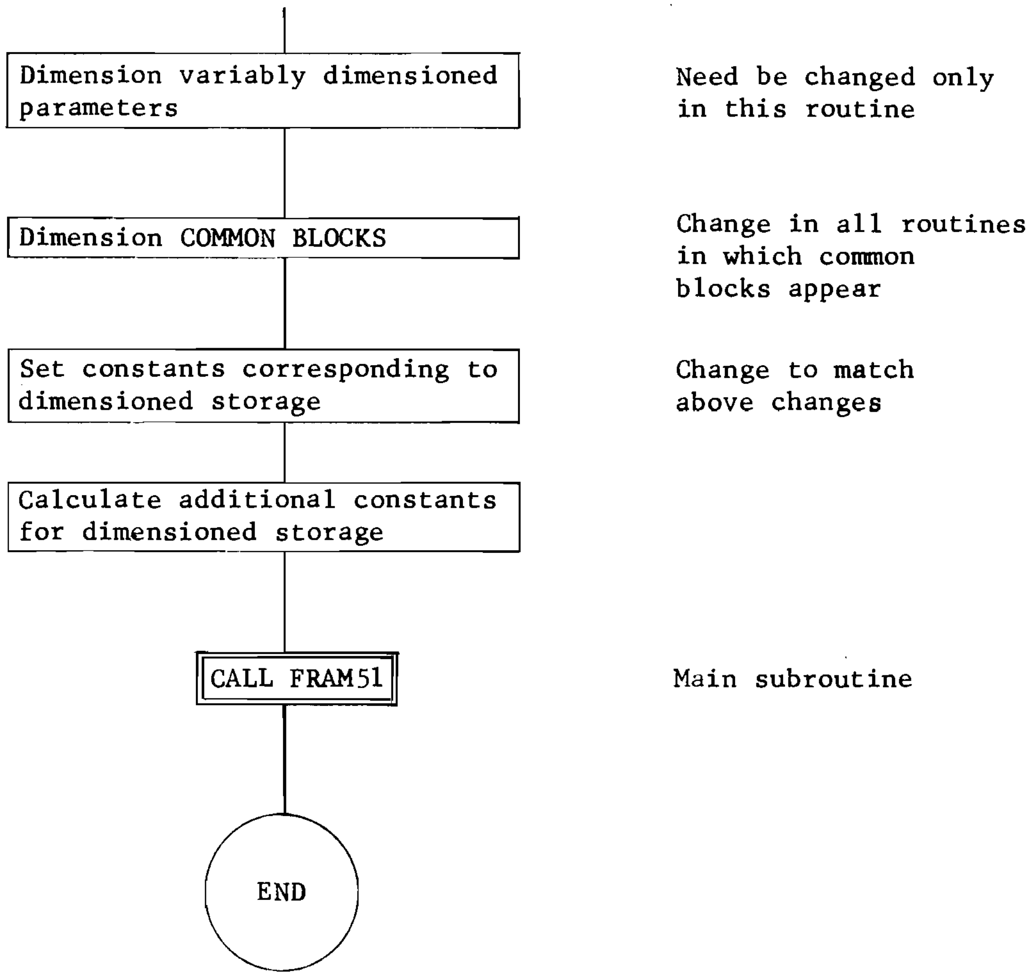
Sections Need Not be Input in Order.

Concentrated Loads May Not be Input at a Distance of 0.0.

APPENDIX F

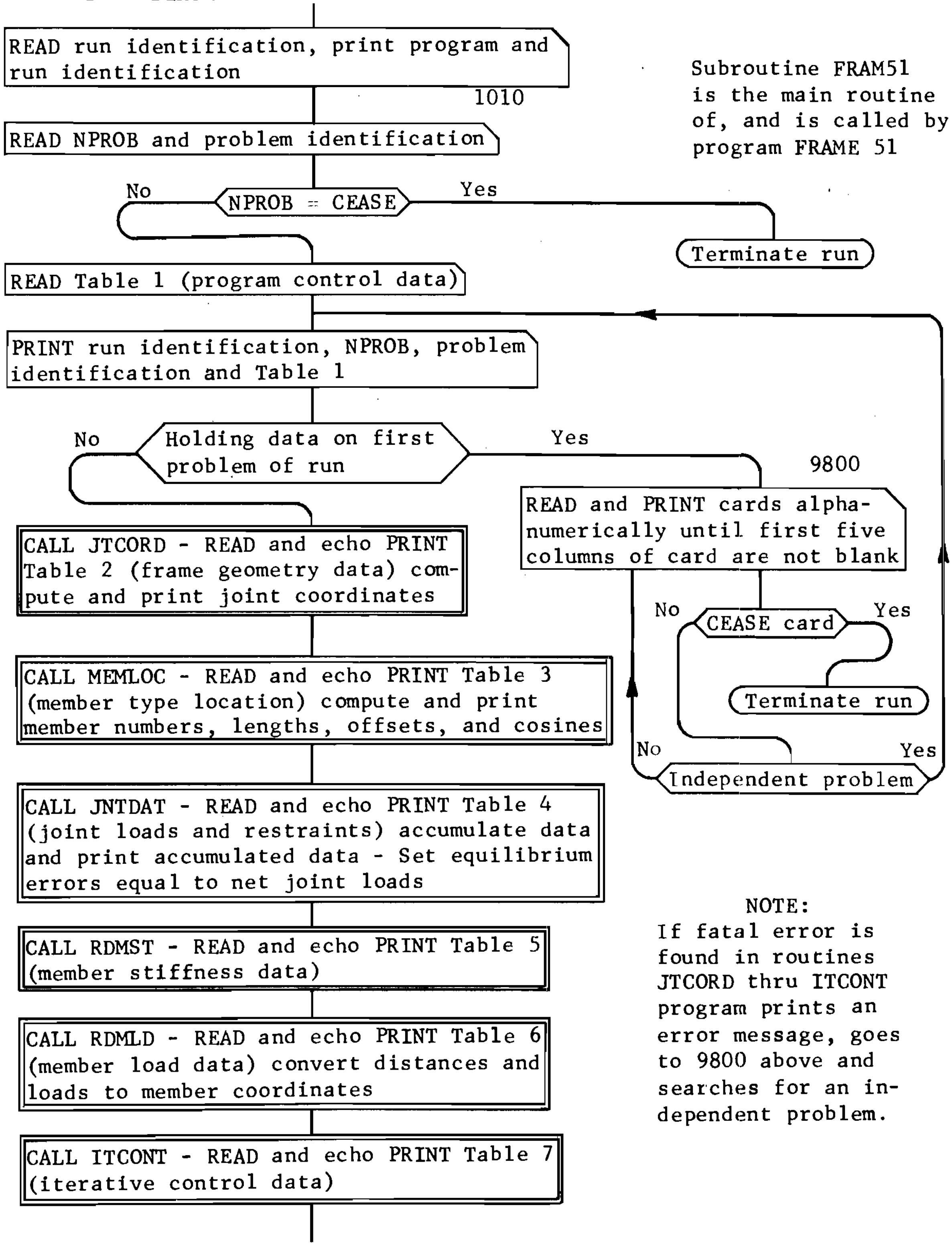
PROGRAM FLOW CHARTS

FLOW DIAGRAM FOR FRAME 51



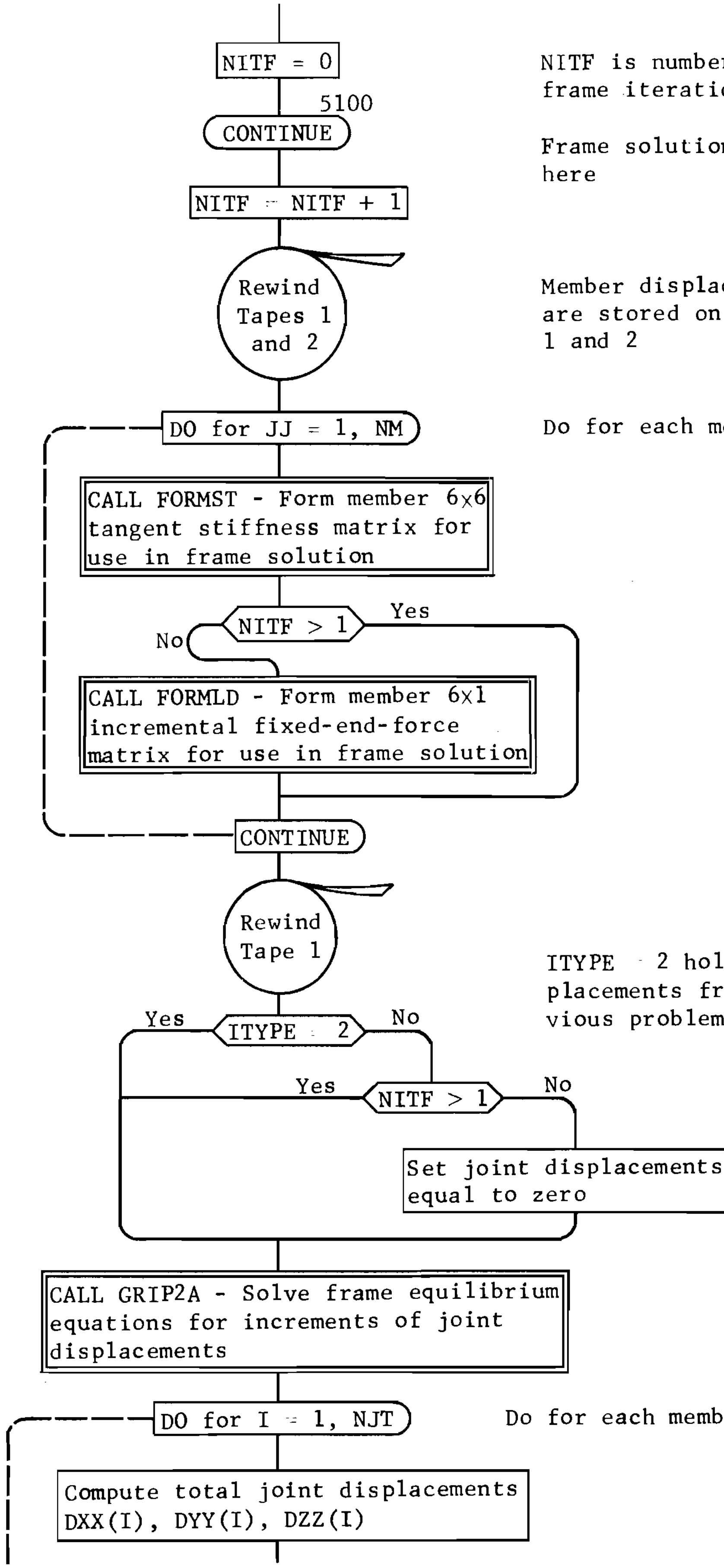
Program dimensions may be easily changed as indicated above. See the program listing and the notation.

FLOW DIAGRAM FOR SUBROUTINE FRAM51



Subroutine FRAM51 is the main routine of, and is called by, program FRAME 51

NOTE:
If fatal error is found in routines JTCORD thru ITCONT program prints an error message, goes to 9800 above and searches for an independent problem.



NITF is number of frame iterations

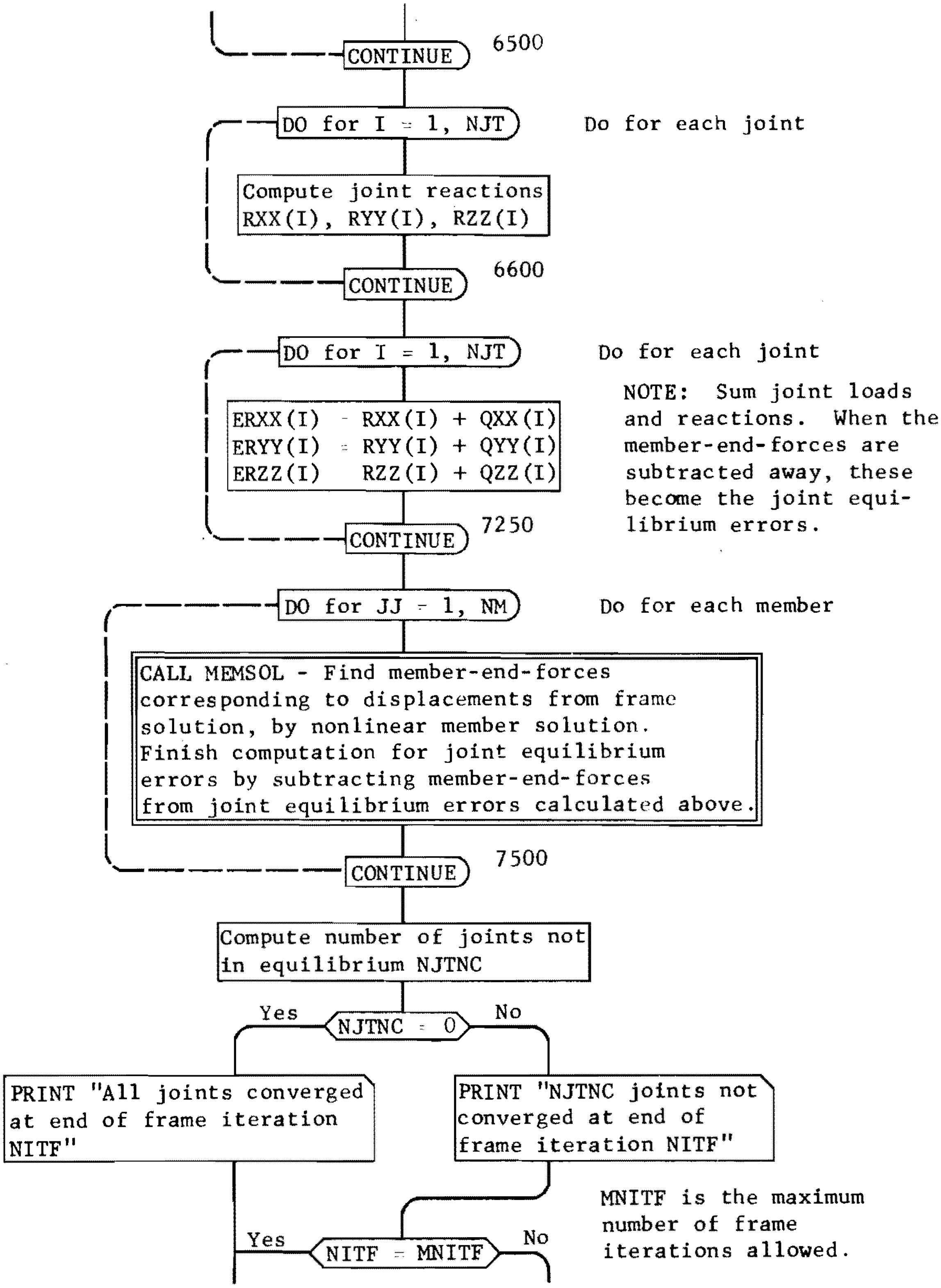
Frame solution starts here

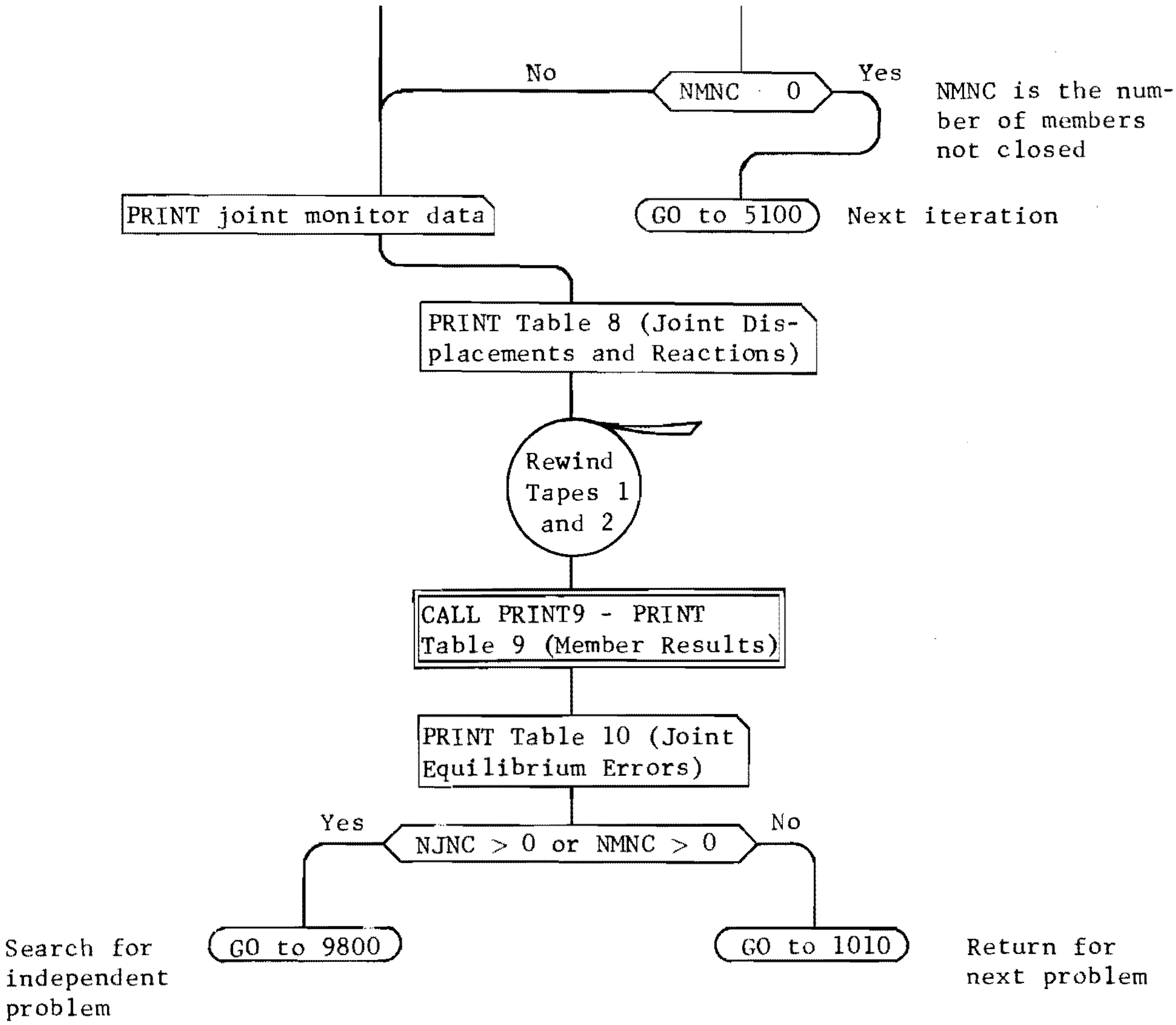
Member displacements are stored on Tapes 1 and 2

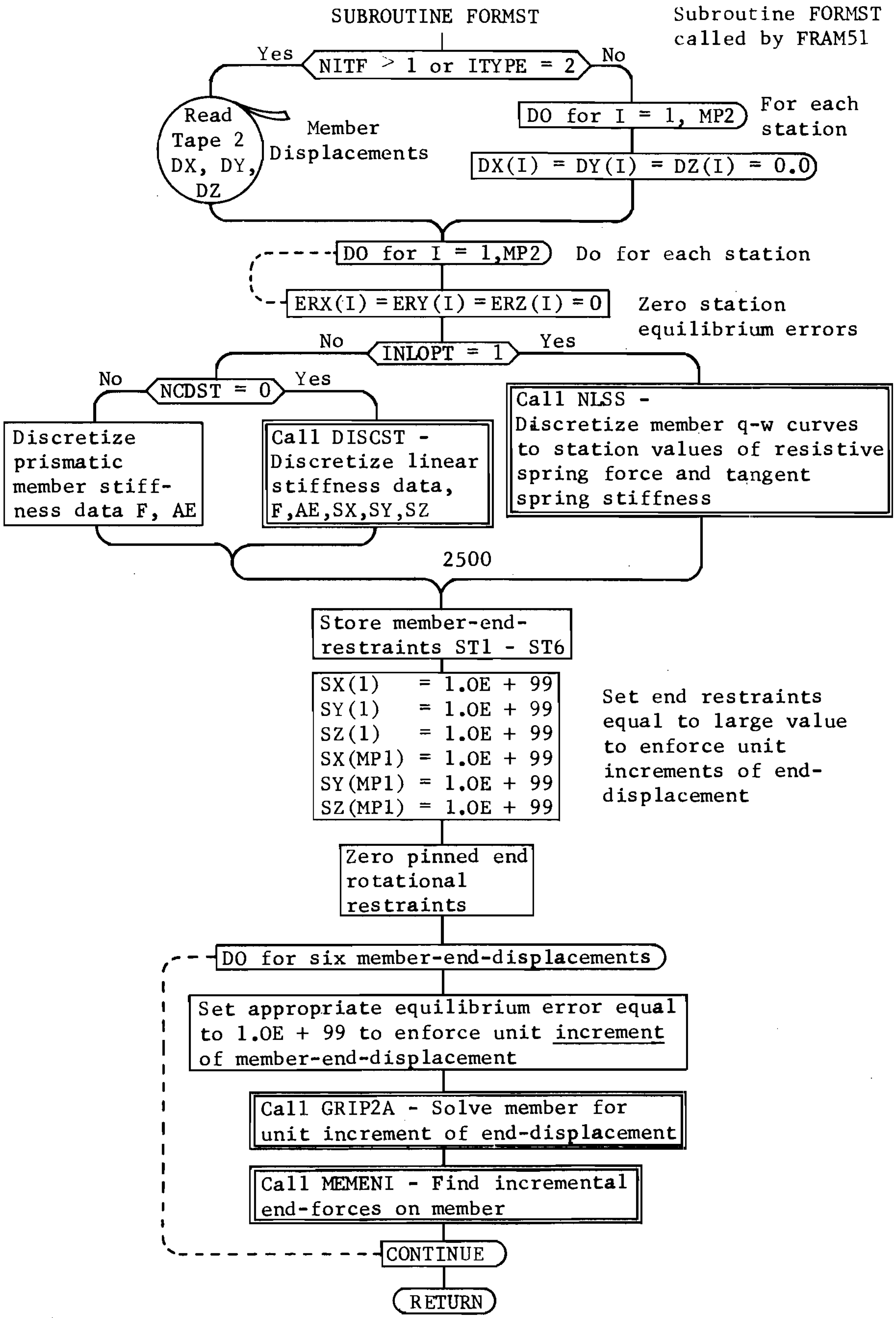
Do for each member

ITYPE = 2 holds displacements from previous problem

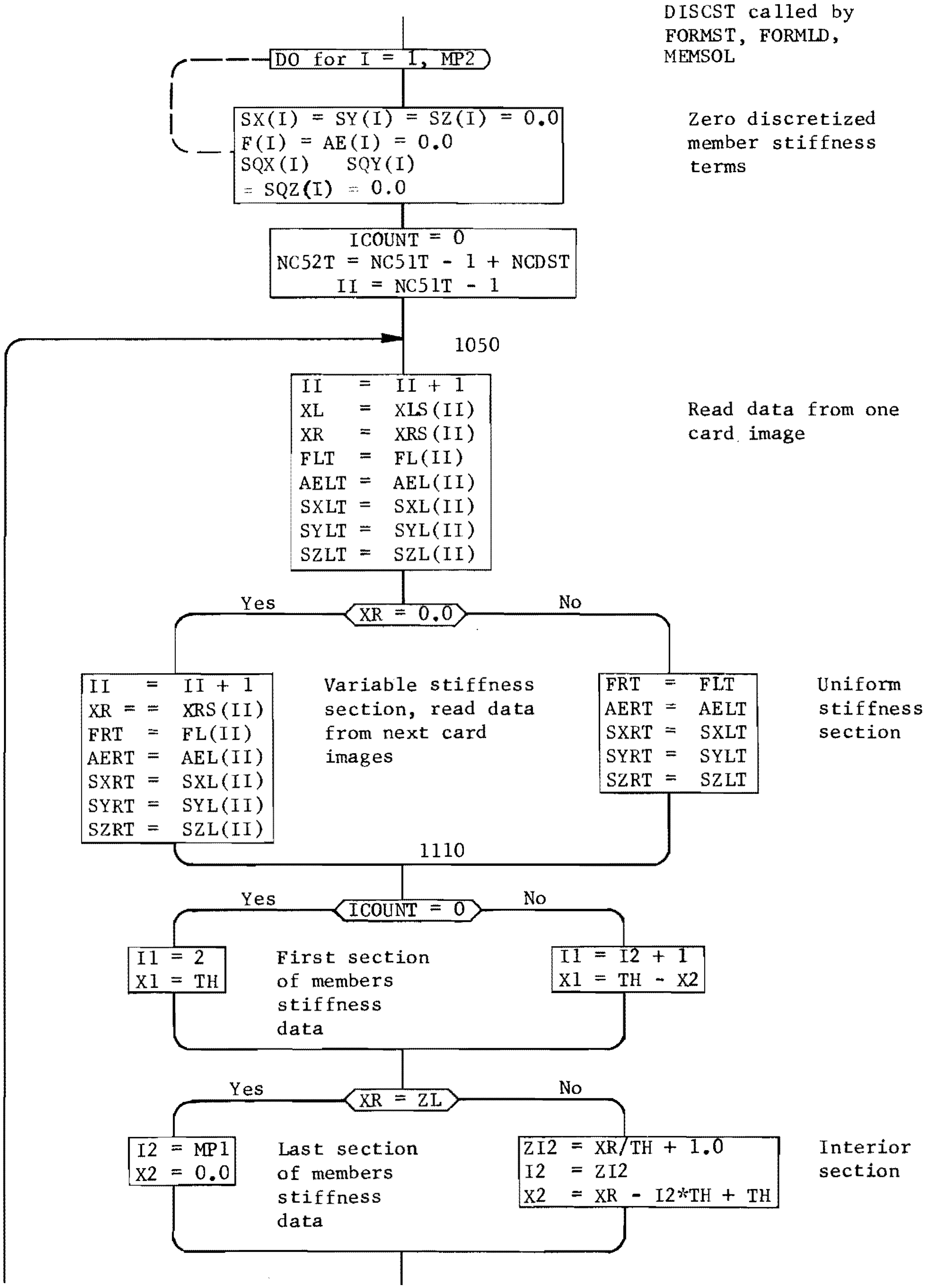
Do for each member

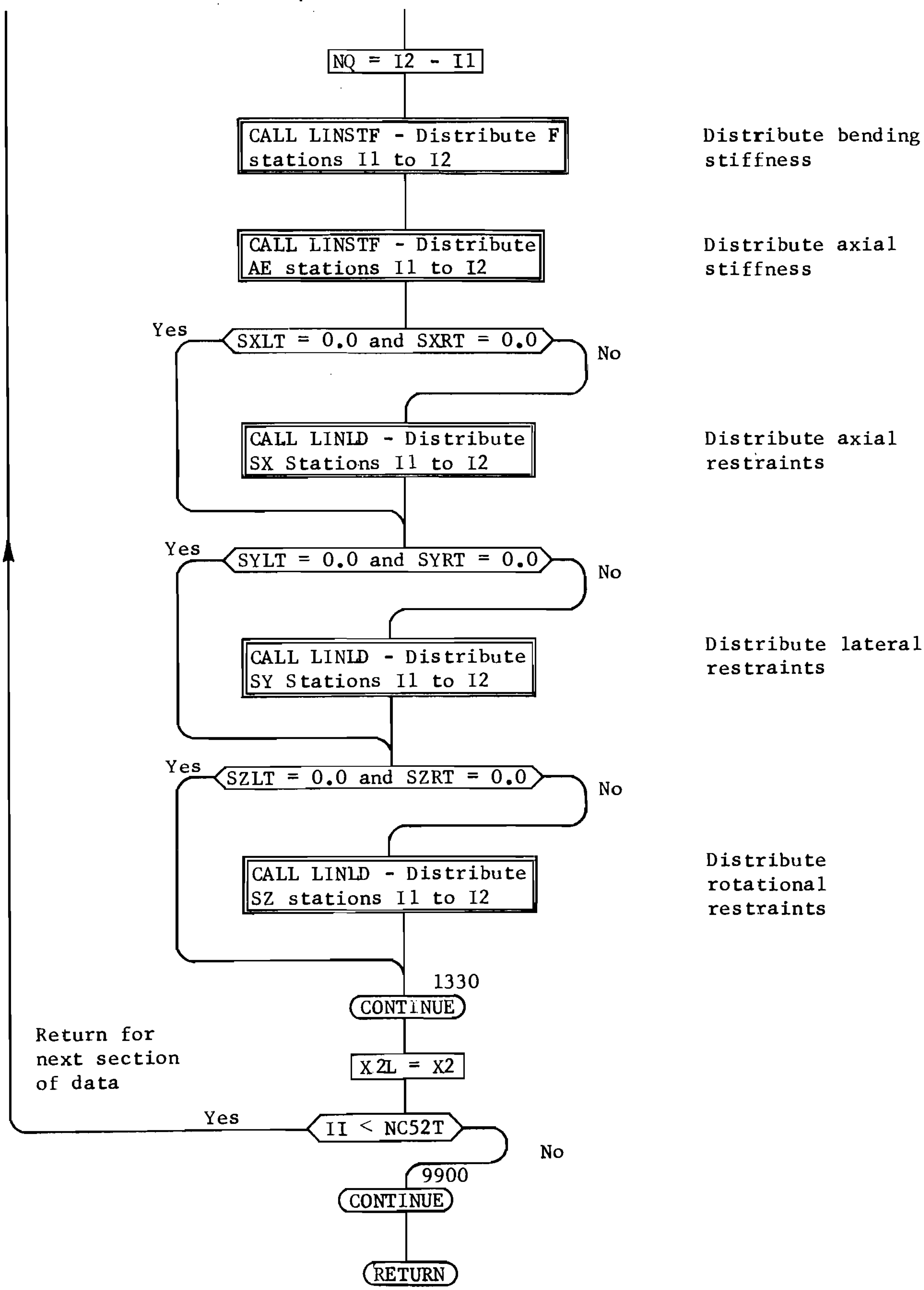

CONTINUE
6500
DO for I = 1, NJT
Do for each joint
Compute joint reactions RXX(I), RYY(I), RZZ(I)
CONTINUE
6600
DO for I = 1, NJT
Do for each joint
NOTE: Sum joint loads and reactions. When the member-end-forces are subtracted away, these become the joint equilibrium errors.
ERXX(I) = RXX(I) + QXX(I)
ERYY(I) = RYY(I) + QYY(I)
ERZZ(I) RZZ(I) + QZZ(I)
CONTINUE
7250
DO for JJ = 1, NM
Do for each member
CALL MEMSOL - Find member-end-forces corresponding to displacements from frame solution, by nonlinear member solution. Finish computation for joint equilibrium errors by subtracting member-end-forces from joint equilibrium errors calculated above.
CONTINUE
7500
Compute number of joints not in equilibrium NJTNC
Yes
NJTNC = 0
No
PRINT "All joints converged at end of frame iteration NITF"
PRINT "NJTNC joints not converged at end of frame iteration NITF"
MNITF is the maximum number of frame iterations allowed.
Yes
NITF = MNITF
No


No
NMNC 0
Yes
NMNC is the number of members not closed
PRINT joint monitor data
GO to 5100
Next iteration
PRINT Table 8 (Joint Displacements and Reactions)
Rewind Tapes 1 and 2
CALL PRINT9 - PRINT Table 9 (Member Results)
PRINT Table 10 (Joint Equilibrium Errors)
Yes
NJNC > 0 or NMNC > 0
No
GO to 9800
GO to 1010
Search for independent problem
Return for next problem

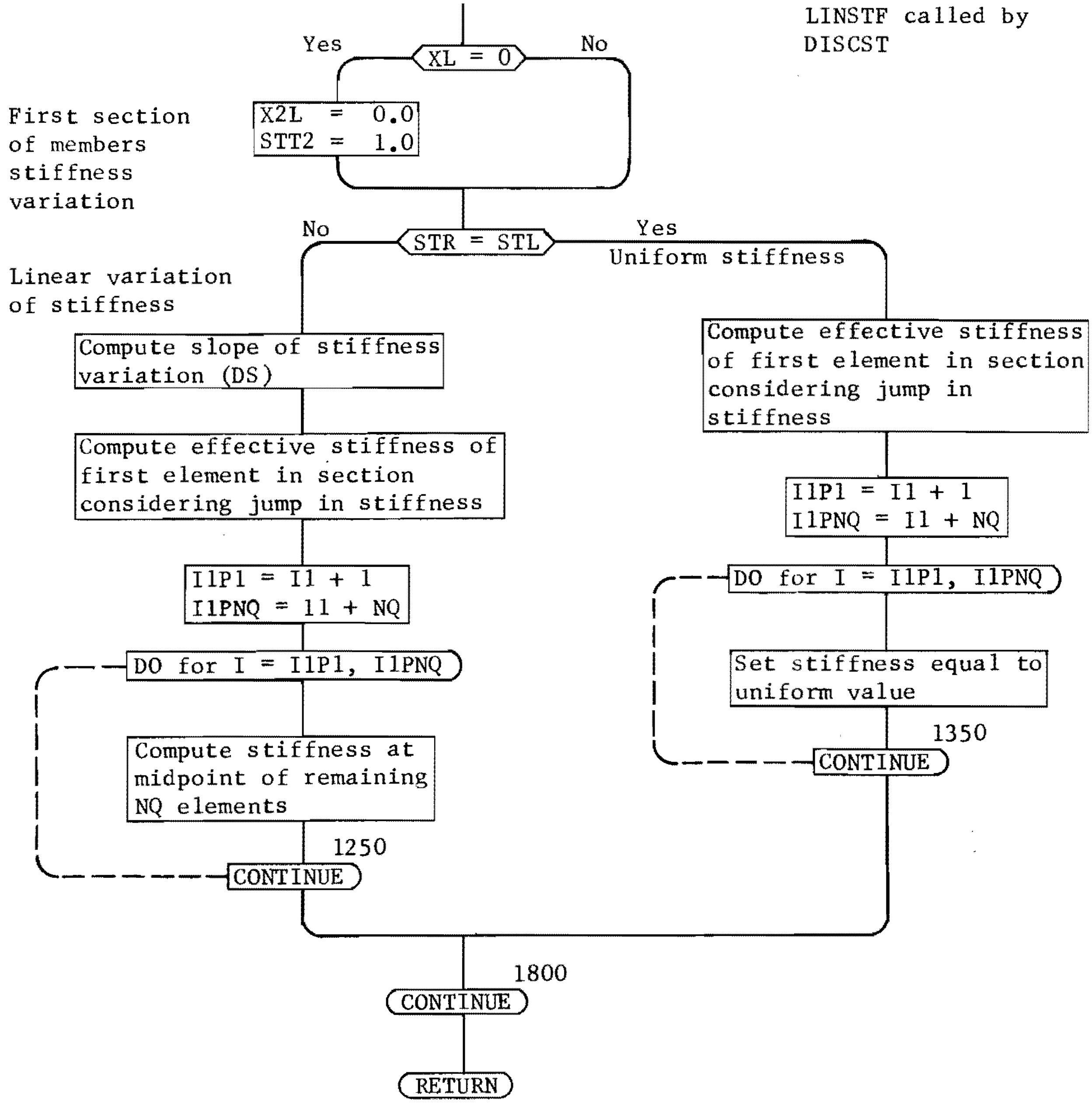

SUBROUTINE FORMST
Subroutine FORMST called by FRAM51
NITF > 1 or ITYPE = 2
Yes
No
Read Tape 2 DX, DY, DZ
Member Displacements
DO for I = 1, MP2
For each station
DX(I) = DY(I) = DZ(I) = 0.0
DO for I = 1,MP2
Do for each station
ERX(I) = ERY(I) = ERZ(I) = 0
Zero station equilibrium errors
INLOPT = 1
No
Yes
NCDST = 0
No
Yes
Discretize prismatic member stiff-ness data F, AE
Call DISCST - Discretize linear stiffness data, F,AE,SX,SY,SZ
Call NLSS - Discretize member q-w curves to station values of resistive spring force and tangent spring stiffness
2500
Store member-end-restraints ST1 - ST6
SX(1) = 1.0E + 99
SY(1) = 1.0E + 99
SZ(1) = 1.0E + 99
SX(MP1) = 1.0E + 99
SY(MP1) = 1.0E + 99
SZ(MP1) = 1.0E + 99
Set end restraints equal to large value to enforce unit increments of end-displacement
Zero pinned end rotational restraints
DO for six member-end-displacements
Set appropriate equilibrium error equal to 1.0E + 99 to enforce unit increment of member-end-displacement
Call GRIP2A - Solve member for unit increment of end-displacement
Call MEMENI - Find incremental end-forces on member
CONTINUE
RETURN

SUBROUTINE DISCST

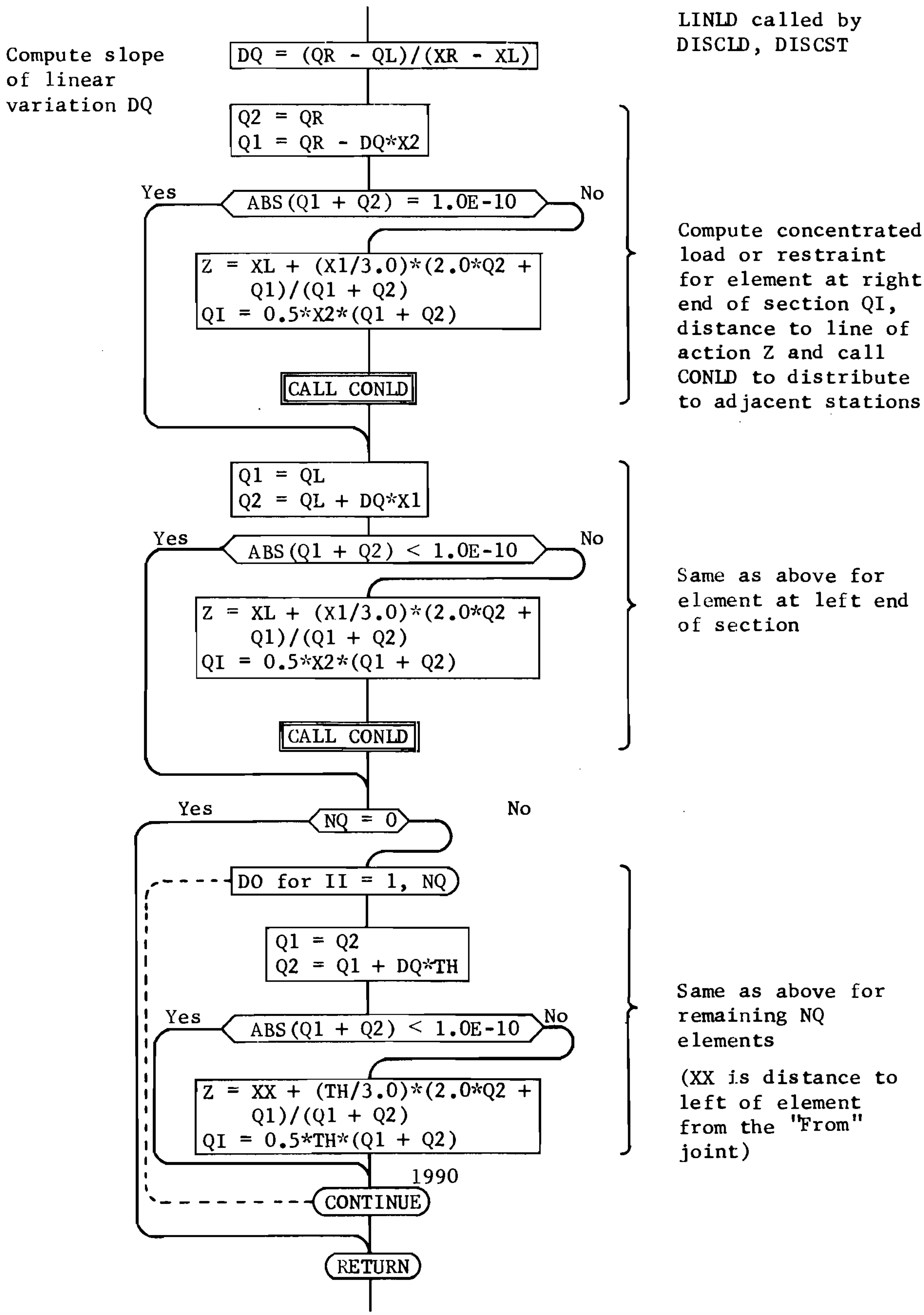



NQ = I2 - I1
CALL LINSTF - Distribute F stations I1 to I2
Distribute bending stiffness
CALL LINSTF - Distribute AE stations I1 to I2
Distribute axial stiffness
Yes
SXLT = 0.0 and SXRT = 0.0
No
CALL LINLD - Distribute SX Stations I1 to I2
Distribute axial restraints
Yes
SYLT = 0.0 and SYRT = 0.0
No
CALL LINLD - Distribute SY Stations I1 to I2
Distribute lateral restraints
Yes
SZLT = 0.0 and SZRT = 0.0
No
CALL LINLD - Distribute SZ stations I1 to I2
Distribute rotational restraints
1330
CONTINUE
Return for next section of data
X2L = X2
Yes
II < NC52T
No
9900
CONTINUE
RETURN

SUBROUTINE LINSTF

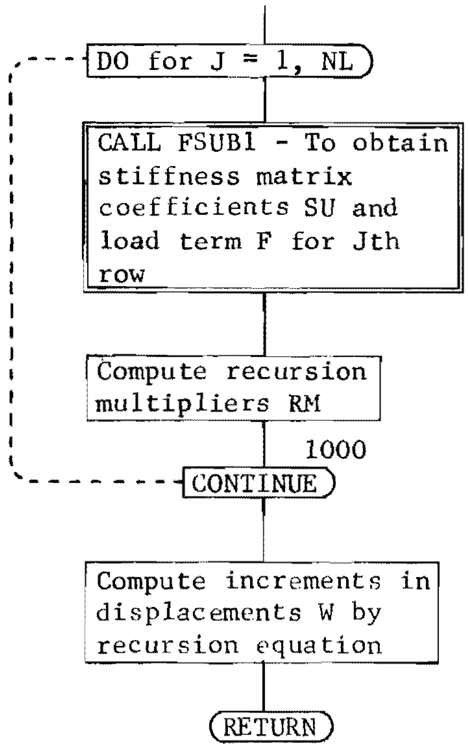


SUBROUTINE LINLD



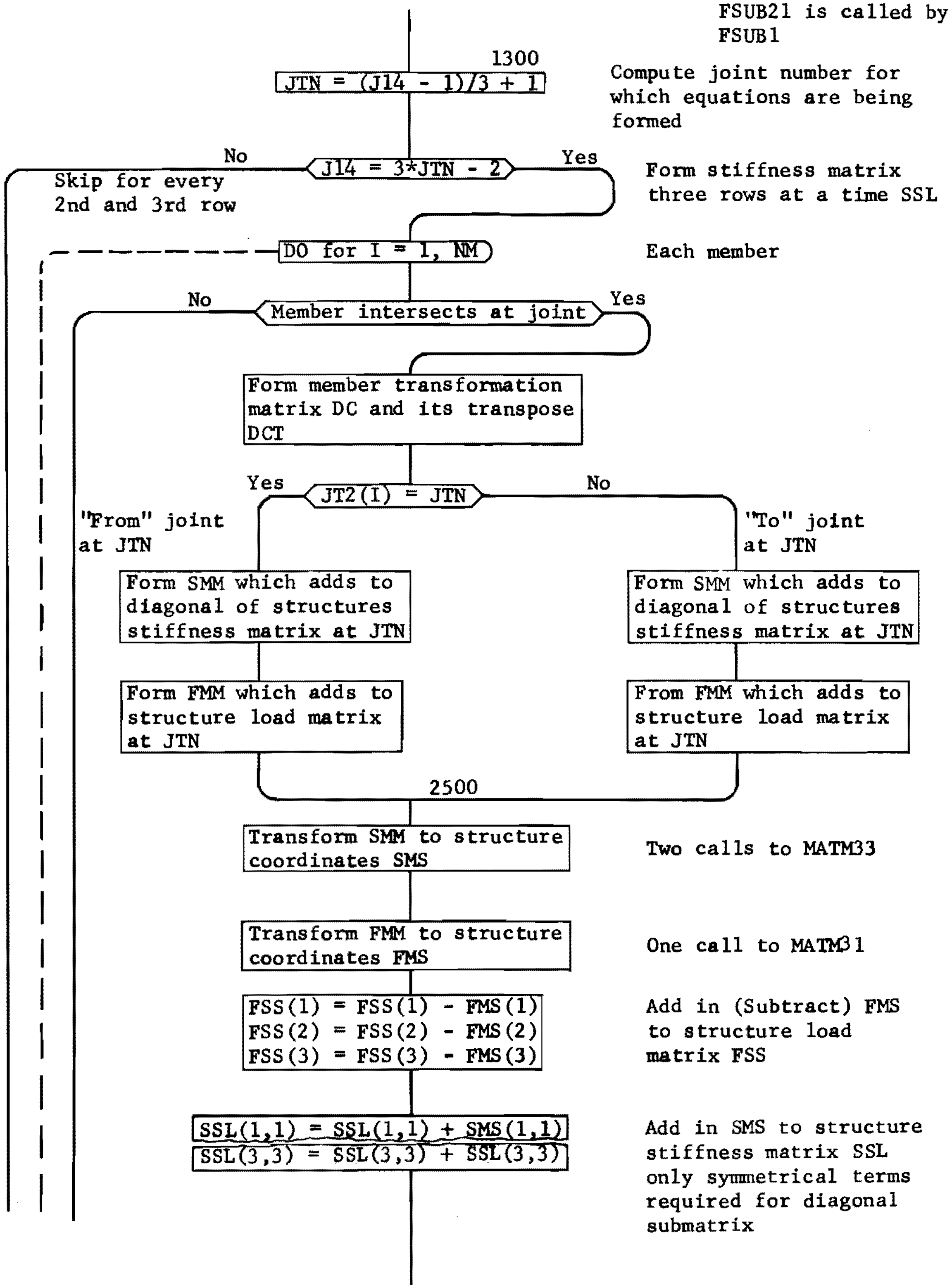
SUBROUTINE GRIP2A

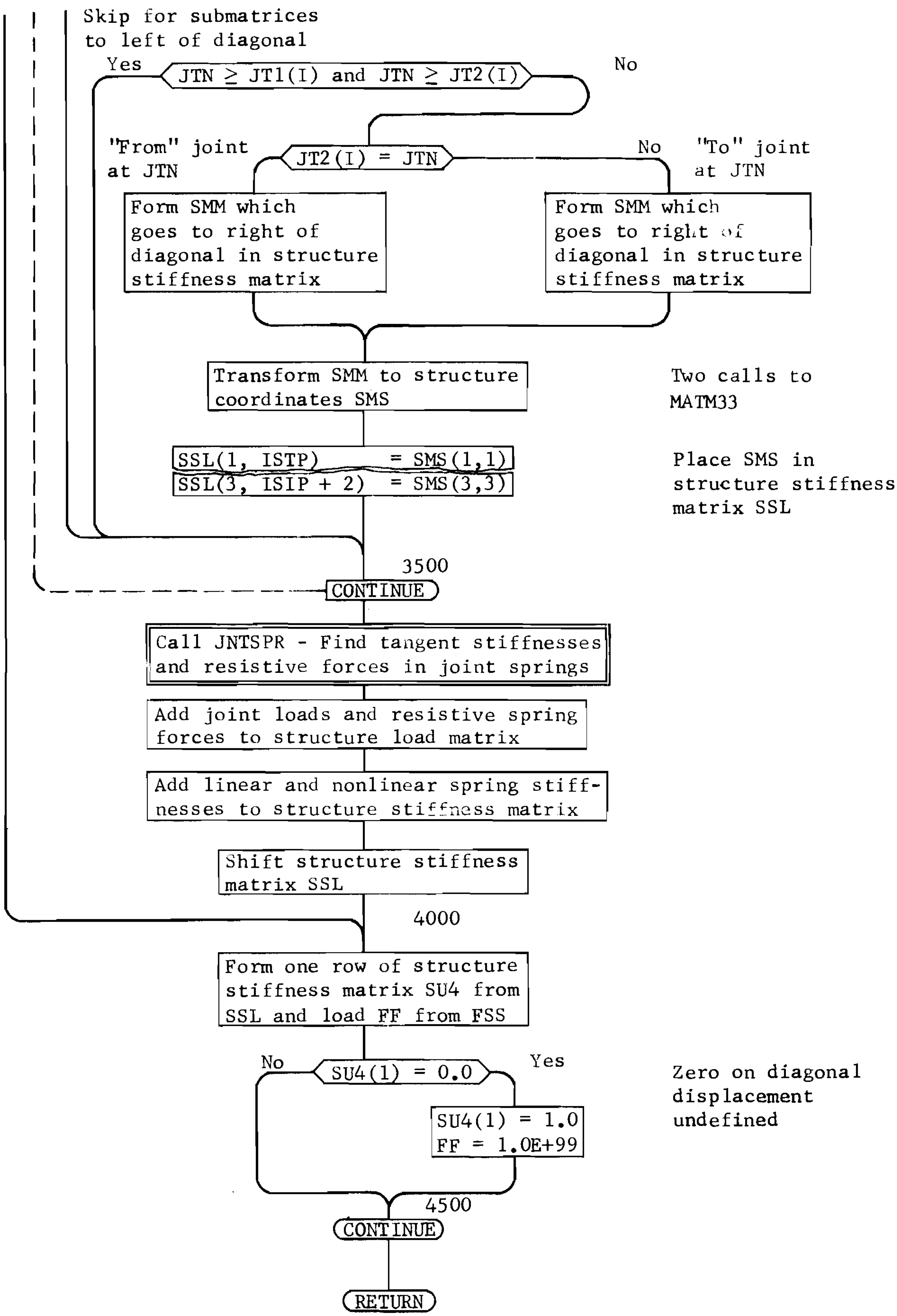
GRIP2A called by
FRAM51, FORMST,
FORMLD, MEMSOL

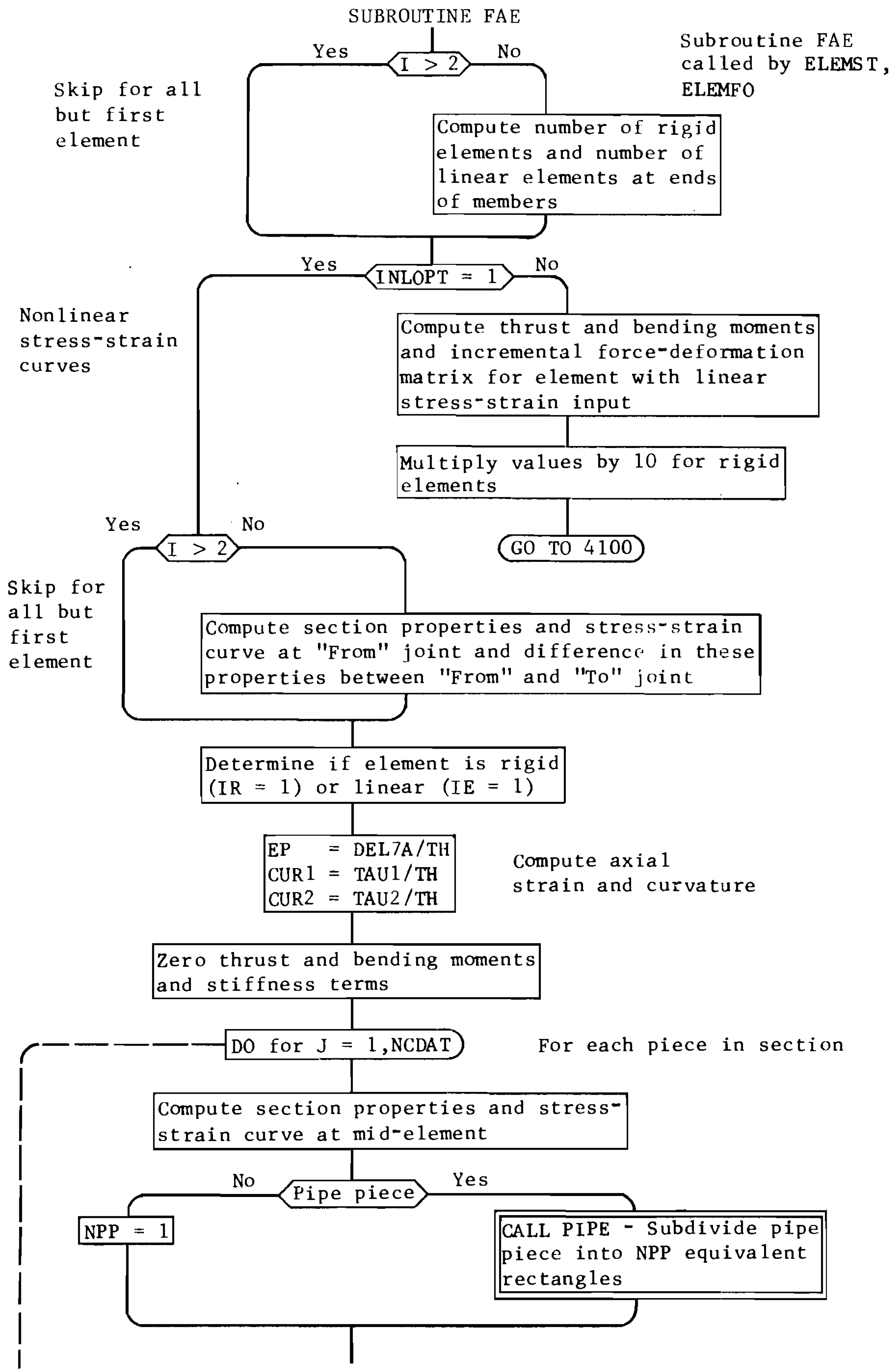


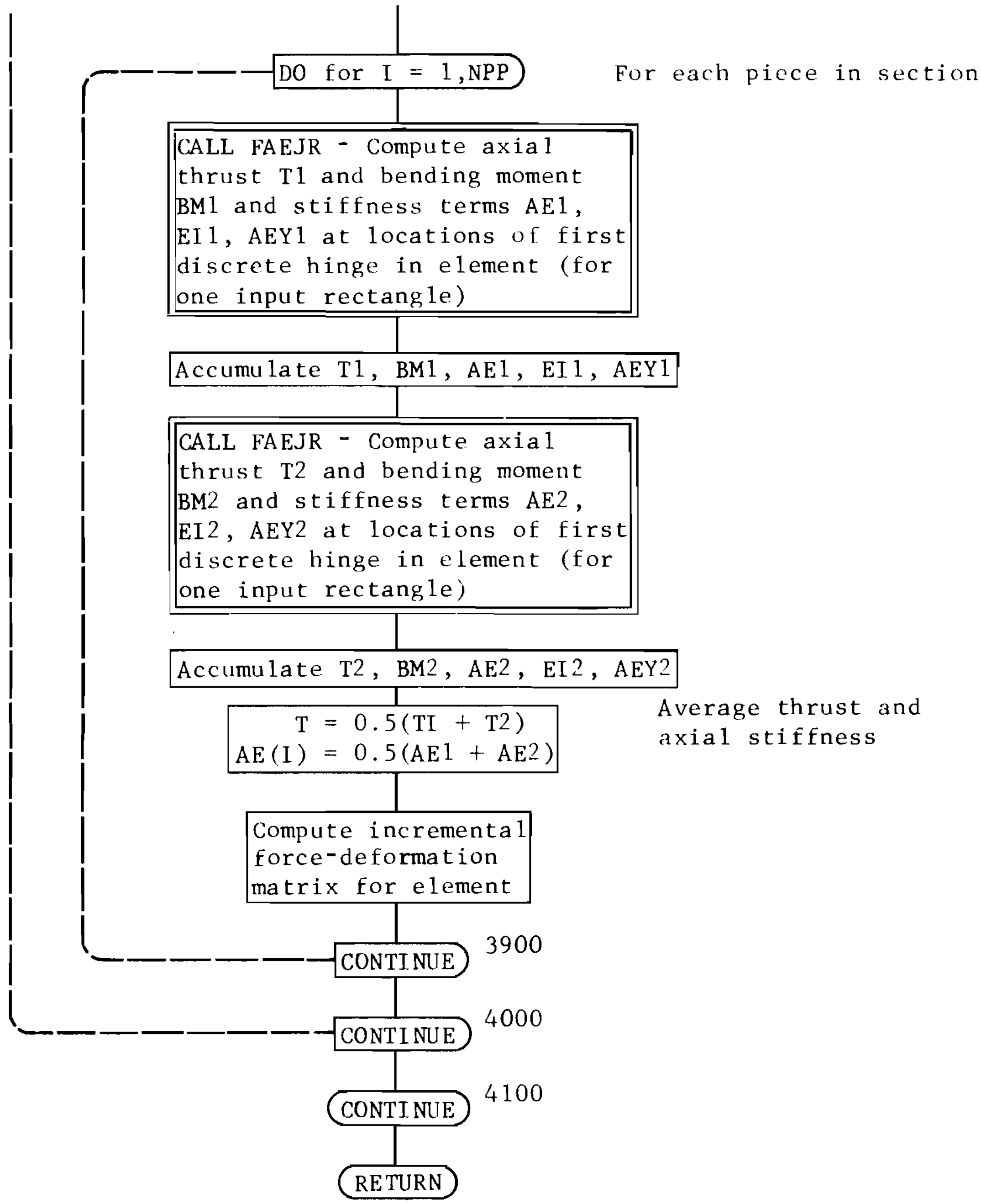
FSUB1 calls FSUB21 to
furnish SU and F for
frame solution or
FSUB22 to furnish SU
and F for member
solutions

SUBROUTINE FSUB21



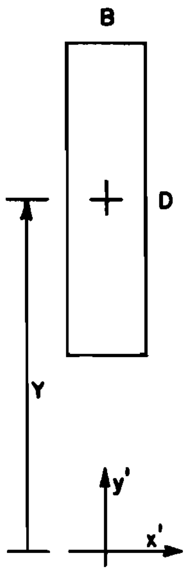

Skip for submatrices
to left of diagonal
Yes
JTN ≥ JT1(I) and JTN ≥ JT2(I)
No
"From" joint
at JTN
JT2(I) = JTN
No
"To" joint
at JTN
Form SMM which
goes to right of
diagonal in structure
stiffness matrix
Form SMM which
goes to right of
diagonal in structure
stiffness matrix
Transform SMM to structure
coordinates SMS
Two calls to
MATM33
SSL(1, ISTP) = SMS(1,1)
SSL(3, ISIP + 2) = SMS(3,3)
Place SMS in
structure stiffness
matrix SSL
3500
CONTINUE
Call JNTSPR - Find tangent stiffnesses
and resistive forces in joint springs
Add joint loads and resistive spring
forces to structure load matrix
Add linear and nonlinear spring stiff-
nesses to structure stiffness matrix
Shift structure stiffness
matrix SSL
4000
Form one row of structure
stiffness matrix SU4 from
SSL and load FF from FSS
No
SU4(1) = 0.0
Yes
Zero on diagonal
displacement
undefined
SU4(1) = 1.0
FF = 1.0E+99
4500
CONTINUE
RETURN


SUBROUTINE FAE
Subroutine FAE called by ELEMST, ELEMFO
I > 2
Yes
No
Skip for all but first element
Compute number of rigid elements and number of linear elements at ends of members
INLOPT = 1
Yes
No
Nonlinear stress-strain curves
Compute thrust and bending moments and incremental force-deformation matrix for element with linear stress-strain input
Multiply values by 10 for rigid elements
GO TO 4100
I > 2
Yes
No
Skip for all but first element
Compute section properties and stress-strain curve at "From" joint and difference in these properties between "From" and "To" joint
Determine if element is rigid (IR = 1) or linear (IE = 1)
EP = DEL7A/TH
CUR1 = TAU1/TH
CUR2 = TAU2/TH
Compute axial strain and curvature
Zero thrust and bending moments and stiffness terms
DO for J = 1,NCDAT
For each piece in section
Compute section properties and stress-strain curve at mid-element
Pipe piece
No
Yes
NPP = 1
CALL PIPE - Subdivide pipe piece into NPP equivalent rectangles

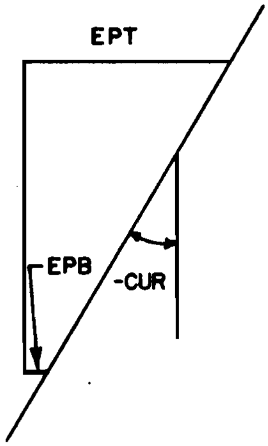

DO for I = 1,NPP
For each piece in section
CALL FAEJR - Compute axial thrust T1 and bending moment BM1 and stiffness terms AE1, EI1, AEY1 at locations of first discrete hinge in element (for one input rectangle)
Accumulate T1, BM1, AE1, EI1, AEY1
CALL FAEJR - Compute axial thrust T2 and bending moment BM2 and stiffness terms AE2, EI2, AEY2 at locations of first discrete hinge in element (for one input rectangle)
Accumulate T2, BM2, AE2, EI2, AEY2
T = 0.5(TI + T2)
AE(I) = 0.5(AE1 + AE2)
Average thrust and axial stiffness
Compute incremental force-deformation matrix for element
CONTINUE
3900
CONTINUE
4000
CONTINUE
4100
RETURN

SUBROUTINE FAEJR

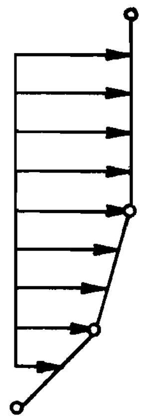
Subroutine FAEJR called by FAE



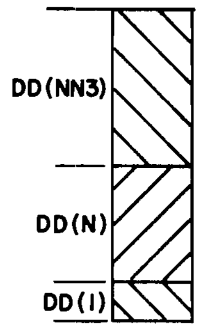
(a) Input rectangle.



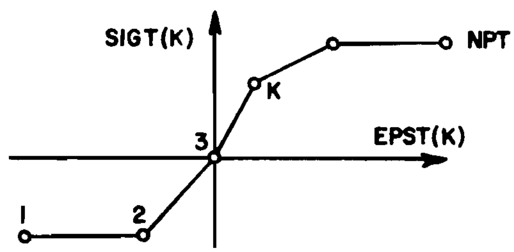
(b) Strain diagram.



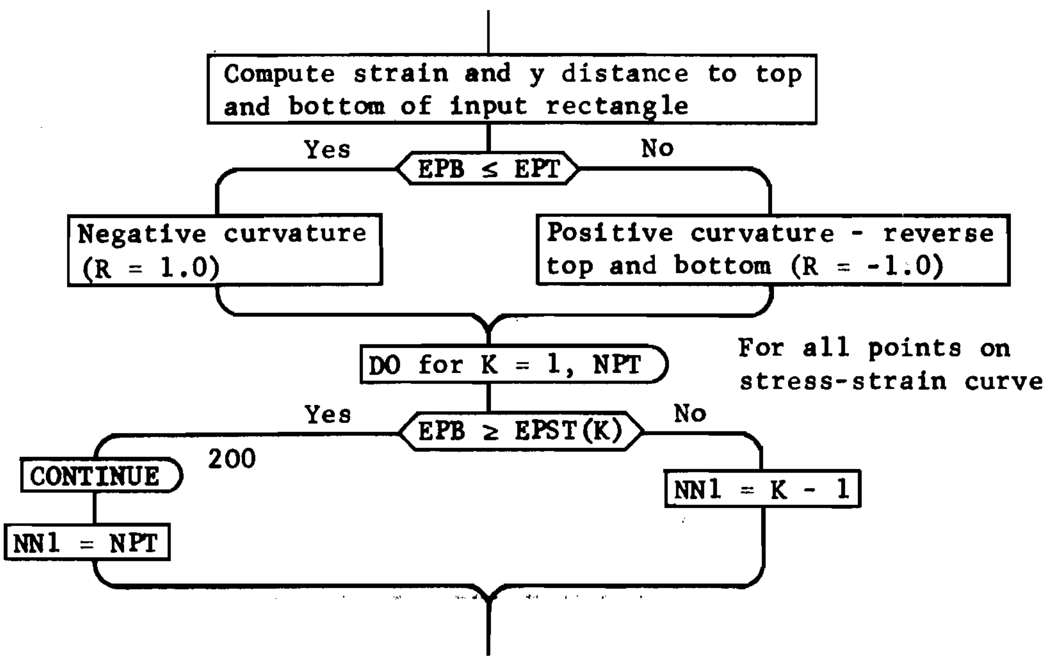
(d) Stress diagram.

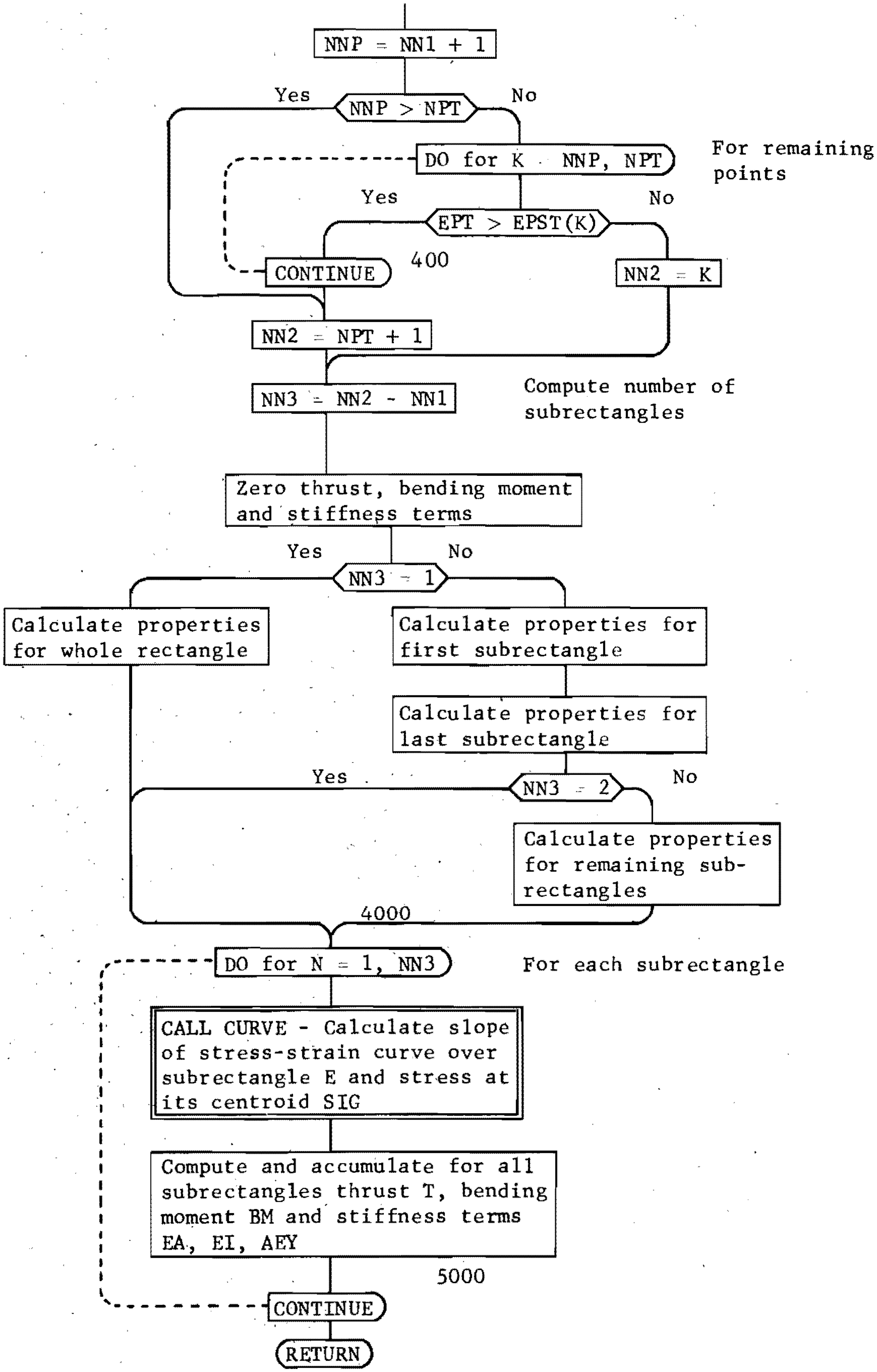


(e) Subrectangles.

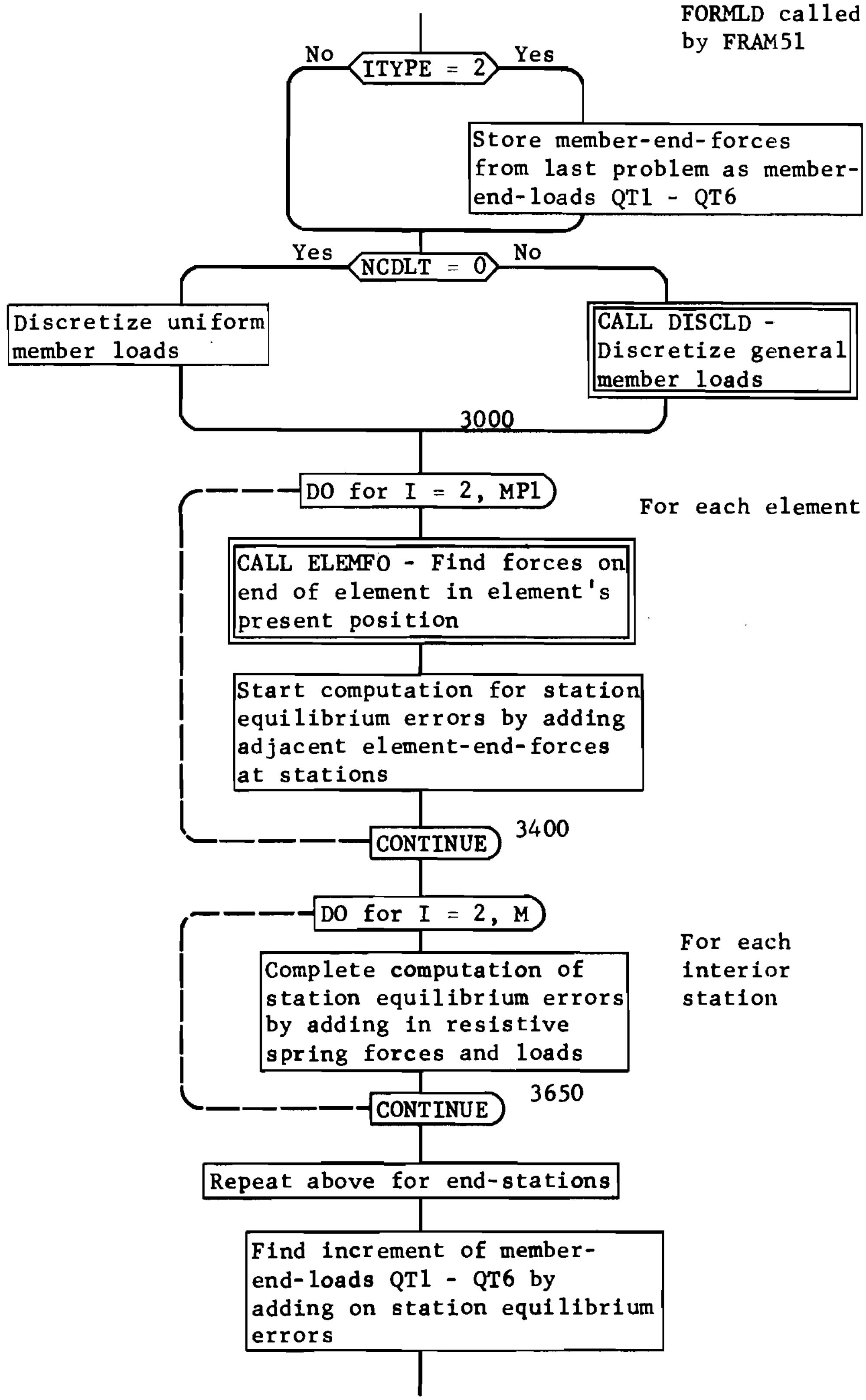


(c) Stress-strain diagram.




NNP = NN1 + 1
Yes
NNP > NPT
No
DO for K = NNP, NPT
For remaining points
Yes
No
EPT > EPST(K)
CONTINUE
400
NN2 = K
NN2 = NPT + 1
NN3 = NN2 - NN1
Compute number of subrectangles
Zero thrust, bending moment and stiffness terms
Yes
No
NN3 = 1
Calculate properties for whole rectangle
Calculate properties for first subrectangle
Calculate properties for last subrectangle
Yes
NN3 = 2
No
Calculate properties for remaining sub-rectangles
4000
DO for N = 1, NN3
For each subrectangle
CALL CURVE - Calculate slope of stress-strain curve over subrectangle E and stress at its centroid SIG
Compute and accumulate for all subrectangles thrust T, bending moment BM and stiffness terms EA, EI, AEY
5000
CONTINUE
RETURN

SUBROUTINE FORMLD

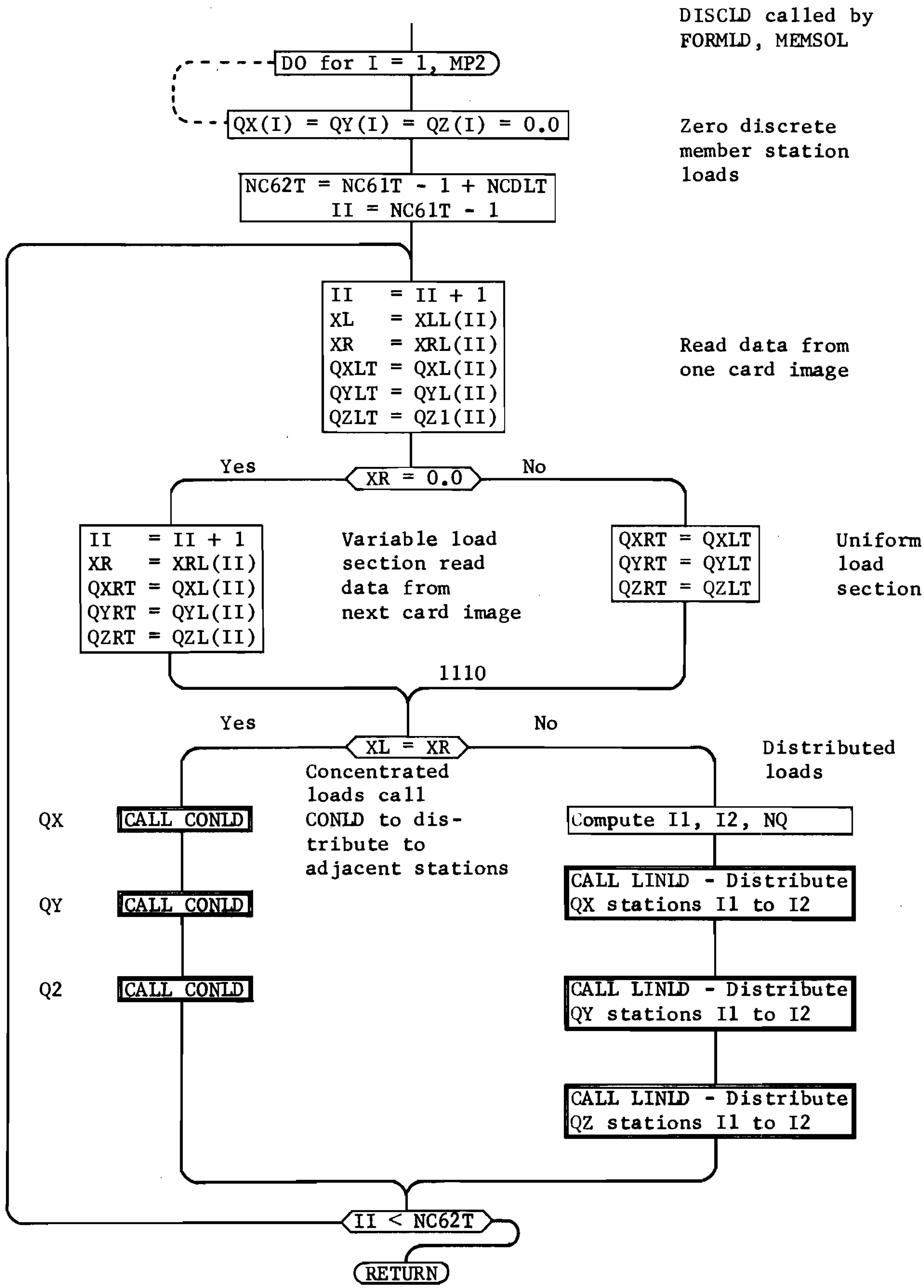


CALL GRIP2A - Solve member for increments of member loads (station equilibrium errors)

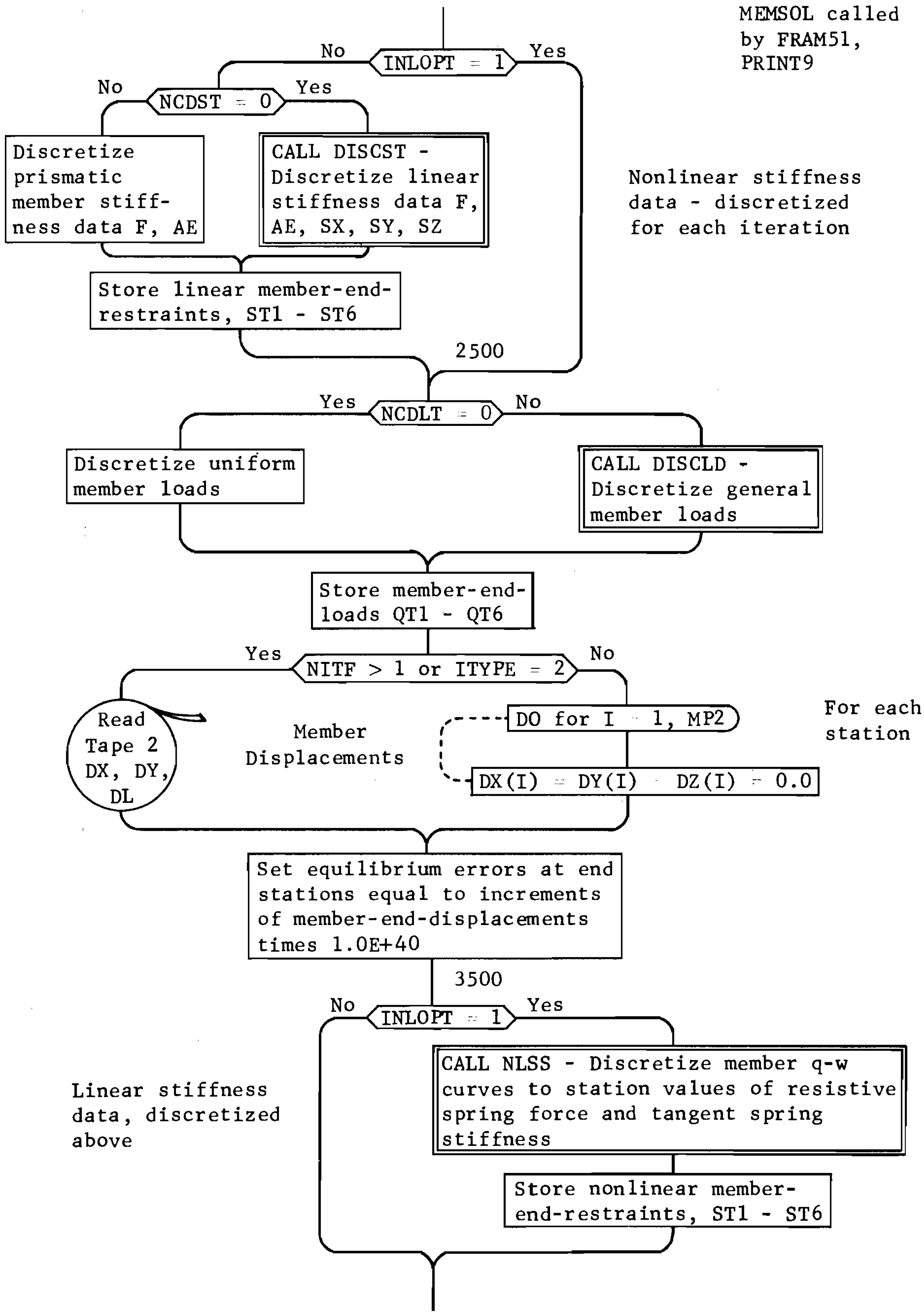
CALL MEMENI - Find incremental fixed-end-forces on member

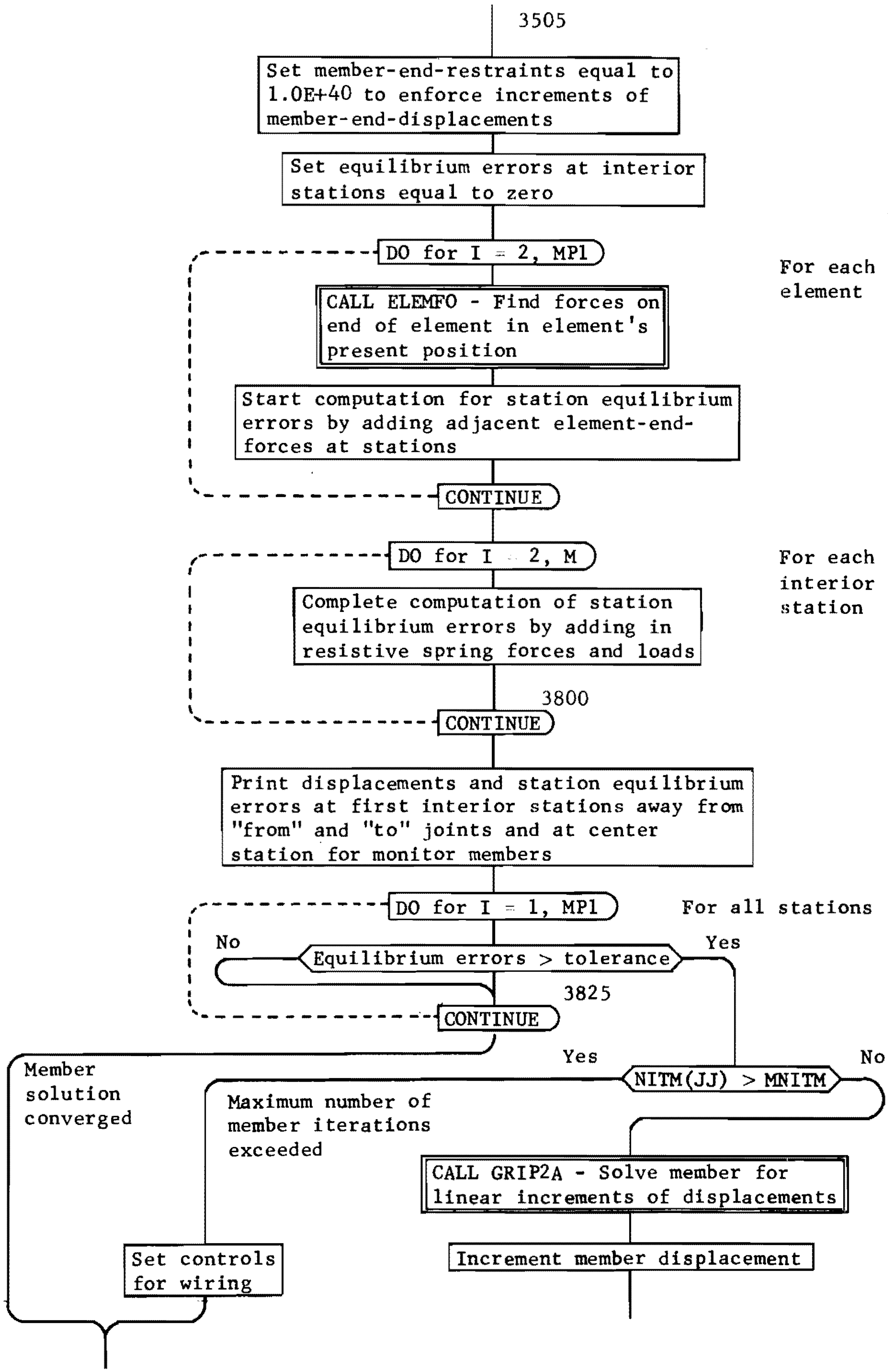
RETURN

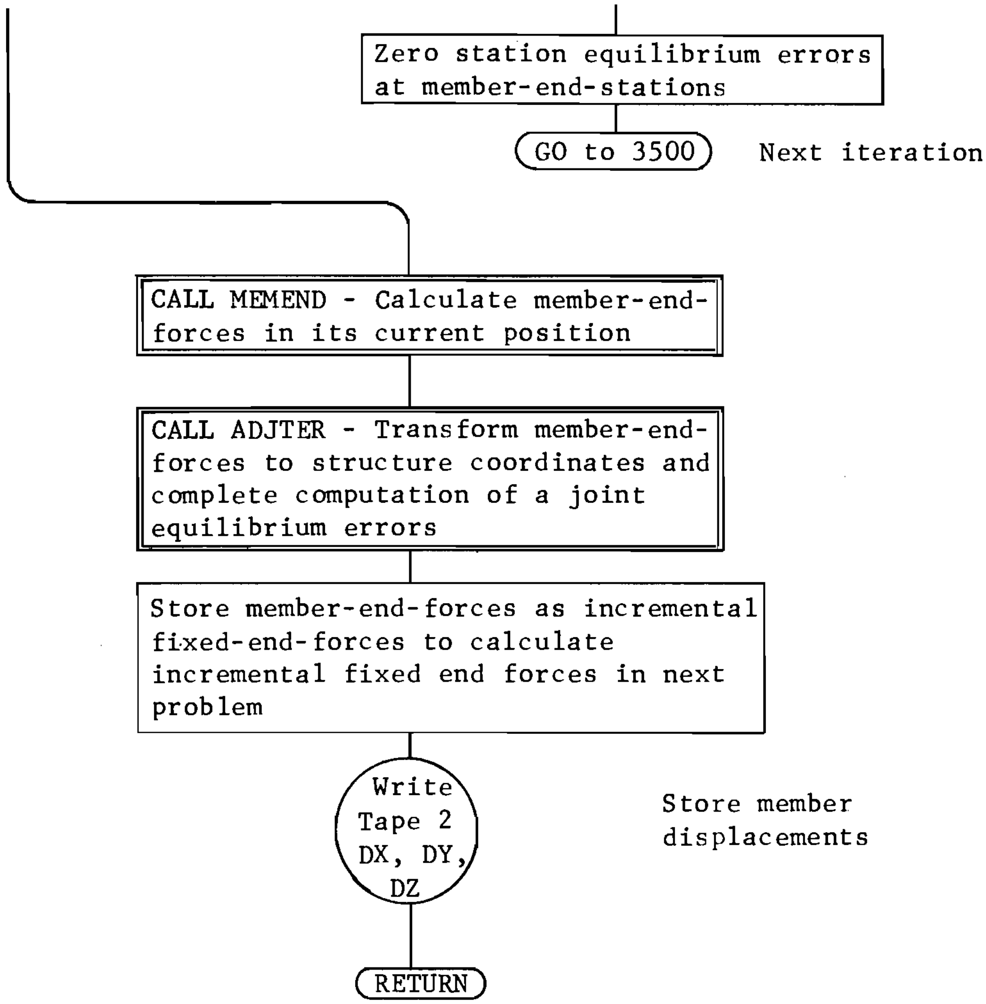
SUBROUTINE DISCLD

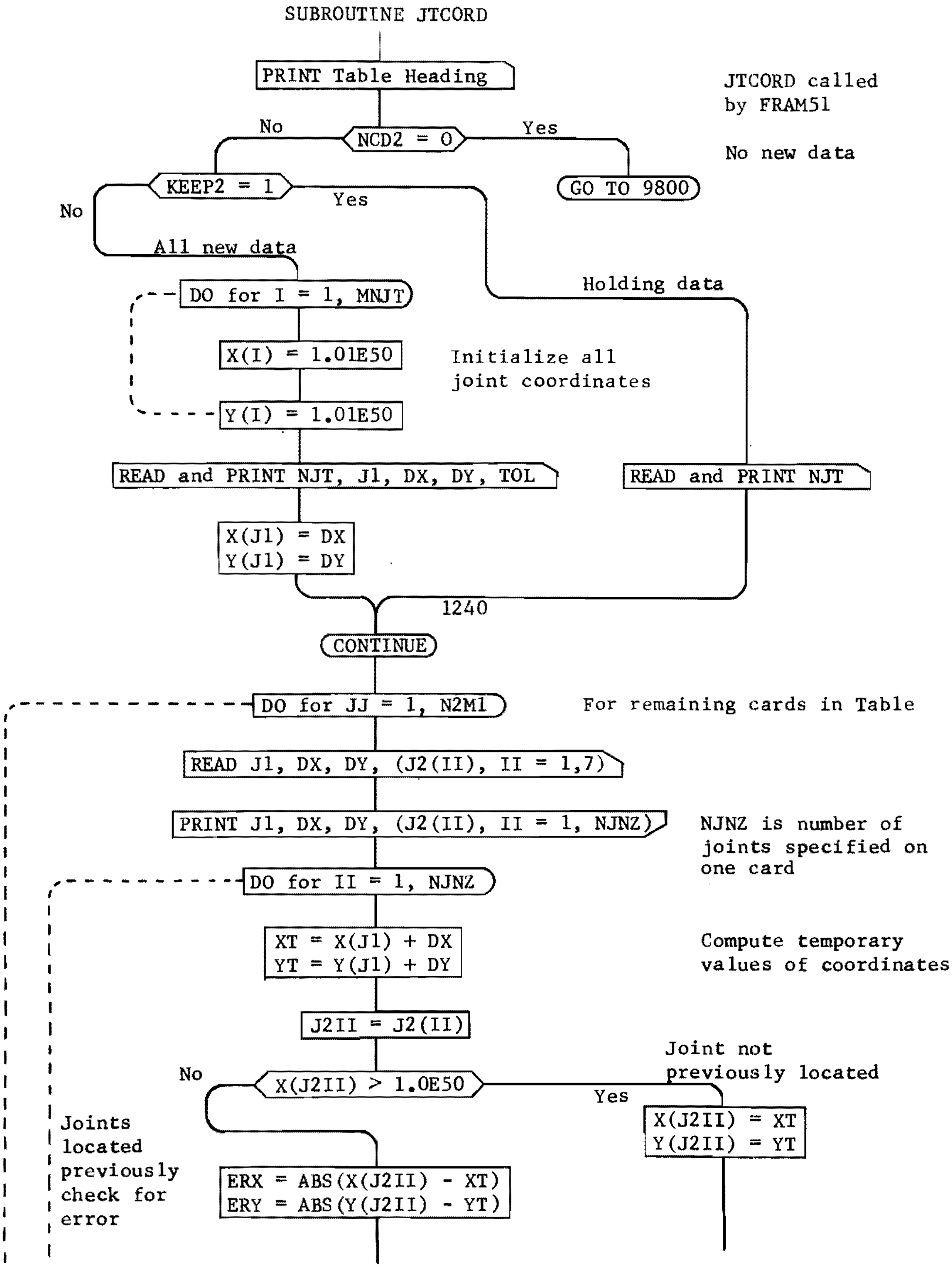


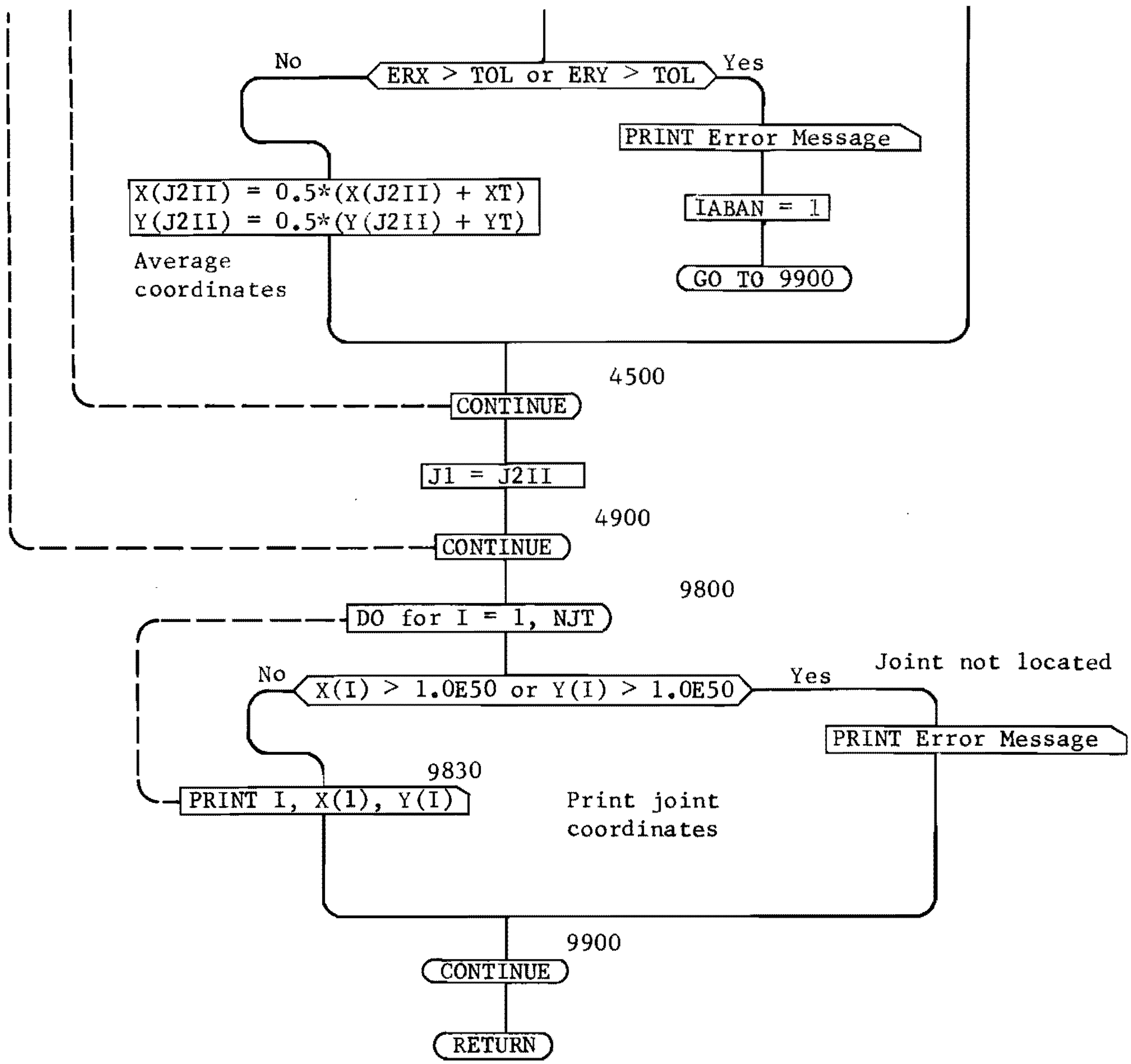
SUBROUTINE MEMSOL




3505
Set member-end-restraints equal to 1.0E+40 to enforce increments of member-end-displacements
Set equilibrium errors at interior stations equal to zero
DO for I = 2, MP1
For each element
CALL ELEMFO - Find forces on end of element in element's present position
Start computation for station equilibrium errors by adding adjacent element-end-forces at stations
CONTINUE
DO for I = 2, M
For each interior station
Complete computation of station equilibrium errors by adding in resistive spring forces and loads
3800
CONTINUE
Print displacements and station equilibrium errors at first interior stations away from "from" and "to" joints and at center station for monitor members
DO for I = 1, MP1
For all stations
No
Equilibrium errors > tolerance
Yes
3825
CONTINUE
Yes
No
NITM(JJ) > MNITM
Member solution converged
Maximum number of member iterations exceeded
CALL GRIP2A - Solve member for linear increments of displacements
Set controls for wiring
Increment member displacement

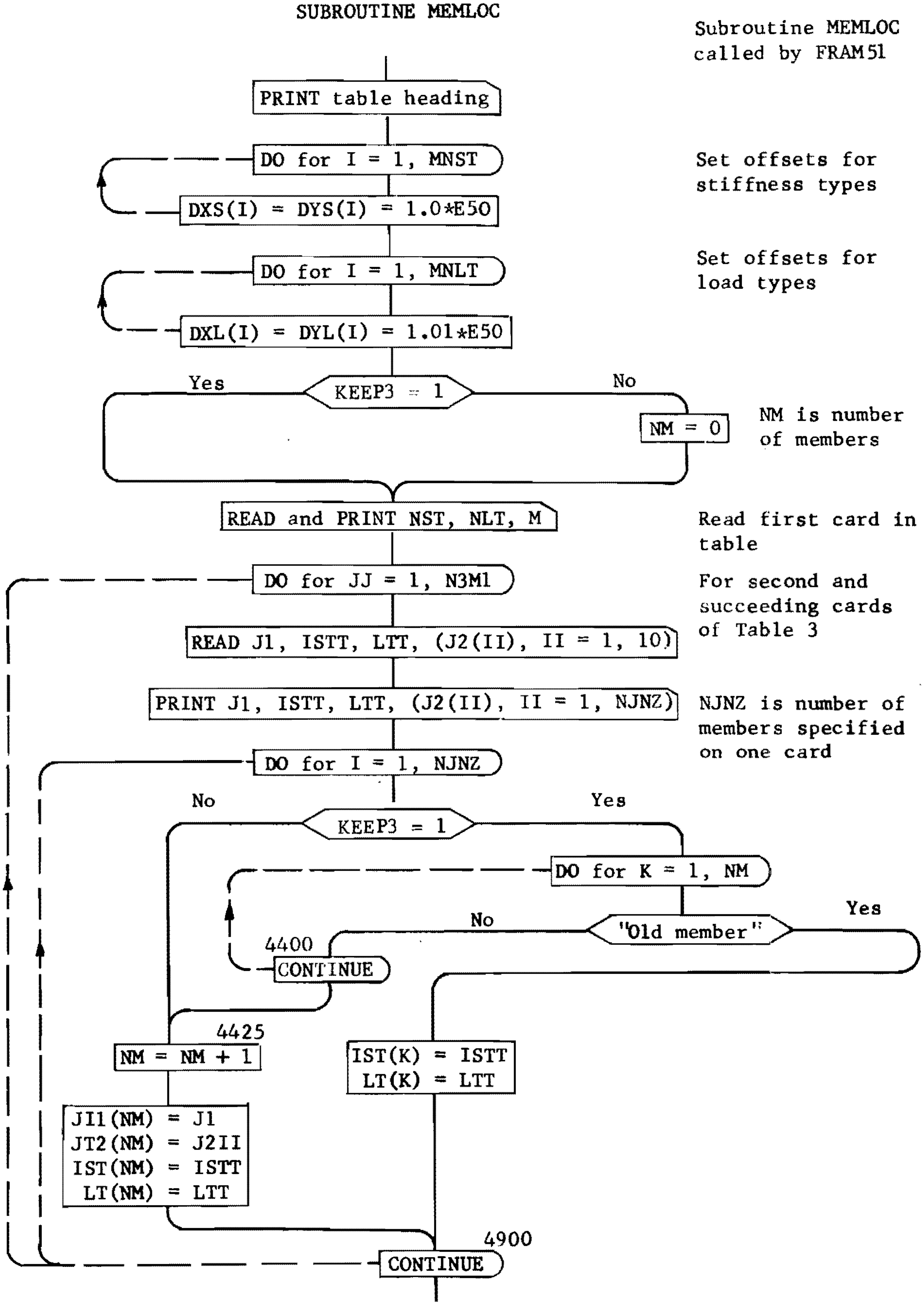

Zero station equilibrium errors at member-end-stations
GO to 3500
Next iteration
CALL MEMEND - Calculate member-end-forces in its current position
CALL ADJTER - Transform member-end-forces to structure coordinates and complete computation of a joint equilibrium errors
Store member-end-forces as incremental fixed-end-forces to calculate incremental fixed end forces in next problem
Write Tape 2 DX, DY, DZ
Store member displacements
RETURN

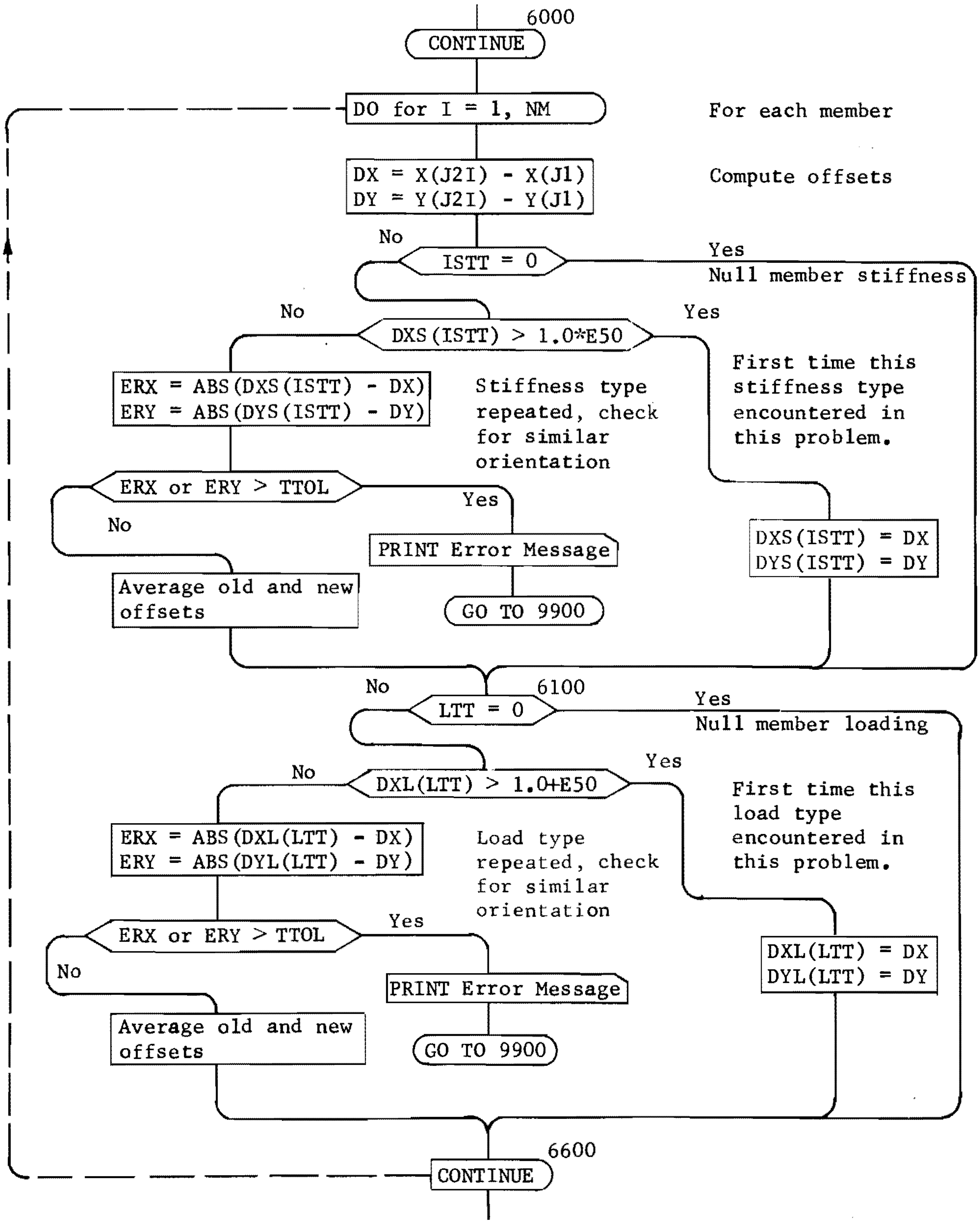

SUBROUTINE JTCORD
PRINT Table Heading
JTCORD called by FRAM51
NCD2 = 0
No
Yes
No new data
GO TO 9800
KEEP2 = 1
No
Yes
All new data
Holding data
DO for I = 1, MNJT
X(I) = 1.01E50
Initialize all joint coordinates
Y(I) = 1.01E50
READ and PRINT NJT, J1, DX, DY, TOL
READ and PRINT NJT
X(J1) = DX
Y(J1) = DY
1240
CONTINUE
DO for JJ = 1, N2M1
For remaining cards in Table
READ J1, DX, DY, (J2(II), II = 1,7)
PRINT J1, DX, DY, (J2(II), II = 1, NJNZ)
NJNZ is number of joints specified on one card
DO for II = 1, NJNZ
XT = X(J1) + DX
YT = Y(J1) + DY
Compute temporary values of coordinates
J2II = J2(II)
Joint not previously located
No
X(J2II) > 1.0E50
Yes
X(J2II) = XT
Y(J2II) = YT
Joints located previously check for error
ERX = ABS(X(J2II) - XT)
ERY = ABS(Y(J2II) - YT)

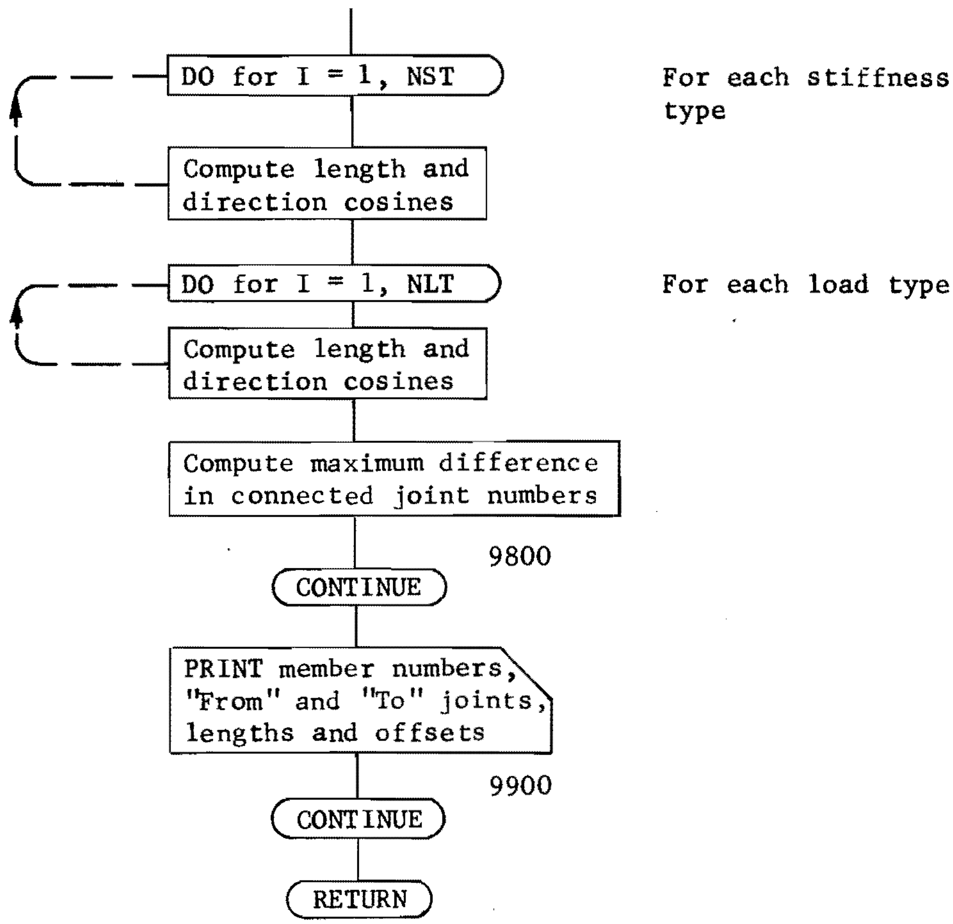


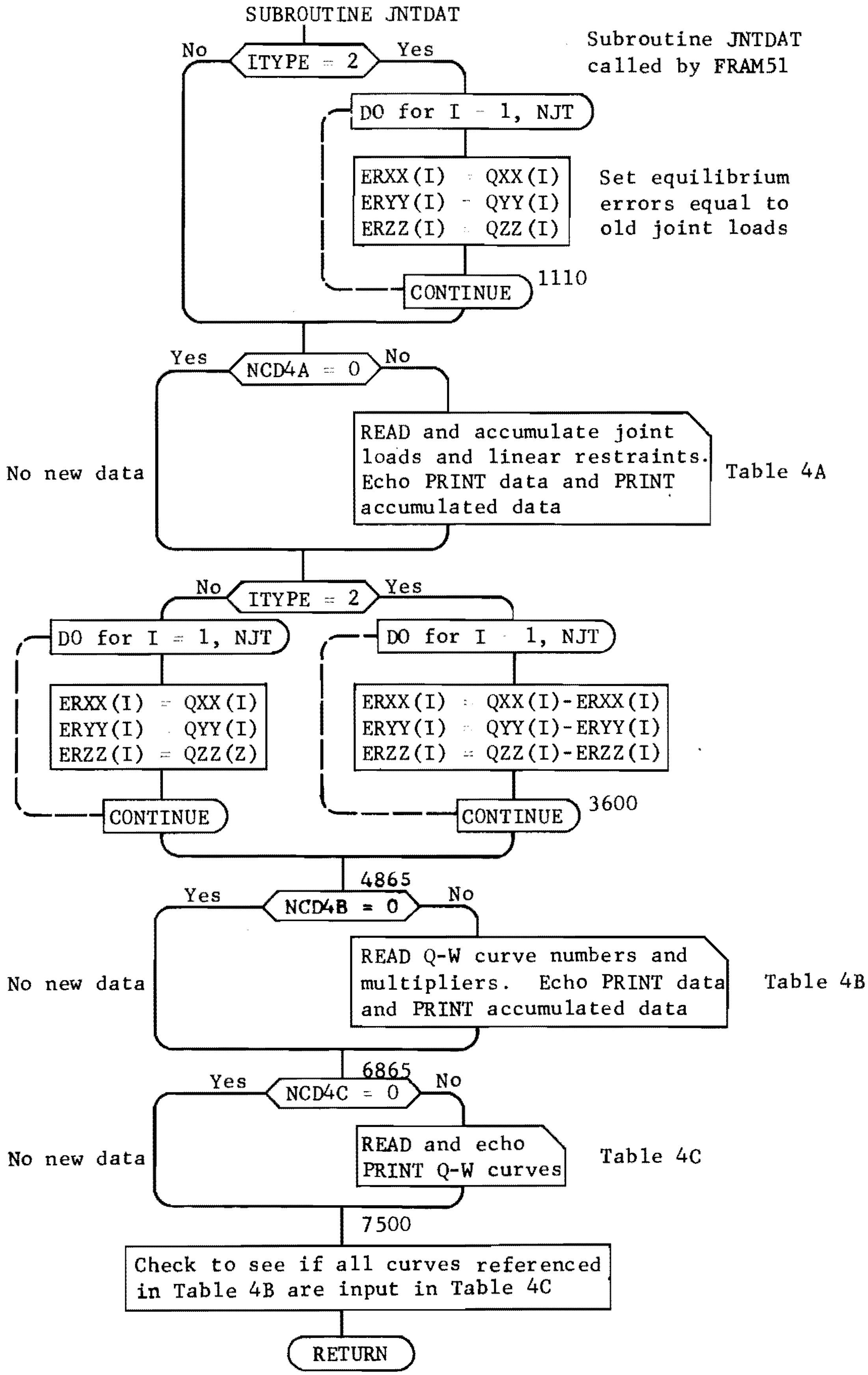
No
ERX > TOL or ERY > TOL
Yes
PRINT Error Message
X(J2II) = 0.5*(X(J2II) + XT)
Y(J2II) = 0.5*(Y(J2II) + YT)
IABAN = 1
Average coordinates
GO TO 9900
4500
CONTINUE
J1 = J2II
4900
CONTINUE
9800
DO for I = 1, NJT
No
X(I) > 1.0E50 or Y(I) > 1.0E50
Yes
Joint not located
PRINT Error Message
9830
PRINT I, X(I), Y(I)
Print joint coordinates
9900
CONTINUE
RETURN

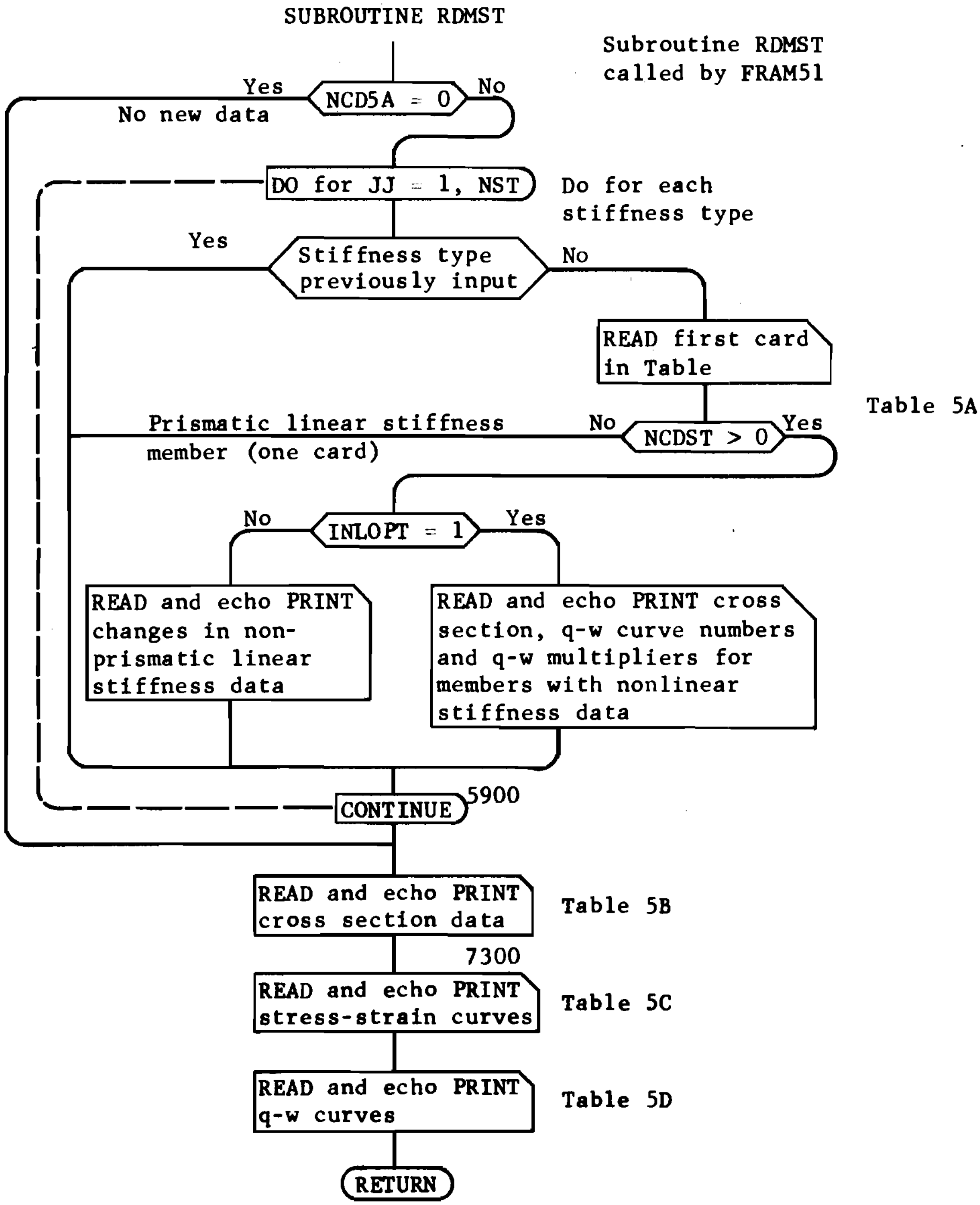
SUBROUTINE MEMLOC



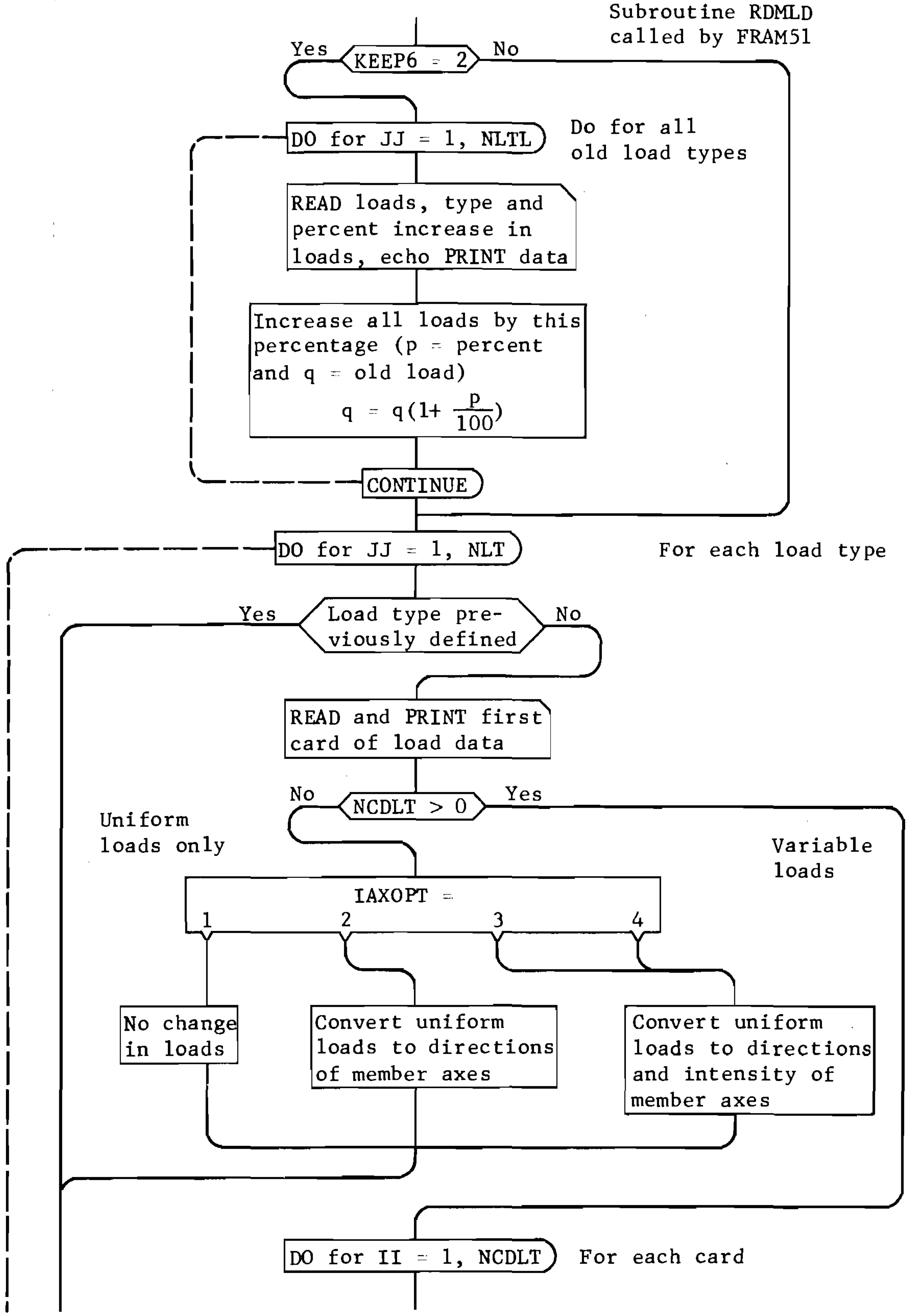

6000
CONTINUE
DO for I = 1, NM
For each member
DX = X(J2I) - X(J1)
DY = Y(J2I) - Y(J1)
Compute offsets
No
ISTT = 0
Yes
Null member stiffness
No
DXS(ISTT) > 1.0*E50
Yes
ERX = ABS(DXS(ISTT) - DX)
ERY = ABS(DYS(ISTT) - DY)
Stiffness type repeated, check for similar orientation
First time this stiffness type encountered in this problem.
ERX or ERY > TTOL
Yes
No
PRINT Error Message
DXS(ISTT) = DX
DYS(ISTT) = DY
Average old and new offsets
GO TO 9900
No
6100
LTT = 0
Yes
Null member loading
No
DXL(LTT) > 1.0+E50
Yes
First time this load type encountered in this problem.
ERX = ABS(DXL(LTT) - DX)
ERY = ABS(DYL(LTT) - DY)
Load type repeated, check for similar orientation
ERX or ERY > TTOL
Yes
No
PRINT Error Message
DXL(LTT) = DX
DYL(LTT) = DY
Average old and new offsets
GO TO 9900
6600
CONTINUE

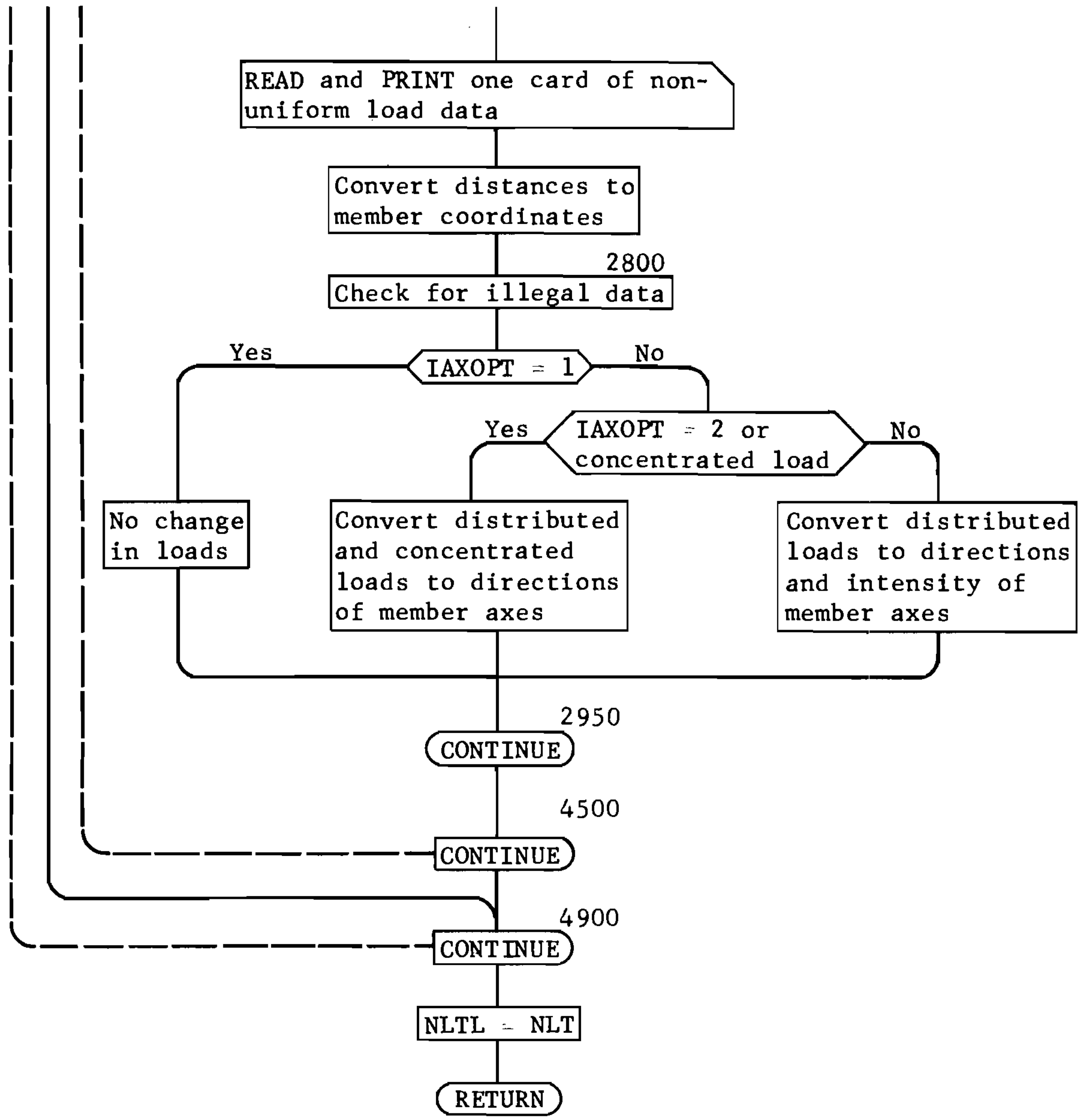

DO for I = 1, NST
Compute length and direction cosines
DO for I = 1, NLT
Compute length and direction cosines
Compute maximum difference in connected joint numbers
9800
CONTINUE
PRINT member numbers, "From" and "To" joints, lengths and offsets
9900
CONTINUE
RETURN
For each stiffness type
For each load type


SUBROUTINE JNTDAT
Subroutine JNTDAT called by FRAM51
No
ITYPE = 2
Yes
DO for I = 1, NJT
ERXX(I) = QXX(I)
ERYY(I) = QYY(I)
ERZZ(I) = QZZ(I)
Set equilibrium errors equal to old joint loads
CONTINUE
1110
Yes
NCD4A = 0
No
No new data
READ and accumulate joint loads and linear restraints. Echo PRINT data and PRINT accumulated data
Table 4A
No
ITYPE = 2
Yes
DO for I = 1, NJT
ERXX(I) = QXX(I)
ERYY(I) = QYY(I)
ERZZ(I) = QZZ(Z)
CONTINUE
DO for I = 1, NJT
ERXX(I) = QXX(I)-ERXX(I)
ERYY(I) = QYY(I)-ERYY(I)
ERZZ(I) = QZZ(I)-ERZZ(I)
CONTINUE
3600
4865
Yes
NCD4B = 0
No
No new data
READ Q-W curve numbers and multipliers. Echo PRINT data and PRINT accumulated data
Table 4B
6865
Yes
NCD4C = 0
No
No new data
READ and echo PRINT Q-W curves
Table 4C
7500
Check to see if all curves referenced in Table 4B are input in Table 4C
RETURN


SUBROUTINE RDMST
Subroutine RDMST called by FRAM51
NCD5A = 0
Yes
No new data
No
DO for JJ = 1, NST
Do for each stiffness type
Stiffness type previously input
Yes
No
READ first card in Table
Table 5A
NCDST > 0
No
Prismatic linear stiffness member (one card)
Yes
INLOPT = 1
No
Yes
READ and echo PRINT changes in non-prismatic linear stiffness data
READ and echo PRINT cross section, q-w curve numbers and q-w multipliers for members with nonlinear stiffness data
CONTINUE
5900
READ and echo PRINT cross section data
Table 5B
7300
READ and echo PRINT stress-strain curves
Table 5C
READ and echo PRINT q-w curves
Table 5D
RETURN

SUBROUTINE RDMLD




READ and PRINT one card of non-uniform load data
Convert distances to member coordinates
2800
Check for illegal data
Yes
IAXOPT = 1
No
Yes
IAXOPT = 2 or concentrated load
No
No change in loads
Convert distributed and concentrated loads to directions of member axes
Convert distributed loads to directions and intensity of member axes
2950
CONTINUE
4500
CONTINUE
4900
CONTINUE
NLTL = NLT
RETURN

APPENDIX G

GLOSSARY OF FORTRAN NOTATIONS

```
C-----NOTATION FOR FRAME 51              14 JULY 1971
C                                                                    14JL1
C                                                                    14JL1
C        A                  CROSS-SECTIONAL AREA                     14JL1
C        AE( )              AREA TIMES MODULUS OF ELASTICITY         14JL1
C        AEL( )             VALUES OF AE( ) AT EDGES OF SECTIONS     14JL1
C        AELT               VALUE OF AE( ) AT LEFT (START) OF SECTION 14JL1
C        AERT               VALUE OF AE( ) AT RIGHT (END) OF SECTION 14JL1
C        AETT2              VALUE OF AE( ) AT MIDDLE OF PARTIAL      14JL1
C                           ELEMENT ON RIGHT (END) OF SECTION        14JL1
C        AEY                SUMMATION OF A*E*Y FOR ALL SUBRECTANGLES 14JL1
C        AEY1,AEY2          AEY AT FIRST AND SECOND DISCRETE         14JL1
C                           ROTATIONAL SPRINGS IN ELEMENT            14JL1
C        AE1, AE2           AE( ) AT FIRST AND SECOND ROTATIONAL     14JL1
C                           SPRINGS IN ELEMENT                       14JL1
C        ALBE               DC1*DC2                                  14JL1
C        ALS                DC1*DC1                                  14JL1
C        AN1( ), AN2( )     ALPHA-NUMERIC IDENTIFIERS                14JL1
C        APROB              ALPHANUMERIC CHECK FOR DUMP OF TEMPORARY 14JL1
C                           PRINTS                                   14JL1
C        B                  WIDTH OF RECTANGLE OR OD OF PIPE         14JL1
C        B( , )             ELEMENT DEFORMATION-DISPLACEMENT MATRIX  14JL1
C        BCL( )             BI( , ) AT LEFT OR FROM JOINT            14JL1
C        BES                DC2*DC2                                  14JL1
C        BI( , )            WIDTH OF RECTANGLE OR OD OF PIPE INPUT   14JL1
C                           FOR X-SECT NUMBER                        14JL1
C        BM                 BENDING MOMENT                           14JL1
C        BML, BMR           BENDING MOMENT AT LEFT AND RIGHT ENDS OF 14JL1
C                           ELEMENT                                  14JL1
C        BM1, BM2           BENDING MOMENTS AT FIRST AND SECOND      14JL1
C                           ROTATIONAL SPRINGS IN ELEMENT            14JL1
C        BM1S( ), BM2S( )   BENDING MOMENTS AT FIRST AND SECOND      14JL1
C                           ROTATIONAL SPRING IN ELEMENT STORED FOR  14JL1
C                           ALL ELEMENTS                             14JL1
C        BT( , )            TRANSPOSE OF B( , )                      14JL1
C        COSCOS             COSI + COSIM1                            14JL1
C        COSI               COSINE OF ROTATION OF MEMBER AT STATION I 14JL1
C        COSIM1             COSINE OF ROTATION OF MEMBER AT STA IM1  14JL1
C        COST               COSINE(THETA)                            14JL1
C        CUR                CURVATURE                                14JL1
C        CUR1, CUR2         CURVATURE AT FIRST AND SECOND ROTATIONAL 14JL1
C                           SPRINGS IN ELEMENT                       14JL1
C        D( , )             ELEMENT FORCE-DEFORMATION MATRIX         14JL1
C        DA( )              AREA OF SUB RECTANGLE                    14JL1
C        DAE                AE OF SUBRECTANGLE                       14JL1
C        DBCL( )            CHANGE IN BI( , ) BETWEEN FROM AND TO    14JL1
C                           JOINTS DIVIDED BY M                      14JL1
C        DC( , )            MATRIX OF DIRECTION COSINES              14JL1
C        DCL                DI( , ) AT LEFT OR FROM JOINT            14JL1
C        DCT( , )           TRANSPOSE OF DC( , )                     14JL1
C        DC1, DC2           DIRECTION COSINES                        14JL1
C        DC1L( ), DC2L( )   DIRECTION COSINES FOR LOAD TYPES         14JL1
C        DC1S( ), DC2S( )   DIRECTION COSINES FOR STIFFNESS TYPES    14JL1
C        DD                 DEPTH OF SUBRECTANGLE                    14JL1
C        DDCL( )            CHANGE IN DI( , ) BETWEEN FROM AND TO    14JL1
C                           JOINTS DIVIDED BY M                      14JL1
C        DDIS               DISTANCES BETWEEN MEMBER OUTPUT STATIONS 14JL1
C        DDX                DIFFERENCE IN HORIZONTAL DISPLACEMENTS   14JL1
C                           OF ENDS OF ELEMENT                       14JL1
C        DDY                DIFFERENCE IN VERTICAL DISPLACEMENTS OF  14JL1
C                           ENDS OF ELEMENT                          14JL1
C        DEL                LENGTH OF SECTION OF MEMBER LOADING      14JL1
C        DELTA              AXIAL DEFORMATION IN ELEMENT             14JL1
C        DEPSL( )           CHANGE IN STAIN BETEEN CORRESPONDING     14JL1
C                           POINTS ON STRESS-STRAIN CURVES AT FROM   14JL1
C                           AND TO JOINTS DIVIDED BY M               14JL1
C        DI( , )            DEPTH OF RECTANGLE OR THICKNESS OF PIPE  14JL1
C                           INPUT FOR X-SECT NUMBERS                 14JL1
C        DIS                DISTANCE FROM THE FROM JOINT TO OUTPUT   14JL1
C                           STATION                                  14JL1
C        DMM( )             MATRIX OF MEMBER-END-DISPLACEMENTS       14JL1
C                           IN MEMBER COORDINATES                    14JL1
C        DMS( )             MATRIX OF MEMBER-END-DISPLACEMENTS       14JL1
C                           IN STRUCTURE COORDINATES                 14JL1
C        DP                 DEPTH OF RECTANGLE OR THICHKNESS OF PIPE 14JL1
C        DQ                 SLOPE OF LINEAR VARIATION IN LOADING OR  14JL1
C                           ELASTIC RESTRAINTS                       14JL1
C        DQQ( )             CHANGE IN FORCE BETWEEN CORRESPONDING    14JL1
C                           POINTS ON MEMBER SUPPORT CURVE AT FROM   14JL1
C                           AND TO JOINTS DIVIDED BY M               14JL1
C        DS                 SLOPE OF LINEAR STIFFNESS VARIATION      14JL1
C        DS( , , )          MATRIX D( , ) STORED FOR ALL STATIONS    14JL1
C        DSIGL( , )         CHANGE IN STRESS BETEEEN CORRESPONDING   14JL1
C                           POINTS ON STRESS-STRAIN CURVE AT FROM    14JL1
C                           AND TO JOINTS DIVIDED BY M               14JL1
C        DT                 THRUST ON ONE SUBRECTANGLE               14JL1
C        DTE                ANGLE CUT OUT BY RADIAL SEGMENT OF PIPE  14JL1
C        DWW( )             CHANGE IN DISPLACEMENT VALUES BETWEEN    14JL1
C                           CORRESPONDING POINTS ON MEMBER SUPPORT   14JL1
C                           CURVES AT FROM AND TO JOINTS DIVIDED BY M 14JL1
C        DX, DY             X AND Y OFFSETS                          14JL1
C        DX( ), DY( ),DZ( ) MEMBER STATION DISPLACEMENTS             14JL1
C        DXL( ), DYL( )     X AND Y OFFSETS FOR LOAD TYPES           14JL1
C        DXS( ), DYS( )     X AND Y OFFSETS FOR STIFFNESS TYPES      14JL1
C        DXX( ), DYY( ),    JOINT DISPLACEMENTS                      14JL1
C        DZZ( )                                                      14JL1
C        DXXMJ( , ),        DISPLACEMENTS STORED FOR MONITOR JOINTS  14JL1
C        DYYMJ( , ),DZZMJ( , )                                       14JL1
C        DXYZ( )            DISPLACEMENTS AT ALL STATIONS ( AXIAL,   14JL1
C                           LATERAL OR ROTATIONAL)                   14JL1
C        DYCL( )            CHANGE IN YCL( ) BETWEEN FROM AND TO     14JL1
C                           JOINTS DIVIDED BY M                      14JL1
C        DZ1, DZ2           ROTATIONS AT ENDS OF ELEMENT             14JL1
C        E                  MODULUS OF ELASTICITY                    14JL1
C        EA                 AE( )                                    14JL1
C        EI                 MOMENT OF INERTIA TIMES MODULUS OF ELAS  14JL1
C        EI1, EI2           EI AT FIRST AND SECOND ROTATIONAL SPRINGS 14JL1
C                           IN ELEMENT                               14JL1
C        EM ( , )           STRAIN MULTIPLIERS                       14JL1
C        EP                 AXIAL STRAIN                             14JL1
C        EPB,EPT            STRAIN AT TOP AND BOTTOM OF RECTANGLE    14JL1
C        EPC( )             STRAIN AT CENTROID OF SUBRECTANGLE       14JL1
C        EPTT               TEMPORARY VALUE OF STRAIN                14JL1
C        EPSL( , )          STRAIN VALUES AT FROM OR LEFT JOINT      14JL1
C        EPSR               STRAIN AT TO OR RIGHT JOINT              14JL1
C        EPST ( )           STRAIN VALUES FOR COMPLETE STRESS-STRAIN 14JL1
C                           CURVE AT MID-ELEMENT                     14JL1
C        EPSTS( )           SYMMETTRICAL PORTION OF EPST( )          14JL1
C        ERRLN              ERROR IN LENGTH OF MEMBER                14JL1
C        ERR1,ERR2          MAXIMUM VALUEO SPECIFED FOR ABSOLUTE     14JL1
C                           VALUE OF FORCE AND MOMENT JOINT EQULIBRIUM14JL1
C                           ERRORS                                   14JL1
C        ERX, ERY           ERROR IN JOINT COORDINATES OR MEMBER     14JL1
```

```
C                       OFFSETS                                   14JL1
C       ERX( ), ERY( ), STATION EQUILIBRIUM ERRORS                14JL1
C       ERZ( )                                                    14JL1
C       ERXX( ), ERYY( ), JOINT EQUILIBRIUM ERRORS                14JL1
C       ERZZ( )                                                   14JL1
C       ERXXMJ( , )       JOINT EQUILIBRIUM ERRORS AT             14JL1
C       ERYYMJ( ,),ERZZMJ( ,) MONITOR JOINTS                      14JL1
C       F( )            MOMENT OF INERTIA TIMES MODULUS OF ELAS   14JL1
C       FEM( )          MEMBER LOADS (STATION EQULIBRIUM ERRORS)  14JL1
C       FF              COEFFICIENT IN LOAD MATRIX                14JL1
C       FL( )           VALUES OF F( ) AT EDGES OF SECTIONS       14JL1
C       FLT             VALUE OF FL( ) AT LEFT (START) OF SECTION 14JL1
C       FMM( )          MEMBER-END-FORCES IN MEMBER COORDINATES   14JL1
C       FMMI( )         INCREMENTAL MEMBER-END-FORCES FOR MEMBER  14JL1
C       FMMT ( )        INCREMENTAL MEMBER-END-FORCES DUE TO      14JL1
C                       END STATION SPRINGS IN STRUCTURE DIRECT   14JL1
C       FMS( )          MEMBER-END-FORCES IN STRUCTURE            14JL1
C                       COORDINATES                               14JL1
C       FMT( )          TEMPORARY FORCE MATRIX                    14JL1
C       FOMM( , )       MEMBER FIXED-END-FORCES                   14JL1
C       FOMMT( )        MEMBER FIXED-END-FORCES FOR ONE MEMBER    14JL1
C       FRT             VALUE OF F( ) AT RIGHT (END) OF SECTION   14JL1
C       FSS( )          STRUCTURE LOAD MATRIX                     14JL1
C       FT( ), FTT( )   TEMPORARY FORCE MATRICES                  14JL1
C       FTT2            VALUE OF F( ) AT MIDDLE OF PARTIAL        14JL1
C                       ELEMENT ON RIGHT (END) OF SECTION         14JL1
C       F1M( )          MEMBER-END-FORCES AT FROM JOINT IN        14JL1
C                       MEMBER COORDINATES                        14JL1
C       F1S( )          MEMBER-END-FORCES AT FROM JOINT IN        14JL1
C                       STRUCTURE COORDINATES                     14JL1
C       F2M( )          MEMBER-END-FORCES AT TO JOINT IN MEMBER   14JL1
C                       COORDINATES                               14JL1
C       F2S( )          MEMBER-END-FORCES AT TO JOINT IN          14JL1
C                       STRUCTURE COORDINATES                     14JL1
C       H               ONE HALF OF ELEMENTS LENGTH               14JL1
C       HCU             H*H*H                                     14JL1
C       HO2             H/2                                       14JL1
C       HPD             H + DELTA                                 14JL1
C       HPDE1I          1/HPD                                     14JL1
C       HPDE2           HPD*HPD                                   14JL1
C       HPDE2I          1/HPDE2                                   14JL1
C       HPDE3I          HPDE2I/HPD                                14JL1
C       HPR             H + R                                     14JL1
C       HPRC1           HPR*COSIM1                                14JL1
C       HPRC2           HPR*COSI                                  14JL1
C       HPRE2           HPR*HPR                                   14JL1
C       HPRS            HPR*HPR - S*S                             14JL1
C       HPRS1           HPR*SINIM1                                14JL1
C       HPRS2           HPR*SINI                                  14JL1
C       HSQ             H*H                                       14JL1
C       IABAN           FATAL ERROR FLAG                          14JL1
C       IAXOPL( )       AXIS OPTIONS FOR LOAD TYPES               14JL1
C       IAXOPS( )       AXIS OPTIONS FOR STIFFNESS TYPES          14JL1
C       IAXOPT          TEMPORARY VALUE OF AXIS OPTION            14JL1
C       IC              BACKWARDS COUNTER                         14JL1
C       ICOUNT          IF EQUAL 0, FIRST SECTION OF MEMBER LINEAR14JL1
C                       STIFFNESS DATA                            14JL1
C       IDJ             MAXIMUM DIFFERENCE IN JOINT NUMBERS       14JL1
C                       CONNECTED BY MEMBERS                      14JL1
C       IE              IF EQUAL TO 1, ELEMENT IS LINEARLY ELASTIC14JL1
C       IFAE            IF EQUAL TO 0, CALL TO SUBROUTINE FAE     14JL1
C                       IS OMITTED AND STORED VALUES USED FOR     14JL1
C                       THRUST,MOMENTS AND STIFFNESS TERMS        14JL1
C       IHB             (BANDWIDTH OF EQ - 1)/2                   14JL1
C       IHBP1           IHB + 1                                   14JL1
C       IHB1            IHB - 1                                   14JL1
C       IMC ( )         IF EQUAL TO 1, MEMBER DID NOT CLOSE       14JL1
C       IMJ( )          IF EQUAL TO 1, MONITOR JOINT              14JL1
C       IMM( )          IF EQUAL TO 1, MONITOR MEMBER             14JL1
C       IM1             I - 1                                     14JL1
C       IPC             CONTROL TO PRINT PARTIAL MEMBER RESULTS   14JL1
C                       FOR THREE MEMBERS ON ONE SHEET            14JL1
C       IP3             I + 3                                     14JL1
C       IP3M            I + 3*M                                   14JL1
C       IP3M1           I + 3*(M-1)                               14JL1
C       INLOP( ),INLOPT NONLINEAR OPTION FOR MEMBER STIFFNESS DATA14JL1
C       IOPL            IOPOP( ) FOR LAST MEMBER                  14JL1
C       IOPOP( ), IOPOPT MEMBER OUTPUT OPTION                     14JL1
C       IP              NUMBER OF EQUIVALENT RECTANGLE            14JL1
C       IPINL( ), IPINLT PIN AT LEFT (FROM) JOINT OPTION          14JL1
C       IPINR( ), INPINRT PIN AT RIGHT (TO) JOINT OPTION          14JL1
C       IP1             I + 1                                     14JL1
C       IP8, IP9, IP10  PRINT OPTIONS FOR TABLES 8, 9, 10         14JL1
C       IR              IF EQUAL TO 1, ELEMENT IS RIGID           14JL1
C       IRECT( , )      IF BLANK, PIECE IS RECTANGLE-IF EQUAL TO  14JL1
C                       1, PIECE IS PIPE                          14JL1
C       ISJ( )          IF EQUAL TO 1, JOINT SUPPORT CURVE IS     14JL1
C                       SYMMETRICAL                               14JL1
C       ISM ( )         IF EQUAL TO 1, MEMBER SUPPORT CURVE IS    14JL1
C                       SYMMETRICAL                               14JL1
C       ISS( ), ISST( ), IF EQUAL TO 1, STRESS-STRAIN CURVE IS    14JL1
C       ISSTT           SYMMETRICAL                               14JL1
C       IST( ), ISTT    STIFFNESS TYPE                            14JL1
C       ISTJR( )        STIFFNESS TYPE OF MEMBER JOINT SPRING     14JL1
C                       IS REFERENCED TO                          14JL1
C       ISTP            3*J21 + 1                                 14JL1
C       ISYM            IF EQUAL TO 1, CURVE IS SYMMETRICAL       14JL1
C       ITES1-ITEST4    ALPHANUMBERIC CONSTANTS                   14JL1
C       ITYPE           PROBLEM TYPE                              14JL1
C       I1, I2          FIRST AND LAST STATION INSIDE SECTION     14JL1
C       I1PNQ           I1 + NQ                                   14JL1
C       I1P1            I1 + 1                                    14JL1
C       JJ              MEMBER NUMBER                             14JL1
C       JM1             J - 1                                     14JL1
C       JNTL            ERROR FLAG FOR JOINT NUMBER TO LARGE      14JL1
C       JP3             J + 3                                     14JL1
C       JTN             JOINT NUMBER                              14JL1
C       JT1( ), JT1T, J1, FROM JOINT                              14JL1
C       J1I                                                       14JL1
C       JT2 ( ), J2I, J2II TO JOINT                               14JL1
C       J1, J14         EQUATION NUMBER                           14JL1
C       J21             ABSOLUTE VALUE OF DIFFERENCE IN JOINT     14JL1
C                       NUMBERS OF MEMBERS                        14JL1
C       KASTER          IF EQUAL TO 1, PRINT ASTERIC BY JOINT     14JL1
C                       TO INDICATE DISPALCEMENT OFF JOINT        14JL1
C                       SUPPORT CURVE                             14JL1
C       KEEP2-KEEP7     HOLD OPTIONS FOR TABLES 2-7               14JL1
C       KEKE            CHECK FOR INDEPENDENT PROBLEM             14JL1
C       KOJ( )          IF EQUAL TO 1, JOINT HAS SUPPORT CURVE    14JL1
C                       LIMIT EXCEEDED                            14JL1
C       KOFFC           IF EQUAL TO 1, CURVE DISPLACEMENT OR      14JL1
C                       STRAIN LIMIT EXCEEDED                     14JL1
C       KOFFOW          IF EQUAL TO 1, MEMBER SUPPORT CURVE LIMIT 14JL1
C                       EXCEEDED                                  14JL1
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C          KOFFSE               IF EQUAL TO 1, STRESS-STRAIN CURVE LIMIT  14JL1
C                               EXCEEDED                                  14JL1
C          KOMJ( , )            IF EQUAL TO 1, MONITOR JOINT HAS SUPPORT  14JL1
C                               CURVE LIMIT EXCEEDED                      14JL1
C          KR,KL                INTEGERS FOR CORRESPONDING POINTS ON      14JL1
C                               OPPOSITE SIDES OF SYMMETRICAL STRESS-     14JL1
C                               STRAIN CURVE                              14JL1
C          LT( ), LTT           LOAD TYPE                                 14JL1
C          L1 - L7              DIMENSION LIMITS                          14JL1
C          L7M1                 L7 - 1                                    14JL1
C          L7M2                 L7 - 2                                    14JL1
C          L7M3                 L7 - 3                                    14JL1
C          M                    NUMBER OF ELEMENTS IN MEMBER              14JL1
C          MDJT                 MAXIMUM VALUE PERMITTED FOR IDJT          14JL1
C          MHB                  MAXIMUM VALUE PERMITTED FOR IHB           14JL1
C          MHB1                 MHB + 1                                   14JL1
C          MJ( )                MONITOR JOINT NUMBER                      14JL1
C          ML                   CONTROL FOR MULTIPLE LOAD OPTION          14JL1
C          MM ( )               MONITOR MEMBER NUMBER                     14JL1
C          MM1                  M - 1                                     14JL1
C          MNCS                 MAXIMUM NUMBER OF CROSS SECTIONS          14JL1
C          MNC5                 MAXIMUM VALUE PERMITTED FOR NC5           14JL1
C          MNC6                 MAXIMUM VALUE PERMITTED FOR NC6           14JL1
C          MNE                  MAXIMUM NUMBER OF ELEMENTS PER MEMBER     14JL1
C          MNITF                MAXIMUM NUMBER OF FRAME ITERATIONS        14JL1
C          MNJS                 MAXIMUM NUMBER OF NONLINEAR JOINT CURVES  14JL1
C          MNJT                 MAXIMUM VALUE PERMITTED FOR NJT           14JL1
C          MNLC                 MAXIMUM VALUE PERMITTED FOR NLC           14JL1
C          MNLT                 MAXIMUM VALUE PERMITTED FOR NLT           14JL1
C          MNM                  MAXIMUM VALUE PERMITTED FOR NM            14JL1
C          MNPCS                MAXIMUM NUMBER OF PIECES IN CROSS SECTION 14JL1
C          MNQWM                MAXIMUM NUMBER OF MEMBER SOIL SUPPORT     14JL1
C                               CURVES                                    14JL1
C          MNST                 MAXIMUM VALUE PERMITTED FOR NST           14JL1
C          MNSS                 MAXIMUM NUMBER OF STRESS-STRAIN CURVES    14JL1
C          MP1                  M + 1                                     14JL1
C          MP2                  M + 2                                     14JL1
C          MP22                 (M + 2)/2                                 14JL1
C          MP221                MP22 - 1                                  14JL1
C          NA( )                CROSS SECTION AREA NUMBER                 14JL1
C          NAL ( )              AREA NUMBER AT FROM OR LEFT JOINT         14JL1
C          NAR ( ),NART         AREA NUMBER AT TO OR RIGHT JOINT          14JL1
C          NC                   CURVE NUMBER                              14JL1
C          NCDA( ), NCDAT       NUMBER OF CARDS THAT FOLLOW DESCRIBING    14JL1
C                               CROSS SECTION                             14JL1
C          NCDL( ), NCDLT       NUMBER OF CARDS THAT FOLLOW FOR LOAD TYPE 14JL1
C          NCDS( ), NCDST       NUMBER OF CARDS THAT FOLLOW FOR STIF TYPE 14JL1
C          NCD2-NCD7            NUMBER OF CARDS IN TABLES 2-7             14JL1
C          NCR5, NCR6           NUMBER OF CARDS READ IN TABLES 5 AND 6    14JL1
C          NC5I( ), NC5         NUMBER OF CARDS IN TABLE 5A ABOVE THE     14JL1
C                               NUMBER OF STIFF TYPES (VARIABLE STIFF)    14JL1
C          NC51T, NC52T         FIRST AND LAST CARD NUMBER OF VARIABLE    14JL1
C                               STIFF DATA FOR MEMBER                     14JL1
C          NC61( ), NC6         NUMBER OF CARDS IN TABLE 6 ABOVE THE      14JL1
C                               NUMBER OF LOADS TYPES (VARIABLE LOADS)    14JL1
C          NC61T, NC62T         FIRST AND LAST CARD NUMBER OF VARIABLE    14JL1
C                               LOAD DATA FOR MEMBER                      14JL1
C          NE                   NUMBER OF ELEMENTS WHICH ARE LIN-ELAS     14JL1
C          NEPTS( , ), NEPT( )  INTEGER VALUES OF STRAIN                  14JL1
C          NEG                  IF EQUAL TO 1, NEGATIVE DISPLACEMENT OR   14JL1
C                               STRAIN ON SYMMETRICAL CURVE               14JL1
C          NFSUB                SWITCH TO CHOOSE APPROPRIATE FSUB         14JL1
C          NITF                 NUMBER OF FRAME ITERATION                 14JL1
C          NITM( )              NUMBER OF MENBER ITERATION                14JL1
C          NITM1                NUMBER OF MEMBER ITERATIONS MINUS ONE     14JL1
C          NJNC                 NUMBER OF JOINTS NOT CLOSED               14JL1
C          NJNZ                 NUMBER OF NON ZERO JOINTS ON DATA CARD IN 14JL1
C                               TABLES 2,3                                14JL1
C          NJT                  NUMBER OF FRAME JOINTS                    14JL1
C          NL,NL4               NUMBER OF SIMULTANEOUS EQUATIONS          14JL1
C          NLE                  NE AT LEFT OR FROM JOINT                  14JL1
C          NLR                  NR AT LEFT OR FROM JOINT                  14JL1
C          NLT                  NUMBER OF LOAD TYPES                      14JL1
C          NLTL                 NLT FOR LAST PROBLEM                      14JL1
C          NM                   NUMBER OF FRAME MEMBERS                   14JL1
C          NMJ                  NUMBER OF MONITOR JOINTS                  14JL1
C          NMNC                 NUMBER OF MEMBERS NOT CLOSED              14JL1
C          NNP                  NN1 + 1                                   14JL1
C          NN1                  NUMBER OF POINT ON STRESS-STRAIN CURVE    14JL1
C                               ON OR JUST BELOW RECTANGLE                14JL1
C          NN2                  NUMBER OF POINT ON STRESS-STRAIN CURVE    14JL1
C                               JUST ABOVE RECTANGLE                      14JL1
C          NN3                  NUMBER OF SUBRECTANGLES                   14JL1
C          NN4                  NN3 - 1                                   14JL1
C          NP                   NUMBER OF POINT                           14JL1
C          NPP                  NUMBER OF TIMES FAEJR IS CALLED ( ONCE    14JL1
C                               FOR RECTANGLE TEN  TIMES FOR PIPE)        14JL1
C          NPROB                ALPHANUMERIC PROBLEM NUMBER               14JL1
C          NPT, NPTT            NUMBER OF POINTS ON CURVE                 14JL1
C          NPT ( )              NUMBER OF POINTS ON JOINT SUPPORT CURVE   14JL1
C          NPTM ( )             NUMBER OF POINTS ON MEMBER SUPPORT CURVE  14JL1
C          NPTS( ),NPTST        NUMBER OF POINTS ON STRESS-STRAIN CURVE   14JL1
C          NQ                   NUMBER OF ELEMENTS REMAINING IN SECTION   14JL1
C          NQJ( , ),NQJT( )     INTEGER VALUES OF FORCE ON JOINT          14JL1
C                               SUPPORT CURVES                            14JL1
C          NQM ( , ), NQMT( )   INTEGER VALUES OF FORCE ON MEMBER         14JL1
C                               SUPPORT CURVES                            14JL1
C          NR                   NUMBER OF ELEMENTS REMAINING RIGID        14JL1
C          NRE                  NE AT RIGHT OR TO JOINT                   14JL1
C          NRR                  NR AT RIGHT OR TO JOINT                   14JL1
C          NSIG ( , ),NSIT( )   INTEGER VALUES OF STRESS ON INPUT CURVE   14JL1
C          NSS( , ),            NUMBER OF STRESS-STRAIN CURVE             14JL1
C          NSSL( ), NSSLT       NUMBER OF STRESS-STRAIN CURVE AT LEFT     14JL1
C                               OR FROM JOINT                             14JL1
C          NSSR( ), NSSRT       NUMBER OF STRESS-STRAIN CURVE AT RIGHT    14JL1
C                               OR TO JOINT                               14JL1
C          NST                  NUMBER OF STIFF TYPES                     14JL1
C          NSTL                 NST FOR LAST PROBLEM                      14JL1
C          NSXP( ), NSYP( )     NUMBER OF JOINT SUPPORT CURVE IN MEMBER   14JL1
C                               X-PRIME AND Y-PRIME DIRECTIONS            14JL1
C          NSXL( ), NSYL( ),    NUMBER OF MEMBER SUPPORT CURVE AT FROM    14JL1
C          NSZL( )              OR LEFT JOINT                             14JL1
C          NSXR( ), NSYR( ),    NUMBER OF MEMBER SUPPORT CURVE AT TO OR   14JL1
C          NSZR( )              RIGHT JOINT                               14JL1
C          NWJ(  , ), NWJT( )   INTEGER VALUES OF DISPLACEMENT FOR JOINT  14JL1
C                               SUPPORT CURVES                            14JL1
C          NWM( , ), NWMT( )    INTEGER VALUES OF DISPLACEMENT FOR        14JL1
C                               MEMBER SUPPORT CURVES                     14JL1
C          N1, N2, NT           SWITCHES TO INCREASE TAPE EFFICIENCY      14JL1
C          NI                   STARTING INDEX TO TAKE ADVANTAGE OF       14JL1
C                               SYMMETRY IN FORMING ELEMENT STIFFNESS     14JL1
C                               MATRIX                                    14JL1
C          N123                 CONTROL WHICH CYCLES 1,2,3                14JL1
C          N2M1                 NCD2 - 1                                  14JL1
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C          N3MI                NCD3 - 1                                   14JL1
C          PRAE( ), PRAET      PRISMATIC AE( )                            14JL1
C          PRAT                PRISMATIC AREA                             14JL1
C          PRINT               ALPHANUMERIC CONSTANT                      14JL1
C          PRIT                PRISMATIC MOMENT OF INERTIA                14JL1
C          PRF( ), PRFT        PRISMATIC F( )                             14JL1
C          Q( )                STATION VALUES FOR SX,SY,SZ,QX,QY,QZ       14JL1
C          QJX,QJY,QJZ         RESISTIVE SPRING FORCES FOR NONLINEAR      14JL1
C                              JOINT SUPPORTS                             14JL1
C          QM( )               FORCE MULTIPLIER FOR MEMBER SUPPORT CURVE  14JL1
C          QMJ( )              FORCE MULTIPLIER FOR JOINT SUPPORT CURVE   14JL1
C          QO( )               CONCENTRATED STATION LOAD OR SPRING        14JL1
C          QI                  CONCENTRATED LOAD OR SPRING BETWEEN        14JL1
C                              STATIONS                                   14JL1
C          QL, QR              INTENSITY OF LOADING OR RESTRAINT AT LEFT  14JL1
C                              (START) AND RIGHT (END) OF SECTION         14JL1
C          QQ( )               VALUES OF FORCE ON SUPPORT CURVE OR        14JL1
C                              STRESS-STRAIN CURVE                        14JL1
C          QQL( )              FORCE VALUES FOR MEMBER SUPPORT CURVE AT   14JL1
C                              LEFT OR FROM JOINT                         14JL1
C          QT1-QT6             LOADS ON MEMBER END STATIONS ( INCREMENTAL14JL1
C                              FOR INCREMENTAL FIXED-END-FORCE SOLUTION,  14JL1
C                              ZERO FOR MEMBER STIFFNESS MATRIX           14JL1
C                              SOLUTIONS AND TOTAL FOR EVALUATION OF      14JL1
C                              TOTAL END-FORCES ON MEMBER)                14JL1
C          QX( ), QY( ), QZ( ) MEMBER STATION LOADS                       14JL1
C          QXL( ), QYL( ),     MEMBER LOADS AT EDGES OF SECTIONS          14JL1
C          QZL( )                                                         14JL1
C          QXLT,QYLT,          VALUES OF QXL( ),QYL( ),QZL( ), AT LEFT    14JL1
C          QZLT                (START) OF SECTION                         14JL1
C          QXRT, QYRT,         VALUES OF QXL( ), QYL( ), QZL( ) AT RIGHT  14JL1
C          QZRT                (END) OF SECTION                           14JL1
C          QXX( ), QYY( ),     JOINT LOADS                                14JL1
C          QZZ( )                                                         14JL1
C          QXXT, QYYT, QZZT    TEMPORARY VALUES OF QXX( ), QYY( ), QZZ( )14JL1
C          QI, Q2              INTENSITY OF LOADING OR RESTRAINTS AT      14JL1
C                              BEGINNING AND END OF ELEMENT               14JL1
C          R                   DIFFERENCE IN AXIAL DISPLACEMENT BETWEEN   14JL1
C                              DISCRETE ROTATIONAL HINGES IN ELEMENT      14JL1
C          R                   SWITCH ( IF EQUAL TO + 1 NEGATIVE          14JL1
C                              CURVATURE, IF EQUAL TO - 1 POSITIVE CURV)  14JL1
C          RA                  MEAN RADIUS OF PIPE                        14JL1
C          T                   THICKNESS OF PIPE                          14JL1
C          RM( , ), RO( )      RECURSION MULTIPLIERS                      14JL1
C          RXX( ), RYY( ),     JOINT REACTIONS                            14JL1
C          RZZ( )                                                         14JL1
C          S                   DIFFERENCE IN LATERAL DISPLACEMENT BETWEEN14JL1
C                              DISCRETE ROTATIONAL SPRINGS IN ELEMENT     14JL1
C          SA( , )             STIFFNESS MATRIX USED FOR MEMBER SPRINGS   14JL1
C                              IN STRUCTURE COORDINATES                   14JL1
C          SC1                 S*COSIM1                                   14JL1
C          SC2                 S*COSI                                     14JL1
C          SEET( , )           ELEMENT STIFFNESS MATRIX (6 X 6)           14JL1
C          SEE3( , )           3 X 3 PORTION OF SEET( , )                 14JL1
C          SEM( , )            3 X 6 MEMBER STIFFNESS MATRIX USED IN      14JL1
C                              MEMBER SOLUTIONS - COMPOSED OF 3 X 3 SUB-  14JL1
C                              MATRICES OF ELEMENT STIFFNESS MATRIX       14JL1
C          SEMS( , )           3 X 3 PORTION OF SEM STORED FOR ELEMENT    14JL1
C                              IP1 WHILE FORMING SEM FOR STATION I        14JL1
C          SE2                 S*S                                        14JL1
C          SIG                 STRESS AT CENTROID OF SUBRECTANGLE         14JL1
C          SIGL( ( , )         STRESS VALUES FOR STRESS-STRAIN CURVE      14JL1
C                              AT LEFT OR FROM JOINT                      14JL1
C          SIGR                STRESS AT RIGHT OR TO JOINT                14JL1
C          SIGT( )             STRESS VALUES FOR COMLETE STRESS-STRAIN    14JL1
C                              CURVES AT MID-ELEMENT                      14JL1
C          SIGTS( )            SYMMETRICAL PART OF SIGT( )                14JL1
C          SINI                SIN OF ROTATION AT STATION I               14JL1
C          SINIM1              SIN OF ROTATION AT STATION IM1             14JL1
C          SINSIN              SINI + SINIM1                              14JL1
C          SINT                SINE(THETA)                                14JL1
C          SJX,SJY,SJZ         TANGENT SPRING STIFFNESSES OF JOINT        14JL1
C                              SUPPORTS                                   14JL1
C          SJXY                OFF-DIAGONAL STIFFNESS TERM FOR JOINT      14JL1
C                              SPRING REFERENCED TO MEMBER COORDINATES    14JL1
C          SL( )               VECTOR OF STIFFNESS MATRIX                 14JL1
C          SM( )               STRESS MULTIPLIERS FOR STRESS-STRAIN CURVE14JL1
C          SMC( , )            MEMBER STIFFNESS MATRICES IN COMPACT FORM 14JL1
C          SMM( , )            MEMBER STIFFNESS MATRIX (3X3) IN MEMBER    14JL1
C                              COORDINATES                                14JL1
C          SMT( )              SINGLE MEMBERS STIFFNESS MATRIX IN         14JL1
C                              COMPACT VECTOR FORM                        14JL1
C          SMS                 MEMBER STIFFNESS MATRIX (3X3) IN           14JL1
C                              STRUCTURE COORDINATES                      14JL1
C          SQX( ), SQY( ),     RESISTIVE SPRING FORCES FOR NONLINEAR      14JL1
C          SQZ( )              STATION SPRINGS                            14JL1
C          SQXYZ( )            RESISTIVE SPRING FORCES FOR ALL STATIONS   14JL1
C                              ( AXIAL, LATERAL, OR ROTATIONAL)           14JL1
C          SSL                 THREE ROWS OF STRUCTURE STIFFNESS MATRIX   14JL1
C                              ( DIAGONAL SUBMATRIX AND THOSE TO RIGHT)   14JL1
C          SS1                 S*SINIM1                                   14JL1
C          SS2                 S*SINI                                     14JL1
C          ST( )               STATION VALUE OF STIFFNESS                 14JL1
C          STA,STB             STIFFNESS (AE OR F) AT START AND END OF    14JL1
C                              ELEMENT OR PIECE OF ELEMENT                14JL1
C          STL, STR            STIFFNESS AT LEFT (START) AND RIGHT (END)  14JL1
C                              OF SECTION                                 14JL1
C          STT1, STT2          STIFFNESS AT MID POINTS OF PARTIAL         14JL1
C                              ELEMENTS AT BEGINNING AND END OF           14JL1
C                              ADJACENT SECTIONS                          14JL1
C          ST1-ST6             RESTRAINTS AT MEMBER END STATIONS          14JL1
C          SU( ), SU4()        COEFF OF STIFF MATRIX (ONE ROW)            14JL1
C          SX( ), SY( ), SZ( ) LINEAR MEMBER STATION RESTRAINTS           14JL1
C          SXL( ), SYL( ),     VALUES OF SX( ), SY( ), SZ( ), AT EDGES    14JL1
C          SZL()               OF SECTIONS                                14JL1
C          SXLT, SYLT, SZLT    VALUES OF SXL( ), SYL( ), SZL( ) AT        14JL1
C                              LEFT (START) OF SECTION                    14JL1
C          SXRT, SYRT, SZRT    VALUES OF SXL( ), SYL( ), SZL( ) AT        14JL1
C                              RIGHT (END) OF SECTION                     14JL1
C          SXT,SYT             TEMPORARY STORAGE VALUES FOR SX( ), SY( )  14JL1
C          SXX( ), SYY( ),     LINEAR JOINT RESTRAINTS                    14JL1
C          SZZ( )                                                         14JL1
C          SXXT, SYYT, SZZT    TEMPORARY VALUES OF SXX( ), SYY( ), SZZ( )14JL1
C          SXYZ( )             SPRING STIFFNESS FOR ALL STATIONS ( AXIAL,14JL1
C                              LATERAL, OR ROTATIONAL)                    14JL1
C          S2                  NEGATIVE OF  SLOPE OF CURVE                14JL1
C          QJ                  RESISTIVE SPRING FORCE OR STRESS           14JL1
C          T                   THRUST                                     14JL1
C          TAU1,TAU2           DISCRETE ANGLE CHANGES AT FIRST AND        14JL1
C                              SECOND DISCRETE ROTATIONAL SPRINGS IN      14JL1
C                              ELEMENT                                    14JL1
C          TE                  ANGLE FROM TOP OF PIPE TO CENTER OF        14JL1
C                              RADIAL SEGMENT                             14JL1
C          TEMP1, TEMP2        TEMPORARY VALUES                           14JL1
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C         TH                  ELEMENT LENGTH                              14JL1
C         THETA               ANGLE AXIALLY DEFORMABLE BAR IN ELEMENT     14JL1
C                             MAKES WITH MEMBER X-PRIME AXIS              14JL1
C         TL, TR              THRUST AT LEFT AND RIGHT ENDS OF ELEMENT    14JL1
C         TM( , )             TEMPORARY MATRIX TO STORE PORTIONS OF       14JL1
C                             ELEMENT STIFFNESS MATRIX DUE TO INITIAL     14JL1
C                             FORCES (INITIAL STRESS MATRIX)              14JL1
C         TOL                 JOINT LOCATION TOLERANCE                    14JL1
C         TT                  AXIAL THRUST IN AXIALY DEFORMABLE CENTER    14JL1
C                             BAR IN ELEMENT                              14JL1
C         TTM                 TT*HPDE3I                                   14JL1
C         TTMHO2              TTM*HO2                                     14JL1
C         TTHETA              TAN(THETA)                                  14JL1
C         TTOL                2*TOL                                       14JL1
C         TTS( )              THRUST IN ELEMENT STORED FOR ALL ELEMENTS   14JL1
C         T1,T2               THRUST AT FIRST AND SECOND DISCRETE         14JL1
C                             ROTATIONAL SPRINGS IN ELEMENT               14JL1
C         T33                 TEMPORARY MATRIX USED TO OBTAIN TRIPLE      14JL1
C                             PRODUCT                                     14JL1
C         UQX( ), UQY( )      UNIFORM MEMBER LOADS                        14JL1
C         UQXT, UQYT          TEMPORARY VALUES OF UQX( ), UQY( )          14JL1
C         U1( ), U2( )        AXIAL FORCES ON ENDS OF ELEMENT             14JL1
C         U1T, U2T            AXIAL FORCES ON ENDS OF ELEMENT             14JL1
C         V                   SHEAR                                       14JL1
C         VL, VR              SHEAR AT LEFT AND RIGHT ENDS OF ELEMENT     14JL1
C         VT                  SHEAR FORCE IN AXIALLY DEFORMABLE CENTER    14JL1
C                             BAR IN ELEMENT                              14JL1
C         VTM                 VT*HPDE3I                                   14JL1
C         VTMHO2              VTM*HO2                                     14JL1
C         V1( ), V2( )        SHEAR FORCES ON ENDS OF ELEMENT             14JL1
C         V1T, V2T            SHEAR FORCE ON ENDS OF ELEMENT              14JL1
C         W( )                VECTOR OF DISPLACEMENT INCREMENTS FROM      14JL1
C                             SUBROUTINE GRIP2A                           14JL1
C         WJ                  DISPLACEMENT OR STRESS                      14JL1
C         WM( )               DISPLACEMENT MULTIPLIER FOR MEMBER SUPPORT14JL1
C                             CURVES                                      14JL1
C         WMJ( )              DISPLACEMENT MULTIPLIER FOR JOINT SUPPORT   14JL1
C                             CURVES                                      14JL1
C         WT( ), WTT( )       TEMPORARY DISPLACEMENT MATRICES             14JL1
C         WW( )               VALUES OF DISPLACEMENT ON SUPPORT CURVE     14JL1
C                             OR STRESS-STRAIN CURVE                      14JL1
C         WWL( )              DISPLACEMENT VALUES FOR MEMBER SUPPORT      14JL1
C                             CURVE AT FROM OR LEFT JOINT                 14JL1
C         W1( ), W2( )        MOMENTS ON ENDS OF ELEMENT                  14JL1
C         W1T, W2T            BENDING MOMENTS ON ENDS OF ELEMENT          14JL1
C         X( ), Y( )          JOINT COORDINATES                           14JL1
C         XL                  DISTANCE TO LEFT (START) OF SECTION         14JL1
C         XLL( )              DISTANCE TO LEFT (START) OF LOAD SECTION    14JL1
C         XLS( )              DISTANCE TO LEFT (START) OF STIFF SECTION   14JL1
C         XR                  DISTANCE TO RIGHT (END) OF SECTION          14JL1
C         XRL                 DISTANCE TO RIGHT (END) OF LOAD SECTION     14JL1
C         XRS( )              DISTANCE TO RIGHT (END) OF STIFF SECTION    14JL1
C         XT, YT              TEMPORARY JOINT COORDINATES                 14JL1
C         XX                  DISTANCE TO STATION ON LEFT OF              14JL1
C                             CONCENTRATED LOAD FROM THE FROM JOINT       14JL1
C         X1, X2              LENGTH OF PARTIAL ELEMENTS AT ENDS OF       14JL1
C                             SECTIONS                                    14JL1
C         X2L                 X2 FROM LAST SECTION                        14JL1
C         Y                   DISTANCE FROM CENTROID OF SUBRECTANGLE      14JL1
C                             TO MEMBERS X-PRIME AXIS                     14JL1
C         YB, YT              Y DISTANCE TO BOTTOM AND TOP OF RECTANGLE   14JL1
C         YC                  DISTANCE FROM CENTROID OF PIPE TO MEMBER    14JL1
C                             X-PRIME AXIS                                14JL1
C         YCL( )              Y( , ) AT LEFT OR FROM JOINT                14JL1
C         YI( , )             CENTROIDAL DISTANCE INPUT FOR X-SECT NUM    14JL1
C         YTT                 TEMPORARY  Y DISTANCE                       14JL1
C         YY( )               Y DISTANCE FOR SUBRECTANGLE                 14JL1
C         WT, WTT             TEMPORARY DISPLACEMENT MATRICES             14JL1
C         Z                   DISTANCE TO CONCENTRATED LOAD FROM STATION14JL1
C                             ON LEFT                                     14JL1
C         ZI                  FLOATING POINT I                            14JL1
C         ZIP                 FLOATING POINT IP                           14JL1
C         ZI1, ZI2            FLOATING POINT I1 AND I2                    14JL1
C         ZL                  MEMBERS LENGTH                              14JL1
C         ZLL( )              LENGTH OF MEMBERS BY LOAD TYPE              14JL1
C         ZLS( )              LENGTH OF MEMBERS BY STIFF TYPE             14JL1
C         ZL2                 ZL*ZL                                       14JL1
C         ZL3                 ZL2*ZL                                      14JL1
C         ZMUL                RATIO OF LENGTH TO MID-ELEMENT TO MEMBERS   14JL1
C                             TOTAL LENGTH                                14JL1
C         ZZ                  DISTANCE FROM STATION ON LEFT TO THE        14JL1
C                             CONCENTRATED LOAD OR SPRING                 14JL1
C
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APPENDIX H

FORTRAN LISTING OF PROGRAM FRAME 51

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      OVERLAY(FRAME51,0,0)                                                    OVERLAY
COMMENT - OMIT THE PREVIOUS CARD UNLESS THE CDC OVERLAY SYSTEM IS USED       OVERLAY
      PROGRAM FRAME51 (INPUT = 500,OUTPUT = 500,TAPE1 = 300,TAPE2 = 300)04FE1
COMMENT - THIS DRIVER ONLY DIMENSIONS PROGRAM                                 24AP0
COMMENT - TO CHANGE DIMENSIONS CHANGE ONLY THIS DRIVER AND DIMENSIONED        24AP0
COMMENT - COMMON BLOCKS IN APPROPRIATE SUBROUTINES                            24AP0
COMMENT - VARIABLE NAMES DO NOT CHANGE IN DIMENSIONED COMMON BLOCKS           24AP0
COMMENT - **********              DIMENSION GUIDE                          **********
COMMENT - RM(L3,L6)           RO(L6)          W(L6)           SL(L3)       **********
COMMENT - SU(L4)                                                           **********
COMMENT - COMMON BLOCK1(MNJT)       BLOCK2(MNST)          BLOCK3(MNLT)     **********
COMMENT - COMMON BLOCK4(MNM)        BLOCK5(MNC5)          BLOCK6(MNC6)     **********
COMMENT - COMMON BLOCK7(L1)         BLOCK8(MNJS)          BLOCK9(MNPCS)    **********
COMMENT - COMMON BLOC10(L5)            BLOC12(MNCS,MNPCS)  BLOC13(MNSS)    **********
COMMENT - COMMON BLOC14(MNQWM)      BLOC16(MNJT)                           **********
COMMENT - *****************************************************************************
      DIMENSION RM(17,126), RO(126), W(126), SL(17), SU(18)                  24MY1
      COMMON /BLOCK1/ X( 20),      Y( 20),      QXX( 20),    QYY( 20),       13FE0
     2    QZZ( 20),    SXX( 20),    SYY( 20),    SZZ( 20),    DXX( 20),       13FE0
     3    DYY( 20),    DZZ( 20),    RXX( 20),    RYY( 20),    RZZ( 20),       13FE0
     4    ERXX( 20),   ERYY( 20),   ERZZ( 20),   QMJ( 20),    WMJ( 20),       08AG0
     5    NSXX( 20),   NSYY( 20),   NSZZ( 20),   IMJ( 20),    NSXP( 20),      20MY1
     6    NSYP( 20),   ISTJR( 20)                                            20MY1
      COMMON /BLOCK2/ DXS( 25),    DYS( 25),    ZLS( 25),    DC1S( 25),      26JA0
     2    DC2S( 25),   PRF( 25),    PRAE( 25),   NCDS( 25),   IAXOPS( 25),    26JA0
     3    IOPOP( 25),  IPINL( 25),  IPINR( 25),  NCS1( 25),   INLOP( 25),     17OC0
     4    NAL( 25),    NSXL( 25),   NSYL( 25),   NSZL( 25),   NAR( 25),       17OC0
     5    NSXR( 25),   NSYR( 25),   NSZR( 25),   QM( 25),     WM( 25)         17OC0
      COMMON /BLOCK3/ DXL( 25),    DYL( 25),    ZLL( 25),    DC1L( 25),      26JA0
     2    DC2L( 25),   UQX( 25),    UQY( 25),    NCDL( 25),   IAXOPL( 25),    26JA0
     3    NC61( 25)                                                          26JA0
      COMMON /BLOCK4/ JT1( 40),    JT2( 40),    IST( 40),    LT( 40),        26JA0
     2    FOMM( 40,6), SMC( 40,21), NITM( 40), IMM( 40),    IMC( 40)         01JL1
      COMMON /BLOCK5/ XLS( 50),    XRS( 50),    FL( 50),     AEL( 50),       26JA0
     2    SXL( 50),    SYL( 50),    SZL( 50)                                 26JA0
      COMMON /BLOCK6/ XLL( 75),    XRL( 75),    QXL( 75),    QYL( 75),       26JA0
     2    QZL( 75)                                                           26JA0
      COMMON /BLOCK7/ F( 42),      AE( 42),     SX( 42),     SY( 42),        04JE0
     2    SZ( 42),     QX( 42),     QY( 42),     QZ( 42),     DX( 42),        04JE0
     3    DY( 42),     DZ( 42),     ERX( 42),    ERY( 42),    ERZ( 42),       04JE0
     4    SQX( 42),    SQY( 42),    SQZ( 42),    U1( 42),     V1( 42),        04JE0
     5    W1( 42),     U2( 42),     V2( 42),     W2( 42),     DS(3,3, 42),    29JA1
     6    BM1S( 42),   BM2S( 42),   TTS( 42)                                 29JA1
      COMMON /BLOCK8/ NPT( 20),    ISJ( 20),    NQJ( 20,11),NWJ( 20,11),     08AG0
     2    NQJT(11),    NWJT(11)                                              08AG0
      COMMON /BLOCK9/ BCL(10),     DBCL(10),    DCL(10),     DDCL(10),       11JU1
     2    YCL(10),     DYCL(10),    NSSL(10),    NSSR(10),    SIGL(10,11),    11JU1
     3    EPSL(10,11),DSIGL(10,11),DEPSL(10,11),ISST(10)                     11JU1
      COMMON /BLOC10/ SSL(3,18)                                              09JU1
      COMMON /BLOC11/ SEET(6,6)                                              16AP1
      COMMON /BLOC12/ NA(20),      NCDA(20),    B1(20,10),  D1(20,10),       19OC0
     2    YI(20,10),   NSS(20,10), SM(20,10),   EM(20,10), IRECT(20,10)      17MY1
      COMMON /BLOC13/ NPTS( 08),    ISS( 08),   NSIG(08,11),NEPS(08,11),     05NO0
     2    NSIT(11),    NEPT(11)                                              24OC0
      COMMON /BLOC14/ NPTM( 20),    ISM( 20),   NQM(20,11), NWM(20,11),      24OC0
     2    NQMT(11),    NWMT(11)                                              24OC0
      COMMON /BLOC15/ EPST(21),    SIGT(21),    EPSTS(11),   SIGTS(11)       05NO0
      COMMON /BLOC16/ ERXXMJ(5,20),ERYYMJ(5,20),ERZZMJ(5,20),                07AP1
     2   DXXMJ(5,20),DYYMJ(5,20),DZZMJ(5,20),KOMJ(5,20),KOJ(20)              07AP1
      COMMON /BLK1/  KEEP2, KEEP3, KEEP4A,KEEP5A,KEEP6, KEEP7,               26JA0
     2         ITYPE, NCD2,  NCD3,  NCD4A, NCD5A, NCD6,  NCD7,               26JA0
     3         IABAN, IFORM, NM,    NJT,   NST,   NLT,   TOL,                26JA0
     4         M,     MP1,   MP2,   ISTT,  LTT,   ITYPEL,IDJ,                12FE0
     5         NSTL,  IP8,   IP9,   IP10,  KEEP4B,KEEP4C,NCD4B,              05AG0
     6         NCD4C, KEEP5B,KEEP5C,KEEP5D,NCD5B, NCD5C, NCD5D               05AG0
      COMMON /BLK2/ XL,XR,X1,X2,I1,I2,NQ,H,TH,HSO,HCU,X2L                    26JA0
      COMMON /BLK3/ MNJT,MNST,MNLT,MNM,MNC5,MNC6,MDJT,MNJS,MNE,MNCS,         11JU1
     2    MNPCS,MNSS,MNQWM                                                   11JU1
      COMMON /BLK4/ ST1,ST2,ST3,ST4,ST5,ST6                                  26JA0
      COMMON /BLK5/ NFSUB,NITF,N1,N2                                         16AP1
      COMMON /BLK6/ QT1,QT2,QT3,QT4,QT5,QT6                                  04JE0
      COMMON /BLK7/ INLOPT,IFAE,KOFFJ,KOFFQW,KOFFSE                          07AP1
      COMMON /BLK8/ NLTL                                                     12FE1
      COMMON / RI / NL, ML, J1                                               08AP0
      COMMON /ITC/ MNITF,ERR1,ERR2,MNITM,ER1,ER2,MM(5),MJ(5)                 07AP1
      COMMON /WARN/ NJNC,NMNC                                                02JL1
            MNJT =  20                                                       06AP0
            MNM  =  40                                                       06AP0
            MNST =  25                                                       06AP0
            MNLT =  25                                                       06AP0
            MNC5 =  50                                                       06AP0
            MNC6 =  75                                                       06AP0
            MDJT = 5                                                         24MY1
            MHB  =  3*MDJT + 2                                               26JA0
            MNE = 40                                                         15AP1
            MNJS = 20                                                        09JU1
            MNCS = 20                                                        11JU1
            MNPCS = 10                                                       11JU1
            MNSS =  8                                                        11JU1
            MNQWM= 20                                                        11JU1
            L1 = MNE + 2                                                     15AP1
            L2 = 3*(MNE + 1)                                                 15AP1
            L3  =  MHB                                                       11FE
            L4  =  MHB + 1                                                   11FE
            L5 = 3*(MDJT + 1)                                                09JU1
            L6 = 3*MNJT                                                      16AP1
         IF (MNJT .LT. L1) L6 = 3*L1                                         05AP1
            L7 = 3*L1 + 1                                                    05AP1
COMMENT - SUBROUTINE FRAM51 IS THE MAIN SUBROUTINE OF PROGRAM FRAME51       08JU1
COMMENT - FRAM51 CALLS PRIMARY INPUT, OUTPUT,AND COMPUTATION SUBROUTINES09JU1
COMMENT - AND PERFORMS SIMPLE INPUT, OUTPUT, AND COMPUTATIONAL FUNCTIONS09JU1
      CALL        FRAM51 ( RM, RO, W, SL, SU, L1, L2, L3, L4, L6, L7 )       30JL0
      END                                                                    26JA0
C
C       ******************************************************************************
C                                       SUBROUTINE
C       ******************************************************************************
C
      SUBROUTINE FRAM51 ( RM, RO, W, SL, SU, L1, L2, L3, L4, L6, L7 )        30JL0
COMMENT - SUBROUTINE FRAM51 IS THE MAIN SUBROUTINE OF PROGRAM FRAME51       08JU1
COMMENT - FRAM51 CALLS PRIMARY INPUT, OUTPUT,AND COMPUTATION SUBROUTINES09JU1
COMMENT - AND PERFORMS SIMPLE INPUT, OUTPUT, AND COMPUTATIONAL FUNCTIONS09JU1
      DIMENSION RM(L3,L6), RO(L6), W(L6), SL(L3), SU(L4)                     08AP0
      DIMENSION SMMT(21),FOMT(6)                                             26JA0
      DIMENSION AN1(40),AN2(20),NPROB(2)                                     26JA0
      COMMON /BLOCK1/ X( 20),      Y( 20),      QXX( 20),    QYY( 20),       13FE0
     2    QZZ( 20),    SXX( 20),    SYY( 20),    SZZ( 20),    DXX( 20),       13FE0
     3    DYY( 20),    DZZ( 20),    RXX( 20),    RYY( 20),    RZZ( 20),       13FE0
     4    ERXX( 20),   ERYY( 20),   ERZZ( 20),   QMJ( 20),    WMJ( 20),       08AG0
     5    NSXX( 20),   NSYY( 20),   NSZZ( 20),   IMJ( 20),    NSXP( 20),      20MY1
     6    NSYP( 20),   ISTJR( 20)                                            20MY1
      COMMON /BLOCK2/ DXS( 25),    DYS( 25),    ZLS( 25),    DC1S( 25),      26JA0
     2    DC2S( 25),   PRF( 25),    PRAE( 25),   NCDS( 25),   IAXOPS( 25),    26JA0
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3    IOPOP( 25), IPINL( 25), IPINR( 25), NC51( 25),  INLOP( 25),     17OC0
4    NAL( 25),   NSXL( 25),  NSYL( 25),  NSZL( 25),  NAR( 25),       17OC0
5    NSXR( 25),  NSYR( 25),  NSZR( 25),  QM( 25),    WM( 25)         17OC0
 COMMON /BLOCK3/ DXL( 25),   DYL( 25),   ZLL( 25),   DC1L( 25),      26JA0
2    DC2L( 25),  UQX( 25),   UQY( 25),   NCDL( 25),  IAXOPL( 25),    26JA0
3    NC61( 25)                                                       26JA0
 COMMON /BLOCK4/ JT1( 40),   JT2( 40),   IST( 40),   LT( 40),        26JA0
2    FOMM( 40,6), SMC( 40,21), NITM( 40), IMM( 40),  IMC( 40)        01JL1
 COMMON /BLOCK5/ XLS( 50),   XR5( 50),   FL( 50),    AEL( 50),       26JA0
2    SXL( 50),   SYL( 50),   SZL( 50)                                26JA0
 COMMON /BLOCK6/ XLL( 75),   XRL( 75),   QXL( 75),   QYL( 75),       26JA0
2    QZL( 75)                                                        26JA0
 COMMON /BLOCK7/ F( 42),     AE( 42),    SX( 42),    SY( 42),        04JE0
2    SZ( 42),    QX( 42),    QY( 42),    QZ( 42),    DX( 42),        04JE0
3    DY( 42),    DZ( 42),    ERX( 42),   ERY( 42),   ERZ( 42),       04JE0
4    SQX( 42),   SQY( 42),   SQZ( 42),   U1( 42),    V1( 42),        04JE0
5    W1( 42),    U2( 42),    V2( 42),    W2( 42),    DS(3,3, 42),    29JA1
6    BM1S( 42),  BM2S( 42),  TTS( 42)                                29JA1
 COMMON /BLOC16/ ERXXMJ(5,20),ERYYMJ(5,20),ERZZMJ(5,20),             07AP1
2   DXXMJ(5,20),DYYMJ(5,20),DZZMJ(5,20),KOMJ(5,20),KOJ(20)           07AP1
 COMMON /BLK1/  KEEP2, KEEP3, KEEP4A,KEEP5A,KEEP6, KEEP7,            26JA0
2         ITYPE, NCD2,  NCD3,  NCD4A, NCD5A, NCD6,  NCD7,            26JA0
3         IABAN, IFORM, NM,    NJT,   NST,   NLT,   TOL,             26JA0
4         M,     MP1,   MP2,   ISTT,  LTT,   ITYPEL,IDJ,             12FE0
5         NSTL,  IP8,   IP9,   IP10,  KEEP4B,KEEP4C,NCD4B,           05AG0
6         NCD4C, KEEP5B,KEEP5C,KEEP5D,NCD5B, NCD5C, NCD5D            05AG0
 COMMON /BLK3/ MNJT,MNST,MNLT,MNM,MNC5,MNC6,MDJT,MNJS,MNE,MNCS,      11JU1
2    MNPCS,MNSS,MNQWM                                                11JU1
 COMMON /BLK5/ NFSUB,NITF,N1,N2                                      04JE0
 COMMON /BLK7/ INLOPT,IFAE,KOFFJ,KOFFQW,KOFFSE                       07AP1
 COMMON / RI / NL, ML, JI                                            08AP0
 COMMON /ITC/ MNITF,ERR1,ERR2,MNITM,ER1,ER2,MM(5),MJ(5)              07AP1
 COMMON /WARN/ NJNC,NMNC                                             02JL1
 COMMON /NIT/ APROB, PRINT                                           16AP1
1 FORMAT  ( 51H     PROGRAM  FRAME 51 - MASTER DECK - MATLOCK-HAYS,24JL1
2         2X,26HREVISION DATE = 24 JULY 71)                          24JL1
10 FORMAT  ( 5H     ,80X  10HI-----TRIM  )                           26JA0
11 FORMAT  ( 5H1    ,80X  10HI-----TRIM  )                           26JA0
12 FORMAT (20A4)                                                     24JL1
13 FORMAT (A4,A1,A4,A1,A2,17A4)                                      24JL1
14 FORMAT ( A4,A1,5X,A2,17A4)                                        24JL1
15 FORMAT  (///,  10H     PROB ,//,5X,A4,A1,5X,A2,17A4)              26JA0
16 FORMAT  (///,  17H     PROB (CONTD),/,5X,A4,A1,5X,A2,17A4,///)    26JA0
50 FORMAT (   51H     SOLUTION ABANDONED IN SEARCH OF AN INDEPENDENT 26JA0
2             10H PROBLEM  ,///,                                     26JA0
3             49H     THE FOLLOWING CARDS WERE DISCARDED IN SEARCH,  26JA0
4             //)                                                    26JA0
51 FORMAT (//,50H     NO HOLD OPTIONS MAY BE EXERCISED ON FIRST PRO, 07FE0
2             15HBLEM OF RUN    )                                    07FE0
100 FORMAT   (5X,15I5,/,10X,11I5)                                    07AG0
101 FORMAT   (8(/), 35H     TABLE 1 - PROGRAM CONTROL DATA,/,        26JA0
2             17H     PROBLEM TYPE,I5,///,25X,12HINPUT TABLES,//,    30MR0
3    10X,  45H TABLE    HOLD DATA FROM    NUMBER OF CARDS,/,         26JA0
4    10X,  45H NUMBER   LAST PROBLEM      ADDED FOR THIS ,/,         26JA0
5    10X,  45H          (1 = YES,0 = NO)  PROBLEM      ,//,          26JA0
6    10X,5H   2,10X,I5,15X,I5,/, 10X,5H   3,10X,I5,15X,I5,/,         26JA0
7    10X,5H  4A,10X,I5,15X,I5,/, 10X,5H  4B,10X,I5,15X,I5,/,         26JA0
8    10X,5H  4C,10X,I5,15X,I5,/, 10X,5H  5A,10X,I5,15X,I5,/,         26JA0
9    10X,5H  5B,10X,I5,15X,I5,/, 10X,5H  5C,10X,I5,15X,I5,/,         26JA0
1    10X,5H  5D,10X,I5,15X,I5,/, 10X,5H   6,10X,I5,15X,I5,/,         26JA0
2    10X,5H   7,10X,I5,15X,I5,/,                                     06AG0
3    25X,  13HOUTPUT TABLES,//,                                      30MR0
4    10X,  25H TABLE   SUPPRESS OUTPUT,/,                            15JL0
5    10X,  25H NUMBER  (1 = YES,0 = NO),//,                          13MR0
6    10X,5H   8,10X,I5,/,10X,5H   9,10X,I5,/,10X,5H  10,10X,I5)      13MR0
151 FORMAT (  50H     TABLE 8 - JOINT DISPLACEMENTS AND REACTIONS  , 10FE0
2 ///,20X,  15HDISPLACEMENTS  ,16X,  10H REACTIONS,//,               10FE0
3      5X,  39HJOINT  DISP(X)    DISP(Y)  ROTATION(Z) ,              30MR0
4           31HREACT(X)   REACT(Y)   REACT(Z) ,// )                  10FE0
152 FORMAT (5X,I5,6E11.3)                                            10FE0
153 FORMAT (5X,1H*,I4,6E11.3)                                        07AP1
154 FORMAT (//,47H     * INDICATES JOINT SUPPORT OFF Q-W CURVE AT,   07AP1
2           20H END OF THIS PROBLEM)                                 07AP1
155 FORMAT (///30H     ***** FRAME ITERATION NO ,I5,6H *****,//,     07AP1
2     5X,   43H MEMB MEMB          MEMBER DISPLACEMENTS    ,         07AP1
3     11X,  25H MEMBER EQULIBRIUM ERRORS,/,                          16AP1
4     5X,   46H  NO  ITER       AXIAL  LATERAL  ROTATIONAL    ,      07AP1
5     3X,   32H AXIAL     LATERAL    ROTATIONAL)                     07AP1
162 FORMAT  (  45H     TABLE 10 - JOINT EQUILIBRIUM ERRORS     ,////, 25MR0
2           40H     JOINT  ERR(X)      ERR(Y)      ERR(Z),/,         24AP0
3           40H            FORCE       FORCE       MOMENT,//)        24AP0
175 FORMAT (///,5X,I5,  37H JOINTS NOT CONVERGED AT END OF FRAME,    16AP1
2           10H ITERATION,I5)                                        16AP1
177 FORMAT (///45H     ALL JOINTS CONVERGED AT END OF ITERATION,I5)  16AP1
181 FORMAT (//,15X, 30H SUMMARY OF FRAME ITERATIONS  ,//,5X,         03SE0
  2 61HJOINT FRAME        JOINT DISPLACEMENTS          JOINT EQUL,03SE0
  3 13HIBRIUM ERRORS,/,5X,                                           03SE0
  4 61H NO  ITER   DISP(X)    DISP(Y)  ROTATION(Z)    ERR(X)      ER,03SE0
  5 15HR(Y)     ERR(Z),//)                                           03SE0
182 FORMAT (5X,2I4,1X,6E11.3)                                        03SE0
183 FORMAT(5X,1H*,I3,I4,1X,6E11.3)                                   07AP1
184 FORMAT (//,48H     * INDICATES JOINT SUPPORT OFF Q-W CURVE FOR,  07AP1
2           15H THAT ITERATION)                                      07AP1
185 FORMAT (//, 8H     ***,I5,35H MEMBERS NOT CLOSED AT END OF SPECI, 01JL1
2       32HFIED NUMBER OF MEMBER ITERATIONS,/,  11H     DURING,      01JL1
3       23H FRAME ITERATION NUMBER,I5, 4H ***)                       01JL1
777 FORMAT (   48H     ***  SOLUTION DID NOT CLOSE - STUDY MONITOR,  02JL1
2           10H DATA *** )                                           02JL1
COMMENT - SET CONTROL CONSTANTS                                      09JU1
            DATA ITEST1,ITEST2,ITEST3,ITEST4,PRINT                   24JL1
2             / 4HCEAS,4H    ,1H ,   3H    , 4HRINT /                24JL1
            ITYPEL = 0                                               07FE0
            N1 = 2                                                   2MMY0
            N2 = 1                                                   2MMY0
COMMENT - READ RUN ID,PRINT PROGRAM ID AND RUN ID                    24AP0
      READ 12,( AN1(II),II = 1,40)                                   26JA0
      PRINT 11                                                       26JA0
      PRINT 1                                                        26JA0
      PRINT 12, (AN1(II), II = 1, 40 )                               26JA0
COMMENT - RETURN HERE TO READ NEW PROBLEM                            24AP0
 1010 READ 14, NPROB, (AN2(II),II = 1, 18 )                          26JA0
COMMENT - IF NPROB = CEASE, TERMINATE RUN                            24AP0
        IF ( NPROB(1) .EQ. ITEST1 ) GO TO 9900                       24JL1
            APROB = AN2(18)                                          16AP1
COMMENT - INPUT AND ECHO PRINT PROGRAM CONTROL DATA (TABLE 1)        24AP0
      READ  100, ITYPE,KEEP2,KEEP3,KEEP4A,KEEP4B,KEEP4C,KEEP5A,KEEP5B, 06AG0
     2    KEEP5C,KEEP5D,KEEP6,KEEP7,IP8,IP9,IP10,NCD2,NCD3,NCD4A,    06AG0
     3    NCD4B,NCD4C,NCD5A,NCD5B,NCD5C,NCD5D,NCD6,NCD7              06AG0
 1050 PRINT 11                                                       26JA0
      PRINT 12, (AN1(II), II = 1, 40 )                               26JA0
      PRINT 15, NPROB, (AN2(II), II = 1,18)                          26JA0
      PRINT 101, ITYPE,KEEP2,NCD2,KEEP3,NCD3,KEEP4A,NCD4A,KEEP4B,NCD4B, 06AG0
     2    KEEP4C,NCD4C,KEEP5A,NCD5A,KEEP5B,NCD5B,KEEP5C,NCD5C,KEEP5D, 06AG0
     3    NCD5D,KEEP6,NCD6,KEEP7,NCD7,IP8,IP9,IP10                   07AG0
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COMMENT - CHECK FOR KEEP OPTION ON FIRST PROBLEM OF RUN                    24AP0
             KEKE = KEEP2 + KEEP3 + KEEP4A + KEEP4B + KEEP4C +            06AG0
     2                KEEP5A + KEEP5B + KEEP5C + KEEP5D + KEEP6 + KEEP7  06AG0
          IF ( ITYPEL .EQ. 0 .AND. KEKE .NE. 0 ) GO TO 1200              07FE0
          GO TO 1300                                                     07FE0
 1200 PRINT 51                                                           07FE0
COMMENT - ABORT PROBLEM.SEARCH FOR INDEPENDENT PROBLEM                   24AP0
          GO TO 9800                                                     07FE0
 1300     CONTINUE                                                       09FE0
COMMENT - IABAN = 1 INDICATES FATAL ERROR FOUND IN SUBROUTINE            24AP0
COMMENT - PROBLEM ABANDONED IN SEARCH OF AN INDEPENDENT PROBLEM          24AP0
             IABAN = 0                                                   26JA0
COMMENT - MAIN PROGRAM STARTS HERE                                       24AP0
      PRINT 11                                                           26JA0
      PRINT 16,NPROB,(AN2(II),II=1,18)                                   26JA0
COMMENT - SUBROUTINE JTCORD INPUTS JOINT GEOMETRY DATA (TABLE 2)         24AP0
COMMENT - CHECKS FOR BAD DATA. COMPUTES JOINT COORDINATES.ECHO PRINTS    24AP0
COMMENT - DATA AND PRINTS COMPUTED JOINT COORDINATES                     24AP0
COMMENT - REPLACE THE OVERLAY CARD BY THE NONOVER CARD UNLESS THE CDC    OVERLAY
COMMENT - OVERLAY SYSTEM IS USED                                         OVERLAY
      CALL OVERLAY(6HJTCORD,1,0)                                         OVERLAY
C     CALL      JTCORD                                                   NONOVER
          IF ( IABAN .EQ. 1 ) GO TO 9800                                 26JA0
      PRINT II                                                           26JA0
      PRINT 16,NPROB,(AN2(II),II=1,18)                                   26JA0
COMMENT - SUBROUTINE  MEMLOC  INPUTS LOCATION OF STIFFNESS AND LOAD      24AP0
COMMENT - TYPES IN FRAME (TABLE 3),CHECKS FOR BAD DATA,COMPUTES MEMBER   24AP0
COMMENT - NUMBERS,LENGTHS OFFSETS AND DIRECTION COSINES,ECHO PRINTS DATA24AP0
COMMENT - AND PRINTS COMPUTED MEMBER NUMBERS,LENGTHS AND OFFSETS         24AP0
COMMENT - REPLACE THE OVERLAY CARD BY THE NONOVER CARD UNLESS THE CDC    OVERLAY
COMMENT - OVERLAY SYSTEM IS USED                                         OVERLAY
      CALL OVERLAY(6HMEMLOC,2,0)                                         OVERLAY
C     CALL      MEMLOC                                                   NONOVER
          IF ( IABAN .EQ. 1) GO TO 9800                                  26JA0
      PRINT 11                                                           26JA0
      PRINT 16,NPROB,(AN2(II),II=1,18)                                   26JA0
COMMENT - SUBROUTINE JNTDAT INPUTS JOINT LOADS AND RESTRAINTS            24AP0
COMMENT - (TABLE 4),CHECKS FOR BAD DATA,ACCUMULATES JOINT LOADS AND      24AP0
COMMENT - RESTRAINTS,ECHO PRINTS DATA AND PRINTS ACCUMULATED DATA        24AP0
COMMENT - EQUILIBRIUM ERRORS ARE SET EQUAL TO NET JOINT LOADS            09JU1
COMMENT - REPLACE THE OVERLAY CARD BY THE NONOVER CARD UNLESS THE CDC    OVERLAY
COMMENT - OVERLAY SYSTEM IS USED                                         OVERLAY
      CALL OVERLAY(6HJNTDAT,3,0)                                         OVERLAY
C     CALL      JNTDAT                                                   NONOVER
          IF ( IABAN .EQ. 1) GO TO 9800                                  26JA0
      PRINT 11                                                           26JA0
      PRINT 16,NPROB,(AN2(II),II=1,18)                                   26JA0
COMMENT - SUBROUTINE RDMST  INPUTS MEMBER STIFFNESS DATA (TABLE 5),      24AP0
COMMENT - CHECKS FOR BAD DATA AND ECHO PRINTS DATA                       09JU1
COMMENT - REPLACE THE OVERLAY CARD BY THE NONOVER CARD UNLESS THE CDC    OVERLAY
COMMENT - OVERLAY SYSTEM IS USED                                         OVERLAY
      CALL OVERLAY(5HRDMST,4,0)                                          OVERLAY
C     CALL      RDMST                                                    NONOVER
          IF ( IABAN .EQ. 1) GO TO 9800                                  26JA0
      PRINT 11                                                           26JA0
      PRINT 16,NPROB,(AN2(II),II=1,18)                                   26JA0
COMMENT - SUBROUTINE RDMLD  INPUTS MEMBER LOAD DATA (TABLE 6) CHECKS     24AP0
COMMENT - FOR BAD DATA, CONVERTS LOADS AND DISTANCES TO MEMBER           24AP0
COMMENT - COORDINATES AND ECHO PRINTS DATA                               24AP0
COMMENT - REPLACE THE OVERLAY CARD BY THE NONOVER CARD UNLESS THE CDC    OVERLAY
COMMENT - OVERLAY SYSTEM IS USED                                         OVERLAY
      CALL OVERLAY(5HRDMLD,5,0)                                          OVERLAY
C     CALL      RDMLD                                                    NONOVER
          IF ( IABAN .EQ. 1) GO TO 9800                                  26JA0
      PRINT 11                                                           26JA0
      PRINT 16,NPROB,(AN2(II),II=1,18)                                   26JA0
COMMENT - SUBROUTINE ITCONT INPUTS ITERATION CONTROL DATA, CHECKS FOR    09JU1
COMMENT - BAD DATA AND ECHO PRINTS DATA                                  09JU1
COMMENT - REPLACE THE OVERLAY CARD BY THE NONOVER CARD UNLESS THE CDC    OVERLAY
COMMENT - OVERLAY SYSTEM IS USED                                         OVERLAY
      CALL OVERLAY(6HITCONT,6,0)                                         OVERLAY
C     CALL      ITCONT                                                   NONOVER
          IF ( IABAN .EQ. 1) GO TO 9800                                  16AP1
             ITYPEL = ITYPE                                              09FE0
             NITF = 0                                                    26MY0
 5100     CONTINUE                                                       26MY0
             IFAE = 1                                                    29JA1
             NT = N2                                                     26MY0
             N2 = N1                                                     27MY0
             N1 = NT                                                     27MY0
             NITF = NITF + 1                                             26MY0
      REWIND  N1                                                         27MY0
      REWIND N2                                                          04JE0
COMMENT - FORM MEMBER STIFFNESS MATRICES AND MEMBER FIXED-END-FORCE      24AP0
COMMENT - MATRICES                                                       24AP0
          DO 5800  JJ = 1,NM                                             26JA0
             ISTT = IST(JJ)                                              26JA0
             LTT = LT(JJ)                                                26JA0
COMMENT - SKIP FOR NULL MEMBER                                           24AP0
          IF (ISTT .EQ. 0) GO TO 5750                                    06AP0
COMMENT - SUBROUTINE FORMST CALCULATES MEMBER (6 X 6) STIFFNESS MATRIX   16JU1
COMMENT - AND TAKING ADVANTAGE OF SYMETRY STORES IN COMPACT VECTOR       16JU1
COMMENT - SMMT(I = 1, 21)                                                16JU1
 5500 CALL      FORMST ( RM, RO, W, SL, SU, SMMT, LI, L3, L4, L6 )       08AP0
          DO 5510  I = 1,21                                              21MY0
 5510        SMC( JJ ,I) = SMMT(I)                                       21MY0
 5700     CONTINUE                                                       26JA0
          IF (NITF .GT. 1) GO TO 5750                                    26MY0
COMMENT - SUBROUTINE FORMLD CALCULATES MEMBER INCREMENTAL FIXED-END-     17JU1
COMMENT - FORCE MATRIX ON FIRST ITERATION OF EACH PROBLEM                17JU1
      CALL      FORMLD ( RM, RO, W, SL, SU, FOMT, LI, L3, L4, L6, JJ)    12SE0
          DO 5710  I = 1,6                                               26JA0
 5710        FOMM(JJ,I) = FOMT(I)                                        11FE0
          GO TO 5800                                                     26JA0
COMMENT - SET FIXED END-FORCE-MATRIX TO NULL MATRIX FOR NULL LOADING     24AP0
 5750     DO 5780  I = 1,6                                               26JA0
 5780        FOMM(JJ,I) = 0.0                                            11FE0
 5800     CONTINUE                                                       26JA0
      REWIND  N1                                                         27MY0
COMMENT - DUMP OF STIFFNESS MATRIX AND LOAD VECTOR,TO ACTIVATE,SET LAST  09JU1
COMMENT - FIVE COLUMNS IN PROBLEM NUMBER CARD EQUAL TO PRINT             10JU1
          IF (APROB .NE. PRINT) GO TO 77777                              16AP1
          DO 5900  JJ = 1,NM                                             26JA0
             ISTT = IST(JJ)                                              26JA0
             LTT = LT(JJ)                                                26JA0
          IF (ISTT .EQ. 0) GO TO 5900                                    26JA0
      PRINT 99 , (SMC( JJ ,I) , I = 1,21)                                11FE0
      PRINT 99, (FOMM(JJ,I), I = 1,6)                                    11FE0
 5900     CONTINUE                                                       26JA0
   99 FORMAT ( / ,7E11.3)                                                26JA0
77777     CONTINUE                                                       16AP1
COMMENT - START SOLUTION OF FRAME JOINT EQUILIBRIUM EQUATIONS            24AP0
COMMENT - SET CONTROL CONSTANTS FOR FRAME SOLUTION                       24AP0
             IHB = 3*IDJ + 2                                             26JA0
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            NL = 3*NJT                                                  08AP0
            ML = I                                                      29MY0
            NFSUB = 21                                                  08AP0
         IF (ITYPE .EQ. 2) GO TO 6300                                   29MY0
         IF (NITF .GT. 1) GO TO 6300                                    06JE0
COMMENT - ZERO JOINT DISPLACEMENT UNLESS HOLDING FROM A PREVIOUS PROBLEM09JU1
COMMENT - OR A PREVIOUS ITERATION                                       09JU1
         DO 6250 I = 1,NJT                                              29MY0
            DXX(I) = 0.0                                                24JL1
            DYY(I) = 0.0                                                24JL1
 6250       DZZ(I) = 0.0                                                24JL1
 6300    CONTINUE                                                       29MY0
COMMENT - CALL GRIP2B FOR SOLUTION OF FRAME JOINT EQUILIBRIUM EQUATIONS 24APC
COMMENT - GRIP2B SOLVES BOTH FRAME JOINT EQUILIBRIUM EQUATIONS AND      24APC
COMMENT - MEMBER EQUILIBRIUM EQUATIONS - GRIP2B CALLS FSUBI WHICH CALLS 24APC
COMMENT - FSUBI1 TO SET UP FRAME EQUATIONS OR FSUBI2 TO SET UP MEMBER   24APC
COMMENT - EQUATIONS                                                     24APC
      CALL        GRIP2A ( RM, RO, W, SL, SU, L3, L4, L6, IHB )         08AP0
COMMENT - ADD ON INCREMENTS OF JOINT DISPLACEMENTS                      09JU1
            J = 0                                                       16AP1
         DO 6500  I = 1, NJT                                            28JA0
            J = J + 1                                                   06MR0
            DXX(I) = DXX(I) + W(J)                                      29MY0
            J = J + 1                                                   06MR0
            DYY(I) = DYY(I) + W(J)                                      29MY0
            J = J + 1                                                   06MR0
            DZZ(I) = DZZ(I) + W(J)                                      29MY0
 6500    CONTINUE                                                       06MR0
            NMJ = 0                                                     07AP1
            KOFFJ = 0                                                   07AP1
COMMENT - SOLVE FOR JOINT REACTIONS                                     24AP0
         DO 6600  I = 1,NJT                                             19FE0
COMMENT - SUBROUTINE JNTSPR CALCULATES THE RESISTIVE SPRING FORCE AND   09JU1
COMMENT - THE SPRING STIFFNESS FOR THE JOINT SPRINGS                    09JU1
      CALL        JNTSPR( SJX, SJY, SJZ, SJXY, QJX, QJY, QJZ, I )       21MY1
            RXX(I) = - SXX(I)*DXX(I) + QJX                              11AG0
            RYY(I) = - SYY(I)*DYY(I) + QJY                              11AG0
            RZZ(I) = - SZZ(I)*DZZ(I) + QJZ                              11AG0
            KOJ(I) = KOFFJ                                              07AP1
         IF (IMJ(I) .EQ. 0) GO TO 6600                                  07AP1
            NMJ = NMJ + 1                                               07AP1
            KOMJ(NMJ,NITF) = KOFFJ                                      07AP1
 6600    CONTINUE                                                       07AP1
COMMENT - COMPUTE FOR EACH JOINT - THE SUM OF APPLIED JOINT LOAD        24APC
COMMENT - AND THE REACTION - WHEN THE APPROPRIATE MEMBER END FORCES ARE 24APO
COMMENT - SUBTRACTED FROM THIS SUM THE RESULT IS THE JOINT EQUILIBRIUM  24APC
COMMENT - ERRORS                                                        24APC
      DO 7250  I = 1,NJT                                                20MR0
            ERXX(I) = QXX(I) + RXX(I)                                   20MR0
         IF (ABS(QXX(I)) .GE. 1.0E+30) ERXX(I) = 0.0                    05SE0
            ERYY(I) = QYY(I) + RYY(I)                                   20MR0
         IF (ABS(QYY(I)) .GE. 1.0E+30) ERYY(I) = 0.0                    05SE0
            ERZZ(I) = QZZ(I) + RZZ(I)                                   16AP1
         IF (ABS(QZZ(I)) .GE. 1.0E+30) ERZZ(I) = 0.0                    05SE0
 7250    CONTINUE                                                       16AP1
      PRINT 155, NITF                                                   020C0
COMMENT - START NONLINEAR MEMBER SOLUTION                               01JU1
            IFAE = 0                                                    29JA1
            NMNC = 0                                                    01JL1
         DO 7500  JJ = 1,NM                                             03JE0
            IMC(JJ) = 0                                                 01JL1
            NITM(JJ) = 0                                                00FE0
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COMMENT - CALL SUBROUTINE MEMSOL FOR ITERATIVE SOLUTION OF MEMBER TO    01JU1
COMMENT - FIND MEMBER-END-FORCES FOR JOINT EQUILIBRIUM CHECK IN FRAME   01JU1
COMMENT - SOLUTION                                                      01JU1
      CALL        MEMSOL ( JJ,RM,RO,W,SL,SU,L1,L3,L4,L6)                20NO0
         IF (IMC(JJ) .EQ. 1)  NMNC = NMNC + 1                           01JL1
 7500    CONTINUE                                                       03JE0
            NMJ = 0                                                     03SE0
COMMENT - SAVE JOINT DISPLACEMENTS AND EQUILIBRIUM ERRORS FROM THIS     09JU1
COMMENT - ITERATION FOR MONITOR JOINTS                                  09JU1
         DO 7700 I = 1,NJT                                              03SE0
         IF (IMJ(I) .EQ. 0) GO TO 7700                                  03SE0
            NMJ = NMJ + 1                                               03SE0
            ERXXMJ(NMJ,NITF) = ERXX(I)                                  03SE0
            ERYYMJ(NMJ,NITF) = ERYY(I)                                  03SE0
            ERZZMJ(NMJ,NITF) = ERZZ(I)                                  03SE0
            DXXMJ(NMJ,NITF) = DXX(I)                                    03SE0
            DYYMJ(NMJ,NITF) = DYY(I)                                    03SE0
            DZZMJ(NMJ,NITF) = DZZ(I)                                    03SE0
 7700    CONTINUE                                                       03SE0
 8000 CONTINUE                                                          13MR1
COMMENT - COMPUTE NUMBER OF JOINTS NOT CLOSED --- SKIP CHECKS CORRESPOND09JU1
COMMENT - ING TO SPECIFIED DISPLACEMENTS                                09JU1
            NJNC = 0                                                    03JL1
         DO 8700  I = 1,NJT                                             11JE0
         IF (ABS(ERXX(I)) .GT. ERR1 .AND. ABS(QXX(I)) .LT. 1.0E+30)     05SE0
     2          GO TO 8600                                              05SE0
         IF (ABS(ERYY(I)) .GT. ERR1 .AND. ABS(QYY(I)) .LT. 1.0E+30)     05SE0
     2          GO TO 8600                                              05SE0
         IF (ABS(ERZZ(I)) .GT. ERR2 .AND. ABS(QZZ(I)) .LT. 1.0E+30)     05SE0
     2          GO TO 8600                                              05SE0
         GO TO 8700                                                     020C0
 8600       NJNC = NJNC + 1                                             03JL1
 8700    CONTINUE                                                       11JE0
         IF (NJNC .EQ. 0) GO TO 8900                                    03JL1
      PRINT 175, NJNC,NITF                                              08JL1
         IF ( NITF .EQ. MNITF) GO TO 8950                               01JU1
         IF (NMNC .GT. 0)  GO TO 8950                                   01JL1
COMMENT - RETURN FOR NEXT FRAME ITERATION                               09JU1
         GO TO 5100                                                     16AP1
 8900 PRINT 177, NITF                                                   16AP1
 8950    CONTINUE                                                       03SE0
         IF (NMNC .GT. 0)  PRINT 185, NMNC, NITF                        01JL1
COMMENT - PRINT SUMMARY OF FRAME ITTERATIONS                            28NO0
      PRINT  181                                                        03SE0
            NMJ = 0                                                     03SE0
            KASTER = 0                                                  07AP1
         DO 8960  I = 1,NJT                                             03SE0
         IF (IMJ(I) .EQ. 0) GO TO 8960                                  03SE0
            NMJ = NMJ + 1                                               03SE0
         DO 8955  J = 1,NITF                                            03SE0
         IF (KOMJ(NMJ,J) .EQ. 1) GO TO 8952                             07AP1
      PRINT 182, I,J,DXXMJ(NMJ,J),DYYMJ(NMJ,J),DZZMJ(NMJ,J),            03SE0
     2   ERXXMJ(NMJ,J), ERYYMJ(NMJ,J), ERZZMJ(NMJ,J)                    03SE0
         GO TO 8955                                                     07AP1
 8952       KASTER = 1                                                  07AP1
      PRINT 183, I,J,DXXMJ(NMJ,J),DYYMJ(NMJ,J),DZZMJ(NMJ,J),            03SE0
     2   ERXXMJ(NMJ,J), ERYYMJ(NMJ,J), ERZZMJ(NMJ,J)                    03SE0
 8955    CONTINUE                                                       03SE0
 8960    CONTINUE                                                       03SE0
         IF (KASTER .EQ. 1) PRINT 184                                   07AP1
COMMENT - PRINT TABLE 8 IF REQUESTED                                    24APC
         IF (IP8 .EQ. 1) GO TO 8970                                     13MR0
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      PRINT 11                                                          10FE0
      PRINT 16,NPROB,(AN2(II),II=1,18)                                  26JA0
          IF (NJNC .GT. 0 .OR. NMNC .GT. 0)  PRINT 777                  02JL1
      PRINT 151                                                         10FE0
              KASTER = 0                                                07AP1
          DO 8965  I = 1,NJT                                            10FE0
          IF (KOJ(I) .EQ. 1) GO TO 8962                                 07AP1
      PRINT 152, I, DXX(I), DYY(I), DZZ(I), RXX(I), RYY(I), RZZ(I)      10FE0
          GO TO 8965                                                    07AP1
 8962         KASTER = 1                                                07AP1
      PRINT 153, I, DXX(I), DYY(I), DZZ(I), RXX(I), RYY(I), RZZ(I)      10FE0
 8965     CONTINUE                                                      07AP1
          IF (KASTER .EQ. 1) PRINT 154                                  07AP1
 8970     CONTINUE                                                      13MR0
COMMENT - PRINT TABLE 9 IF REQUESTED                                    16NO0
          IF (IP9 .EQ. 1) GO TO 8980                                    16NO0
      REWIND N1                                                         30NO0
      REWIND N2                                                         30NO0
              NT = N1                                                   18NO0
              N1 = N2                                                   18NO0
              N2 = NT                                                   18NO0
COMMENT - SUBROUTINE PRINT9 OUTPUTS MEMBER RESULTS                      09JU1
      CALL        PRINT9 (AN2,NPROB,RM,RO,W,SL,SU,L1,L3,L4,L6)          23NO0
 8980     CONTINUE                                                      16NO0
COMMENT - PRINT TABLE 10 (JOINT EQUILIBRIUM ERRORS)IF REQUESTED         24APC
          IF (IP10 .EQ. 1) GO TO 8990                                   25MR0
      PRINT 11                                                          25MR0
      PRINT 16,NPROB,(AN2(II),II=1,18)                                  26JA0
          IF (NJNC .GT. 0 .OR. NMNC .GT. 0)  PRINT 777                  02JL1
      PRINT 162                                                         16AP1
      DO 8985  I = 1,NJT                                                21MR0
 8985 PRINT 152, I, ERXX(I), ERYY(I), ERZZ(I)                           21MR8
 8990 CONTINUE                                                          13MR0
          IF (NMNC .GT. 0 .OR. NJNC .GT. 0) GO TO 9800                  03JL1
COMMENT - RETURN FOR NEW PROBLEM                                        24APC
 9000     GO TO 1010                                                    26JA0
COMMENT - SOLUTION ABANDONED - SEARCH FOR INDEPENDENT PROBLEM BEGINS     24APC
COMMENT - HERE                                                          24APC
 9800 PRINT 50                                                          26JA0
 9810 READ  13,NPROB,AN2(19),AN2(20),(AN2(II),II=1,18)                  24JL1
          IF (NPROB(1) .NE. ITEST2 .OR. NPROB(2) .NE. ITEST3)           24JL1
     2    GO TO 9840                                                    24JL1
      PRINT 13,NPROB,AN2(19),AN2(20),(AN2(II),II=1,18)                  24JL1
          GO TO 9810                                                    26JA0
 9840     IF (NPROB(1) .EQ. ITEST1) GO TO 9900                          24JL1
      READ  100, ITYPE,KEEP2,KEEP3,KEEP4A,KEEP4B,KEEP4C,KEEP5A,KEEP5B,  06AG0
     2    KEEP5C,KEEP5D,KEEP6,KEEP7,IP8,IP9,IP10,NCD2,NCD3,NCD4A,       06AG0
     3    NCD4B,NCD4C,NCD5A,NCD5B,NCD5C,NCD5D,NCD6,NCD7                 06AG0
              KEKE = KEEP2 + KEEP3 + KEEP4A + KEEP4B + KEEP4C +         06AG0
     2                KEEP5A + KEEP5B + KEEP5C + KEEP5D + KEEP6 + KEEP7 06AG0
          IF (KEKE .EQ. 0 .AND. ITYPE .LE. 2) GO TO 1050                09FE0
      PRINT 12,NPROB,(AN2(II), II = 1,18)                               24JL1
      PRINT 100, ITYPE,KEEP2,KEEP3,KEEP4A,KEEP4B,KEEP4C,KEEP5A,KEEP5B,  06AG0
     2    KEEP5C,KEEP5D,KEEP6,KEEP7,IP8,IP9,IP10,NCD2,NCD3,NCD4A,       06AG0
     3    NCD4B,NCD4C,NCD5A,NCD5B,NCD5C,NCD5D,NCD6,NCD7                 06AG0
          GO TO 9810                                                    26JA0
 9900     CONTINUE                                                      26JA0
      RETURN                                                            26JA0
      END                                                               14DE0
C
C         ****************************************************************
C                                     SUBROUTINE
C         ****************************************************************
C
      SUBROUTINE FORMST ( RM, RO, W, SL, SU, SMMT, L1, L3, L4, L6 )     08AP0
COMMENT - SUBROUTINE FORMST CALCULATES MEMBER (6 X 6) STIFFNESS MATRIX  16JU1
COMMENT - AND TAKING ADVANTAGE OF SYMETRY STORES IN COMPACT VECTOR      16JU1
COMMENT - SMMT(I = 1, 21)                                               16JU1
COMMENT - MEMBER 6 X 6 STIFFNESS MATRIX STORED AS 21 X 1 VECTOR SMMT AS 21JU1
COMMENT - SHOWN BELOW                                                   21JU1
COMMENT -     1    S         R        L                                 21JU1
COMMENT -     2    7    Y         I                                     21JU1
COMMENT -     3    8   12    M        C                                 21JU1
COMMENT -     4    9   13   16    M        A                            21JU1
COMMENT -     5   10   14   17   19   E                                 21JU1
COMMENT -     6   11   15   18   20   21   T                            21JU1
      DIMENSION FMMI(6), SMMT(21)                                       15JE0
      DIMENSION RM(L3,L6), RO(L6), W(L6), SL(L3), SU(L4)                08AP0
      COMMON /BLOCK2/ DXS( 25),   DYS( 25),   ZLS( 25),   DCIS( 25),    26JA0
     2    DC2S( 25),  PRF( 25),   PRAE( 25),  NCDS( 25),  IAXOPS( 25),  26JA0
     3    IOPOP( 25), IPINL( 25), IPINR( 25), NC51( 25),  INLOP( 25),   17OC0
     4    NAL( 25),   NSXL( 25),  NSYL( 25),  NSZL( 25),  NAR( 25),     17OC0
     5    NSXR( 25),  NSYR( 25),  NSZR( 25),  QM( 25),    WM( 25)       17OC0
      COMMON /BLOCK5/ XLS( 50),   XRS( 50),   FL( 50),    AEL( 50),     26JA0
     2    SXL( 50),   SYL( 50),   SZL( 50)                              26JA0
      COMMON /BLOCK7/ F( 42),     AE( 42),    SX( 42),    SY( 42),      04JE0
     2    SZ( 42),    QX( 42),    QY( 42),    QZ( 42),    DX( 42),      04JE8
     3    DY( 42),    DZ( 42),    ERX( 42),   ERY( 42),   ERZ( 42),     04JE0
     4    SQX( 42),   SQY( 42),   SQZ( 42),   U1( 42),    V1( 42),      04JE0
     5    W1( 42),    U2( 42),    V2( 42),    W2( 42),    DS(3,3, 42),  29JA1
     6    BM1S( 42),  BM2S( 42),  TTS( 42)                              29JA1
      COMMON /BLK1/  KEEP2, KEEP3, KEEP4A,KEEP5A,KEEP6, KEEP7,          26JA0
     2        ITYPE, NCD2,  NCD3,  NCD4A, NCD5A, NCD6,  NCD7,           26JA0
     3        IABAN, IFORM, NM,    NJT,   NST,   NLT,   TOL,            26JA0
     4        M,     MP1,   MP2,   ISTT,  LTT,   ITYPEL,IDJ,            12FE0
     5        NSTL,  IP8,   IP9,   IP10,  KEEP4B,KEEP4C,NCD4B,          05AG0
     6        NCD4C, KEEP5B,KEEP5C,KEEP5D,NCD5B, NCD5C, NCD5D           05AG0
      COMMON /BLK2/ XL,XR,X1,X2,I1,I2,NQ,H,TH,HSQ,HCU,X2L               26JA0
      COMMON /BLK3/ MNJT,MNST,MNLT,MNM,MNC5,MNC6,MDJT,MNJS,MNE,MNCS,    11JU1
     2    MNPCS,MNSS,MNQWM                                              11JU1
      COMMON /BLK4/ ST1,ST2,ST3,ST4,ST5,ST6                             26JA0
      COMMON /BLK5/ NFSUB,NITF,N1,N2                                    04JE0
      COMMON /BLK6/ QT1,QT2,QT3,QT4,QT5,QT6                             04JE0
      COMMON /BLK7/ INLOPT,IFAE,KOFFJ,KOFFQ,,KOFFSE                     07AP1
      COMMON / RI / NL, ML, JI                                          08AP0
COMMENT - SET TEMPORARY CONTROL CONSTANTS FOR STIFF TYPE ISTT           13MY0
              IPINLT = IPINL(ISTT)                                      26JA0
              IPINRT = IPINR(ISTT)                                      26JA0
              ZL = ZLS(ISTT)                                            26JA0
              PRFT = PRF(ISTT)                                          26JA0
              PRAET = PRAE(ISTT)                                        26JA0
              NCDST = NCDS(ISTT)                                        26JA0
              NC51T = NC51(ISTT)                                        26JA0
              INLOPT = INLOP(ISTT)                                      01NO0
COMMENT - COMPUTE CONSTANTS FOR MEMBER SOLUTIONS FOR STIFFNESS VALUES   13MY0
              TH = ZL/M                                                 26JA0
              H = 0.5*TH                                                26JA0
              HSQ = H*H                                                 26JA0
              HCU = HSQ*H                                               26JA0
              NL = 3*MP1                                                26MY0
              ML = 1                                                    07MY1
              NFSUB = 22                                                07MY1
          IF (NITF .GT. 1) GO TO 1200                                   07MY1
          IF (ITYPE .EQ. 2) GO TO 1200                                  07MY1
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COMMENT - ZERO MEMBER DISPLACEMENTS                                      16JU1
          DO 1150  I = 1,MP2                                              07MY1
               DX(I) = 0.0                                                24JL1
               DY(I) = 0.0                                                24JL1
 1150          DZ(I) = 0.0                                                24JL1
          GO TO 1300                                                      07MY1
COMMENT - READ MEMBER DISPLACEMENTS                                      16JU1
 1200 READ (N1) ((DX(I), DY(I), DZ(I)), I = 1,MP2)                        07MY1
 1300     CONTINUE                                                        07MY1
COMMENT - ZERO MEMBER INCREMENTAL LOADS                                  27MY0
          DO 1800  I = 1,MP2                                              27MY0
               ERX(I) = 0.0                                               24JL1
               ERY(I) = 0.0                                               24JL1
 1800          ERZ(I) = 0.0                                               24JL1
          IF (INLOPT .EQ. 1) GO TO 2400                                   01ND0
          IF (NCDST .EQ. 0) GO TO 2100                                    27MY0
COMMENT - SUBROUTINE DISCST DISCRETIZES MEMBER LINEAR STIFFNESS DATA     16JU1
COMMENT - F, AE, SX, SY, SZ                                              16JU1
     CALL      DISCST ( NCSIT, NCDST, ZL, LI )                            11FE0
          GO TO 2500                                                      27MY0
 2100     CONTINUE                                                        27MY0
COMMENT - PRISMATIC MEMBER WITH CONSTANT F AND AE                        16JU1
          DO 2200  I = 1,MP2                                              27MY0
               SX(I) = 0.0                                                24JL1
               SY(I) = 0.0                                                24JL1
               SZ(I) = 0.0                                                24JL1
               SQX(I) = 0.0                                               24JL1
               SQY(I) = 0.0                                               24JL1
               SQZ(I) = 0.0                                               24JL1
               AE(I) = PRAET                                              27MY0
               F(I) = PRFT                                                27MY0
 2200     CONTINUE                                                        27MY0
               AE(1) = 0.0                                                24JL1
               AE(MP2) = 0.0                                              24JL1
               F(1) = 0.0                                                 24JL1
               F(MP2) = 0.0                                               24JL1
          GO TO 2500                                                      01N00
 2400     CONTINUE                                                        27MY0
COMMENT - SUBROUTINE NLSS DISCRETIZES DISTRIBUTED MEMBER Q - W CURVES    16JU1
COMMENT - TO STATION VALUES OF RESISTIVE SPRING FORCES  SQX, SQY, SQZ   16JU1
COMMENT - AND SPRING STIFFNESS  SX, SY, SZ                               16JU1
     CALL      NLSS(L1)                                                   05FE1
 2500     CONTINUE                                                        02N00
COMMENT - STORE MEMBER END RESTRAINTS ST1 -  ST6                         13MY0
               ST1 = SX(1)                                                26JA0
               ST2 = SY(1)                                                26JA0
               ST3 = SZ(1)                                                26JA0
               ST4 = SX(MP1)                                              26JA0
               ST5 = SY(MP1)                                              26JA0
               ST6 = SZ(MP1)                                              26JA0
COMMENT - ZERO MEMBER-END-LOADS                                          16JU1
               QT1 = 0.0                                                  24JL1
               QT2 = 0.0                                                  24JL1
               QT3 = 0.0                                                  24JL1
               QT4 = 0.0                                                  24JL1
               QT5 = 0.0                                                  24JL1
               QT6 = 0.0                                                  24JL1
COMMENT - SET MEMBER END RESTRAINTS TO 1.0E40  FOR SIX MEMBER SOLUTIONS 13MY0
               SX(1) = 1.0E40                                             24JL1
               SY(1) = 1.0E40                                             24JL1
               SZ(1) = 1.0E40                                             24JL1
               SX(MP1) = 1.0E40                                           24JL1
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               SY(MP1) = 1.0E40                                           24JL1
               SZ(MP1) = 1.0E40                                           24JL1
COMMENT - ZERO PINNED END ROTATION RESTRAINTS                            13MY0
          IF ( IPINLT .EQ. 1) SZ(1) = 0.0                                 26JA0
          IF ( IPINRT .EQ. 1) SZ(MP1) = 0.0                               26JA0
COMMENT - UNIT INCREMENT OF DISP FOR FIRST COLUMN OF STIFF MATRIX        16JU1
               ERX(1) = 1.0E40                                            27MY0
COMMENT - CALL GRIP2A TO SOLVE MEMBER FOR UNIT INCREMENT OF DISPLACEMENT16JU1
     CALL      GRIP2A ( RM,RO,W,SL,SU,L3,L4,L6,4)                         27MY0
               ERX(1) = 0.0                                               27MY0
COMMENT - CALL MEMENI TO FIND INCREMENTAL END-FORCES WHICH ARE STIFFNESS16JU1
COMMENT - TERMS IN ONE COLUMN OF STIFFNESS MATRIX                        16JU1
     CALL      MEMENI ( W,FMMI,L6 )                                       15JE0
          DO 3350  KK = 1,6                                               27MY0
 3350          SMMT(KK) = FMMI(KK)                                        27MY0
COMMENT - SET MULTIPLE LOAD OPTION FOR REMAINING SOLUTIONS               16JU1
               ML = -1                                                    27MY0
COMMENT - UNIT INCREMENT OF DISP FOR SECOND COLUMN OF STIFF MATRIX       16JU1
               ERY(1) = 1.0E40                                            27MY0
     CALL      GRIP2A ( RM,RO,W,SL,SU,L3,L4,L6,5)                         27MY0
               ERY(1) = 0.0                                               27MY0
     CALL      MEMENI ( W,FMMI,L6 )                                       15JE0
          DO 3450  KK = 2,6                                               27MY0
 3450          SMMT(KK + 5) = FMMI(KK)                                    27MY0
          IF (IPINLT .LE. 0) GO TO 3500                                   07MY1
COMMENT - ZERO STIFFNESS FOR PINNED CONNECTIONS                          07MY1
               SMMT( 3) = 0.0                                             24JL1
               SMMT( 8) = 0.0                                             24JL1
               SMMT(12) = 0.0                                             24JL1
               SMMT(13) = 0.0                                             24JL1
               SMMT(14) = 0.0                                             24JL1
               SMMT(15) = 0.0                                             24JL1
          GO TO 3575                                                      07MY1
COMMENT - UNIT INCREMENT OF DISP FOR THIRD  COLUMN OF STIFF MATRIX       16JU1
 3500          ERZ(1) = 1.0E40                                            27MY0
     CALL      GRIP2A ( RM,RO,W,SL,SU,L3,L4,L6,5)                         27MY0
               ERZ(1) = 0.0                                               27MY0
     CALL      MEMENI ( W,FMMI,L6 )                                       15JE0
          DO 3550  KK = 3,6                                               27MY0
 3550          SMMT(KK +  9) = FMMI(KK)                                   27MY0
COMMENT - UNIT INCREMENT OF DISP FOR FOURTH COLUMN OF STIFF MATRIX       16JU1
 3575          ERX(MP1) = 1.0E40                                          27AG0
     CALL      GRIP2A ( RM,RO,W,SL,SU,L3,L4,L6,5)                         27MY0
               ERX(MP1) = 0.0                                             27MY0
     CALL      MEMENI ( W,FMMI,L6 )                                       15JE0
          DO 3650  KK = 4,6                                               27MY0
 3650          SMMT(KK + 12) =  FMMI(KK)                                  27MY0
COMMENT - UNIT INCREMENT OF DISP FOR FIFTH  COLUMN OF STIFF MATRIX       16JU1
               ERY(MP1) = 1.0E40                                          27MY0
     CALL      GRIP2A ( RM,RO,W,SL,SU,L3,L4,L6,5)                         27MY0
               ERY(MP1) = 0.0                                             27MY0
     CALL      MEMENI ( W,FMMI,L6 )                                       15JE0
          DO 3750  KK = 5,6                                               27MY0
 3750          SMMT(KK + 14) =  FMMI(KK)                                  27MY0
          IF (IPINRT .LE. 0) GO TO 3800                                   27AG0
COMMENT - ZERO STIFFNESS FOR PINNED CONNECTIONS                          07MY1
               SMMT( 6) = 0.0                                             24JL1
               SMMT(11) = 0.0                                             24JL1
               SMMT(15) = 0.0                                             24JL1
               SMMT(18) = 0.0                                             24JL1
               SMMT(20) = 0.0                                             24JL1
               SMMT(21) = 0.0                                             24JL1
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         GO TO 9900                                                        07MYI
COMMENT - UNIT INCREMENT OF DISP FOR SIXTH  COLUMN OF STIFF MATRIX         16JUI
 3800          ERZ(MP1) = 1.0E40                                           07MYI
      CALL       GRIP2A ( RM,RO,W,SL,SU,L3,L4,L6,5)                        27MYO
               ERZ(MP1) = 0.0                                              27MYO
      CALL       MEMENI ( W,FMMI,L6 )                                      15JEO
               SMMT(2I) = FMMI(6)                                          27AGO
 9900    CONTINUE                                                          26JAO
      RETURN                                                               26JAO
      END                                                                  26JAO
C
C        ********************************************************************
C                                     SUBROUTINE
C        ********************************************************************
C
      SUBROUTINE DISCST ( NC51T, NCDST, ZL, L1)                            11FEO
COMMENT - SUBROUTINE DISCST DISCRETIZES MEMBER LINEAR STIFFNESS DATA       16JU1
COMMENT - F, AE, SX, SY, SZ                                                16JU1
COMMENT - NONLINEAR SPRING RESISTIVE FORCES SQX, SQY, SQZ ARE ZEROED       16JU1
      COMMON /BLOCK5/ XLS( 50),   XRS( 50),   FL( 50),    AEL( 50),        26JAO
     2    SXL( 50),   SYL( 50),   SZL( 50)                                 26JAO
      COMMON /BLOCK7/ F( 42),     AE( 42),    SX( 42),    SY( 42),         04JEO
     2    SZ( 42),    QX( 42),    QY( 42),    QZ( 42),    DX( 42),         04JEO
     3    DY( 42),    DZ( 42),    ERX( 42),   ERY( 42),   ERZ( 42),        04JEO
     4    SQX( 42),   SQY( 42),   SQZ( 42),   U1( 42),    V1( 42),         04JEO
     5    W1( 42),    U2( 42),    V2( 42),    W2( 42),    DS(3,3, 42),     29JAI
     6    BM1S( 42),  BM2S( 42),  TTS( 42)                                 29JAI
      COMMON /BLK1/  KEEP2, KEEP3, KEEP4A,KEEP5A,KEEP6, KEEP7,             26JAO
     2        ITYPE, NCD2,  NCD3,  NCD4A, NCD5A, NCD6,  NCD7,              26JAO
     3        IABAN, IFORM, NM,    NJT,   NST,   NLT,   TOL,               26JAO
     4        M,     MP1,   MP2,   ISTT,  LTT,   ITYPEL,IDJ,               12FEO
     5        NSTL,  IP8,   IP9,   IP10,  KEEP4B,KEEP4C,NCD4B,             05AGO
     6        NCD4C, KEEP5B,KEEP5C,KEEP5D,NCD5B, NCD5C, NCD5D              05AGO
      COMMON /BLK2/ XL,XR,X1,X2,I1,I2,NQ,H,TH,HSQ,HCU,X2L                  26JAO
COMMENT - ZERO MEMBER STIFFNESS DATA                                       13MYO
      DO 1020 I = 1,MP2                                                    26JAO
               SX(I) = 0.0                                                 26JAO
               SY(I) = 0.0                                                 26JAO
               SZ(I) = 0.0                                                 26JAO
               F(I) = 0.0                                                  26JAO
               AE(I) = 0.0                                                 26JAO
               SQX(I) = 0.0                                                24JL1
               SQY(I) = 0.0                                                24JLI
               SQZ(I) = 0.0                                                24JL1
 1020    CONTINUE                                                          26JAO
               ICOUNT = 0                                                  26JAO
               NC52T = NC51T - 1 + NCDST                                   26JAO
COMMENT - I1 GOES FROM NC51T TO NC52T                                      13MYO
               I1 = NC51T - 1                                              26JAO
 1050          I1 = I1 + 1                                                 26JAO
COMMENT - READ DATA FROM ONE CARD IMAGE  (STIFFNESS AT LEFT OF SECTION)    13MYO
               XL = XLS(I1)                                                26JAO
               XR = XRS(I1)                                                26JAO
               FLT = FL(I1)                                                26JAO
               AELT = AEL(I1)                                              26JAO
               SXLT = SXL(I1)                                              26JAO
               SYLT = SYL(I1)                                              26JAO
               SZLT = SZL(I1)                                              26JAO
         IF (XR .NE. 0.0) GO TO 1100                                       26JAO
COMMENT - VARIABLE STIFFNESS SECTION READ ONE CARD IMAGE (STIFFNESS AT     13MYO
COMMENT - RIGHT OF SECTION)                                                13MYO
               I1 = I1 + 1                                                 26JAO
               XR = XRS(I1)                                                26JAO
               FRT = FL(I1)                                                26JAO
               AERT = AEL(I1)                                              26JAO
               SXRT = SXL(I1)                                              26JAO
               SYRT = SYL(I1)                                              26JAO
               SZRT = SZL(I1)                                              26JAO
         GO TO 1110                                                        26JAO
COMMENT - UNIFORM STIFFNESS SECTION SET STIFFNESS ON RIGHT EQUAL TO        13MYO
COMMENT - STIFFNESS ON LEFT                                                13MYO
 1100          FRT = FLT                                                   26JAO
               AERT = AELT                                                 26JAO
               SXRT = SXLT                                                 26JAO
               SYRT = SYLT                                                 26JAO
               SZRT = SZLT                                                 26JAO
 1110    CONTINUE                                                          26JAO
         IF  (ICOUNT .NE. 0 ) GO TO 1210                                   26JAO
COMMENT - FIRST SECTION OF MEMBERS STIFFNESS DATA                          13MYO
               ICOUNT = 1                                                  26JAO
               I1 = 2                                                      26JAO
               X1 = TH                                                     26JAO
         GO TO 1250                                                        26JAO
 1210    CONTINUE                                                          11MYO
               I1 = I2 + 1                                                 26JAO
               X1 = TH - X2                                                26JAO
 1250    CONTINUE                                                          26JAO
         IF (XR .NE. ZL) GO TO 1260                                        26JAO
COMMENT - LAST SECTION OF MEMBERS STIFFNESS DATA                           13MYO
               I2 = MP1                                                    26JAO
               X2 = 0.0                                                    26JAO
         GO TO 1270                                                        26JAO
 1260          ZI2 = XR/TH + 1.0                                           26JAO
               I2 = ZI2                                                    26JAO
               X2 = XR - I2*TH + TH                                        26JAO
 1270          NQ = I2 - I1                                                26JAO
COMMENT - SUBROUTINE LINSTF DISTRIBUTES F AND AE                           13MYO
      CALL        LINSTF ( FLT, FRT, F, FTT2, L1 )                         11FEO
      CALL        LINSTF (AELT, AERT, AE, AETT2, L1 )                      11FEO
COMMENT - SUBROUTINE LINLD DISTRIBUTES SX,SY,SZ, QX,QY, AND QZ             13MYO
         IF (SXLT .EQ. 0.0 .AND. SXRT .EQ. 0.0) GO TO 1280                 11MYO
      CALL        LINLD ( SXLT, SXRT, SX, L1 )                             11FEO
 1280    IF (SYLT .EQ. 0.0 .AND. SYRT .EQ. 0.0) GO TO 1290                 11MYO
      CALL        LINLD ( SYLT, SYRT, SY, L1 )                             11FEO
 1290    IF (SZLT .EQ. 0.0 .AND. SZRT .EQ. 0.0) GO TO 1330                 11MYO
      CALL        LINLD ( SZLT, SZRT, SZ, L1 )                             11FEO
 1330    CONTINUE                                                          26JAO
               X2L = X2                                                    26JAO
COMMENT - RETURN FOR IMAGE OF NEXT DATA CARD IF II LESS THAN NC52T         13MYO
 9000    IF (I1 .LT. NC52T) GO TO 1050                                     26JAO
 9900    CONTINUE                                                          26JAO
      RETURN                                                               26JAO
      END                                                                  26JAO
C
C        ********************************************************************
C                                     SUBROUTINE
C        ********************************************************************
C
      SUBROUTINE LINSTF (STL,STR,ST,STT2,L1)                               11FEO
COMMENT - SUBROUTINE LINSTIFF DISCRESTIZES LINEAR VARIATIONS IN LINEAR     14JL1
COMMENT - STIFNESS PROPERTIES F( ) AND AE( )                               14JL1
      DIMENSION ST(L1)                                                     11FEO
      COMMON /BLK2/ XL,XR,X1,X2,I1,I2,NQ,H,TH,HSQ,HCU,X2L                  26JAO
         IF ( XL .NE. 0.0 ) GO TO 1150                                     26JAO
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COMMENT - FIRST SECTION OF MEMBER                                        13MY0
                X2L = 0.0                                                26JA0
                STT2 = 1.0                                               26JA0
 1150     CONTINUE                                                       26JA0
          IF ( STR .EQ. STL ) GO TO 1310                                 26JA0
COMMENT - LINEAR STIFFNESS SECTION                                       13MY0
COMMENT - CALCULATE SLOPE OF LINEAR STIFFNESS VARIATION                  13MY0
                DS = (STR - STL)/(XR-XL)                                 26JA0
COMMENT - FIRST ELEMENT (TH LONG) OF SECTION                             13MY0
COMMENT - COMPUTE EFFECTIVE STIFFNESS OF ELEMENT CONSIDERING JUMP AT     15MY0
COMMENT - START OF SECTION                                               15MY0
                STA = STL                                                26JA0
                STB = STL + DS*X1                                        26JA0
                STT1 = 0.5*(STA + STB)                                   26JA0
                ST(I1) = (TH*STT1*STT2)/(X2L*STT1 + X1*STT2)             26JA0
          IF (NQ .EQ. 0 ) GO TO 1250                                     26JA0
                I1P1 = I1 + 1                                            26JA0
                I1PNQ = I1 + NQ                                          26JA0
COMMENT - REMAINING NQ ELEMENTS                                          13MY0
COMMENT - COMPUTE STIFFNESS AT MID POINT OF ELEMENT                      15MY0
          DO 1210 I  = I1P1, I1PNQ                                       26JA0
                STA = STB                                                26JA0
                STB = STA + DS*TH                                        26JA0
 1210           ST(I) = 0.5*(STA + STB)                                  26JA0
 1250     CONTINUE                                                       26JA0
                STA = STB                                                26JA0
                STB = STR                                                26JA0
                STT2 = 0.5*(STA + STB)                                   26JA0
 1290     GO TO 1800                                                     26JA0
COMMENT - UNIFORM STIFFNESS SECTION                                      13MY0
COMMENT - FIRST ELEMENT (TH LONG) OF SECTION                             13MY0
COMMENT - COMPUTE EFFECTIVE STIFFNESS OF ELEMENT CONSIDERING JUMP AT     15MY0
COMMENT - START OF SECTION                                               15MY0
 1310           STT1 = STL                                               26JA0
                ST(I1) = (TH*STT1*STT2)/(X2L*STT1 + X1*STT2)             26JA0
          IF (NQ .EQ. 0 ) GO TO 1360                                     26JA0
                I1P1 = I1 + 1                                            26JA0
                I1PNQ = I1 + NQ                                          26JA0
COMMENT - REMAINING NQ ELEMENTS HAVE CONSTANT STIFFNESS                  15MY0
          DO 1350 I  = I1P1, I1PNQ                                       26JA0
 1350           ST(I)  = STL                                             26JA0
 1360           STT2 = STL                                               26JA0
 1800     CONTINUE                                                       26JA0
      RETURN                                                             26JA0
      END                                                                26JA0
C
C         ****************************************************************
C                                 SUBROUTINE
C         ****************************************************************
C
      SUBROUTINE LINLD  ( QL, QR, Q,L1)                                  11FE0
COMMENT - SUBROUTINE LINLD DISTRIBUTES SX, SY, SZ, QX, QY, AND QZ        15MY0
      DIMENSION Q(L1)                                                    11FE0
      COMMON /BLK2/ XL,XR,X1,X2,I1,I2,NQ,H,TH,HSQ,HCU,X2L                26JA0
COMMENT -COMPUTE SLOPE OF LINEAR VARIATION                               15MY0
                DQ = (QR - QL)/(XR - XL)                                 26JA0
COMMENT - COMPUTE CONCENTRATED LOAD OR RESTRAINT FOR ELEMENT AT RIGHT    15MY0
COMMENT - END OF SECTION Q1, DISTANCE TO LINE OF ACTION Z AND CALL       15MY0
COMMENT - CONLD TO DISTRIBUTE TO ADJACENT STATIONS                       15MY0
                Q2 = QR                                                  26JA0
                Q1 = QR - DQ*X2                                          26JA0
          IF ( ABS (Q1 + Q2) .LE. 1.0E-10 ) GO TO 1005                   26JA0
                Z = XR - X2 + (X2/3.0)*(2.0*Q2 + Q1)/(Q1 + Q2)           26JA0
                Q1 = 0.5*X2*(Q1 + Q2)                                    26JA0
          IF ( ABS(Q1) .LE. 1.0E-10 ) GO TO 1005                         26JA0
      CALL         CONLD  ( Q1, Z,  Q, L1 )                              11FE0
COMMENT - SAME AS ABOVE FOR ELEMENT AT LEFT END OF SECTION               15MY0
 1005           Q1 = QL                                                  26JA0
                Q2 = QL + DQ*X1                                          26JA0
          IF ( ABS (Q1 + Q2) .LE. 1.0E-10 ) GO TO 1009                   26JA0
                Z = XL + (X1/3.0)*(2.0*Q2 + Q1)/(Q1 + Q2)                26JA0
                Q1 = 0.5*X1*(Q1 + Q2)                                    26JA0
          IF ( ABS(Q1) .LE. 1.0E-10 ) GO TO 1009                         26JA0
      CALL         CONLD  ( Q1, Z,  Q, L1 )                              11FE0
 1009     IF ( NQ .EQ. 0 ) GO TO 2000                                    26JA0
 1020           XX = XL + X1                                             26JA0
COMMENT - SAME AS ABOVE FOR REMAINING NQ ELEMENTS                        15MY0
          DO 1990 II = 1,NQ                                              26JA0
                Q1 = Q2                                                  26JA0
                Q2 = Q1 + DQ*TH                                          26JA0
          IF ( ABS(Q1 + Q2) .LE. 1.0E-10) GO TO 1990                     11MY0
                Z = XX + (TH/3.0)*(2.0*Q2 + Q1)/(Q1 + Q2)                26JA0
                XX = XX + TH                                             26JA0
                QI = 0.5*TH*(Q1 + Q2)                                    26JA0
      CALL         CONLD  ( QI, Z,  Q, L1 )                              11FE0
 1990     CONTINUE                                                       26JA0
 2000     CONTINUE                                                       26JA0
      RETURN                                                             26JA0
      END                                                                26JA0
C
C         ****************************************************************
C                                 SUBROUTINE
C         ****************************************************************
C
      SUBROUTINE CONLD  ( QI, Z, QO, L1)                                 11FE0
COMMENT - SUBROUTINE CONLD DISTRIBUTES CONCENTRATED VALUE OF LOADS,      01JL1
COMMENT - SPRING, STIFFNESSES, AND RESISTIVE SPRING FORCES TO ADJACENT   01JL1
COMMENT - STATIONS I AND IP1                                             01JL1
      DIMENSION QO(L1)                                                   11FE0
      COMMON /BLK2/ XL,XR,X1,X2,I1,I2,NQ,H,TH,HSQ,HCU,X2L                26JA0
                ZI = Z/TH  + 1.0                                         26JA0
                I = ZI                                                   26JA0
                ZZ = Z - I*TH + TH                                       09JU1
                IP1 = I + 1                                              26JA0
                QO(I) = QO(I) + QI*(TH - ZZ)/TH                          09JU1
                QO(IP1) = QO(IP1) + QI*ZZ/TH                             09JU1
      RETURN                                                             26JA0
      END                                                                26JA0
C
C         ****************************************************************
C                                 SUBROUTINE
C         ****************************************************************
C
      SUBROUTINE MEMENI (W,FMMI,L6)                                      15JE0
COMMENT - MEMENI COMPUTES THE INCREMENTAL MEMBER-END FORCES FOR FINDING  12JY1
COMMENT - INCREMENTAL FIXED-END-FORCES AND TANGENT STIFFNESS MATRIX      12JY1
      DIMENSION W(L6)                                                    15JE0
      DIMENSION SEE3(3,3), WT(3), FMMT(3), FMMI(6),SA(3,3)               19SE0
      COMMON /BLOCK2/ DXS( 25),   DYS( 25),   ZLS( 25),   DC1S( 25),     26JA0
     2    DC2S( 25),  PRF( 25),   PRAE( 25),  NCDS( 25),  IAXOPS( 25),   26JA0
     3    IOPOP( 25), IPINL( 25), IPINR( 25), NC51( 25),  INLOP( 25),    17OC0
     4    NAL( 25),   NSXL( 25),  NSYL( 25),  NSZL( 25),  NAR( 25),      17OC0
     5    NSXR( 25),  NSYR( 25),  NSZR( 25),  QM( 25),    WM( 25)        17OC0
      COMMON /BLOCK7/ F( 42),     AE( 42),    SX( 42),    SY( 42),       04JE0
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     2    SZ( 42),    QX( 42),    QY( 42),    QZ( 42),    DX( 42),      04JE0
     3    DY( 42),    DZ( 42),    ERX( 42),   ERY( 42),   ERZ( 42),     04JE0
     4    SQX( 42),   SQY( 42),   SQZ( 42),   U1( 42),    V1( 42),      04JE0
     5    W1( 42),    U2( 42),    V2( 42),    W2( 42),    DS(3,3, 42),  29JA1
     6    BM1S( 42),  BM2S( 42),  TTS( 42)                              29JA1
      COMMON /BLOC11/ SEET(6,6)                                         30JE0
      COMMON /BLK1/  KEEP2, KEEP3, KEEP4A,KEEP5A,KEEP6, KEEP7,          26JA0
     2        ITYPE, NCD2,  NCD3,  NCD4A, NCD5A, NCD6,  NCD7,           26JA0
     3        IABAN, IFORM, NM,    NJT,   NST,   NLT,   TOL,            26JA0
     4        M,     MPI,   MP2,   ISTT,  LTT,   ITYPEL,IDJ,            12FE0
     5        NSTL,  IP8,   IP9,   IP10,  KEEP4B,KEEP4C,NCD4B,          05AG0
     6        NCD4C, KEEP5B,KEEP5C,KEEP5D,NCD5B, NCD5C, NCD5D           05AG0
      COMMON /BLK2/ XL,XR,X1,X2,I1,I2,NQ,H,TH,HSQ,HCU,X2L               26JA0
      COMMON /BLK4/ ST1,ST2,ST3,ST4,ST5,ST6                             04JE0
      COMMON /BLK6/ QT1,QT2,QT3,QT4,QT5,QT6                             04JE0
      COMMON /BLK7/ INLOPT,IFAE,KOFFJ,KOFFQW,KOFFSE                     07AP1
            IAXOPT = IAXOPS(ISTT)                                       29SE0
COMMENT - COMPUTE INCREMENTAL ELEMENT-END-FORCES ON ELEMENT NUMBER 2    12JY1
COMMENT - FORM ELEMENT STIFFNESS MATRIX                                 12JY1
      CALL        ELEMST (2)                                            15JE0
          DO 100  I = 1,3                                               15JE0
              WT(I) = W(I)                                              15JE0
          DO 100  J = 1,3                                               15JE0
              SEE3(I,J) = SEET(I,J)                                     15JE0
  100     CONTINUE                                                      15JE0
COMMENT - MULTIPLY ELEMENT STIFFNESS MATRIX TIMES INCREMENTS OF MEMBER  12JY1
COMMENT - DISPLACEMENTS AT MEMBERS END                                  12JY1
      CALL        MATM31 (SEE3, WT, FMMT)                               15JE0
          DO 150  I = 1,3                                               15JE0
              FMMI(I) = FMMT(I)                                         15JE0
  150     CONTINUE                                                      15JE0
          DO 200  I = 1,3                                               15JE0
              IP3 = I + 3                                               15JE0
              WT(I) = W(IP3)                                            15JE0
          DO 200  J = 1,3                                               15JE0
              JP3 = J + 3                                               15JE0
              SEE3(I,J) = SEET(I,JP3)                                   15JE0
  200     CONTINUE                                                      15JE0
COMMENT - MULTIPLY ELEMENT STIFFNESS MATRIX TIMES INCREMENTS OF MEMBER  12JY1
COMMENT - DISPLACEMENTS AT FIRST STATION INSIDE MEMBERS END             12JY1
      CALL        MATM31 (SEE3,WT,FMMT)                                 15JE0
          DO 250  I = 1,3                                               15JE0
              FMMI(I) = FMMI(I) + FMMT(I)                               15JE0
  250     CONTINUE                                                      15JE0
COMMENT - COMPUTE INCREMENTAL ELEMENT-END-FORCES ON ELEMENT NUMBER MP1  12JY1
COMMENT - FORM ELEMENT STIFFNESS MATRIX                                 12JY1
      CALL        ELEMST(MP1)                                           15JE0
          DO 600  I = 1,3                                               15JE0
              IP3M1 = I + 3*(M - 1)                                     15JE0
              WT(I) = W(IP3M1)                                          15JE0
              IP3 = I + 3                                               15JE0
          DO 600  J = 1,3                                               15JE0
              SEE3(I,J) = SEET(IP3,J)                                   15JE0
  600     CONTINUE                                                      15JE0
COMMENT - MULTIPLY ELEMENT STIFFNESS MATRIX TIMES INCREMENTS OF MEMBER  12JY1
COMMENT - DISPLACEMENTS AT MEMBERS END                                  12JY1
      CALL        MATM31 (SEE3, WT, FMMT)                               15JE0
          DO 650  I = 1,3                                               15JE0
              IP3 = I + 3                                               15JE0
              FMMI(IP3) = FMMT(I)                                       15JE0
  650     CONTINUE                                                      15JE0
          DO 700  I = 1,3                                               15JE0
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              IP3 = I + 3                                               15JE0
              IP3M = I + 3*M                                            15JE0
              WT(I) = W(IP3M)                                           15JE0
          DO 700  J = 1,3                                               15JE0
              JP3 = J + 3                                               15JE0
              SEE3(I,J) = SEET(IP3,JP3)                                 15JE0
  700     CONTINUE                                                      15JE0
COMMENT - MULTIPLY ELEMENT STIFFNESS MATRIX TIMES INCREMENTS OF MEMBER  12JY1
COMMENT - DISPLACEMENTS AT FIRST STATION INSIDE MEMBERS END             12JY1
      CALL        MATM31 (SEE3, WT, FMMT)                               15JE0
          DO 750  I = 1,3                                               15JE0
              IP3 = I + 3                                               15JE0
              FMMI(IP3) = FMMI(IP3) + FMMT(I)                           15JE0
  750     CONTINUE                                                      15JE0
COMMENT - ADD ON INCREMENTAL END-LOADS AND INCREMENTAL SPRING FORCES AT 12JY1
COMMENT - END STATIONS                                                  12JY1
              FMMI(3) = FMMI(3) + ST3*W(3) - QT3                        13MY1
              FMMI(6) = FMMI(6) + ST6*WT(3) - QT6                       13MY1
          IF (IAXOPT .EQ. 2) GO TO 800                                  05SE0
              FMMI(1) = FMMI(1) + ST1*W(1) - QT1                        13MY1
              FMMI(2) = FMMI(2) + ST2*W(2) - QT2                        13MY1
              FMMI(4) = FMMI(4) + ST4*WT(1) - QT4                       13MY1
              FMMI(5) = FMMI(5) + ST5*WT(2) - QT5                       13MY1
          GO TO 900                                                     05SE0
COMMENT - MEMBER SPRINGS IN STRUCTURE DIRECTIONS                        12JY1
  800 CALL        SANGLE (SA,ST4,ST5)                                   05SE0
      CALL        MATM31 (SA,WT,FMMT)                                   05SE0
              FMMI(4) = FMMI(4) + FMMT(1) - QT4                         13MY1
              FMMI(5) = FMMI(5) + FMMT(2) - QT5                         13MY1
              WT(1) = W(1)                                              05SE0
              WT(2) = W(2)                                              05SE0
              WT(3) = 0.0                                               05SE0
      CALL        SANGLE (SA,ST1,ST2)                                   05SE0
      CALL        MATM31(SA,WT,FMMT)                                    05SE0
              FMMI(1) = FMMI(1) + FMMT(1) - QT1                         13MY1
              FMMI(2) = FMMI(2) + FMMT(2) - QT2                         13MY1
  900     CONTINUE                                                      05SE0
      RETURN                                                            15JE0
      END                                                               15JE0
C
C         *****************************************************************
C                                     SUBROUTINE
C         *****************************************************************
C
      SUBROUTINE GRIP2A ( RM, RO, W, SL, SU, L3, L4, L6, M    )         15MY0
COMMENT - GRIP2A SOLVES BOTH FRAME JOINT EQUILIBRIUM EQUATIONS AND      24APC
COMMENT - MEMBER EQUILIBRIUM EQUATIONS - GRIP2B CALLS FSUB1 WHICH CALLS 24APC
COMMENT - FSUB11 TO SET UP FRAME EQUATIONS OR FSUB12 TO SET UP MEMBER   24APC
COMMENT - EQUATIONS                                                     24APC
C  $  $  $  $  $  $  $  $  $  $  $  $  REVISION DATE =    07 APR 70      DATE
C--------RM(M,NL) , RO(NL)    , W(NL) , SL(M) , SU(M+1)  -**-  DIMENSION GUIDE
C        NL IS ORDER                                                    06AP0
C   ***   NL MUST BE GREATER THAN 2                                     06AP0
C        M  IS HALF-WIDTH  ( J = 2*M + 1 ), WHERE J IS THE BAND WIDTH   06AP0
C   ***   M MUST BE GREATER THAN 1                                      06AP0
C        RM(  )       RECURSION MULTIPLIERS                             06AP0
C        F            CONSTANT TERM FOR THE I-TH ROW                    06AP0
C        W (  )       SOLUTION VECTOR                                   06AP0
      DIMENSION RM(L3,L6), RO(L6), W(L6), SL(L3), SU(L4)                08AP0
      COMMON /RI/ NL, ML, J1                                            20JA9
              J1 = 1                                                    11JL8
              M1 = M - 1                                                11JL8
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            MP = M + 1                                                  11JL8
            NLM1 = NL - 1                                               11JL8
            NLMM = NL - M                                               11JL8
            IZ = 0                                                      25JL8
            I2 = 1                                                      25JL8
            I3 = 1                                                      25JL8
C************************************************************************
C                        CALCULATE RECURSION MULTIPLIERS               *
C************************************************************************
            SL(1) = 0.0                                                 07APO
      CALL       FSUB1 ( SU, F , M, L4 )                                08APO
         IF ( ML ) 210, 100, 100                                        11JL8
  100       RM(M,1) = -1.0 / SU(MP)                                     25JL8
         DO 150  I = 1 , M1                                             25JL8
            IB = MP - I                                                 25JL8
            RM(I,IB) = SU(I+1)                                          25JL8
  150    CONTINUE                                                       25JL8
            RO(1) = SU(1)                                               06APO
  210       W(1) = RM(M,1) * ( -F )                                     11JL8
         DO 1000  J = 2 , NL                                            11JL8
            J1 = J - 1                                                  07APO
         IF ( J.GT.M )  J1 = M1                                         06APO
         DO 250  I = 1, J1                                              07APO
            IB = J1 + 2 - I                                             07APO
            SL(IB) = SL(IB-1)                                           07APO
  250    CONTINUE                                                       07APO
            SL(1) = SU(1)                                               07APO
            J1 = J                                                      11JL8
      CALL       FSUB1 ( SU, F , M, L4 )                                08APO
            J1 = J - 1                                                  07APO
         IF ( J.GT.M )  J1 = M1                                         06APO
         IF ( ML ) 750, 290, 290                                        11JL8
  290       IX = J + M1                                                 25JL8
         IF ( IX - NL - 1 ) 299 , 295 , 292                             25JL8
  292       I3 = I3 + 1                                                 25JL8
  295       IZ = IZ - 1                                                 25JL8
            I2 = I2 + 1                                                 25JL8
  299       II = IX + IZ                                                25JL8
            IE = I3                                                     07APO
         DO 300  I = I2 , M                                             25JL8
            RM(I,II) = SU(I+1)                                          25JL8
            II = II - 1                                                 25JL8
  300    CONTINUE                                                       11JL8
            RO(J) = SU(1)                                               06APO
         DO 400  L = 1 , J1                                             06APO
            TEMP = RM(M,J-L) * RM(M-L,J)                                06APO
         IF((J+M-L).LE.NL)    RM(L,M+J-L) = RM(L,M+J-L) + SL(L) * TEMP  06APO
            LXX = 1                                                     07APO
         IF ( IE.GT.1 )       LXX = IE                                  07APO
         IF ( IE.GT.1 )       IE = IE - 1                               07APO
            LXX = LXX + L                                               07APO
         DO 350  I = LXX, M                                             06APO
            RM(I,J+M-I) = RM(I,J+M-I) + RM(I-L,J+M-I) * TEMP            06APO
  350    CONTINUE                                                       06APO
  400    CONTINUE                                                       11JL8
         IF ( J.GT.M )  RM(M,J) = RM(M,J) + SL(M) * RM(M,J-M) * SL(M)   05APO
            RM(M,J) = -1.0 / RM(M,J)                                    11JL8
C        COMPUTE PRELIMINARY VALUE FOR W(J)                             25JL8
  750       W(J) = 0.0                                                  11JL8
         DO 800  I = 1 , J1                                             11JL8
            W(J) = W(J) + RM(M-I,J) * W(J-I)                            11JL8
  800    CONTINUE                                                       11JL8
```

```
         IF ( J.GT.M )  W(J) = W(J) + RO(J-M) * W(J-M)                  07APO
            W(J) = RM(M,J) * ( W(J) - F )                               11JL8
 1000    CONTINUE                                                       11JL8
C************************************************************************
C                        CALCULATE RECURSION EQUATION                  *
C************************************************************************
            K = 0                                                       11JL8
         DO 3000  L = 1, NLM1                                           06APO
            J = NL - L                                                  06APO
            TEMP = W(J)                                                 06APO
            W(J) = 0                                                    06APO
            K = K + 1                                                   11JL8
         DO 2100  I = 1, M1                                             06APO
            W(J) = W(J) + RM(M-I,J+I) * W(J+I)                          06APO
         IF ( I.EQ.K )       GO TO 2200                                 06APO
 2100    CONTINUE                                                       11JL8
 2200    IF ( J.LE.NLMM )    W(J) = W(J) + RO(J) * W(J,M)               06APO
            W(J) = RM(M,J) * W(J) + TEMP                                06APO
 3000    CONTINUE                                                       11JL8
      RETURN                                                            11JL8
      END                                                               11JL8
C
C        ****************************************************************
C                                SUBROUTINE
C        ****************************************************************
C
      SUBROUTINE FSUB1 ( SU, FF, M, L4 )                                26MY0
COMMENT - FSUB1 CALLS FSUB2, FOR FRAME SOLUTIONS AND FSUB22 FOR MEMBER  12JY1
COMMENT - SOLUTIONS                                                     12JY1
      DIMENSION SU (L4)                                                 26MY0
      COMMON /BLKS/ NFSUB,NITF,N1,N2                                    04JE0
         IF (NFSUB .EQ. 21) CALL FSUB21 (SU, FF, L4, M)                 26MY0
         IF (NFSUB .EQ. 22) CALL FSUB22 (SU, FF, L4)                    26MY0
      RETURN                                                            26MY0
      END                                                               26MY0
C
C        ****************************************************************
C                                SUBROUTINE
C        ****************************************************************
C
      SUBROUTINE FSUB21 ( SU4, FF, L4, IHB )                            29MY0
COMMENT - SUBROUTINE FSUB21 FURNISHES RIGHT SIDE OF SYMMETRIC STIFFNESS 21MY0
COMMENT - MATRIX SU4 AND LOAD TERM FF TO GRIP2A FOR FRAME SOLUTION      21MY0
COMMENT - SU4 IS ONE ROW OF STIFFNESS MATRIX AND FF IS CORRESPONDING    21MY0
COMMENT - LOAD                                                          21MY0
COMMENT - FSUB11 FORMS SSL (3 ROWS OF SU) AND FSS (3 LOADS) EVERY THIRD 21MY0
COMMENT - CALL FROM GRIP2A AND FURNISHES S4 AND FF FOR EACH CALL        21MY0
      DIMENSION SU4(L4)                                                 21MY0
      DIMENSION SMM(3,3),SMS(3,3),DC(3,3),DCT(3,3),T33(3,3),            21MY0
     2 FMM(3),FSS(3),FMS(3)                                             21MY0
      COMMON /BLOCK1/ X( 20),     Y( 20),     QXX( 20),   QYY( 20),     13FE0
     2    QZZ( 20),   SAX( 20),   SYY( 20),   SZZ( 20),   DXX( 20),     13FE0
     3    DYY( 20),   DZZ( 20),   RXX( 20),   RYY( 20),   RZZ( 20),     13FE0
     4    ERXX( 20),  ERYY( 20),  ERZZ( 20),  QMJ( 20),   WMJ( 20),     08AG0
     5    NSXX( 20),  NSYY( 20),  NSZZ( 20),  IMJ( 20),   NSXP( 20),    20MY1
     6    NSYP( 20),  ISTJR( 20)                                        20MY1
      COMMON /BLOCK2/ DXS( 25),   DYS( 25),   ZLS( 25),   DC1S( 25),    26JA0
     2    DC2S( 25),  PRF( 25),   PRAE( 25),  NCDS( 25),  IAXOPS( 25),  26JA0
     3    IOPOP( 25), IPINL( 25), IPINR( 25), NCS1( 25),  INLOP( 25),   17OC0
     4    NAL( 25),   NSXL( 25),  NSYL( 25),  NSZL( 25),  NAR( 25),     17OC0
     5    NSXR( 25),  NSYR( 25),  NSZR( 25),  QM( 25),    WM( 25)       17OC0
      COMMON /BLOCK3/ DXL( 25),   DYL( 25),   ZLL( 25),   DC1L( 25),    26JA0
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 2    DC2L( 25),  UQX( 25),   UQY( 25),   NCDL( 25),  IAXOPL( 25),  26JA0
 3    NC61( 25)                                                     26JA0
      COMMON /BLOCK4/ JT1( 40),   JT2( 40),   IST( 40),   LT( 40),  26JA0
 2    FOMM( 40,6), SMC( 40,21), NITM( 40), IMM( 40),  IMC( 40)      01JL1
      COMMON /BLOC10/ SSL(3,18)                                     09JU1
      COMMON /BLK1/  KEEP2, KEEP3, KEEP4A,KEEP5A,KEEP6, KEEP7,      26JA0
 2          ITYPE, NCD2,  NCD3,  NCD4A, NCD5A, NCD6,  NCD7,         26JA0
 3          IABAN, IFORM, NM,    NJT,   NST,   NLT,   TOL,          26JA0
 4          M,     MP1,   MP2,   ISTT,  LTT,   ITYPEL,IDJ,          12FE0
 5          NSTL,  IP8,   IP9,   IP10,  KEEP4B,KEEP4C,NCD4B,        05AG0
 6          NCD4C, KEEP5B,KEEP5C,KEEP5D,NCD5B, NCD5C, NCD5D         05AG0
      COMMON /BLK5/ NFSUB,NITF,N1,N2                                07MY1
      COMMON / RI / NL, ML, J1                                      08AP0
      COMMON /NIT/ APROB, PRINT                                     07MY1
            NL4 = NL                                                08AP0
            ML4 = ML                                                08AP0
            J14 = J1                                                08AP0
      IF (J14 .NE. 1 )  GO TO 1300                                  26JA0
COMMENT - SET CONSTANTS ON FIRST CALL FROM GRIP2A                   21MY0
            IHBP1 = IHB + 1                                         26JA0
            IHB1 = IHB - 1                                          26JA0
            DC(1,3) = 0.0                                           24JL1
            DC(2,3) = 0.0                                           24JL1
            DC(3,1) = 0.0                                           24JL1
            DC(3,2) = 0.0                                           24JL1
            DCT(1,3) = 0.0                                          24JL1
            DCT(2,3) = 0.0                                          24JL1
            DCT(3,1) = 0.0                                          24JL1
            DCT(3,2) = 0.0                                          24JL1
            DC(3,3) = 1.0                                           24JL1
            DCT(3,3) = 1.0                                          24JL1
COMMENT - COMPUTE JOINT NUMBER FOR WHICH EQUATIONS ARE BEING FORMED 21MY0
 1300       JTN = (J14 - 1)/3 + 1                                   26JA0
COMMENT - SKIP FOR EVERY SECOND AND THIRD EQUATION (CALL FROM GRIP2A) 21MY0
      IF (J14 .NE. 3*JTN - 2)  GO TO 4000                           26JA0
COMMENT - ZERO SSL AND FSS                                          21MY0
      DO 1400 I = 1, 3                                              26JA0
      DO 1400 J = 1,IHBP1                                           26JA0
 1400       SSL(I,J) = 0.0                                          26JA0
            FSS(1) = 0.0                                            24JL1
            FSS(2) = 0.0                                            24JL1
            FSS(3) = 0.0                                            24JL1
COMMENT - DO FOR EACH MEMBER - ADD ITS STIFFNESS MATRIX AND LOAD MATRIX 21MY0
COMMENT - INTO STRUCTURE STIFFNESS MATRIX SSL AND LOAD MATRIX FSS   21MY0
      DO 3500  JJ = 1,NM                                            02JE0
      IF   ( JT1(JJ) .NE. JTN .AND. JT2(JJ) .NE. JTN )   GO TO 3500 07MY1
            ISTT = IST(JJ)                                          02JE0
COMMENT - SKIP FOR NULL MEMBER                                      21MY0
      IF ( ISTT .EQ. 0 ) GO TO 3500                                 29JA0
COMMENT - FORM TRANSFORMATION MATRIX AND ITS TRANSPOSE              21MY0
            DC(1,1) = DC1S(ISTT)                                    26JA0
            DC(1,2) = DC2S(ISTT)                                    26JA0
            DC(2,1) = - DC(1,2)                                     26JA0
            DC(2,2) = DC(1,1)                                       26JA0
            DCT(1,1) = DC(1,1)                                      26JA0
            DCT(1,2) = DC(2,1)                                      26JA0
            DCT(2,1) = DC(1,2)                                      26JA0
            DCT(2,2) = DC(2,2)                                      25JA0
      IF ( JT2(JJ) .EQ. JTN ) GO TO 2300                            02JE0
COMMENT - FORM SMM FOR MEMBER WITH FROM JOINT AT JOINT JTN          21MY0
            SMM(1,1) = SMC(JJ,1)                                    02JE0
            SMM(1,2) = SMC(JJ,2)                                    02JE0
            SMM(1,3) = SMC(JJ,3)                                    02JE0
            SMM(2,1) = SMC(JJ,2)                                    02JE0
            SMM(2,2) = SMC(JJ,7)                                    02JE0
            SMM(2,3) = SMC(JJ,8)                                    29MY0
            SMM(3,1) = SMC(JJ,3)                                    29MY0
            SMM(3,2) = SMC(JJ,8)                                    29MY0
            SMM(3,3) = SMC(JJ,12)                                   29MY0
COMMENT - FORM FMM FOR MEMBER WITH FROM JOINT AT JOINT JTN          21MY0
 2250       FMM(1) =  FOMM(JJ,1)                                    20MY0
            FMM(2) =  FOMM(JJ,2)                                    20MY0
            FMM(3) =  FOMM(JJ,3)                                    20MY0
      GO TO 2500                                                    26JA0
 2300 CONTINUE                                                      27JA0
COMMENT - FORM SMM FOR MEMBER WITH  TO  JOINT AT JOINT JTN          21MY0
            SMM(1,1) = SMC(JJ,16)                                   29MY0
            SMM(1,2) = SMC(JJ,17)                                   29MY0
            SMM(1,3) = SMC(JJ,18)                                   29MY0
            SMM(2,1) = SMC(JJ,17)                                   29MY0
            SMM(2,2) = SMC(JJ,19)                                   29MY0
            SMM(2,3) = SMC(JJ,20)                                   29MY0
            SMM(3,1) = SMC(JJ,18)                                   29MY0
            SMM(3,2) = SMC(JJ,20)                                   29MY0
            SMM(3,3) = SMC(JJ,21)                                   29MY0
COMMENT - FORM FMM FOR MEMBER WITH  TO  JOINT AT JOINT JTN          21MY0
 2350       FMM(1) =  FOMM(JJ,4)                                    21MY0
            FMM(2) =  FOMM(JJ,5)                                    21MY0
            FMM(3) =  FOMM(JJ,6)                                    21MY0
 2500 CONTINUE                                                      26JA0
COMMENT - TRANSFORM SMM AND FMM TO STRUCTURE COORDINATES SMS AND FMS 21MY0
      CALL MATM33 ( DCT, SMM, T33)                                  20MY0
      CALL MATM33 ( T33, DC,  SMS)                                  20MY0
 2550 CALL MATM31 ( DCT, FMM, FMS)                                  20MY0
COMMENT - ADD (SUBTRACT) IN FMS TO STRUCTURE LOAD MATRIX FSS        21MY0
            FSS(1) = FSS(1) - FMS(1)                                20MY0
            FSS(2) = FSS(2) - FMS(2)                                20MY0
            FSS(3) = FSS(3) - FMS(3)                                20MY0
COMMENT - ADD IN SMS TO DIAGONAL SUBMATRIX OF SSL - SYMMETRICAL TERMS 21MY0
            SSL(1,1) = SSL(1,1)   +   SMS(1,1)                      20MY0
            SSL(1,2) = SSL(1,2)   +   SMS(1,2)                      20MY0
            SSL(1,3) = SSL(1,3)   +   SMS(1,3)                      20MY0
            SSL(2,2) = SSL(2,2)   +   SMS(2,2)                      20MY0
            SSL(2,3) = SSL(2,3)   +   SMS(2,3)                      20MY0
            SSL(3,3) = SSL(3,3)   +   SMS(3,3)                      20MY0
COMMENT - SKIP FOR SMM WHICH ARE TO LEFT OF DIAGONAL                21MY0
      IF ( JTN .GE. JT1(JJ) .AND. JTN .GE. JT2(JJ) ) GO TO 3500     02JE0
      IF ( JT2(JJ) .EQ. JTN ) GO TO 2700                            02JE0
COMMENT - FORM SMM FOR MEMBER WITH FROM JOINT AT JOINT JTN          21MY0
            SMM(1,1) = SMC(JJ,4)                                    29MY0
            SMM(1,2) = SMC(JJ,5)                                    29MY0
            SMM(1,3) = SMC(JJ,6)                                    29MY0
            SMM(2,1) = SMC(JJ,9)                                    29MY0
            SMM(2,2) = SMC(JJ,10)                                   29MY0
            SMM(2,3) = SMC(JJ,11)                                   29MY0
            SMM(3,1) = SMC(JJ,13)                                   29MY0
            SMM(3,2) = SMC(JJ,14)                                   29MY0
            SMM(3,3) = SMC(JJ,15)                                   29MY0
      GO TO 3000                                                    26JA0
COMMENT - FORM SMM FOR MEMBER WITH  TO  JOINT AT JOINT JTN          21MY0
 2700       SMM(1,1) = SMC(JJ,4)                                    29MY0
            SMM(1,2) = SMC(JJ,9)                                    29MY0
            SMM(1,3) = SMC(JJ,13)                                   29MY0
            SMM(2,1) = SMC(JJ,5)                                    29MY0
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             SMM(2,2) = SMC(JJ,10)                                       29MY0
             SMM(2,3) = SMC(JJ,14)                                       29MY0
             SMM(3,1) = SMC(JJ,6)                                        29MY0
             SMM(3,2) = SMC(JJ,11)                                       29MY0
             SMM(3,3) = SMC(JJ,15)                                       29MY0
 3000     CONTINUE                                                       26JA0
COMMENT - TRANSFORM SMM TO STRUCTURE COORDINATES SMS                     21MY0
      CALL        MATM33 ( DCT, SMM, T33 )                               20MY0
      CALL        MATM33 ( T33, DC, SMS )                                20MY0
COMMENT - PLACE SMS IN SSL                                               21MY0
             J21 =        JT2(JJ) - JT1(JJ)                              07MY1
             J21 = IABS(J21)                                             07MY1
             ISTP = 3*J21 + 1                                            26JA0
             SSL(1,ISTP)        =  SMS(1,1)                              20MY0
             SSL(1,ISTP + 1)    =  SMS(1,2)                              20MY0
             SSL(1,ISTP + 2)    =  SMS(1,3)                              20MY0
             SSL(2,ISTP)        =  SMS(2,1)                              20MY0
             SSL(2,ISTP + 1)    =  SMS(2,2)                              20MY0
             SSL(2,ISTP + 2)    =  SMS(2,3)                              20MY0
             SSL(3,ISTP)        =  SMS(3,1)                              20MY0
             SSL(3,ISTP + 2)    =  SMS(3,3)                              20MY0
             SSL(3,ISTP + 1)    =  SMS(3,2)                              20MY0
 3500     CONTINUE                                                       26JA0
COMMENT - CALL JNTSPR TO FIND SPRING RESISTIVE FORCES AND TANGENT STIFF  01JU1
COMMENT - NESSES  - SPRING FORCES ARE ADDED INTO LOAD MATRIX ONLY ON     01JU1
COMMENT - FIRST ITERATION FROM A ZERO DISPLACEMENT START                  1JU1
      CALL        JNTSPR (SJX, SJY, SJZ, SJXY, QJX, QJY, QJZ, JTN)       20MY1
COMMENT - ADD IN JOINT LOADS                                             21MY0
          IF (NITF .EQ. 1 .AND. ITYPE .EQ. 1) GO TO 3550                 24JL1
             QJX = 0.0                                                   24JL1
             QJY = 0.0                                                   24JL1
             QJZ = 0.0                                                   24JL1
 3550     CONTINUE                                                       24JL1
             FSS(1) = FSS(1) + ERXX(JTN) + QJX                           12AG0
             FSS(2) = FSS(2) + ERYY(JTN) + QJY                           12AG0
             FSS(3) = FSS(3) + ERZZ(JTN) + QJZ                           12AG0
COMMENT - ADD IN JOINT RESTRAINTS                                        21MY0
             SSL(1,1) = SSL(1,1) + SXX(JTN) + SJX                        11AG0
             SSL(1,2) = SSL(1,2) + SJXY                                  21MY1
             SSL(2,2) = SSL(2,2) + SYY(JTN) + SJY                        11AG0
             SSL(3,3) = SSL(3,3) + SZZ(JTN) + SJZ                        11AG0
COMMENT - SHIFT SSL TO FACILITATE OBTAINING SU FROM 2ND AND 3RD ROW      21MY0
COMMENT - OF SSL                                                         21MY0
          DO 3600  I = 1,IMB                                             27JA0
 3600        SSL(2,I) = SSL(2, I + 1)                                    27JA0
          DO 3700  I = 1,IMB1                                            27JA0
 3700        SSL(3,I) = SSL(3,I + 2)                                     27JA0
             SSL(2,IMBP1) = 0.0                                          24JL1
             SSL(3,IMBP1) = 0.0                                          24JL1
             SSL(3,IMB)   = 0.0                                          24JL1
 4000     CONTINUE                                                       26JA0
             N123 =  J14 - 3*JTN + 3                                     05MR0
             IC = IMBP1                                                  27JA0
COMMENT - FORM SU FROM ROW(N123) OF SSL                                  21MY0
          DO 4300  I = 1,IMBP1                                           27JA0
             SU4(I) = SSL(N123,IC)                                       27JA0
 4300        IC = IC - 1                                                 27JA0
 4400        FF = FSS(N123)                                              27JA0
 4450        K = IMBP1                                                   05MR0
          IF (SU4(K) .NE. 0.0) GO TO 4500                                05MR0
COMMENT - ZERO ON DIAGONAL OF MATRIX - DISPLACEMENT UNDEFINED - SET      21MY0
COMMENT - DISPLACEMENT EQUAL TO 1.0E40                                   21MY0
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             SU4(K)  = 1.0                                               05MR0
 4480        FF = 1.0E40                                                 05MR0
 4500     CONTINUE                                                       05MR0
          IF (APROB .NE. PRINT) GO TO 77777                              07MY1
COMMENT - DUMP OF STRUCTURE STIFFNESS AND LOAD MATRIX, TO ACTIVATE SET   01JU1
COMMENT - LAST FIVE COLUMNS IN PROBLEM NUMBER CARD EQUAL TO PRINT        01JU1
      PRINT 4778,(SU4(I), I = 1,IMBP1), FF                               07MY1
 4778 FORMAT (1X, 10E11.3)                                               07MY1
77777     CONTINUE                                                       07MY1
      RETURN                                                             26JA0
      END                                                                26JA0
C
C         ****************************************************************
C                                 SUBROUTINE
C         ****************************************************************
C
      SUBROUTINE FSUB22 (SU, FF, L4)                                     26MY0
COMMENT - FSUB22 FURNISHES THE RIGHT SIDE OF SYMMETRIC STIFFNESS MATRIX  14JL1
COMMENT - SU AND LOAD TERM FF TO GRIP2A FOR MEMBER SOLUTIONS             14JL1
COMMENT - SU IS ONE ROW OF STIFFNESS MATRIX AND FF IS CORRESPONDING LOAD 14JL1
COMMENT - FSUB22 FORMS SEM ( 3 ROWS OF SU ) AND FEM ( 3 LOADS ) EVERY    14JL1
COMMENT - THIRD CALL FROM GRIP2A AND FURNISHES SU AND FF FOR EACH CALL   14JL1
      DIMENSION SU(L4)                                                   26MY0
      DIMENSION SEMS(3,3), SEM(3,6),FEM(3),SA(3,3)                       27MY0
      COMMON /BLOCK2/ DXS( 25),   DYS( 25),   ZLS( 25),   DC1S( 25),     26JA0
     2    DC2S( 25),  PRF( 25),   PRAE( 25),  NCDS( 25),  IAXOPS( 25),   26JA0
     3    IOPOP( 25), IPINL( 25), IPINR( 25), NC5I( 25),  INLOP( 25),    17OC0
     4    NAL( 25),   NSXL( 25),  NSYL( 25),  NSZL( 25),  NAR( 25),      17OC0
     5    NSXR( 25),  NSYR( 25),  NSZR( 25),  QM( 25),    WM( 25)        17OC0
      COMMON /BLOCK7/ F( 42),     AE( 42),    SX( 42),    SY( 42),       04JE0
     2    SZ( 42),    QX( 42),    QY( 42),    QZ( 42),    DX( 42),       04JE0
     3    DY( 42),    DZ( 42),    ERX( 42),   ERY( 42),   ERZ( 42),      04JE0
     4    SQX( 42),   SQY( 42),   SQZ( 42),   U1( 42),    V1( 42),       04JE0
     5    W1( 42),    U2( 42),    V2( 42),    W2( 42),    OS(3,3, 42),   29JA1
     6    BM1S( 42),  BM2S( 42),  TTS( 42)                               29JA1
      COMMON /BLOC11/ SEET(6,6)                                          30JE0
      COMMON /BLK1/  KEEP2, KEEP3, KEEP4A,KEEP5A,KEEP6, KEEP7,           26JA0
     2        ITYPE, NCD2,  NCD3,  NCD4A, NCD5A, NCD6,  NCD7,            26JA0
     3        IABAN, IFORM, NM,    NJT,   NST,   NLT,   TOL,             26JA0
     4        M,     MP1,   MP2,   ISTT,  LTT,   ITYPEL,IDJ,             12FE0
     5        NSTL,  IP8,   IP9,   IP10,  KEEP4B,KEEP4C,NCD4B,           05AG0
     6        NCD4C, KEEP5B,KEEP5C,KEEP5D,NCD5B, NCD5C, NCD5D            05AG0
      COMMON /BLK2/ XL,XR,X1,X2,I1,I2,NQ,M,TH,HSQ,HCU,X2L                26JA0
      COMMON / R1 / NL, ML, J1                                           26MY0
             IAXOPT = IAXOPS(ISTT)                                       09SE0
COMMENT - I IS STATION NUM -- IP1 IS ELEMENT NUM -- J1 IS EQUATION NUM   14JL1
             I = (J1 - 1)/3 + 1                                          26MY0
COMMENT - SKIP FOR EVERY SECOND AND THIRD EQUATION                       14JL1
          IF (J1 .NE. 3*I - 2) GO TO 4000                                26MY0
          IF (ML .EQ. -1) GO TO 2800                                     07MY1
          IF (I .NE. 1) GO TO 2100                                       26MY0
          DO 1600  JJ = 1, 3                                             26MY0
          DO 1600  KK = 1, 3                                             26MY0
             SEMS(JJ,KK) = 0.0                                           26MY0
 1600     CONTINUE                                                       26MY0
 2100     CONTINUE                                                       26MY0
          IF (I .LT. MP1) GO TO 2400                                     15SE0
          DO 2300  JJ = 1,6                                              15SE0
          DO 2300  KK = 1,6                                              15SE0
 2300        SEET(JJ,KK) = 0.0                                           15SE0
          GO TO 2500                                                     15SE0
 2400        IP1 = I + 1                                                 15SE0
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COMMENT - CALL ELEMST TO OBTAIN 6 X 6 ELEMENT STIFFNESS MATRIX          14JL1
      CALL       ELEMST (IPI)                                           15SE0
 2500     CONTINUE                                                      15SE0
COMMENT - FORM THREE ROWS OF MEMBER STIFFNESS MATRIX SEM                14JL1

          DO 2600  JJ = 1, 3                                            26MY0
          DO 2600  KK = 1, 3                                            26MY0
               SEM(JJ,KK) = SEET(JJ,KK) + SEMS(JJ,KK)                   26MY0
               SEM(JJ,KK + 3) = SEET(JJ,KK + 3)                         26MY0
               SEMS(JJ,KK) = SEET(JJ+ 3, KK + 3)                        26MY0
 2600     CONTINUE                                                      26MY0
COMMENT - ADD IN SPRING STIFFNESSES                                     14JL1
               SEM(3,3) = SEM(3,3) + SZ(I)                              26MY0
          IF (I .EQ. 1 .OR. I .EQ. MP1) GO TO 2650                      07MY1
          IF ( IAXOPT .EQ. 2) GO TO 2700                                05SE0
 2650          SEM(1,1) = SEM(1,1) + SX(I)                              26MY0
               SEM(2,2) = SEM(2,2) + SY(I)                              26MY0
          GO TO 2800                                                    05SE0
COMMENT - MEMBER SPRINGS IN STRUCTURE DIRECTIONS                        14JL1
 2700          SXT = SX(I)                                              05SE0
               SYT = SY(I)                                              05SE0
      CALL         SANGLE (SA,SXT,SYT)                                  05SE0
               SEM(1,1) = SEM(1,1) + SA(1,1)                            05SE0
               SEM(1,2) = SEM(1,2) + SA(1,2)                            05SE0
               SEM(2,1) = SEM(2,1) + SA(2,1)                            05SE0
               SEM(2,2) = SEM(2,2) + SA(2,2)                            05SE0
 2800          FEM(1) = ERX(I)                                          26MY0
               FEM(2) = ERY(I)                                          26MY0
               FEM(3) = ERZ(I)                                          26MY0
          DO 3600  K = 1,5                                              27JA0
 3600          SEM(2,K) = SEM(2, K + 1)                                 27JA0
          DO 3700  K = 1,4                                              27JA0
 3700          SEM(3,K) = SEM(3,K + 2)                                  27JA0
               SEM(2,6) = 0.0                                           24JL1
               SEM(3,6) = 0.0                                           24JL1
               SEM(3,5) = 0.0                                           24JL1
 4000     CONTINUE                                                      26MY0
               N123 = J1 - 3*I + 3                                      26MY0
          IF (ML .EQ. -I) GO TO 4300                                    28MY0
               IC = 6                                                   26MY0
COMMENT - FORM SU FROM ONE ROW OF SEM                                   14JL1
          DO 4200  JJ = 1, 6                                            26MY0
               SU(JJ) = SEM(N123,IC)                                    26MY0
 4200          IC = IC - 1                                              26MY0
 4300           FF = FEM(N123)                                          28MY0
      RETURN                                                            26MY0
      END                                                               26MY0
C
C         ******************************************************************
C                                     SUBROUTINE
C         ******************************************************************
C
      SUBROUTINE ELEMST (I)                                             21MY0
COMMENT - SUBROUTINE ELEMST FORMS THE ELEMENT 6 X 6 STIFFNESS MATRIX    13JU1
      DIMENSION B(6,6), BT(6,6), D(6,6), TM(6,6)                        21MY0
      COMMON /BLOCK7/ F( 42),     AE( 42),     SX( 42),     SY( 42),    04JE0
     2     SZ( 42),     QX( 42),     QY( 42),     QZ( 42),     DX( 42), 04JE0
     3     DY( 42),     DZ( 42),     ERX( 42),    ERY( 42),    ERZ( 42),04JE0
     4     SQX( 42),    SQY( 42),    SQZ( 42),    U1( 42),     V1( 42), 04JE0
     5     W1( 42),     U2( 42),     V2( 42),     W2( 42),   DS(3,3, 42),29JA1
     6     BM1S( 42),   BM2S( 42),   TTS( 42)                           29JA1
      COMMON /BLOC11/ SEET(6,6)                                         21MY0
      COMMON /BLK2/ XL,XR,X1,X2,I1,I2,NQ,H,TH,HSQ,HCU,X2L               26JA0
      COMMON /BLK7/ INLOPT,IFAE,KOFFJ,KOFFQW,KOFFSE                     07AP1
               IM1 = I - 1                                              21MY0
COMMENT - COMPUTE ELEMENT DEFORMATIONS                                  13JU1
               DDX = DX(I) - DX(IM1)                                    21MY0
               DDY = DY(I) - DY(IM1)                                    21MY0
               DZ1 = DZ(IM1)                                            21MY0
               DZ2 = DZ(I)                                              21MY0
               COSIM1 = COS(DZ1)                                        21MY0
               COSI   = COS(DZ2)                                        21MY0
               SINIM1 = SIN(DZ1)                                        21MY0
               SINI   = SIN(DZ2)                                        21MY0
               COSCOS = COSI + COSIM1                                   21MY0
               SINSIN = SINI + SINIM1                                   21MY0
               R = DDX + H*(1.0 - 0.5*COSCOS)                           21MY0
               S = DDY - 0.5*H*SINSIN                                   21MY0
               HPR = H + R                                              21MY0
               HPD = (HPR*HPR + S*S)**0.5                               21MY0
               DELTA     = HPD - H                                      21MY0
               THETA = ATAN(S/HPR)                                      21MY0
               TAU1 = THETA - DZ1                                       21MY0
               TAU2 = DZ2 - THETA                                       21MY0
COMMENT - COMPUTE FOR CONVENIENCE                                       13JU1
               HPRS1 = HPR*SINIM1                                       21MY0
               HPRS2 = HPR*SINI                                         21MY0
               HPRC1 = HPR*COSIM1                                       21MY0
               HPRC2 = HPR*COSI                                         21MY0
               SC1    = S*COSIM1                                        21MY0
               SC2    = S*COSI                                          21MY0
               SS1    = S*SINIM1                                        21MY0
               SS2    = S*SINI                                          21MY0
               HPDE1I = 1.0/HPD                                         21MY0
               HPDE2I = HPDE1I*HPDE1I                                   21MY0
               HO2 = 0.5*H                                              21MY0
COMMENT - FORM THE TRANSPOSE OF THE ELEMENT DEFORMATION-DISPLACEMENT    13JU1
COMMENT - MATRIX                                                        13JU1
               BT(1,1)  = -HPR*HPDE1I                                   21MY0
               BT(2,1)  = -S*HPDE1I                                     21MY0
               BT(3,1)  = HO2*HPDE1I*(HPRS1 - SC1)                      21MY0
               BT(4,1) = - BT(1,1)                                      21MY0
               BT(5,1) = - BT(2,1)                                      21MY0
               BT(6,1)  = HO2*HPDE1I*(HPRS2 - SC2)                      21MY0
               BT(1,2)  = S*HPDE2I                                      21MY0
               BT(2,2)  = -HPR*HPDE2I                                   21MY0
               BT(3,2)  = -1.0 -HO2*HPDE2I*(HPRC1 + SS1)                21MY0
               BT(4,2) = -BT(1,2)                                       21MY0
               BT(5,2) = -BT(2,2)                                       21MY0
               BT(6,2)  = -HO2*HPDE2I*(HPRC2 + SS2)                     21MY0
               BT(1,3) = BT(4,2)                                        21MY0
               BT(2,3) = BT(5,2)                                        21MY0
               BT(3,3)  = HO2*HPDE2I*(HPRC1 + SS1)                      21MY0
               BT(4,3) = BT(1,2)                                        21MY0
               BT(5,3) = BT(2,2)                                        21MY0
               BT(6,3)  = 1.0 - BT(6,2)                                 21MY0
          IF (IFAE .EQ. 1) GO TO 700                                    29JA1
          DO 500  J = 1,3                                               29JA1
          DO 500  K = 1,3                                               29JA1
 500           D(J,K) = DS(J,K,I)                                       29JA1
               TT = TTS(I)                                              29JA1
               BM1 = BM1S(I)                                            29JA1
               BM2 = BM2S(I)                                            29JA1
          GO TO 800                                                     07MY1
```

```
COMMENT - CALL FAE TO FIND INTERNAL FORCES IN ELEMENT TT, VM1, BM2 AND  13JU1
COMMENT - ELEMENT FORCE-DEFORMATION MATRIX D                            13JU1
  700 CALL      FAE (DELTA, TAU1, TAU2, I, D, TT, BM1, BM2 )            07MY1
  800     CONTINUE                                                      07MY1
COMMENT - FORM FIRST PART OF TRIPLE PRODUCT                             13JU1
      CALL      MATMPY (BT,6,3,D,3,TM)                                  21MY0
COMMENT - FORM THE ELEMENT DEFORMATION-DISPLACEMENT MATRIX              13JU1
          DO 850 K = 1,3                                                21MY0
          DO 850  J = 1,6                                               21MY0
  850        B(K,J) = BT(J,K)                                           21MY0
COMMENT - COMPLETE THE TRIPLE PRODUCT                                   13JU1
      CALL      MATMPY (TM,6,3,B,6,SEET)                                21MY0
COMMENT - COMPUTE FOR CONVENIENCE                                       12JU1
                HPDE3I = HPDE2I*HPDE1I                                  21MY0
                SE2       = S*S                                         21MY0
                HPRE2     = HPR*HPR                                     21MY0
                TTM       = TT*HPDE3I                                   21MY0
                TTMHO2    = TTM*HO2                                     21MY0
                HPDE2     = HPD*HPD                                     21MY0
COMMENT - COMPUTE THE PORTION OF THE INITIAL STRESS MATRIX DUE TO THRUST13JU1
                TM(1,1)  =  TTM*SE2                                     21MY0
                TM(1,2)  = -TTM*S*HPR                                   21MY0
                TM(1,3)  = -TTMHO2 *S*(SS1 + HPRC1)                     21MY0
                TM(1,4)  = -TM(1,1)                                     21MY0
                TM(1,5)  = -TM(1,2)                                     21MY0
                TM(1,6)  = -TTMHO2 *S*(SS2 + HPRC2)                     21MY0
                TM(2,2)  =  TTM*HPRE2                                   21MY0
                TM(2,3)  =  TTM*HO2*HPR*(SS1 + HPRC1)                   21MY0
                TM(2,4)  =  TM(1,5)                                     21MY0
                TM(2,5)  = -TM(2,2)                                     21MY0
                TM(2,6)  =  TTMHO2 *HPR*(SS2 + HPRC2)                   21MY0
                TM(3,3)  =  TTMHO2 *(HO2*(SS1 + HPRC1)**2     +         21MY0
     2                          HPDE2*(SS1 + HPRC1))                    21MY0
                TM(3,4)  = -TM(1,3)                                     21MY0
                TM(3,5)  = -TM(2,3)                                     21MY0
                TM(3,6)  =  TTMHO2 * HO2*(SS1 + HPRC1)*(SS2 + HPRC2)    21MY0
                TM(4,4)  =  TM(1,1)                                     21MY0
                TM(4,5)  =  TM(1,2)                                     21MY0
                TM(4,6)  = -TM(1,6)                                     21MY0
                TM(5,5)  =  TM(2,2)                                     21MY0
                TM(5,6)  = -TM(2,6)                                     21MY0
                TM(6,6)  =  TTMHO2 *(HO2*(SS2 + HPRC2)**2     +         21MY0
     2                          HPDE2*(SS2 + HPRC2))                    21MY0
                N1 = 0                                                  21MY0
COMMENT - ADD ON TO ELEMENT STIFFNESS MATRIX                            13JU1
          DO 998  K = 1,6                                               21MY0
                N1  = N1 + 1                                            21MY0
          DO 998 J = N1, 6                                              21MY0
                SEET(K,J) = SEET(K,J) + TM(K,J)                         21MY0
                SEET(J,K) = SEET(K,J)                                   21MY0
  998     CONTINUE                                                      21MY0
                VT = (BM2 - BM1)/HPD                                    21MY0
                VTM       = VT*HPDE3I                                   21MY0
                VTMHO2    = VTM*HO2                                     21MY0
                HPRS      = HPRE2 - SE2                                 21MY0
COMMENT - COMPUTE THE PORTION OF THE INITIAL STRESS MATRIX DUE TO SHEAR 13JU1
                TM(1,1)  = -VTM*HPR*S*2.0                               21MY0
                TM(1,2)  =  VTM*HPRS                                    21MY0
                TM(1,3)  =  VTMHO2*(HPRS*COSIM1 + S*HPR*SINIM1*2.0)     21MY0
                TM(1,4)  = -TM(1,1)                                     21MY0
                TM(1,5)  = -TM(1,2)                                     21MY0
                TM(1,6)  =  VTMHO2*(HPRS*COSI    + S*HPR*SINI   *2.0)   21MY0
```

```
                TM(2,2) = -TM(1,1)                                      21MY0
                TM(2,3)  =  VTMHO2*(-HPRS*SINIM1 + S*HPR*COSIM1*2.0)    21MY0
                TM(2,4)  =  TM(1,5)                                     21MY0
                TM(2,5)  = -TM(2,2)                                     21MY0
                TM(2,6)  =  VTMHO2*(-HPRS*SINI    + S*HPR*COSI   *2.0)  21MY0
                TM(3,3)  = -VTMHO2*(HPDE2*(HPR*SINIM1 - S*COSIM1)   +   21MY0
     2    H*HPRS*SINIM1*COSIM1 + H   *HPR*S*(SINIM1**2    - COSIM1**2  )) 21MY0
                TM(3,4)  = -TM(1,3)                                     21MY0
                TM(3,5)  = -TM(2,3)                                     21MY0
                TM(3,6)  = -VTMHO2*HO2*(HPRS*(SINIM1*COSI + COSIM1*SINI) 21MY0
     2     +  S*HPR*(SINIM1*SINI - COSIM1*COSI)*2.0)                    21MY0
                TM(4,4)  =  TM(1,1)                                     21MY0
                TM(4,5)  =  TM(1,2)                                     21MY0
                TM(4,6)  = -TM(1,6)                                     21MY0
                TM(5,5)  =  TM(2,2)                                     21MY0
                TM(5,6)  = -TM(2,6)                                     21MY0
                TM(6,6)  = -VTMHO2*(HPDE2*(HPR*SINI    - S*COSI   )  +  21MY0
     2    H*HPRS*SINI   *COSI    + H   *HPR*S*(SINI    **2    - COSI   **2  )) 21MY0
                N1 = 0                                                  21MY0
COMMENT - ADD ON TO ELEMENT STIFFNESS MATRIX                            13JU1
          DO 999  K = 1,6                                               21MY0
                N1  = N1 + 1                                            21MY0
          DO 999 J = N1, 6                                              21MY0
                SEET(K,J) = SEET(K,J) + TM(K,J)                         21MY0
                SEET(J,K) = SEET(K,J)                                   21MY0
  999     CONTINUE                                                      21MY0
      RETURN                                                            21MY0
      END                                                               21MY0
C
C         ******************************************************************
C                                   SUBROUTINE
C         ******************************************************************
C
C
      SUBROUTINE ELEMFO (DX1,DY1,DZ1,DX2,DY2,DZ2,I,U1T,V1T,W1T,U2T,V2T, 21MY0
     2    W2T)                                                          21MY0
COMMENT - SUBROUTINE ELEMFO EVALUATES THE END-FORCES ON A DISCRETE      17JU1
COMMENT - ELEMNT, GIVEN THE ELEMENT-END-DISPLACEMENTS                   17JU1
      DIMENSION D(6,6)                                                  01NO0
      COMMON /BLOCK7/ F( 42),     AE( 42),     SX( 42),     SY( 42),    04JE0
     2      SZ( 42),     QX( 42),     QY( 42),     QZ( 42),     DX( 42), 21MY0
     3     DY( 42),     DZ( 42),     ERX( 42),    ERY( 42),    ERZ( 42), 21MY0
     4     SQX( 42),    SQY( 42),    SQZ( 42),    U1( 42),     V1( 42), 04JE0
     5     W1( 42),     U2( 42),     V2( 42),     W2( 42),     OS(3,3, 42), 29JA1
     6     BM1S( 42),   BM2S( 42),   TTS( 42)                           29JA1
      COMMON /BLK2/ XL,XR,X1,X2,I1,I2,NQ,H,TH,HSQ,HCU,X2L               21MY0
COMMENT - COMPUTE THE ELEMENT DEFORMATIONS                              13JU1
                DDX = DX2 - DX1                                         21MY0
                DDY = DY2 - DY1                                         21MY0
                COSIM1 = COS(DZ1)                                       21MY0
                COSI   = COS(DZ2)                                       21MY0
                SINIM1 = SIN(DZ1)                                       21MY0
                SINI   = SIN(DZ2)                                       21MY0
                COSCOS = COSI + COSIM1                                  21MY0
                SINSIN = SINI + SINIM1                                  21MY0
                R = DDX + H*(1.0 - 0.5*COSCOS)                          21MY0
                S = DDY - 0.5*H*SINSIN                                  21MY0
                DELTA = ((H + R)*(H + R) + S*S)**0.5 - H                21MY0
                TTHETA = S/(H + R)                                      21MY0
                THETA =  ATAN(TTHETA)                                   21MY0
                TAU1 = THETA -  DZ1                                     21MY0
                TAU2 =  DZ2 - THETA                                     21MY0
                SINT = S/(H + DELTA)                                    21MY0
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                COST = (H + R)/(H + DELTA)                                 21MY0
COMMENT - CALL FAE TO COMPUTE THE INTERNAL FORCES IN THE ELEMENT          13JU1
      CALL       FAE ( DELTA, TAU1, TAU2, I, D, TT, BM1, BM2 )             01NO0
                VT  = (BM2 - BM1) /(H + DELTA)                             21MY0
                U2T = TT*COST   + VT*SINT                                  21MY0
                V2T = TT*SINT  -  VT*COST                                  21MY0
                U1T = -U2T                                                 21MY0
                V1T = -V2T                                                 23MY0
                W1T = -BM1 + 0.5*(- U1T*SINIM1 +  V1T*COSIM1)*H            23MY0
                W2T =  BM2 + 0.5*(- U1T*SINI   +  V1T*COSI  )*H            23MY0
COMMENT - STORE FOR USE BY ELEMST                                          13JU1
          DO 2100  J = 1,3                                                 29JA1
          DO 2100  K = 1,3                                                 29JA1
 2100           DS(J,K,I) = D(J,K)                                         29JA1
                TTS(I) =TT                                                 29JA1
                BM1S(I) = BM1                                              29JA1
                BM2S(I) = BM2                                              29JA1
                RETURN                                                     23MY0
      END                                                                  23MY0
C
C         *****************************************************************
C                              SUBROUTINE
C         *****************************************************************
C
      SUBROUTINE MATMPY(A,M1,N1,B,N2,C)                                    07MY1
COMMENT - SUBROUTINE MATMPY MULTIPLIES A N1XM1 MATRIX A TIMES A N1XN2     13JU1
COMMENT - MATRIX B TO YIELD THE M1XN2 MATRIX C                             13JU1
      DIMENSION A(6,6), B(6,6), C(6,6)                                     07MY1
      DO 25 I = 1,M1                                                       07MY1
      DO 25 J = 1,N2                                                       07MY1
      C(I,J) = 0                                                           07MY1
      DO 25 K = 1,N1                                                       07MY1
   25 C(I,J)= A(I,K)*B(K,J) + C(I,J)                                       07MY1
   11 RETURN                                                               07MY1
      END                                                                  07MY1
C
C         *****************************************************************
C                              SUBROUTINE
C         *****************************************************************
C
      SUBROUTINE  FAE (DELTA, TAU1, TAU2, I, D, TT, BM1, BM2)              02NO0
COMMENT - SUBROUTINE FAE COMPUTES THE AVERAGE AXIAL THRUST AND THE        02JL1
COMMENT - BENDING MOMENTS AT THE TWO DISCRETE HINGES IN AN ELEMENT, AND  02JL1
COMMENT - ALSO THE INCREMENTAL FORCE-DEFORMATION MATRIX FOR AN ELEMENT   02JL1
COMMENT - FOR LINEAR STRESS-STRAIN CURVES (INLOPT = 0) THE EQUATIONS OF  02JL1
COMMENT - FRAME 21 ARE USED FOR NONLINEAR STRESS-STRAIN CURVES            02JL1
COMMENT - (INLOPT = 1) A NUMERICAL INTEGRATION IS DONE                     02JL1
      DIMENSION D(6,6)                                                     02NO0
      COMMON /BLOCK2/ DXS( 25),   DYS( 25),   ZLS( 25),   DC1S( 25),       26JA0
     2    DC2S( 25),  PRF( 25),   PRAE( 25),  NCDS( 25),  IAXOPS( 25),     26JA0
     3    IOPOP( 25), IPINL( 25), IPINR( 25), NC51( 25),  INLOP( 25),      17OC0
     4    NAL( 25),   NSXL( 25),  NSYL( 25),  NSZL( 25),  NAR( 25),        17OC0
     5    NSXR( 25),  NSYR( 25),  NSZR( 25),  QM( 25),    WM( 25)          17OC0
      COMMON /BLOCK7/ F( 42),     AE( 42),    SX( 42),    SY( 42),         04JE0
     2    SZ( 42),    QX( 42),    QY( 42),    QZ( 42),    DX( 42),         04JE0
     3    DY( 42),    DZ( 42),    ERX( 42),   ERY( 42),   ERZ( 42),        04JE0
     4    SQX( 42),   SQY( 42),   SQZ( 42),   U1( 42),    V1( 42),         04JE0
     5    W1( 42),    U2( 42),    V2( 42),    W2( 42),    DS(3,3, 42),     29JA1
     6    BM1S( 42),  BM2S( 42),  TTS( 42)                                 29JA1
      COMMON /BLOCK9/ BCL(10),    DBCL(10),   DCL(10),    DDCL(10),        11JU1
     2    YCL(10),    DYCL(10),   NSSL(10),   NSSH(10),   SIGL(10,11),     11JU1
     3    EPSL(10,11),DSIGL(10,11),DEPSL(10,11),ISST(10)                   11JU1
      COMMON /BLOC12/ NA(20),     NCDA(20),   BI(20,10),  DI(20,10),       19OC0
     2    YI(20,10),  NSS(20,10), SM(20,10),  EM(20,10), IRECT(20,10)      17MY1
      COMMON /BLOC13/ NPTS( 08),   ISS( 08),   NSIG(08,11),NEPS(08,11),    05NO0
     2    NSIT(11),   NEPT(11)                                             24OC0
      COMMON /BLOC15/ EPST(21),   SIGT(21),   EPSTS(11),  SIGTS(11)        05NO0
      COMMON /BLK1/   KEEP2, KEEP3, KEEP4A,KEEP5A,KEEP6, KEEP7,            26JA0
     2        ITYPE, NCD2,  NCD3,  NCD4A, NCD5A, NCD6,  NCD7,              26JA0
     3        IABAN, IFORM, NM,    NJT,   NST,   NLT,   TOL,               26JA0
     4        M,     MP1,   MP2,   ISTT,  LTT,   ITYPEL,IDJ,               12FE0
     5        NSTL,  IP8,   IP9,   IP10,  KEEP4B,KEEP4C,NCD4B,             05AG0
     6        NCD4C, KEEP5B,KEEP5C,KEEP5D,NCD5B, NCD5C, NCD5D              05AG0
      COMMON /BLK2/ XL,XR,X1,X2,I1,I2,NQ,H,TH,HSQ,HCU,X2L                  26JA0
      COMMON /BLK7/ INLOPT,IFAE,KOFFJ,KOFFQW,KOFFSE                        07AP1
          IF (I .GT. 2) GO TO 1500                                         21DE0
COMMENT - SKIP FOR ALL BUT FIRST ELEMENT                                   02JL1
COMMENT - COMPUTE NUMBER OF RIGID ELEMENTS AND NUMBER OF LINEAR ELEMENTS02JL1
COMMENT - AT ENDS OF MEMBERS                                               02JL1
                NR = - IPINL(ISTT)/10                                      22DE0
                NE = - IPINL(ISTT) - 10*NR                                 22DE0
                NLR = 1 + NR                                               22DE0
                NLE = NLR + NE                                             22DE0
                NR = - IPINR(ISTT)/10                                      22DE0
                NE = - IPINR(ISTT) - 10*NR                                 22DE0
                NRR = MP2 - NR                                             08JA1
                NRE = NRR - NE                                             22DE0
 1500     CONTINUE                                                         21DE0
          IF (INLOPT .EQ. 1) GO TO 2100                                    02NO0
COMMENT - COMPUTE THRUST AND BENDING MOMENTS AND INCREMENTAL FORCE        02JL1
COMMENT - DEFORMATION MATRIX FOR ELEMENT WITH LINEAR STRESS-STRAIN CURVE02JL1
                D(1,1) = AE(I)/TH                                          02NO0
                D(2,2) = F(I)/H                                            02NO0
                D(3,3) = D(2,2)                                            02NO0
                D(1,2) = 0.0                                               24JL1
                D(1,3) = 0.0                                               24JL1
                D(2,1) = 0.0                                               24JL1
                D(2,3) = 0.0                                               24JL1
                D(3,1) = 0.0                                               24JL1
                D(3,2) = 0.0                                               24JL1
                BM1  = F(I)*TAU1/H                                         02NO0
                BM2  = F(I)*TAU2/H                                         02NO0
                TT   = AE(I)*DELTA/TH                                      02NO0
          IF (I .GT. NLR .AND. I .LT. NRR) GO TO 4100                      21DE0
COMMENT - MULTIPLY VALUES BY 10 FOR RIGID ELEMENT                          02JL1
                BM1 = BM1*10.0                                             21DE0
                BM2 = BM2*10.0                                             21DE0
                TT = TT*10.0                                               21DE0
                D(1,1) = D(1,1)*10.0                                       21DE0
                D(2,2) = D(2,2)*10.0                                       21DE0
                D(3,3) = D(3,3)*10.0                                       21DE0
          GO TO 4100                                                       02NO0
 2100     CONTINUE                                                         02NO0
          IF (I .GT. 2) GO TO 2500                                         05NO0
COMMENT - SKIP FOR ALL BUT FIRST ELEMENT                                   02JL1
COMMENT - COMPUTE SECTION PROPERTIES AND STRESS-STRAIN CURVE AT MEMBERS  02JL1
COMMENT - FROM JOINT AND DIFFERENCE IN THESE PROPERTIES BETWEEN FROM AND02JL1
COMMENT - TO JOINTS                                                        02JL1
                NALT = NAL(ISTT)                                           05NO0
                NART = NAR(ISTT)                                           05NO0
                NCDAT = NCDA(NALT)                                         05NO0
          DO 2200  J = 1,NCDAT                                             05NO0
                BCL(J) = BI(NALT,J)                                        05NO0
                DBCL(J) = (BI(NART,J) - BCL(J))/M                          05NO0
```

```
          DCL(J) = DI(NALT,J)                                               05NO0
          DDCL(J) = (DI(NART,J) - DCL(J))/M                                 07MY1
          YCL(J) = YI(NALT,J)                                               05NO0
          DYCL(J) = (YI(NART,J) - YCL(J))/M                                 05NO0
          NSSL(J) = NSS(NALT,J)                                             05NO0
          NSSR(J) = NSS(NART,J)                                             05NO0
          NSSLT = NSSL(J)                                                   05NO0
          NSSRT = NSSR(J)                                                   24NO0
          NPTST = NPTS(NSSLT)                                               05NO0
          ISST(J) = ISS(NSSLT)                                              05NO0
      DO 2180 K = 1,NPTST                                                   05NO0
          SIGL(J,K) = NSIG(NSSLT,K)*SM (NALT,J)                             30NO0
          SIGR = NSIG(NSSRT,K)*SM(NART,J)                                   24NO0
          EPSL(J,K) = NEPS(NSSLT,K)*EM(NALT,J)                              24NO0
          EPSR = NEPS(NSSRT,K)*EM(NART,J)                                   15DE0
          DSIGL(J,K) = (SIGL(J,K) - SIGR)/M                                 05NO0
          DEPSL(J,K) = (EPSL(J,K) - EPSR)/M                                 15DE0
 2180 CONTINUE                                                              05NO0
 2200 CONTINUE                                                              05NO0
 2500 CONTINUE                                                              05NO0
COMMENT - (IR = 1) FOR RIGID ELEMENT                                        02JL1
COMMENT - (IE = 1) FOR LINEAR ELEMENT                                       02JL1
          IR = 0                                                            11DE0
          IE = 0                                                            22DE0
      IF (I .LE. NLR) IR = 1                                                11DE0
      IF (I .LE. NLE) IE = 1                                                22DE0
      IF (I .GE. NRR) IR = 1                                                11DE0
      IF (I .GE. NRE) IE = 1                                                22DE0
          ZMUL = I - 2                                                      05NO0
          ZMUL = ZMUL + 0.5                                                 05NO0
COMMENT - COMPUTE DEFORMATIONS IN ELEMENT                                   02JL1
          EP = DELTA/TH                                                     05NO0
          CUR1 = TAU1/H                                                     05NO0
          CUR2 = TAU2/H                                                     05NO0
COMMENT - ZERO ELEMENT THRUST, BENDING MOMENTS, AND STIFFNESS TERMS         02JL1
          BM1 = 0.0                                                         02JL1
          BM2 = 0.0                                                         02JL1
          T1 = 0.0                                                          03JL1
          T2 = 0.0                                                          03JL1
          EI1 = 0.0                                                         02JL1
          EI2 = 0.0                                                         02JL1
          AE1 = 0.0                                                         02JL1
          AE2 = 0.0                                                         02JL1
          AEY1 = 0.0                                                        02JL1
          AEY2 = 0.0                                                        02JL1
          D(2,3) = 0.0                                                      24JL1
          D(3,2) = 0.0                                                      24JL1
      DO 4000  J = 1, NCDAT                                                 05NO0
COMMENT - COMPUTE SECTION PROPERTIES AND STRESS-STRAIN CURVE AT             02JL1
COMMENT - MID-ELEMENT                                                       02JL1
          B = BCL(J) + ZMUL*DBCL(J)                                         05NO0
          DP = DCL(J) + ZMUL*DDCL(J)                                        05NO0
          Y = YCL(J) + ZMUL*DYCL(J)                                         05NO0
          NSSLT = NSSL(J)                                                   05NO0
          NPTST = NPTS(NSSLT)                                               05NO0
      DO 2600  K = 1,NPTST                                                  05NO0
          EPSTS(K) = EPSL(J,K) + ZMUL*DEPSL(J,K)                            05NO0
 2600     SIGTS(K) = SIGL(J,K) + ZMUL*DSIGL(J,K)                            05NO0
      IF (ISST (J) .EQ. 1) GO TO 2650                                       05NO0
      DO 2610 K = 1, NPTST                                                  05NO0
          EPST(K) = EPSTS(K)                                                05NO0
          SIGT(K) = SIGTS(K)                                                05NO0
```

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 2610     CONTINUE                                                          16NO0
          ISSTT = 0                                                         18NO0
          NPT = NPTST                                                       05NO0
      GO TO 2700                                                            05NO0
 2650     EPST(NPTST) = EPSTS(1)                                            05NO0
          SIGT(NPTST) = SIGTS(1)                                            05NO0
      DO 2675  K = 2,NPTST                                                  05NO0
          KR = K + NPTST - 1                                                05NO0
          KL = KR - 2*(K - 1)                                               05NO0
          EPST(KR) =  EPSTS(K)                                              05NO0
          EPST(KL) = -EPSTS(K)                                              05NO0
          SIGT(KR) = SIGTS(K)                                               05NO0
 2675     SIGT(KL) = -SIGTS(K)                                              05NO0
          NPT = 2*(NPTST) - 1                                               05NO0
          ISSTT = 1                                                         05NO0
 2700 CONTINUE                                                              05NO0
COMMENT - SUBDIVIDE PIPE PIECE INTO TEN EQUIVALENT RECTANGLES. (TWENTY      02JL1
COMMENT - EQUAL RADIAL SEGMENTS WITH SEGMENTS IN OPPOSITE SIDES OF Y        02JL1
COMMENT - AXIS COMBINED)                                                    02JL1
          NPP = 1                                                           17MY1
      IF (IRECT(NALT,J) .EQ. 1) NPP = 10                                    17MY1
COMMENT - DO FOR EACH RECTANGLE IN PIECE                                    02JL1
      DO 3900 IP = 1,NPP                                                    17MY1
      IF (NPP .EQ. 10) CALL PIPE (B,DP,Y,IP,NPP)                            17MY1
COMMENT - CALL FAEJR TO COMPUTE AXIAL THRUST, BENDING MOMENT AND            02JL1
COMMENT - STIFFNESS TERMS FOR ONE RECTANGLE AT LOCATION OF FIRST            02JL1
COMMENT - DISCRETE SPRING IN ELEMENT                                        02JL1
    CALL      FAEJR (T,BM,EA,EI,AEY,ISSTT,NPT,Y,B,DP,EP,CUR1,IR,IE)         02JL1
COMMENT - ACCUMULATE VALUES FOR ALL RECTANGLES                              02JL1
          BM1 = BM1 + BM                                                    05NO0
          EI1 = EI1 + EI                                                    02JL1
          AEY1 = AEY1 + AEY                                                 02JL1
          AE1 = AE1 + EA                                                    02JL1
          T1 = T1 + T                                                       02JL1
COMMENT - CALL FAEJR TO COMPUTE AXIAL THRUST, BENDING MOMENT AND            02JL1
COMMENT - STIFFNESS TERMS FOR ONE RECTANGLE AT LOCATION OF SECOND           02JL1
COMMENT - DISCRETE SPRING IN ELEMENT                                        02JL1
    CALL      FAEJR (T,BM,EA,EI,AEY,ISSTT,NPT,Y,B,DP,EP,CUR2,IR,IE)         02JL1
COMMENT - ACCUMULATE VALUES FOR ALL RECTANGLES                              02JL1
          BM2 = BM2 + BM                                                    05NO0
          EI2 = EI2 + EI                                                    02JL1
          AEY2 = AEY2 + AEY                                                 02JL1
          AE2 = AE2 + EA                                                    02JL1
          T2 = T2 + T                                                       02JL1
 3900 CONTINUE                                                              17MY1
 4000 CONTINUE                                                              11MR1
COMMENT - COMPUTE AVERAGE THRUST AND AXIAL STIFFNESS FOR ELEMENT            02JL1
        TT = 0.5*(T1 + T2)                                                  03JL1
          AE(I) = 0.5*(AE1 + AE2)                                           02JL1
COMMENT - COMPUTE INCREMENTAL FORCE DEFORMATION MATRIX FOR ELEMENT          02JL1
          D(1, 1) = AE(I)/TH                                                02JL1
          D(2, 2) = EI1/H                                                   02JL1
          D(3, 3) = EI2/H                                                   02JL1
          D(1, 2) = - AEY1/TH                                               02JL1
          D(2, 1) = D(1, 2)                                                 02JL1
          D(1, 3) = - AEY2/TH                                               02JL1
          D(3, 1) =  D(1, 3)                                                02JL1
 4100 CONTINUE                                                              02NO0
    RETURN                                                                  02NO0
    END                                                                     02NO0
C
C         **************************************************************
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C                                  SUBROUTINE
C        ***************************************************************
C
      SUBROUTINE PIPE (B,DP,Y,IP,NPP)                                   17MY1
COMMENT - SUBROUTINE PIPE IS CALLED NPP TIMES BY SUBROUTINE FAEJR FOR  14JL1
COMMENT - THIN WALLED PIPE PIECES- EACH TIME SUBROUTINE PIPE FURNISHES 14JL1
COMMENT - THE DEPTH AND THE WIDTH OF A RECTANGLE WHICH IS EQUIVALENT TO 14JL1
COMMENT - TWO EQUAL RADIAL SEGMENTS OF THE PIPE PIECE                  14JL1
         IF (IP  .NE. 1) GO TO 10                                      17MY1
             RA = 0.5*(B - DP)                                         19MY1
             T = DP                                                    17MY1
             YC = Y                                                    17MY1
             DTE = ACOS(-1.0)/NPP                                      17MY1
   10        ZIP = IP                                                  17MY1
             ZIP = ZIP - 0.5                                           17MY1
             TE =  DTE*ZIP                                             17MY1
             DP = RA*SIN(TE)*DTE                                       17MY1
             B = 2.*T/SIN(TE)                                          20MY1
             Y = YC +  RA*COS(TE)                                      17MY1
      RETURN                                                           17MY1
      END                                                              17MY1
C
C        ***************************************************************
C                                  SURROUTINE
C        ***************************************************************
C
      SUBROUTINE FAEJR (T,BM,EA,EI,AEY,ISSTT,NPT,Y,B,DP,EP,CUR,IR,IE)   03JU1
COMMENT - SUBROUTINE FAEJR SUBDIVIDES THE INPUT RECTANGLES INTO        02JL1
COMMENT - SUB-RECTANGLES EACH OF WHICH HAS  A LINEAR STRESS-STRAIN     02JL1
COMMENT - CURVE OVER IT, FOR THE NUMERICAL INTEGRATION OF THE          02JL1
COMMENT - STRESS- STRAIN CURVE TO FIND AXIAL THRUST T, BENDING MOMENT M,02JL1
COMMENT - AXIAL STIFFNESS EA, BENDING STIFFNESS EI, AND AXIAL BENDING  02JL1
COMMENT - STIFFNESS AEY                                                02JL1
      DIMENSION DA(22),DI(22),YY(22),EPC(22)                           12NO0
      COMMON /BLOC15/ EPST(21),   SIGT(21),   EPSTS(11),  SIGTS(11)     02NO0
      COMMON /BLK7/ INLOPT,IFAE,KOFFJ,KOFFQW,KOFFSE                    07AP1
COMMENT - COMPUTE STRAIN AND Y DISTANCES FOR TOP AND BOTTOM OF INPUT   02JL1
COMMENT - RECTANGLE                                                    02JL1
             YB = Y - 0.5*DP                                           14NO0
             YT = YB + DP                                              14NO0
             EPB = EP - YB*CUR                                         14NO0
             EPT = EP - YT*CUR                                         14NO0
             R =  1.0                                                  10NO0
         IF (EPB .LE. EPT) GO TO 100                                   02NO0
COMMENT - REVERSE FOR POSITIVE CURVATURE                               02JL1
             ET = EPB                                                  02NO0
             EPB = EPT                                                 02NO0
             EPT = ET                                                  02NO0
             YTT = YT                                                  17NO0
             YT = YB                                                   17NO0
             YB = YTT                                                  17NO0
             R = -1.0                                                  10NO0
  100    CONTINUE                                                      02NO0
COMMENT - FIND FIRST POINT ON STRESS-STRAIN CURVE ON OR BELOW RECTANGLE 02JL1
         DO 200 K = 1,NPT                                              02NO0
         IF (EPB .GE. EPST(K)) GO TO 200                               07MY1
             NN1 = K - 1                                               02NO0
         GO TO 300                                                     02NO0
  200    CONTINUE                                                      02NO0
             NN1 = NPT                                                 02NO0
  300    CONTINUE                                                      02NO0
             NNP = NN1 + 1                                             02NO0
         IF (NNP .GT. NPT) GO TO 410                                   02NO0
COMMENT -  FIND FIRST POINT ABOVE RECTANGLE                            02JL1
         DO 400 K = NNP, NPT                                           02NO0
         IF (EPT .GT. EPST(K)) GO TO 400                               07MY1
             NN2 = K                                                   02NO0
         GO TO 500                                                     02NO0
  400    CONTINUE                                                      02NO0
  410        NN2 = NPT + 1                                             02NO0
  500    CONTINUE                                                      02NO0
COMMENT - COMPUTE NUMBER OF SUBRECTANGLES                              02JL1
             NN3 = NN2 - NN1                                           12NO0
COMMENT - NPTT POINTS USED TO ENTER STRESS STRAIN CURVE                02JL1
             NPTT = NPT                                                12NO0
COMMENT - SYMMETRICAL CURVE USE ONLY POSITIVE BRANCH                   02JL1
             IF (ISSTT .EQ. 1) NPTT = (NPT + 1)/2                      12NO0
COMMENT - ZERO THRUST,BENDING MOMENT AND STIFFNESS TERMS               02JL1
             T = 0.0                                                   03JU1
             BM = 0.0                                                  03JU1
             EA = 0.0                                                  03JU1
             AEY = ^.0                                                 03JU1
             EI = 0.0                                                  03JU1
         IF (NN3 .NE. 1)  GO TO 1200                                   03JU1
COMMENT - CALCULATE PROPERTIES FOR WHOLE RECTANGLE                     02JL1
             DA(1) = B*DP                                              12NO0
             DI(1) =  1/12*B*DP**3                                     12NO0
             YY(1) = Y                                                 12NO0
             EPC(1) = 0.5*(EPB + EPT)                                  03JU1
         GO TO 4000                                                    12NO0
COMMENT - CALCULATE PROPERTIES FOR FIRST RECTANGLE                     02JL1
 1200         DD = -R*(EPST(NNP) - EPB)/CUR                            02JL1
             DA(1) = B*DD                                              16NO0
             DI(1) =  1/12*B*DD**3                                     12NO0
             YY(1) = YB + 0.5*DD*R                                     12NO0
             EPC(1) = (EPB + EPST(NNP))*0.5                            12NO0
             YTT = YB + DD*R                                           12NO0
COMMENT - CALCULATE PROPERTIES FOR LAST SUBRECTANGLE                   02JL1
             DD =-R*(EPT - EPST(NN2 - 1))/CUR                          12NO0
             DA(NN3) = B*DD                                            12NO0
             DI(NN3) =  1/12*B*DD**3                                   12NO0
             YY(NN3) = YT - 0.5*DD*R                                   12NO0
             EPC(NN3) = (EPT + EPST(NN2 - 1))*0.5                      12NO0
         IF (NN3 .EQ. 2) GO TO 4000                                    12NO0
             NN4 = NN3 - 1                                             12NO0
             K = NN1                                                   12NO0
COMMENT - CALCULATE PROPERTIES FOR REMAINING SUBRECTANGLES             02JL1
         DO 3000 N = 2,NN4                                             12NO0
             K = K + 1                                                 12NO0
             DD =-R*(EPST(K + 1) - EPST(K))/CUR                        12NO0
             DA(N) = B*DD                                              12NO0
             DI(N) =  1/12*B*DD**3                                     12NO0
             YY(N) = YTT + 0.5*DD*R                                    12NO0
             EPC(N) = 0.5*(EPST(K + 1) + EPST(K))                      19NO0
             YTT = YTT + DD*R                                          17NO0
 3000    CONTINUE                                                      12NO0
 4000    CONTINUE                                                      12NO0
COMMENT -  DO FOR EACH SUBRECTANGLE                                    02JL1
             DO 5000  N = 1,NN3                                        07MY1
             EPT = EPC(N)                                              11DE0
COMMENY - ZERO STRAIN USED TO ENTER CURVE WITH FOR RIGID OR LINEAR     02JL1
COMMENT - ELEMENT                                                      02JL1
         IF (IR .EQ. 1 .OR. IE .EQ. 1) EPT = 0.0                       22DE0
COMMENT - CALL CURVE TO FIND NEGATIVE OF SLOPE OF STRESS-STRAIN CURVE  02JL1
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COMMENT --ACOMPUTE AND ACCUMULATE T,BM,EA,AE,AEY                        02JL1
COMMENT - AND STRESS AT CENTEROID OF SUBRECTANGLE SIGMA                 02JL1
      CALL       CURVE (SIGTS,EPSTS,EPT,   NPTT,ISSTT,SIG,S2,KOFFSE)    12N00
                 E = -S2                                                12N00
COMMENT - E = 10*E FOR RIGID ELEMENT                                    02JL1
          IF (IR.EQ. 1)  E = 10.*E                                      07MY1
          IF (IR .EQ. 1 .OR. IE .EQ. 1)  SIG = SIG + E*EPC(N)           21DE0
                 DT = SIG*DA(N)                                         12N00
                 DAE = E*DA(N)                                          12N00
                 EA = EA + DAE                                          03JU1
                 EI = EI + E*(DI(N) + DA(N)*YY(N)**2)                   12N00
                 AEY = AEY + DAE*YY(N)                                  03JU1
                 T = T + DT                                             12N00
                 BM = BM + DI(N)*E*CUR - DT*YY(N)                       12N00
 5000     CONTINUE                                                      12N00
      RETURN                                                            02N00
      END                                                               02N00
C
C         ***************************************************************
C                               SUBROUTINE
C         ***************************************************************
C
      SUBROUTINE NLSS(L1)                                               260C0
COMMENT - SUBROUTINE NLSS DISCRETIZES DISTRIBUTED MEMBER Q - W CURVES   16JU1
COMMENT - TO STATION VALUES OF RESISTIVE SPRING FORCES  SQX, SQY, SQZ   16JU1
COMMENT - AND SPRING STIFFNESS  SX, SY, SZ                              16JU1
      DIMENSION DC(3,3),DCT(3,3),WT(3),WTT(3),FT(3),FTT(3)              20FE1
      COMMON /BLOCK2/ DXS( 25),    DYS( 25),    ZLS( 25),    DC1S( 25), 26JA0
     2    DC2S( 25),  PRF( 25),   PRAE( 25),  NCDS( 25),  IAXOPS( 25),  26JA0
     3    IOPOP( 25), IPINL( 25), IPINR( 25), NCS1( 25),  INLOP( 25),   170C0
     4    NAL( 25),   NSXL( 25),  NSYL( 25),  NSZL( 25),  NAR( 25),     170C0
     5    NSXR( 25),  NSYR( 25),  NSZR( 25),  QM( 25),    WM( 25)       170C0
      COMMON /BLOCK7/ F( 42),      AE( 42),     SX( 42),     SY( 42),   04JE0
     2    SZ( 42),    QX( 42),    QY( 42),    QZ( 42),    DX( 42),      04JE0
     3    DY( 42),    DZ( 42),    ERX( 42),   ERY( 42),   ERZ( 42),     04JE0
     4    SQX( 42),   SQY( 42),   SQZ( 42),   U1( 42),    V1( 42),      04JE0
     5    W1( 42),    U2( 42),    V2( 42),    W2( 42),    DS(3,3, 42),  29JA1
     6    BM1S( 42),  BM2S( 42),  TTS( 42)                              29JA1
      COMMON /BLK1/  KEEP2, KEEP3, KEEP4A,KEEP5A,KEEP6, KEEP7,          26JA0
     2         ITYPE, NCD2,  NCD3,  NCD4A, NCD5A, NCD6,  NCD7,          26JA0
     3         IABAN, IFORM, NM,    NJT,   NST,   NLT,   TOL,           26JA0
     4         M,     MP1,   MP2,   ISTT,  LTT,   ITYPEL,IDJ,           12FE0
     5         NSTL,  IP8,   IP9,   IP10,  KEEP4B,KEEP4C,NCD4B,         05AG0
     6         NCD4C, KEEP5B,KEEP5C,KEEP5D,NCD5B, NCD5C, NCD5D          05AG0
           IAXOPT = IAXOPS(ISTT)                                        20FE1
        IF (IAXOPT .EQ. 1) GO TO 2100                                   20FE1
 COMMENT - TRANSFORM MEMBER DISP TO STRUCT COORD FOR IAXOPT = 2         20FE1
                DC(1,3) = 0.0                                           24JL1
                DC(2,3) = 0.0                                           24JL1
                DC(3,1) = 0.0                                           24JL1
                DC(3,2) = 0.0                                           24JL1
                DCT(1,3) = 0.0                                          24JL1
                DCT(2,3) = 0.0                                          24JL1
                DCT(3,1) = 0.0                                          24JL1
                DCT(3,2) = 0.0                                          24JL1
                DC(3,3) = 1.0                                           24JL1
                DCT(3,3) = 1.0                                          24JL1
                DC(1,1) = DC1S(ISTT)                                    26JA0
                DC(1,2) = DC2S(ISTT)                                    26JA0
                DC(2,1) = - DC(1,2)                                     26JA0
                DC(2,2) = DC(1,1)                                       26JA0
                DCT(1,1) = DC(1,1)                                      26JA0
                DCT(1,2) = DC(2,1)                                      26JA0
                DCT(2,1) = DC(1,2)                                      26JA0
                DCT(2,2) = DC(2,2)                                      26JA0
                WT(3) = 0.0                                             24JL1
                FT(3) = 0.0                                             24JL1
          DO 1300  I = 1,MP1                                            20FE1
COMMENT - F AND AE USED AS TEMP STOR FOR DX AND DY ONLY IN THIS SUB     20FE1
                F(I) = DX(I)                                            20FE1
                AE(I) = DY(I)                                           20FE1
                WT(1) = DX(I)                                           20FE1
                WT(2) = DY(I)                                           20FE1
      CALL MATH31 (DCT,WT,WTT)                                          20FE1
                DX(I) = WTT(1)                                          20FE1
                DY(I) = WTT(2)                                          20FE1
 1300     CONTINUE                                                      20FE1
 2100     CONTINUE                                                      20FE1
COMMENT - AXIAL RESTRAINTS                                              13JU1
          DO 2200  I = 1,MP2                                            260C0
                SQX(I) = 0.0                                            05FE1
 2200           SX(I) = 0.0                                             260C0
          IF (NSXL(ISTT) .EQ. 0) GO TO 2300                             260C0
      CALL       NLSSJR    (SX,DX,SQX,L1,NSXL(ISTT),NSXR(ISTT),QM(ISTT), 01FE1
     2    WM(ISTT))                                                     01FE1
 2300     CONTINUE                                                      260C0
COMMENT - LATERAL RESTRAINTS                                            13JU1
          DO 3200  I = 1,MP2                                            260C0
                SQY(I) = 0.0                                            05FE1
 3200           SY(I) = 0.0                                             260C0
          IF (NSYL(ISTT) .EQ. 0) GO TO 3300                             260C0
      CALL       NLSSJR    (SY,DY,SQY,L1,NSYL(ISTT),NSYR(ISTT),QM(ISTT), 01FE1
     2    WM(ISTT))                                                     01FE1
 3300     CONTINUE                                                      260C0
COMMENT - ROTATIONAL RESTRAINTS                                         13JU1
          DO 4200  I = 1,MP2                                            260C0
                SQZ(I) = 0.0                                            05FE1
 4200           SZ(I) = 0.0                                             260C0
          IF (NSZL(ISTT) .EQ. 0) GO TO 4300                             260C0
      CALL       NLSSJR    (SZ,DZ,SQZ,L1,NSZL(ISTT),NSZR(ISTT),QM(ISTT), 01FE1
     2    WM(ISTT))                                                     01FE1
 4300     CONTINUE                                                      260C0
          IF (IAXOPT .EQ. 1) GO TO 5400                                 20FE1
          DO 5100  I = 1,MP1                                            20FE1
COMMENT - RETURN DX AND DY TO MEMBER COORD                              20FE1
                DX(I) = F(I)                                            20FE1
                DY(I) = AE(I)                                           20FE1
COMMENT - TRANSFORM SQX AND SQY TO MEMBER COORD                         20FE1
                FT(1) = SQX(I)                                          20FE1
                FT(2) = SQY(I)                                          20FE1
      CALL MATH31 (DC,FT,FTT)                                           24FE1
                SQX(I) = FTT(1)                                         20FE1
                SQY(I) = FTT(2)                                         20FE1
 5100 CONTINUE                                                          20FE1
 5400 CONTINUE                                                          20FE1
      RETURN                                                            260C0
      END                                                               260C0
C
C         ***************************************************************
C                               SUBROUTINE
C         ***************************************************************
C
      SUBROUTINE NLSSJR    (SXYZ,DXYZ,SQXYZ,L1,NSL,NSR,QMT,WMT)         01FE1
COMMENT - SUBROUTINE NLSSJR FURNISHES THE DISCRETIZED VALUES OF         13JU1
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COMMENT - RESISTIVE SPRING FORCE AND TANGENT SPRING STIFFNESS TO NLSS   13JU1
COMMENT - FOR AXIAL LATERAL AND ROTATIONAL SPRINGS                      13JU1
      DIMENSION SXYZ(L1), DXYZ(L1), SQXYZ(L1)                           01FE1
      DIMENSION QQL(11),WWL(11),DQQ(11),DWW(11),QQ(11),WW(11)           01FE1
      COMMON /BLOC14/ NPTM( 20),   ISM( 20),  NQM(20,11), NWM(20,11),   24OC0
     2   NQMT(11),    NWMT(11)                                          24OC0
      COMMON /BLK1/  KEEP2, KEEP3, KEEP4A,KEEP5A,KEEP6, KEEP7,          26JA0
     2        ITYPE, NCD2,  NCD3,  NCD4A, NCD5A, NCD6,  NCD7,           26JA0
     3        IABAN, IFORM, NM,    NJT,   NST,   NLT,   TOL,            26JA0
     4        M,     MP1,   MP2,   ISTT,  LTT,   ITYPEL,IDJ,            12FE0
     5        NSTL,  IP8,   IP9,   IP10,  KEEP4B,KEEP4C,NCD4B,          05AG0
     6        NCD4C, KEEP5B,KEEP5C,KEEP5D,NCD5B, NCD5C, NCD5D           05AG0
      COMMON /BLK2/ XL,XR,X1,X2,I1,I2,NQ,H,TH,HSQ,HCU,X2L               26JA0
      COMMON /BLK7/ INLOPT,IFAE,KOFFJ,KOFFQW,KOFFSE                     07AP1
COMMENT - DO FOR EACH ELEMENT                                           14JL1
      DO 2600  I = 2,MP1                                                01FE1
COMMENT - SKIP FOR ALL BUT FIRST ELEMENT                                13JU1
      IF (I .GT. 2) GO TO 1900                                          01FE1
         ISYM = ISM(NSL)                                                01FE1
         NPT = NPTM(NSL)                                                01FE1
      DO 1600  J = 1,NPT                                                01FE1
         QQL(J)  = NQM(NSL,J)*QMT                                       01FE1
         WWL(J)  = NWM(NSL,J)*WMT                                       01FE1
         DQQ(J)  = (NQM(NSR,J)*QMT    - QQL(J))/M                       01FE1
         DWW(J)  = (NWM(NSR,J)*WMT - WWL(J))/M                          01FE1
 1600 CONTINUE                                                          01FE1
 1900 CONTINUE                                                          01FE1
COMMENT - COMPUTE CONCENTRATED Q-W CURVE AT MID-ELEMENT BY INPERPOLATION13JU1
COMMENT - WITH RESPECT TO FORCE AND DISPLACEMENT AND MULTIPLYING FORCE  13JU1
COMMENT - VALUES BY TH                                                  13JU1
         ZMUL = I - 2                                                   01FE1
         ZMUL = ZMUL + 0.5                                              01FE1
      DO 2100  J = 1,NPT                                                01FE1
         QQ(J) = QQL(J) + ZMUL*DQQ(J)                                   01FE1
         QQ(J) = QQ(J)*TH                                               01FE1
 2100    WW(J) = WWL(J) + ZMUL*DWW(J)                                   01FE1
COMMENT - COMPUTE DISPLACEMENT AT MID-ELEMENT AS AVERAGE OF ADJACENT    13JU1
COMMENT - STATION (NODAL POINT) DISPALCEMENTS                           13JU1
         WJ = 0.5*(DXYZ(I - 1) + DXYZ(I))                               01FE1
COMMENT - CALL CURVE TO FIND RESISITIVE FORCE AND TANGENT STIFFNESS     13JU1
      CALL      CURVE (QQ,WW,WJ,NPT,ISYM,QJ,S2,KOFFQW)                  01FE1
         Z = ZMUL*TH                                                    19FE0
COMMENT - CALL CONLD TO DISTRIBUTE FORCE TO ADJACENT STATIONS           13JU1
      CALL      CONLD (QJ,Z,SQXYZ,L1)                                   01FE1
COMMENT - CALL CONLD TO DISTRIBUTE STIFFNESS TO ADJACENT STATIONS       13JU1
      CALL      CONLD (S2,Z,SXYZ,L1)                                    01FE1
 2600 CONTINUE                                                          01FE1
      RETURN                                                            01FE1
      END                                                               01FE1
C
C         ****************************************************************
C                                  SUBROUTINE
C         ****************************************************************
C
      SUBROUTINE MEMEND (   FMM, L6)                                    05SE0
COMMENT - MEMEND EVALUATES THE TOTAL FORCES ON THE ENDS OF THE MEMBERS  13JU1
      DIMENSION FMM(6),SA(3,3),WT(3),FT(3)                              05SE0
      COMMON /BLOCK2/ DXS( 25),   DYS( 25),   ZLS( 25),   DC1S( 25),    26JA0
     2   DC2S( 25),  PRF( 25),   PRAF( 25),  NCDS( 25),  IAXOPS( 25),   26JA0
     3   IOPOP( 25), IPINL( 25), IPINR( 25), NCS1( 25),  INLOP( 25),    17OC0
     4   NAL( 25),   NSXL( 25),  NSYL( 25),  NSZL( 25),  NAR( 25),      17OC0
     5   NSXR( 25),  NSYR( 25),  NSZR( 25),  QM( 25),    WM( 25)        17OC0
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      COMMON /BLOCK7/ F( 42),     AE( 42),    SX( 42),    SY( 42),      04JE0
     2   SZ( 42),   QX( 42),   QY( 42),   QZ( 42),   DX( 42),           04JE0
     3   DY( 42),   DZ( 42),   ERX( 42),  ERY( 42),  ERZ( 42),          04JE0
     4   SQX( 42),  SQY( 42),  SQZ( 42),  U1( 42),   V1( 42),           04JE0
     5   W1( 42),   U2( 42),   V2( 42),   W2( 42),   DS(3,3, 42),       29JA1
     6   BM1S( 42), BM2S( 42), TTS( 42)                                 29JA1
      COMMON /BLK1/  KEEP2, KEEP3, KEEP4A,KEEP5A,KEEP6, KEEP7,          26JA0
     2        ITYPE, NCD2,  NCD3,  NCD4A, NCD5A, NCD6,  NCD7,           26JA0
     3        IABAN, IFORM, NM,    NJT,   NST,   NLT,   TOL,            26JA0
     4        M,     MP1,   MP2,   ISTT,  LTT,   ITYPEL,IDJ,            12FE0
     5        NSTL,  IP8,   IP9,   IP10,  KEEP4B,KEEP4C,NCD4B,          05AG0
     6        NCD4C, KEEP5B,KEEP5C,KEEP5D,NCD5B, NCD5C, NCD5D           05AG0
      COMMON /BLK4/ ST1,ST2,ST3,ST4,ST5,ST6                             26JA0
      COMMON /BLK6/ QT1,QT2,QT3,QT4,QT5,QT6                             04JE0
      COMMON /BLK7/ INLOPT,IFAE,KOFFJ,KOFFQW,KOFFSE                     07AP1
         IAXOPT = IAXOPS(ISTT)                                          09SE0
         DX1 = DX(1)                                                    10MY1
         DY1 = DY(1)                                                    10MY1
         DZ1 = DZ(1)                                                    10MY1
         DX2 = DX(2)                                                    10MY1
         DY2 = DY(2)                                                    10MY1
         DZ2 = DZ(2)                                                    10MY1
         I = 2                                                          26MY0
COMMENT - CALL ELEMFO TO FIND THE FORCES ON ELEMENT NUMBER 2            13JU1
      CALL      ELEMFO (DX1,DY1,DZ1,DX2,DY2,DZ2,I,U1T,V1T,W1T,U2T,V2T,26MY0
     2          W2T)                                                    26MY0
      IF (INLOPT .EQ. 0) SQX(1) = -ST1*DX1                              20FE1
         FMM(1) = U1T - SQX(1) - QT1                                    20FE1
      IF (INLOPT .EQ. 0) SQY(1) = -ST2*DY1                              20FE1
         FMM(2) = V1T - SQY(1) - QT2                                    20FE1
      IF (INLOPT .EQ. 0) SQZ(1) = -ST3*DZ1                              20FE1
         FMM(3) = W1T - SQZ(1) - QT3                                    20FE1
         DX1 = DX(M)                                                    10MY1
         DY1 = DY(M)                                                    10MY1
         DZ1 = DZ(M)                                                    10MY1
         DX2 = DX(MP1)                                                  10MY1
         DY2 = DY(MP1)                                                  10MY1
         DZ2 = DZ(MP1)                                                  10MY1
         I = MP1                                                        26MY0
COMMENT - CALL ELEMFO TO FIND THE FORCES ON ELEMENT NUMBER MP1          13JU1
      CALL      ELEMFO (DX1,DY1,DZ1,DX2,DY2,DZ2,I,U1T,V1T,W1T,U2T,V2T,  26MY0
     2   W2T)                                                           26MY0
COMMENT - ADD ON THE LOADS ON THE END-STATIONS AND THE RESISTIVE SPRING 13JU1
COMMENT - FORCES ON THE END-STATIONS                                    13JU1
      IF (INLOPT .EQ. 0) SQX(MP1) = -ST4*DX2                            20FE1
         FMM(4) = U2T -SQX(MP1) - QT4                                   20FE1
      IF (INLOPT .EQ. 0) SQY(MP1) = -ST5*DY2                            20FE1
         FMM(5) = V2T -SQY(MP1) - QT5                                   20FE1
      IF (INLOPT .EQ. 0) SQZ(MP1) = -ST6*DZ2                            20FE1
         FMM(6) = W2T - SQZ(MP1) - QT6                                  20FE1
      RETURN                                                            26MY0
      END                                                               26MY0
C
C         ****************************************************************
C                                  SUBROUTINE
C         ****************************************************************
C
      SUBROUTINE FORMLD ( RM, RO, W, SL, SU, FOMT, L1, L3, L4, L6, JJ)  14JU0
COMMENT - SUBROUTINE FORMLD CALCULATES MEMBER INCREMENTAL FIXED-END-    17JU1
COMMENT - FORCE MATRIX ON FIRST ITERATION OF EACH PROBLEM               17JU1
      DIMENSION RM(L3,L6), RO(L6), W(L6), SL(L3), SU(L4)                08AP0
      DIMENSION FOMT(6),WT(3),FT(3),SA(3,3)                             19SE0
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      COMMON /BLOCK2/ DXS( 25),    DYS( 25),    ZLS( 25),    DC1S( 25),      26JA0
     2    DC2S( 25),  PRF( 25),    PRAE( 25),   NCDS( 25),   IAXOPS( 25),    26JA0
     3    IOPOP( 25), IPINL( 25),  IPINR( 25),  NCS1( 25),   INLOP( 25),     17OC0
     4    NAL( 25),   NSXL( 25),   NSYL( 25),   NSZL( 25),   NAR( 25),       17OC0
     5    NSXR( 25),  NSYR( 25),   NSZR( 25),   QM( 25),     WM( 25)         17OC0
      COMMON /BLOCK3/ DXL( 25),    DYL( 25),    ZLL( 25),    DC1L( 25),      26JA0
     2    DC2L( 25),  UQX( 25),    UQY( 25),    NCDL( 25),   IAXOPL( 25),    26JA0
     3    NC61( 25)                                                          26JA0
      COMMON /BLOCK4/ JT1( 40),    JT2( 40),    IST( 40),    LT( 40),        26JA0
     2    FOMM( 40,6), SMC( 40,21), NITM( 40), IMM( 40),     IMC( 40)        01JL1
      COMMON /BLOCK5/ XLS( 50),    XRS( 50),    FL( 50),     AEL( 50),       26JA0
     2    SXL( 50),   SYL( 50),    SZL( 50)                                  26JA0
      COMMON /BLOCK6/ XLL( 75),    XRL( 75),    QXL( 75),    QYL( 75),       26JA0
     2    QZL( 75)                                                           26JA0
      COMMON /BLOCK7/ F( 42),      AE( 42),     SX( 42),     SY( 42),        04JE0
     2    SZ( 42),    QX( 42),     QY( 42),     QZ( 42),     DX( 42),        04JE0
     3    DY( 42),    DZ( 42),     ERX( 42),    ERY( 42),    ERZ( 42),       04JE0
     4    SQX( 42),   SQY( 42),    SQZ( 42),    U1( 42),     V1( 42),        04JE0
     5    W1( 42),    U2( 42),     V2( 42),     W2( 42),     DS(3,3, 42),    29JA1
     6    BM1S( 42),  BM2S( 42),   TTS( 42)                                  29JA1
      COMMON /BLK1/  KEEP2, KEEP3, KEEP4A,KEEP5A,KEEP6, KEEP7,               26JA0
     2         ITYPE, NCO2,  NCD3,  NCD4A, NCD5A, NCD6,  NCD7,               26JA0
     3         IABAN, IFORM, NM,    NJT,   NST,   NLT,   TOL,                26JA0
     4         M,     MP1,   MP2,   ISTT,  LTT,   ITYPEL,IDJ,                12FE0
     5         NSTL,  IP8,   IP9,   IP10,  KEEP4B,KEEP4C,NCD4B,              05AG0
     6         NCD4C, KEEP5B,KEEP5C,KEEP5D,NCD5B, NCD5C, NCD5D               05AG0
      COMMON /BLK2/ XL,XR,X1,X2,I1,I2,NQ,H,TH,HSQ,HCU,X2L                    26JA0
      COMMON /BLK3/ MNJT,MNST,MNLT,MNM,MNC5,MNC6,MDJT,MNJS,MNE,MNCS,         11JU1
     2    MNPCS,MNSS,MNQWM                                                   11JU1
      COMMON /BLK4/ ST1,ST2,ST3,ST4,ST5,ST6                                  26JA0
      COMMON /BLK6/ QT1,QT2,QT3,QT4,QT5,QT6                                  04JE0
      COMMON /BLK7/ INLOPT,IFAE,KOFFJ,KOFFQW,KOFFSE                          07AP1
      COMMON / RI / NL, ML, J1                                               08AP0
          IF (ITYPE .EQ. 1) GO TO 2400                                       04JU0
COMMENT - STORE EXISTING MEMBER-ENDFORCES AS MEMBER-END-LOADS                17JU1
                QT1 = FOMM(JJ,1)                                             04JU0
                QT2 = FOMM(JJ,2)                                             04JU0
                QT3 = FOMM(JJ,3)                                             04JU0
                QT4 = FOMM(JJ,4)                                             04JU0
                QT5 = FOMM(JJ,5)                                             04JU0
                QT6 = FOMM(JJ,6)                                             04JU0
 2400     CONTINUE                                                           30MY1
          IF (LTT .GT. 0) GO TO 2500                                         30MY1
COMMENT - ZERO LOADS FOR LOAD TYPE ZERO * NOTE* FIXED-END-FORCE-MATRIX       17JU1
COMMENT - CALCULATED FOR MEMBER WITH NO LOADS FOR PRESTRESSING OR            17JU1
COMMENT - TEMPERATURE EFFECTS AND CASE WHERE LOADS ARE REMOVED               17JU1
          DO 2450  I = 1,MP1                                                 30MY1
                QX(I) = 0.0                                                  24JL1
                QY(I) = 0.0                                                  24JL1
 2450           QZ(I) = 0.0                                                  24JL1
          GO TO 3000                                                         30MY1
 2500     CONTINUE                                                           30MY1
COMMENT - SET TEMPORARY CONTROL CONSTANTS FOR LOAD TYPE WHICH IS             16MY0
COMMENT - HAVING ITS FIXED-END-FORCE MATRIX FORMED                           16MY0
                UQXT = UQX(LTT)                                              26JA0
                UQYT = UQY(LTT)                                              26JA0
                NCDLT = NCDL(LTT)                                            26JA0
                NC61T = NC61(LTT)                                            26JA0
          IF (NCDLT .NE. 0) GO TO 2900                                       30MY1
COMMENT - DISCRETIZE UNIFORM MEMBER LOADS                                    16MY0
          DO 2800  I = 2,M                                                   26JA0
                QX(I) = UQXT*TH                                              26JA0
                QY(I) = UQYT*TH                                              26JA0
 2800           QZ(I) = 0.0                                                  26JA0
                QX(1) = 0.5*UQXT*TH                                          24JL1
                QY(1) = 0.5*UQYT*TH                                          24JL1
                QZ(1) = 0.0                                                  24JL1
                QX(MP1) = 0.5*UQXT*TH                                        24JL1
                QY(MP1) = 0.5*UQYT*TH                                        24JL1
                QZ(MP1) = 0.0                                                24JL1
                QX(MP2) = 0.0                                                24JL1
                QY(MP2) = 0.0                                                24JL1
                QZ(MP2) = 0.0                                                24JL1
          GD TO 3000                                                         26JA0
COMMENT - NONUNIFORM LOADS                                                   16MY0
COMMENT - SUBROUTINE DISCLD DISCRETIZES GENERAL MEMBER LOADS QX, QY, QZ      16MY0
 2900 CALL      DISCLD ( NC61T, NCDLT, ZL, L1 )                              11FE0
 3000     CONTINUE                                                           26JA0
COMMENT - DO FOR EACH ELEMENT                                                17JU1
          DD 3400  I = 2,MP1                                                 28MY0
                IM1 = I - 1                                                  28MY0
COMMENT - SUBROUTINE ELEMFO EVALUATES THE END-FORCES ON A DISCRETE           17JU1
COMMENT - ELEMNT, GIVEN THE ELEMENT-END-DISPLACEMENTS                        17JU1
      CALL      ELEMFO (DX(IM1),DY(IM1),DZ(IM1),DX(I),DY(I),DZ(I),I,         28MY0
     2    U1T,V1T,W1T,U2T,V2T,W2T)                                           28MY0
COMMENT - START COMPUTATION FOR STATION EQUILIBRIUM ERRORS BY ADDING          17JU1
COMMENT - ADJACENT ELEMENT-END-FORCES AT STATIONS                            17JU1
                ERX(IM1) = ERX(IM1) + U1T                                    28MY0
                ERY(IM1) = ERY(IM1) + V1T                                    28MY0
                ERZ(IM1) = ERZ(IM1) + W1T                                    28MY0
                ERX(I) = ERX(I) + U2T                                        28MY0
                ERY(I) = ERY(I) + V2T                                        28MY0
                ERZ(I) = ERZ(I) + W2T                                        28MY0
 3400     CONTINUE                                                           28MY0
COMMENT - COMPLETE CALCULATIONS BY ADDING IN LOADS AND SPRING FORCES         17JU1
COMMENT - DO FOR EACH INTERIOR STATION                                       17JU1
          DO 3800  I = 2,M                                                   28MY0
          IF (INLOPT .EQ. 0) SQZ(I) = -SZ(I)*DZ(I)                           20FE1
                ERZ(I) = QZ(I) - ERZ(I) + SQZ(I)                             20FE1
          IF (IAXOPT .EQ. 2) GO TO 3650                                      05SE0
          IF (INLOPT .EQ. 0) SQX(I) = -SX(I)*DX(I)                           20FE1
                ERX(I) = QX(I) - ERX(I) + SQX(I)                             20FE1
          IF (INLOPT .EQ. 0) SQY(I) = -SY(I)*DY(I)                           20FE1
                ERY(I) = QY(I) - ERY(I) + SQY(I)                             20FE1
          GO TO 3800                                                         05SE0
 3650     CONTINUE                                                           05SE0
COMMENT - TRANSFORM SPRING FORCES AND STIFFNESSES IF SPECIFIED IN            17JU1
COMMENT - STRUCTURE DIRECTIONS                                               17JU1
                SXT = SX(I)                                                  05SE0
                SYT = SY(I)                                                  05SE0
      CALL      SANGLE (SA,SXT,SYT)                                          05SE0
                WT(1) = DX(I)                                                10MY1
                WT(2) = DY(I)                                                10MY1
                WT(3) = 0.0                                                  10MY1
      CALL      MATM31 (SA,WT , FT)                                          05SE0
          IF (INLOPT .EQ. 0) SQX(I) = -FT(1)                                 20FE1
                ERX(I) = QX(I) - ERX(I) + SQX(I)                             20FE1
          IF (INLOPT .EQ. 0) SQY(I) = - FT(2)                                20FE1
                ERY(I) = QY(I) - ERY(I) + SQY(I)                             20FE1
 3800     CONTINUE                                                           03JE0
COMMENT - DO FOR END STATIONS                                                17JU1
          IF (INLOPT .EQ. 0) SQZ(1) = -ST3*DZ(1)                             20FE1
                ERZ(1) = QZ(1) - ERZ(1) + SQZ(1)                             20FE1
          IF (INLOPT .EQ. 0) SQZ(MP1) = -ST6*DZ(MP1)                         20FE1
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          ERZ(MP1) = QZ(MP1) - ERZ(MP1) +SQZ(MP1)                        20FE1
      IF (IAXOPT .EQ. 2) GO TO 3900                                        17SE0
       IF (INLOPT .EQ. 0) SQX(1) = -ST1*DX(1)                              20FE1
          ERX(1) = QX(1) - ERX(1) + SQX(1)                                 20FE1
       IF (INLOPT .EQ. 0) SQY(1) = -ST2*DY(1)                              20FE1
          ERY(1) = QY(1) - ERY(1) +SQY(1)                                  20FE1
       IF (INLOPT .EQ. 0) SQX(MP1) = -ST4*DX(MP1)                          20FE1
          ERX(MP1) = QX(MP1) - ERX(MP1) +SQX(MP1)                          20FE1
       IF (INLOPT .EQ. 0) SQY(MP1) = -ST5*DY(MP1)                          20FE1
          ERY(MP1) = QY(MP1) - ERY(MP1) +SQY(MP1)                          20FE1
       GO TO 4100                                                          17SE0
 3900  CONTINUE                                                            17SE0
COMMENT - TRANSFORM SPRING FORCES AND STIFFNESSES IF SPECIFIED IN         17JU1
COMMENT - STRUCTURE DIRECTIONS                                             17JU1
      CALL      SANGLE (SA,ST1,ST2)                                        17SE0
          WT(1) = DX(1)                                                    17SE0
          WT(2) = DY(1)                                                    10MY1
          WT(3) = 0.0                                                      10MY1
      CALL      MATM31 (SA,WT,FT)                                          17SE0
       IF (INLOPT .EQ. 0) SQX(1) = -FT(1)                                  20FE1
          ERX(1) = QX(1) - ERX(1) + SQX(1)                                 20FE1
       IF (INLOPT .EQ. 0) SQY(1) = -FT(2)                                  20FE1
          ERY(1) = QY(1) - ERY(1) + SQY(1)                                 20FE1
      CALL      SANGLE (SA,ST4,ST5)                                        17SE0
          WT(1) = DX(MP1)                                                  17SE0
          WT(2) = DY(MP1)                                                  10MY1
      CALL      MATM31 (SA,WT,FT)                                          17SE0
       IF (INLOPT .EQ. 0) SQX(MP1) = -FT(1)                                20FE1
          ERX(MP1) = QX(MP1) - ERX(MP1) + SQX(MP1)                         20FE1
       IF (INLOPT .EQ. 0) SQY(MP1) = -FT(2)                                20FE1
          ERY(MP1) = QY(MP1) - ERY(MP1) + SQY(MP1)                         20FE1
 4100  CONTINUE                                                            04FE1
          QT1 = QT1 + ERX(1)                                               04JU0
          QT2 = QT2 + ERY(1)                                               04JU0
          QT3 = QT3 + ERZ(1)                                               04JU0
          QT4 = QT4 + ERX(MP1)                                             04JU0
          QT5 = QT5 + ERY(MP1)                                             04JU0
          QT6 = QT6 + ERZ(MP1)                                             04JU0
COMMENT - CALL GRIP2A FOR SOLUTION OF MEMBER INCREMENTAL LOADS (STATION 17JU1
COMMENT - EQUILIBRIUM ERRORS)                                              17JU1
      CALL      GRIP2A ( RM,RO,W,SL,SU,L3,L4,L6,5)                         10MY1
COMMENT - CALL MEMENI FOR CACULATION OF INCREMENTAL FIXED-END-FORCES      17JU1
      CALL      MEMENI ( W,FOMT,L6 )                                       14SE0
 9900  CONTINUE                                                            26JA0
      RETURN                                                               26JA0
      END                                                                  26JA0
C
C       ******************************************************************
C                                 SURROUTINE
C       ******************************************************************
C
      SUBROUTINE DISCLD ( NC61T, NCDLT, ZL, L1 )                           11FE0
      COMMON /BLOCK6/ XLL( 75),   XRL( 75),   QXL( 75),   QYL( 75),        26JA0
     2   QZL( 75)                                                          26JA0
      COMMON /BLOCK7/ F( 42),     AE( 42),    SX( 42),    SY( 42),         21MY0
     2   SZ( 42),    QX( 42),    QY( 42),    QZ( 42),    DX( 42),          04JE0
     3   DY( 42),    DZ( 42),    ERX( 42),   ERY( 42),   ERZ( 42),         04JE0
     4   SQX( 42),   SQY( 42),   SQZ( 42),   U1( 42),    V1( 42),          04JE0
     5   W1( 42),    U2( 42),    V2( 42),    W2( 42),    DS(3,3, 42),      29JA1
     6   BM1S( 42),  BM2S( 42),  TTS( 42)                                  29JA1
      COMMON /BLK1/  KEEP2, KEEP3, KEEP4A,KEEP5A,KEEP6, KEEP7,             26JA0
     2        ITYPE, NCD2,  NCD3,  NCD4A, NCD5A, NCD6,  NCD7,              26JA0
     3        IABAN, IFORM, NM,    NJT,   NST,   NLT,   TOL,               26JA0
     4        M,     MP1,   MP2,   ISTT,  LTT,   ITYPEL,IDJ,               12FE0
     5        NSTL,  IP8,   IP9,   IP10,  KEEP4B,KEEP4C,NCD4B,             05AG0
     6        NCD4C, KEEP5B,KEEP5C,KEEP5D,NCD5B, NCD5C, NCD5D              05AG0
      COMMON /BLK2/ XL,XR,X1,X2,I1,I2,NQ,H,TH,HSQ,HCU,X2L                  26JA0
COMMENT - ZERO MEMBER LOAD DATA                                            15MY0
         DO 1020  I = 1,MP2                                                26JA0
            QX(I) = 0.0                                                    24JL1
            QY(I) = 0.0                                                    24JL1
 1020       QZ(I) = 0.0                                                    24JL1
            NC62T = NC61T - 1 + NCDLT                                      26JA0
            II = NC61T - 1                                                 26JA0
COMMENT - II GOES FROM NC61T TO NC62T                                      15MY0
 1050       II = II + 1                                                    26JA0
COMMENT - READ DATA FROM ONE CARD IMAGE (LOADS AT LEFT OF SECTION)         15MY0
            XL = XLL(II)                                                   26JA0
            XR = XRL(II)                                                   26JA0
            QXLT = QXL(II)                                                 26JA0
            QYLT = QYL(II)                                                 26JA0
            QZLT = QZL(II)                                                 26JA0
         IF (XR .NE. 0.0) GO TO 1100                                       26JA0
COMMENT - VARIABLE LOADING SECTION READ ONE CARD IMAGE (LOADS AT           15MY0
COMMENT - RIGHT OF SECTION)                                                15MY0
            II = II + 1                                                    26JA0
            XR = XRL(II)                                                   26JA0
            QXRT = QXL(II)                                                 26JA0
            QYRT = QYL(II)                                                 26JA0
            QZRT = QZL(II)                                                 26JA0
         GO TO 1110                                                        26JA0
 1100       QXRT = QXLT                                                    26JA0
            QYRT = QYLT                                                    26JA0
            QZRT = QZLT                                                    26JA0
 1110    CONTINUE                                                          26JA0
         IF ( XL .NE. XR) GO TO 2100                                       26JA0
COMMENT - CONCENTRATED LOADS CALL CONLD TO DISTRIBUTE CONCENTRATED         15MY0
COMMENT - LOADS TO ADJACENT STATIONS                                       15MY0
      CALL      CONLD ( QXLT, XL, QX, L1 )                                 11FE0
      CALL      CONLD ( QYLT, XL, QY, L1 )                                 11FE0
      CALL      CONLD ( QZLT, XL, QZ, L1 )                                 11FE0
         GO TO 2200                                                        26JA0
 2100    CONTINUE                                                          26JA0
            ZI1 = XL/TH + 2.0                                              26JA0
            I1 = ZI1                                                       26JA0
            X1 = I1*TH - XL - TH                                           26JA0
            ZI2 = XR/TH + 1.0                                              26JA0
            I2 = ZI2                                                       26JA0
            X2 = XR - I2*TH + TH                                           26JA0
            NQ = I2 - I1                                                   26JA0
COMMENT - DISTRIBUTION LOADS CALL LINLD TO DISTRIBUTE LOADS STATIONS       15MY0
COMMENT - I1 TO I2                                                         15MY0
         IF (QXLT .EQ. 0.0 .AND. QXRT .EQ. 0.0) GO TO 2150                 11MY0
      CALL      LINLD ( QXLT, QXRT, QX, L1 )                               11FE0
 2150    IF (QYLT .EQ. 0.0 .AND. QYRT .EQ. 0.0) GO TO 2160                 11MY0
      CALL      LINLD ( QYLT, QYRT, QY, L1 )                               11FE0
 2160    IF (QZLT .EQ. 0.0 .AND. QZRT .EQ. 0.0) GO TO 2200                 11MY0
      CALL      LINLD ( QZLT, QZRT, QZ, L1 )                               11FE0
 2200    CONTINUE                                                          26JA0
 9000    IF (II .LT. NC62T) GO TO 1050                                     26JA0
 9900    CONTINUE                                                          26JA0
      RETURN                                                               26JA0
      END                                                                  26JA0
C
```

```
C
C         ************************************************************
C                                      SUBROUTINE
C         ************************************************************
C
      SUBROUTINE MATM33 ( AA, BB, CC )                                  26JA0
C         THIS SUBROUTINE MULTIPLIES A 3X3 MATRIX ,AA, TIMES A          26JA0
C         3X3 MATRIX ,BB, TO PRODUCE A 3X3 MATRIX ,CC                   26JA0
      DIMENSION AA(3,3),BB(3,3),CC(3,3)                                 26JA0
          DO 25  I = 1,3                                                26JA0
          DO 25  J = 1,3                                                26JA0
              CC(I,J) = 0.0                                             26JA0
          DO 25  K = 1,3                                                26JA0
              CC(I,J) = AA(I,K)*BB(K,J) + CC(I,J)                       26JA0
   25     CONTINUE                                                      26JA0
      RETURN                                                            26JA0
      END                                                               26JA0
C
C         ************************************************************
C                                      SUBROUTINE
C         ************************************************************
C
C
      SUBROUTINE MATM31 ( AA, B,  C  )                                  26JA0
C         THIS SUBROUTINE MULTIPLIES A 3X3 MATRIX ,AA, TIMES A          26JA0
C         3X1 MATRIX ,B, TO PRODUCE A 3X1 MATRIX ,C                     26JA0
      DIMENSION AA(3,3),B(3),C(3)                                       26JA0
          DO 25  I = 1,3                                                26JA0
              C(I) = 0.0                                                26JA0
          DO 25  K = 1,3                                                26JA0
              C(I) =AA(I,K)*B(K) + C(I)                                 26JA0
   25     CONTINUE                                                      26JA0
      RETURN                                                            26JA0
      END                                                               26JA0
C
C         ************************************************************
C                                      SUBROUTINE
C         ************************************************************
C
      SUBROUTINE JNTSPR (SJX, SJY, SJZ, SJXY, QJX, QJY, QJZ, JTN)       20MY1
COMMENT - JNTSPR CALCULATES THE RESISTIVE SPRING FORCES AND TANGENT     13JU1
COMMENT - STIFFNESS OF ALL JOINT SPRINGS                                13JU1
      DIMENSION QQ(11), WW(11)                                          11AG0
      COMMON /BLOCK1/ X( 20),     Y( 20),     QXX( 20),   QYY( 20),    13FE0
     2    QZZ( 20),   SXX( 20),   SYY( 20),   SZZ( 20),   DXX( 20),    13FE0
     3    DYY( 20),   DZZ( 20),   RXX( 20),   RYY( 20),   RZZ( 20),    13FE0
     4    ERXX( 20),  ERYY( 20),  ERZZ( 20),  QMJ( 20),   WMJ( 20),    08AG0
     5    NSXX( 20),  NSYY( 20),  NSZZ( 20),  IMJ( 20),   NSXP( 20),   20MY1
     6    NSYP( 20),  ISTJR( 20)                                        20MY1
      COMMON /BLOCK2/ DXS( 25),   DYS( 25),   ZLS( 25),   DC1S( 25),   26JA0
     2    DC2S( 25),  PRF( 25),   PRAE( 25),  NCDS( 25),  IAXOPS( 25), 26JA0
     3    IOPOP( 25), IPINL( 25), IPINR( 25), NC51( 25),  INLOP( 25),  17OC0
     4    NAL( 25),   NSXL( 25),  NSYL( 25),  NSZL( 25),  NAR( 25),    17OC0
     5    NSXR( 25),  NSYR( 25),  NSZR( 25),  QM( 25),    WM( 25)       17OC0
      COMMON /BLOCK8/ NPT( 20),   ISJ( 20),   NQJ( 20,11),NWJ( 20,11), 08AG0
     2    NQJT(11),   NWJT(11)                                          08AG0
      COMMON /BLK7/ INLOPT,IFAE,KOFFJ,KOFFQW,KOFFSE                     07AP1
          IF (NSXX(JTN) .EQ. 0) GO TO 3510                              11AG0
COMMENT - X - CURVE                                                     13JU1
              NC = NSXX(JTN)                                            11AG0
              NPTT = NPT(NC)                                            11AG0
              ISYM = ISJ(NC)                                            11AG0
          DO 3505  I = 1, NPTT                                          11AG0
              QQ(I) = QMJ(JTN)*NQJ(NC,I)                                11AG0
 3505         WW(I) = WMJ(JTN)*NWJ(NC,I)                                11AG0
              WJ = DXX(JTN)                                             11AG0
     CALL       CURVE (QQ, WW, WJ, NPTT, ISYM, QJX, SJX, KOFFJ)         11AG0
          GO TO 3511                                                    08AG0
 3510     CONTINUE                                                      11AG0
              QJX = 0.0                                                 24JL1
              SJX = 0.0                                                 24JL1
 3511     IF (NSYY(JTN) .EQ. 0) GO TO 3520                              08AG0
COMMENT - Y - CURVE                                                     13JU1
              NC = NSYY(JTN)                                            11AG0
              NPTT = NPT(NC)                                            11AG0
              ISYM = ISJ(NC)                                            11AG0
          DO 3515  I = 1, NPTT                                          11AG0
              QQ(I) = QMJ(JTN)*NQJ(NC,I)                                11AG0
 3515         WW(I) = WMJ(JTN)*NWJ(NC,I)                                11AG0
              WJ = DYY(JTN)                                             11AG0
     CALL       CURVE (QQ, WW, WJ, NPTT, ISYM, QJY, SJY, KOFFJ)         11AG0
          GO TO 3521                                                    08AG0
 3520     CONTINUE                                                      11AG0
              QJY = 0.0                                                 24JL1
              SJY = 0.0                                                 24JL1
 3521     IF (NSZZ(JTN) .EQ. 0) GO TO 3530                              08AG0
COMMENT - Z - CURVE                                                     13JU1
              NC = NSZZ(JTN)                                            11AG0
              NPTT = NPT(NC)                                            11AG0
              ISYM = ISJ(NC)                                            11AG0
          DO 3525  I = 1, NPTT                                          11AG0
              QQ(I) = QMJ(JTN)*NQJ(NC,I)                                11AG0
 3525         WW(I) = WMJ(JTN)*NWJ(NC,I)                                11AG0
              WJ = DZZ(JTN)                                             11AG0
     CALL       CURVE (QQ, WW, WJ, NPTT, ISYM, QJZ, SJZ, KOFFJ)         11AG0
          GO TO 3531                                                    08AG0
 3530     CONTINUE                                                      11AG0
              QJZ = 0.0                                                 24JL1
              SJZ = 0.0                                                 24JL1
 3531     CONTINUE                                                      08AG0
          IF (NSXP(JTN) .EQ. 0) GO TO 3710                              20MY1
COMMENT - X-PRIME CURVE                                                 13JU1
              NC = NSXP(JTN)                                            20MY1
              NPTT = NPT(NC)                                            20MY1
              ISYM = ISJ(NC)                                            20MY1
          DO 3705 I = 1,NPTT                                            20MY1
              QQ(I) = QMJ(JTN)*NQJ(NC,I)                                20MY1
 3705         WW(I) = WMJ(JTN)*NWJ(NC,I)                                20MY1
              ISTT = ISTJR(JTN)                                         20MY1
              WJ = DC1S(ISTT)*DXX(JTN) + DC2S(ISTT)*DYY(JTN)            20MY1
     CALL       CURVE (QQ, WW, WJ, NPTT, ISYM, QJT, SJT, KOFFJ)         20MY1
              QJX = QJX + QJT*DC1S(ISTT)                                20MY1
              QJY = QJY + QJT*DC2S(ISTT)                                20MY1
              SJX = SJX + SJT*DC1S(ISTT)**2                             20MY1
              SJY = SJY + SJT*DC2S(ISTT)**2                             20MY1
              SJXY = SJT*DC1S(ISTT)*DC2S(ISTT)                          20MY1
          GO TO 3711                                                    20MY1
 3710     CONTINUE                                                      20MY1
              SJXY = 0.0                                                20MY1
 3711     IF (NSYP(JTN) .EQ. 0) GO TO 3810                              20MY1
COMMENT - Y-PRIME CURVE                                                 13JU1
              NC = NSYP(JTN)                                            20MY1
              NPTT = NPT(NC)                                            20MY1
              ISYM = ISJ(NC)                                            20MY1
          DO 3805 I = 1,NPTT                                            20MY1
              QQ(I) = QMJ(JTN)*NQJ(NC,I)                                20MY1
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3805          WW(I) = WMJ(JTN)*NWJ(NC,I)                                  20MY1
              ISTT = ISTJR(JTN)                                           20MY1
              WJ = -DC2S(ISTT)*DXX(JTN) + DC1S(ISTT)*DYY(JTN)             20MY1
     CALL        CURVE (QQ, WW, WJ, NPTT, ISYM, QJT, SJT, KOFFJ)          20MY1
              QJX = QJX - QJT*DC2S(ISTT)                                  20MY1
              QJY = QJY + QJT*DC1S(ISTT)                                  20MY1
              SJX = SJX + SJT*DC2S(ISTT)**2                               20MY1
              SJY = SJY + SJT*DC1S(ISTT)**2                               20MY1
              SJXY = SJXY - SJT*DC1S(ISTT)*DC2S(ISTT)                     20MY1
3810      CONTINUE                                                        20MY1
      RETURN                                                              11AG0
      END                                                                 11AG0
C
C         ****************************************************************
C                                   SUBROUTINE
C         ****************************************************************
C
      SUBROUTINE CURVE (QQ, WW, WJ, NPT, ISYM, QJ, S2, KOFFC)             11AG0
COMMENT - SUBROUTINE CURVE INTERPOLATES ALONG A STRESS-STRAIN OR          13JU1
COMMENT - SUPPORT CURVE (MEMBER OR JOINT) TO FIND THE STRESS OR FORCE QJ13JU1
COMMENT - CORRESPONDING TO THE STRAIN OR DISPLACEMENT WJ AND THE          13JU1
COMMENT - NEGATIVE OF THE SLOPE OF THE CURVE S2 BETWEEN ADJACENT POINTS  13JU1
COMMENT - ON THE CURVE - IF WJ IS OFF-CURVE, KOFFC IS SET EQUAL TO 1      13JU1
COMMENT - IF WJ IS EXACTLY ON A POINT, THE SLOPE OF THE SEGMENT TO THE    13JU1
COMMENT - RIGHT (INCREASING DEFORMATION)) IS USED                         13JU1
      DIMENSION QQ(11), WW(11)                                            11AG0
              NEG = 0                                                     11AG0
          IF (ISYM .EQ. 1 .AND. WJ .LT. 0.0) GO TO 2100                   11AG0
          GO TO 2200                                                      11AG0
2100      WJ = - WJ                                                       11AG0
              NEG = 1                                                     11AG0
2200      CONTINUE                                                        11AG0
          DO 3040 NP = 2,NPT                                              11AG0
          IF (WJ - WW(NP)) 3045,3055,3040                                 11AG0
3040      CONTINUE                                                        11AG0
              NP = NPT                                                    11AG0
          GO TO 3050                                                      11AG0
3045      IF (WJ - WW(1)) 3050,3055,3055                                  11AG0
3050          KOFFC = 1                                                   11AG0
3055          NP = NP - 1                                                 11AG0
              S2 = - (QQ(NP + 1) - QQ(NP))/(WW(NP + 1) - WW(NP))          11AG0
              QJ = QQ(NP) - S2*(WJ - WW(NP))                              11AG0
          IF (NEG .EQ. 0) GO TO 4300                                      11AG0
              QJ = -QJ                                                    11AG0
              WJ = -WJ                                                    11AG0
4300      CONTINUE                                                        11AG0
      RETURN                                                              11AG0
      END                                                                 11AG0
C
C         ****************************************************************
C                                   SUBROUTINE
C         ****************************************************************
C
      SUBROUTINE SANGLE (SA,SXT,SYT)                                      05SE0
      DIMENSION SA(3,3)                                                   05SE0
COMMENT - SANGLE COMPUTES THE STIFFNESS MATRIX FOR MEMBER SPRINGS IN      13JU1
COMMENT - STRUCTURE DIRECTIONS                                            13JU1
      COMMON /BLOCK2/ DXS( 25),    DYS( 25),    ZLS( 25),    DC1S( 25),   26JA0
     2    DC2S( 25),   PRF( 25),    PRAE( 25),   NCDS( 25),   IAXOPS( 25), 26JA0
     3    IOPOP( 25),  IPINL( 25),  IPINR( 25),  NC51( 25),   INLOP( 25),  17OC0
     4    NAL( 25),    NSXL( 25),   NSYL( 25),   NSZL( 25),   NAR( 25),    17OC0
     5    NSXR( 25),   NSYR( 25),   NSZR( 25),   QM( 25),     WM( 25)      17OC0
      COMMON /BLK1/  KEEP2, KEEP3, KEEP4A,KEEP5A,KEEP6, KEEP7,            26JA0
     2        ITYPE, NCD2,  NCD3,  NCD4A, NCD5A, NCD6,  NCD7,             26JA0
     3        IABAN, IFORM, NM,    NJT,   NST,   NLT,   TOL,              26JA0
     4        M,     MP1,   MP2,   ISTT,  LTT,   ITYPEL,IDJ,              12FE0
     5        NSTL,  IP8,   IP9,   IP10,  KEEP4B,KEEP4C,NCD4B,            05AG0
     6        NCD4C, KEEP5B,KEEP5C,KEEP5D,NCD5B, NCD5C, NCD5D             05AG0
        ALS = DC1S(ISTT)**2                                               05SE0
        BES = DC2S(ISTT)**2                                               05SE0
        ALBE = DC1S(ISTT)*DC2S(ISTT)                                      05SE0
        SA(1,1) = ALS*SXT + BES*SYT                                       05SE0
        SA(1,2) = ALBE*( -SXT + SYT)                                      05SE0
        SA(2,1) = SA(1,2)                                                 05SE0
        SA(2,2) = BES*SXT + ALS*SYT                                       05SE0
        SA(1,3) = 0.0                                                     24JL1
        SA(2,3) = 0.0                                                     24JL1
        SA(3,1) = 0.0                                                     24JL1
        SA(3,2) = 0.0                                                     24JL1
        SA(3,3) = 0.0                                                     24JL1
      RETURN                                                              05SE0
      END                                                                 05SE0
C
C         ****************************************************************
C                                   SUBROUTINE
C         ****************************************************************
C
      SUBROUTINE MEMSOL ( JJ,RM,RO,W,SL,SU,L1,L3,L4,L6)                   20NO0
COMMENT - SUBROUTINE MEMSOL DOES THE ITERATIVE NONLINEAR MEMBER SOLUTION09JU1
COMMENT - THIS SOLUTION IS REQUIRED TO FIND THE MEMBER-END-FORCES FOR     09JU1
COMMENT - THE JOINT EQUILIBRIUM CHECK AND FOR THE FINAL MEMBER SOLUTION  09JU1
      DIMENSION RM(L3,L6), RO(L6), W(L6), SL(L3), SU(L4)                  08AP0
      DIMENSION DC(3,3), DMM(3), SA(3,3),  DMS(3), FMM(6), FMT(3)         03JE0
      COMMON /BLOCK1/ X( 20),      Y( 20),      QXX( 20),    QYY( 20),    13FE0
     2    QZZ( 20),    SXX( 20),    SYY( 20),    SZZ( 20),    DXX( 20),    13FE0
     3    DYY( 20),    DZZ( 20),    RXX( 20),    RYY( 20),    RZZ( 20),    13FE0
     4    ERXX( 20),   ERYY( 20),   ERZZ( 20),   QMJ( 20),    WMJ( 20),    08AG0
     5    NSXX( 20),   NSYY( 20),   NSZZ( 20),   IMJ( 20),    NSXP( 20),   20MY1
     6    NSYP( 20),   ISTJR( 20)                                         20MY1
      COMMON /BLOCK2/ DXS( 25),    DYS( 25),    ZLS( 25),    DC1S( 25),   26JA0
     2    DC2S( 25),   PRF( 25),    PRAE( 25),   NCDS( 25),   IAXOPS( 25), 26JA0
     3    IOPOP( 25),  IPINL( 25),  IPINR( 25),  NC51( 25),   INLOP( 25),  17OC0
     4    NAL( 25),    NSXL( 25),   NSYL( 25),   NSZL( 25),   NAR( 25),    17OC0
     5    NSXR( 25),   NSYR( 25),   NSZR( 25),   QM( 25),     WM( 25)      17OC0
      COMMON /BLOCK3/ DXL( 25),    DYL( 25),    ZLL( 25),    DC1L( 25),   26JA0
     2    DC2L( 25),   UQX( 25),    UQY( 25),    NCDL( 25),   IAXOPL( 25), 26JA0
     3    NC61( 25)                                                       26JA0
      COMMON /BLOCK4/ JT1( 40),    JT2( 40),    IST( 40),    LT( 40),     26JA0
     2    FOMM( 40,6), SMC( 40,21), NITM( 40),  IMM( 40),    IMC( 40)     01JL1
      COMMON /BLOCK5/ XLS( 50),    XRS( 50),    FL( 50),     AEL( 50),    26JA0
     2    SXL( 50),    SYL( 50),    SZL( 50)                              26JA0
      COMMON /BLOCK6/ XLL( 75),    XRL( 75),    QXL( 75),    QYL( 75),    26JA0
     2    QZL( 75)                                                        26JA0
      COMMON /BLOCK7/ F( 42),      AE( 42),     SX( 42),     SY( 42),     04JE0
     2    SZ( 42),     QX( 42),     QY( 42),     QZ( 42),     DX( 42),     04JE0
     3    DY( 42),     DZ( 42),     ERX( 42),    ERY( 42),    ERZ( 42),    04JE0
     4    SQX( 42),    SQY( 42),    SQZ( 42),    U1( 42),     V1( 42),     04JE0
     5    W1( 42),     U2( 42),     V2( 42),     W2( 42),     DS(3,3, 42), 29JA1
     6    BM1S( 42),   BM2S( 42),   TTS( 42)                              29JA1
      COMMON /BLK1/  KEEP2, KEEP3, KEEP4A,KEEP5A,KEEP6, KEEP7,            26JA0
     2        ITYPE, NCD2,  NCD3,  NCD4A, NCD5A, NCD6,  NCD7,             26JA0
     3        IABAN, IFORM, NM,    NJT,   NST,   NLT,   TOL,              26JA0
     4        M,     MP1,   MP2,   ISTT,  LTT,   ITYPEL,IDJ,              12FE0
     5        NSTL,  IP8,   IP9,   IP10,  KEEP4B,KEEP4C,NCD4B,            05AG0
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    6        NCD4C, KEEP5B,KEEP5C,KEEP5D,NCD5B, NCD5C, NCD5D                 05AG0
      COMMON /BLK2/ XL,XR,X1,X2,I1,I2,NQ,M,TH,HSQ,HCU,X2L                   26JA0
      COMMON /BLK3/ MNJT,MNST,MNLT,MNM,MNC5,MNC6,MDJT,MNJS,MNE,MNCS,        11JU1
     2    MNPCS,MNSS,MNOWM                                                  11JU1
      COMMON /BLK4/ ST1,ST2,ST3,ST4,ST5,ST6                                 26JA0
      COMMON /BLK5/ NFSUB,NITF,N1,N2                                        04JE0
      COMMON /BLK6/ QT1,QT2,QT3,QT4,QT5,QT6                                 04JE0
      COMMON /BLK7/ INLOPT,IFAE,KOFFJ,KOFFQW,KOFFSE                         07AP1
      COMMON / RI / NL, ML, J1                                              08AP0
      COMMON /ITC/ MNITF,ERR1,ERR2,MNITM,ER1,ER2,MM(5),MJ(5)                07AP1
      COMMON /NIT/ APROB,PRINT                                              01JU1
   51 FORMAT (/,5X,2I5,/,15H      FROM JOINT,2X,6E11.3,/,                   05SE0
     2         15H      CENTERLINE,2X,6E11.3,/,                             05SE0
     3         15H       TO JOINT ,2X,6E11.3)                               05SE0
   52 FORMAT ( /,11H      MEMBER,I5,  26H CONVERGED AFTER ITERATION,I5,     10MY1
     2    //)                                                               10MY1
   53 FORMAT (//,11H      MEMBER,I5,  30H NOT CONVERGED AFTER ITERATION,    10MY1
     2   I5,//)                                                             10MY1
   54 FORMAT (    46H     ** LIMIT OF MEMBERS Q-W CURVE EXCEEDED ON,        07AP1
     2         24H PRECEEDING ITERATION **)                                 07AP1
   55 FORMAT (    44H     ** LIMIT OF MEMBERS STRESS-STRAIN CURVE,          07AP1
     2         33H EXCEEDED ON PRECEEDING ITERATION)                        07AP1
COMMENT - SET TEMPORARY CONTROL CONSTANTS                                   16MY0
              MP22 = MP2/2                                                  10MY1
              ISTT = IST(JJ)                                                16MR0
              LTT = LT(JJ)                                                  16MR0
         IF ( ISTT .EQ. 0 ) GO TO 9900                                      13MR0
              IAXOPT = IAXOPS(ISTT)                                         05SE0
              IPINLT = IPINL(ISTT)                                          13MR0
              IPINRT = IPINR(ISTT)                                          13MR0
              ZL = ZLS(ISTT)                                                13MR0
              PRFT = PRF(ISTT)                                              13MR0
              PRAET = PRAE(ISTT)                                            13MR0
              NCDST = NCDS(ISTT)                                            13MR0
              NC51T = NC51(ISTT)                                            13MR0
              INLOPT = INLOP(ISTT)                                          10MY1
              TH = ZL/M                                                     13MR0
              H = 0.5*TH                                                    13MR0
              HSQ = H*H                                                     13MR0
              HCU = HSQ*H                                                   13MR0
              NL = 3*MP1                                                    05JE0
              ML = 1                                                        13MR0
              NFSUB = 22                                                    03JE0
         IF (INLOPT .EQ. 1) GO TO 2500                                      13N00
         IF (NCDST .EQ. 0) GO TO 2100                                       13N00
COMMENT - NONPRISMATIC MEMBER DISCRETIZE MEMBER STIFFNESS DATA              16MY0
     CALL        DISCST (NC51T,NCDST,ZL,L1)                                 13N00
         GO TO 2400                                                         24FE1
 2100    CONTINUE                                                           10MY1
COMMENT - PRISMATIC MEMBER DISCRETIZE MEMBER STIFFNESS DATA                 16MY0
         DO 2300  I = 1,MP2                                                 13MR0
              SX(I) = 0.0                                                   24JL1
              SY(I) = 0.0                                                   24JL1
              SZ(I) = 0.0                                                   24JL1
              SQX(I) = 0.0                                                  24JL1
              SQY(I) = 0.0                                                  24JL1
              SQZ(I) = 0.0                                                  24JL1
              AE(I) = PRAET                                                 13MR0
 2300         F(I) = PRFT                                                   13MR0
              AE(1) = 0.0                                                   24JL1
              F(1) = 0.0                                                    24JL1
              AE(MP2) = 0.0                                                 24JL1
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              F(MP2) = 0.0                                                  24JL1
 2400    CONTINUE                                                           24FE1
COMMENT - STORE MEMBER - END - RESTRAINTS (LINEAR SPRINGS)                  01JL1
              ST1 = SX(1)                                                   13MR0
              ST2 = SY(1)                                                   13MR0
              ST3 = SZ(1)                                                   13MR0
              ST4 = SX(MP1)                                                 13MR0
              ST5 = SY(MP1)                                                 13MR0
              ST6 = SZ(MP1)                                                 13MR0
 2500    CONTINUE                                                           10MY1
         IF (NITM(JJ) .EQ. MNITM + 1) GO TO 2700                            28N00
COMMENT - SKIP FOR FINAL MEMBER SOLUTION                                    01JL1
COMMENT - SET UP MEMBERS TRANSFORMATION MATRIX DC                           16MY0
              DC(1,3) = 0.0                                                 24JL1
              DC(2,3) = 0.0                                                 24JL1
              DC(3,1) = 0.0                                                 24JL1
              DC(3,2) = 0.0                                                 24JL1
              DC(3,3) = 1.0                                                 13MR0
              DC(1,1) = DC1S(ISTT)                                          13MR0
              DC(1,2) = DC2S(ISTT)                                          13MR0
              DC(2,1) = -DC(1,2)                                            13MR0
              DC(2,2) = DC(1,1)                                             13MR0
 2700    CONTINUE                                                           13MR0
         IF (LTT .NE. 0 ) GO TO 2750                                        13MR0
COMMENT - ZERO MEMBER LOADS FOR LOAD TYPE ZERO                              16MY0
         DO 2720  I = 1,MP2                                                 17MR0
              QX(I) = 0.0                                                   24JL1
              QY(I) = 0.0                                                   24JL1
 2720         QZ(I) = 0.0                                                   24JL1
         GO TO 3000                                                         13MR0
COMMENT - SET CONTROL CONSTANTS                                             16MY0
 2750         UQXT = UQX(LTT)                                               13MR0
              UQYT = UQY(LTT)                                               13MR0
              NCDLT = NCDL(LTT)                                             13MR0
              NC61T = NC61(LTT)                                             13MR0
         IF (NCDLT .NE. 0) GO TO 2900                                       13MR0
COMMENT - UNIFORMLY LOADED MEMBER DISCRETIZE MEMBER LOADS                   16MY0
         DO 2800  I = 2,M                                                   13MR0
              QX(I) = UQXT*TH                                               13MR0
              QY(I) = UQYT*TH                                               13MR0
 2800         QZ(I) = 0.0                                                   13MR0
              QX(1) = 0.5*UQXT*TH                                           24JL1
              QY(1) = 0.5*UQYT*TH                                           24JL1
              QZ(1) = 0.0                                                   24JL1
              QX(MP1) = 0.5*UQXT*TH                                         24JL1
              QY(MP1) = 0.5*UQYT*TH                                         24JL1
              QZ(MP1) = 0.0                                                 24JL1
              QX(MP2) = 0.0                                                 24JL1
              QY(MP2) = 0.0                                                 24JL1
              QZ(MP2) = 0.0                                                 24JL1
         GO TO 3000                                                         13MR0
COMMENT - DISCRETIZE GENERAL MEMBER LOADS                                   16MY0
 2900 CALL       DISCLD ( NC61T, NCDLT, ZL , L1 )                           13MR0
 3000    CONTINUE                                                           13MR0
COMMENT - STORE MEMBER-END-LOADS QT1 -QT6                                   16MY0
              QT1 = QX(1)                                                   13MR0
              QT2 = QY(1)                                                   13MR0
              QT3 = QZ(1)                                                   13MR0
              QT4 = QX(MP1)                                                 13MR0
              QT5 = QY(MP1)                                                 13MR0
              QT6 = QZ(MP1)                                                 13MR0
         IF (NITF .GT. 1) GO TO 3080                                        03JE0
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      IF (ITYPE .EQ. 2) GO TO 3080                                      03JE0
      IF (NITM(JJ) .EQ. MNITM + 1) GO TO 3080                           05DE0
COMMENT - SKIP FOR FINAL MEMBER SOLUTION                                01JL1
      DO 3050  I = 1,MP2                                                03JE0
             DX(I) = 0.0                                                24JL1
             DY(I) = 0.0                                                24JL1
 3050        DZ(I) = 0.0                                                24JL1
      GO TO 3100                                                        03JE0
 3080 READ  (N1)   ((DX(I),DY(I),DZ(I)), I = 1,MP2)                     03JE0
 3100     CONTINUE                                                      03JE0
      IF (NITM(JJ) .EQ. MNITM + 1) GO TO 3300                           28NO0
COMMENT - SKIP FOR FINAL MEMBER SOLUTION                                01JL1
COMMENT - SET MEMBER-END-DISPLACEMENTS IN STRUCTURE COORDINATES DMS     16MY0
COMMENT - EQUAL TO STRUCTURE JOINT DISPLACEMENTS AT FROM JOINT          16MY0
             J1I = JT1(JJ)                                              08AP0
             DMS(1) = DXX(J1I)                                          08AP0
             DMS(2) = DYY(J1I)                                          08AP0
             DMS(3) = DZZ(J1I)                                          08AP0
COMMENT - TRANSFORM DMS TO DMM AT FROM JOINT                            16MY0
     CALL        MATM31 (DC,DMS,DMM)                                    13MR0
COMMENT - SET MEMBER END-LOADS TO 1.0E40  TIMES DMM AT FROM JOINT       16MY0
             ERX(1) = (DMM(1) - DX(1))*1.0E40                           03JE0
             ERY(1) = (DMM(2) - DY(1))*1.0E40                           03JE0
      IF (IPINLT .EQ. 1) GO TO 3120                                     16MR0
             ERZ(1) = (DMM(3) - DZ(1))*1.0E40                           03JE0
      GO TO 3150                                                        16MR0
 3120        ERZ(1) = 0.0                                               03JE0
 3150     CONTINUE                                                      16MR0
COMMENT - REPEAT ABOVE FOR TO JOINT                                     16MY0
             J2I = JT2(JJ)                                              08AP0
             DMS(1) = DXX(J2I)                                          08AP0
             DMS(2) = DYY(J2I)                                          08AP0
             DMS(3) = DZZ(J2I)                                          08AP0
     CALL        MATM31 (DC,DMS,DMM)                                    13MR0
             ERX(MP1) = (DMM(1) - DX(MP1))*1.0E40                       03JE0
             ERY(MP1) = (DMM(2) - DY(MP1))*1.0E40                       03JE0
      IF (IPINRT .EQ. 1) GO TO 3220                                     16MR0
             ERZ(MP1) = (DMM(3) - DZ(MP1))*1.0E40                       03JE0
      GO TO 3250                                                        16MR0
 3220        ERZ(MP1) = 0.0                                             03JE0
 3250     CONTINUE                                                      16MR0
 3300     CONTINUE                                                      00FE0
 3500     CONTINUE                                                      00FE0
COMMENT - START ITERATIVE SOLUTION FOR MEMBER DISPLACEMENTS CONSISTENT   01JL1
COMMENT - WITH APPLIED LOADS AND IMPOSED DISPLACEMENTS FROM FRAME       01JL1
COMMENT - SOLUTION                                                      01JL1
      IF (INLOPT .EQ. 0) GO TO 3505                                     05FE1
             KOFFQW = 0                                                 07AP1
     CALL NLSS(L1)                                                      05FE1
COMMENT - STORE MEMBER - END - RESTRAINTS (NONLINEAR SPRINGS)           01JL1
             ST1 = SX(1)                                                13MR0
             ST2 = SY(1)                                                13MR0
             ST3 = SZ(1)                                                13MR0
             ST4 = SX(MP1)                                              13MR0
             ST5 = SY(MP1)                                              13MR0
             ST6 = SZ(MP1)                                              13MR0
 3505 CONTINUE                                                          05FE1
COMMENT - SET MEMBER END RESTRAINTS EQUAL TO 1.0E40 FOR MEMBER SOLUTION  28NO0
             SX(1) = 1.0E40                                             24JL1
             SY(1) = 1.0E40                                             24JL1
             SZ(1) = 1.0E40                                             24JL1
             SX(MP1) = 1.0E40                                           24JL1
             SY(MP1) = 1.0E40                                           24JL1
             SZ(MP1) = 1.0E40                                           24JL1
COMMENT - ZERO PINNED END ROTATIONAL RESTRAINTS                         16MY0
      IF (IPINLT .EQ. 1) SZ(1) = 0.0                                    13MR0
      IF (IPINRT .EQ. 1) SZ(MP1) = 0.0                                  13MR0
COMMENT - ZERO INTERIOR STATION EQUILIBRIUM ERRORS                      01JL1
      DO 3510  I = 2,M                                                  05SE0
             ERX(I) = 0.0                                               24JL1
             ERY(I) = 0.0                                               24JL1
 3510        ERZ(I) = 0.0                                               24JL1
             NITM(JJ) = NITM(JJ) + 1                                    00FE0
             NITM1 = NITM(JJ) - 1                                       10MY1
             KOFFSE = 0                                                 07AP1
COMMENT - DO FOR EACH ELEMENT                                           01JL1
      DO 3600  I = 2,MP1                                                03JE0
             IM1 = I - 1                                                28MY0
COMMENT - COMPUTE FORCES ON ENDS OF DISCRETE ELEMENT                    01JL1
     CALL        ELEMFO (DX(IM1),DY(IM1),DZ(IM1),DX(I),DY(I),DZ(I),I,   28MY0
    2     U1T,V1T,W1T,U2T,V2T,W2T)                                      28MY0
      IF (NITM(JJ) .NE. MNITM + 2) GO TO 3530                           28NO0
             U1(I) = U1T                                                28NO0
             V1(I) = V1T                                                28NO0
             W1(I) = W1T                                                28NO0
             U2(I) = U2T                                                28NO0
             V2(I) = V2T                                                28NO0
             W2(I) = W2T                                                28NO0
      GO TO 3600                                                        02DE0
 3530 CONTINUE                                                          28NO0
COMMENT - COMPUTE PARTIAL EQUILIBRIUM ERRORS BY SUMMING FORCES ON       01JL1
COMMENT - ADJACENT ELEMENTS                                             01JL1
      IF (I .EQ. 2 .AND. IPINLT .EQ. 1) ERZ(1) = W1T                    29AG0
      IF (I .EQ. 2) GO TO 3550                                          03JE0
             ERX(IM1) = ERX(IM1) + U1T                                  28MY0
             ERY(IM1) = ERY(IM1) + V1T                                  28MY0
             ERZ(IM1) = ERZ(IM1) + W1T                                  28MY0
      IF ( I .EQ. MP1 .AND. IPINRT .EQ. 1) ERZ(MP1) = W2T               29AG0
      IF (I .EQ. MP1) GO TO 3600                                        03JE0
 3550        ERX(I) = ERX(I) + U2T                                      28MY0
             ERY(I) = ERY(I) + V2T                                      28MY0
             ERZ(I) = ERZ(I) + W2T                                      28MY0
 3600 CONTINUE                                                          03JE0
      IF (NITM(JJ) .EQ. MNITM + 2) GO TO 4300                           28NO0
COMMENT - SKIP FOR FINAL MEMBER SOLUTION                                01JL1
COMMENT - DO FOR EACH INTERIOR STATION                                  01JL1
      DO 3800  I = 2,M                                                  28MY0
COMMENT - ADD STATIONS LOADS AND STATION RESISTIVE SPRING FORCES TO     01JL1
COMMENT - COMPLETE COMPUTATION OF EQUILIBRIUM ERRORS                    01JL1
      IF (INLOPT .EQ. 0) SQX(I) = -SX(I)*DX(I)                          20FE1
             ERX(I) = QX(I) - ERX(I) + SQX(I)                           20FE1
      IF (INLOPT .EQ. 0) SQY(I) = -SY(I)*DY(I)                          20FE1
             ERY(I) = QY(I) - ERY(I) + SQY(I)                           20FE1
      IF (INLOPT .EQ. 0) SQZ(I) = -SZ(I)*DZ(I)                          20FE1
             ERZ(I) = QZ(I) - ERZ(I) + SQZ(I)                           20FE1
 3800 CONTINUE                                                          03JE0
      IF (INLOPT .EQ. 0) SQZ(1) = -SZ(1)*DZ(1)                          20FE1
      IF (IPINLT .EQ. 1) ERZ(1) = QZ(1) -ERZ(1) + SQZ(1)                20FE1
      IF (INLOPT .EQ. 0) SQZ(MP1) = -SZ(MP1)*DZ(MP1)                    20FE1
      IF (IPINRT .EQ. 1) ERZ(MP1) = QZ(MP1) -ERZ(MP1) + SQZ(MP1)        20FE1
      IF (NITM1 .EQ. 0) GO TO 3815                                      03SE0
      IF (IMM(JJ) .EQ. 0) GO TO 3815                                    03SE0
COMMENT - PRINT DISPLACEMENTS AND EQUILIBRIUM ERRORS AT FIRST INTERIOR  01JL1
COMMENT - STATIONS AND CENTER STATION FOR MONITOR MEMBERS               01JL1
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      PRINT 51, JJ,  NITM1,     DX(2), DY(2), DZ(2), ERX(2), ERY(2),    03SE0
     2     ERZ(2), DX(MP22),DY(MP22),DZ(MP22),ERX(MP22),ERY(MP22),      030C0
     3     ERZ(MP22),DX(M),DY(M),DZ(M),ERX(M),ERY(M),ERZ(M)             28NO0
           IF (KOFFOW .EQ. 1) PRINT 54                                  07AP1
           IF (KOFFSE .EQ. 1) PRINT 55                                  07AP1
           IF (APROB .NE. PRINT) GO TO 3815                             01JU1
COMMENT - DUMP OF ALL STATION DISPLACEMENTS AND EQUILIBRIUM ERRORS. TO  01JL1
COMMENT - ACTIVATE SET LAST FIVE COLUMNS IN PROBLEM NUMBER CARD EQUAL   01JL1
COMMENT - TO PRINT                                                      01JL1
           DO 3805 I = 1,MP1                                            01JU1
 3805 PRINT 7777,DX(I),DY(I),DZ(I),ERX(I),ERY(I),ERZ(I)                 01JU1
 7777 FORMAT (17X,6E11.3)                                               01JU1
 3815      CONTINUE                                                     030C0
COMMENT - COMPARE EQULIBRIUM ERRORS WITH SPECIFED TOLERANCES            01JU1
           DO 3825  I = 1,MP1                                           11JE0
           IF (ABS(ERX(I)) .GT. ER1)  GO TO 3850                        10JE0
           IF (ABS(ERY(I)) .GT. ER1)  GO TO 3850                        10JE0
           IF (ABS(ERZ(I)) .GT. ER2)  GO TO 3850                        10JE0
 3825      CONTINUE                                                     11JE0
           GO TO 4200                                                   11JE0
 3850 CONTINUE                                                          11JE0
           IF (NITM(JJ) .LE. MNITM)   GO TO 3880                        01JL1
COMMENT - IF MAXIMUN NUMBER OF MEMBER ITERATIONS SET IMC = 1 AND STOP   01JL1
COMMENT - ITERATION PROCESS                                             01JL1
                 IMC(JJ) = 1                                            01JL1
           GO TO 4250                                                   01JL1
COMMENT - SOLVE MEMBER FOR LINEAR INCREMENTS OF DISPLACEMENT            01JL1
 3880 CALL        GRIP2A ( RM,RO,W,SL,SU,L3,L4,L6,5)                    10MY1
COMMENT - INCREMENT MEMBER DISPLACEMENTS                                01JL1
                 J = 1                                                  03JE0
           DO 3900  I = 1,MP1                                           03JE0
                 DX(I) = DX(I) + W(J)                                   03JE0
                 J = J + 1                                              03JE0
                 DY(I) = DY(I) + W(J)                                   03JE0
                 J = J + 1                                              03JE0
                 DZ(I) = DZ(I) + W(J)                                   03JE0
                 J = J + 1                                              03JE0
 3900      CONTINUE                                                     03JE0
COMMENT - ZERO EQUILIBRIUM ERRORS AT END STATIONS                       01JL1
                 ERX(1) = 0.0                                           24JL1
                 ERY(1) = 0.0                                           24JL1
                 ERZ(1) = 0.0                                           24JL1
                 ERX(MP1) = 0.0                                         24JL1
                 ERY(MP1) = 0.0                                         24JL1
                 ERZ(MP1) = 0.0                                         24JL1
           GO TO 3500                                                   10MY1
 4200      CONTINUE                                                     10JE0
      PRINT 52, JJ, NITM1                                               10MY1
           GO TO 4300                                                   10MY1
 4250      PRINT 53, JJ, NITM1                                          10MY1
COMMENT - CALCULATE MEMBER - END - FORCES                               01JL1
 4300 CALL        MEMEND (  FMM,L6)                                     10MY1
           IF (NITM(JJ) .NE. MNITM + 2) GO TO 4350                      28NO0
                 U1(2) = FMM(1)                                         28NO0
                 V1(2) = FMM(2)                                         28NO0
                 W1(2) = FMM(3)                                         28NO0
                 U2(MP1) = FMM(4)                                       28NO0
                 V2(MP1) = FMM(5)                                       28NO0
                 W2(MP1) = FMM(6)                                       28NO0
           GO TO 4475                                                   28NO0
 4350      CONTINUE                                                     28NO0
COMMENT - SUBTRACT MEMBER - END - FORCES FROM JOINT EQUILIBRIUM ERRORS  01JL1
COMMENT - TO COMPLETE COMPUTATION OF JOINT EQUILIBRIUM ERRORS           01JL1
      CALL        ADJTER ( FMM(1),FMM(4),JT1(JJ),JT2(JJ),DC1S(ISTT),    04JE0
     2     DC2S(ISTT))                                                  04JE0
COMMENT - STORE MEMBER - END - FORCES AS MEMBER INCREMENTAL FIXED -     01JL1
COMMENT - END - FORCES TO CALCULATE INCREMENTAL FIXED - END- FORCES     01JL1
COMMENT - IN NEXT PROBLEM                                               01JL1
           DO 4400  I = 1,6                                             14SE0
 4400           FOMM(JJ,I) = FMM(I)                                     14SE0
 4475      CONTINUE                                                     28NO0
COMMENT - STORE MEMBER DISPLACEMENTS                                    01JL1
      WRITE (N2)  ((DX(I),DY(I),DZ(I)),I=1,MP2)                         04JE0
 9900      CONTINUE                                                     17MR0
      RETURN                                                            13MR0
      END                                                               13MR0
C
C      *****************************************************************
C                                SUBROUTINE
C      *****************************************************************
C
      SUBROUTINE ADJTER (F1M, F2M, J1, J2, DC1, DC2)                    23MR0
COMMENT - SUBROUTINE ADJTER TRANSFORMS MEMBER-END-FORCES TO STRUCTURE   20MY0
COMMENT - COORDINATES AND SUBTRACTS FROM APPROPRIATE JOINT EQUILIBRIUM  20MY0
COMMENT - ERROR FOR FRAME                                               20MY0
      DIMENSION  F1M(3), F2M(3), F1S(3), F2S(3)                         21MR0
      DIMENSION  DCT(3,3)                                               21MR0
      COMMON /BLOCK1/ X( 20),      Y( 20),      QXX( 20),    QYY( 20),  13FE0
     2     QZZ( 20),   SXX( 20),   SYY( 20),   SZZ( 20),   DXX( 20),    13FE0
     3     DYY( 20),   DZZ( 20),   RXX( 20),   RYY( 20),   RZZ( 20),    13FE0
     4     ERXX( 20),  ERYY( 20),  ERZZ( 20),  QMJ( 20),   WMJ( 20),    08AG0
     5     NSXX( 20),  NSYY( 20),  NSZZ( 20),  IMJ( 20),   NSXP( 20),   20MY1
     6     NSYP( 20),  ISTJR( 20)                                       20MY1
COMMENT - FORM TRANSPOSE OF MEMBER TRANSFORMATION MATRIX                20MY0
                 DCT(1,3) = 0.0                                         24JL1
                 DCT(2,3) = 0.0                                         24JL1
                 DCT(3,1) = 0.0                                         24JL1
                 DCT(3,2) = 0.0                                         24JL1
                 DCT(3,3) = 1.0                                         21MR0
                 DCT(1,1) = DC1                                         21MR0
                 DCT(1,2) = -DC2                                        21MR0
                 DCT(2,1) = DC2                                         21MR0
                 DCT(2,2) = DC1                                         21MR0
COMMENT - TRANSFORM MEMBER-END-FORCES AT FROM JOINT TO STRUCTURE COORD  20MY0
      CALL        MATM31 (DCT,F1M,F1S)                                  21MR0
COMMENT - ACCUMULATE JOINT EQUILIBRIUM ERROR AT MEMBERS FROM JOINT      20MY0
                 ERXX(J1) = ERXX(J1) - F1S(1)                           23MR0
                 ERYY(J1) = ERYY(J1) - F1S(2)                           23MR0
                 ERZZ(J1) = ERZZ(J1) - F1S(3)                           23MR0
COMMENT - TRANSFORM MEMBER-END-FORCES AT TO JOINT TO STRUCTURE COORD    20MY0
      CALL        MATM31 (DCT,F2M,F2S)                                  23MR0
COMMENT - ACCUMULATE JOINT EQUILIBRIUM ERROR AT MEMBERS TO JOINT        20MY0
                 ERXX(J2) = ERXX(J2) - F2S(1)                           23MR0
                 ERYY(J2) = ERYY(J2) - F2S(2)                           23MR0
                 ERZZ(J2) = ERZZ(J2) - F2S(3)                           23MR0
      RETURN                                                            21MR0
      END                                                               21MR0
C
C      *****************************************************************
C                                SUBROUTINE
C      *****************************************************************
C
      SUBROUTINE PRINT9 (AN2,NPROB,RM,RO,W,SL,SU,L1,L3,L4,L6)           23NO0
COMMENT - SUBROUTINE PRINT9 OUTPUTS MEMBER RESULTS                      09JU1
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      DIMENSION AN2(20), NPROB(2)                                        24JL1
      COMMON /BLOCK2/ DXS( 25),   DYS( 25),   ZLS( 25),   DC1S( 25),     26JA0
     2    DC2S( 25),  PRF( 25),   PRAE( 25),  NCDS( 25),  IAXOPS( 25),   26JA0
     3    IOPOP( 25), IPINL( 25), IPINR( 25), NC51( 25),  INLOP( 25),    17OC0
     4    NAL( 25),   NSXL( 25),  NSYL( 25),  NSZL( 25),  NAR( 25),      17OC0
     5    NSXR( 25),  NSYR( 25),  NSZR( 25),  QM( 25),    WM( 25)        17OC0
      COMMON /BLOCK4/ JT1( 40),   JT2( 40),   IST( 40),   LT( 40),       26JA0
     2    FOMM( 40,6), SMC( 40,21), NITM( 40), IMM( 40),  IMC( 40)       01JL1
      COMMON /BLOCK7/ F( 42),     AE( 42),    SX( 42),    SY( 42),       04JE0
     2    SZ( 42),    QX( 42),    QY( 42),    QZ( 42),    DX( 42),       04JE0
     3    OY( 42),    DZ( 42),    ERX( 42),   ERY( 42),   ERZ( 42),      04JE0
     4    SQX( 42),   SQY( 42),   SQZ( 42),   U1( 42),    V1( 42),       04JE0
     5    W1( 42),    U2( 42),    V2( 42),    W2( 42),    DS(3,3, 42),   29JA1
     6    BM1S( 42),  BM2S( 42),  TTS( 42)                               29JA1
      COMMON /BLK1/  KEEP2, KEEP3, KEEP4A,KEEP5A,KEEP6, KEEP7,           26JA0
     2         ITYPE, NCD2,  NCD3,  NCD4A, NCD5A, NCD6,  NCD7,           26JA0
     3         IABAN, IFORM, NM,    NJT,   NST,   NLT,   TOL,            26JA0
     4         M,     MP1,   MP2,   ISTT,  LTT,   ITYPEL,IDJ,            12FE0
     5         NSTL,  IP8,   IP9,   IP10,  KEEP4B,KEEP4C,NCD4B,          05AG0
     6         NCD4C, KEEP5B,KEEP5C,KEEP5D,NCD5B, NCD5C, NCD5D           05AG0
      COMMON /BLK2/ XL,XR,X1,X2,I1,I2,NQ,H,TH,HSQ,HCU,X2L                26JA0
      COMMON /BLK5/ NFSUB,NITF,N1,N2                                     10MY1
      COMMON /BLK7/ INLOPT,IFAE,KOFFJ,KOFFQW,KOFFSE                      07AP1
      COMMON /ITC/ MNITF,ERR1,ERR2,MNITM,ER1,ER2,MM(5),MJ(5)             07AP1
      COMMON /WARN/ NJNC,NMNC                                            02JL1
   11 FORMAT  (  5H1      ,80X    10HI-----TRIM  )                       25MR0
   16 FORMAT (    17H       PROB (CONTD), /5X,A4,A1,5X,A2,17A4,/)        18MY0
   51 FORMAT  (   30H       TABLE 9 - MEMBER RESULTS ,/  )               25MR0
   52 FORMAT  (   40H       TABLE 9 - MEMBER RESULTS (CONTD)    ,/  )    30MR0
   53 FORMAT (    52H       ** LIMIT OF MEMBERS Q-W CURVE EXCEEDED ON THIS,07AP1
     2            11H PROBLEM **)                                        07AP1
   54 FORMAT (    44H       ** LIMIT OF MEMBERS STRESS-STRAIN CURVE,     07AP1
     2            25H EXCEEDED ON THIS PROBLEM)                          07AP1
   61 FORMAT  (   18H       MEMBER NUMBER,I5,15H     STIFF TYPE,I5,      30MR0
     2            15H       LOAD TYPE , I5 )                             30MR0
   71 FORMAT  (   14H       LENGTH = ,E11.3, 13H     ALPHA = ,E11.3,     30MR0
     2            13H        BETA = ,E11.3 )                             30MR0
   81 FORMAT  (   20H       GOES FROM JOINT, I5 ,  9H TO JOINT,I5)       25MR0
   91 FORMAT  (   36H       OUTPUT DISTANCES ARE FROM JOINT, I5,         25MR0
     2            25H ALONG THE MEMBER AXIS    )                         25MR0
   99 FORMAT (//,50H        ***  MEMBER DID NOT CONVERGE AT END OF SPECIF, 01JL1
     2 28HIED NUMBER OF ITERATIONS *** )                                 01JL1
  101 FORMAT  (  49H       ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH,  25MR0
     2       30H RESPECT TO THE MEMBER AXES    ,//,                      01JL1
     3      26X,  15H DISPLACEMENTS , 21X,  7H FORCES,//,                25MR0
     4            50H          DISTANCE      AXIAL    LATERAL   ROTATIONAL , 25MR0
     5            30H  AXIAL        SHEAR      MOMENT ,/)                25MR0
  111 FORMAT  ( 5X,7E11.3)                                               25MR0
  201 FORMAT  (  46H       ALL OUTPUT FORCES ARE WITH RESPECT TO THE,    25MR0
     2            15H MEMBER AXES    , // , 15X,                         25MR0
     3            10H AT JOINT , I5,  12X, 10H AT JOINT , I5,//,5X,      25MR0
     4            15H AXIAL FORCE = ,E11.3,5X,  15H AXIAL FORCE = ,E11.3,25MR0
     5     /, 5X, 15H SHEAR        = ,E11.3,5X,  15H SHEAR       = ,E11.3,30MR0
     6     /, 5X, 15H MOMENT       = ,E11.3,5X,  15H MOMENT      = ,E11.3,29JA1
     7     ///)                                                          29JA1
  777 FORMAT (    48H       ***  SOLUTION DID NOT CLOSE - STUDY MONITOR,  02JL1
     2            10H DATA *** )                                         02JL1
      DO 8000 JJ = 1,NM                                                  18NO0
            NITM(JJ) = MNITM + 1                                         23NO0
COMMENT - SUBROUTINE MEMSOL DOES THE ITERATIVE NONLINEAR MEMBER SOLUTION09JU1
COMMENT - THIS SOLUTION IS REQUIRED TO FIND THE MEMBER-END-FORCES FOR   09JU1
COMMENT - THE JOINT EQUILIBRIUM CHECK AND FOR THE FINAL MEMBER SOLUTION 09JU1
      CALL        MEMSOL (JJ,RM,RO,W,SL,SU,L1,L3,L4,L6)                  23NO0
COMMENT - SKIP FOR COMPLETE OUTPUT                                       19MY0
          IF ( IOPOP(ISTT) .EQ. 0 ) GO TO 1600                           25MR0
          IF ( JJ .EQ. 1 )  GO TO 1500                                   25MR0
COMMENT - PRINT PARTIAL RESULTS FOR 3 MEMBERS ON 1 SHEET                 19MY0
          IF ( IOPL .NE. 1 ) GO TO 1500                                  25MR0
          IPC = IPC + 1                                                  12JU1
          IF (IPC .EQ. 4) GO TO 1500                                     12JU1
          GO TO 2100                                                     25MR0
 1500           IPC = 1                                                  12JU1
 1600     CONTINUE                                                       25MR0
COMMENT - PRINT HEADINGS                                                 19MY0
      PRINT 11                                                           25MR0
      PRINT 16, NPROB, (AN2(II), II = 1, 18)                             09JE0
          IF ( JJ .EQ. 1 )  GO TO 1700                                   25MR0
      PRINT  52                                                          25MR0
         GO TO 2100                                                      25MR0
 1700 PRINT  51                                                          25MR0
 2100     CONTINUE                                                       25MR0
          IF (NJNC .GT. 0 .OR. NMNC .GT. 0)  PRINT 777                   02JL1
          IF (IMC(JJ) .EQ. 1)  PRINT  99                                 01JL1
 2500 PRINT 61, JJ, ISTT, LTT                                            30MR0
      PRINT 71, ZLS(ISTT), DC1S(ISTT), DC2S(ISTT)                        30MR0
      PRINT  81, JT1( JJ )  JT2( JJ )                                    25MR0
          IF ( IOPOP(ISTT)   Q. 1 )  GO TO 5100                          25MR0
 2800 PRINT 91, JT1( JJ )                                                25MR0
 3100 PRINT 101                                                          25MR0
COMMENT - PRINT COMPLETE MEMBER RESULTS                                  19MY0
               DIS = 0.0                                                 30MY1
               T = -U1(2)                                                30MY1
               V = V1(2)                                                 30MY1
               BM = -W1(2)                                               12JU1
      PRINT 111, DIS,DX(1),DY(1),DZ(1),T,V,BM                            30MY1
          DO 3800  I = 2,M                                               30MY1
               IP1 = I + 1                                               30MY1
               DIS = DIS + TH                                            30MY1
               T       =  0.5*(U2(I) - U1(IP1))                          17MR0
               V       = -0.5*(V2(I) - V1(IP1))                          17MR0
               BM      =  0.5*(W2(I) - W1(IP1))                          17MR0
      PRINT 111, DIS,DX(I),DY(I),DZ(I),T,V,BM                            30MY1
 3800     CONTINUE                                                       10MY1
               DIS = DIS + TH                                            30MY1
               T = U2(MP1)                                               30MY1
               V = -V2(MP1)                                              30MY1
               BM = W2(MP1)                                              30MY1
      PRINT 111,DIS,DX(MP1),DY(MP1),DZ(MP1),T,V,BM                       30MY1
          GO TO 7100                                                     25MR0
 5100     CONTINUE                                                       25MR0
COMMENT - PRINT PARTIAL  MEMBER RESULTS                                  19MY0
               TL    = - U1(2)                                           01DE0
               VL    =   V1(2)                                           01DE0
               BML    = -W1(2)                                           01DE0
               TR       = U2(MP1)                                        29JA1
               VR       = -V2(MP1)                                       29JA1
               BMR       = W2(MP1)                                       29JA1
      PRINT 201,JT1(JJ),JT2(JJ),TL, TR,VL,VR,BML,BMR                     30MY1
 7100     CONTINUE                                                       25MR0
               IOPL = IOPOP(ISTT)                                        25MR0
          IF (KOFFQW .EQ. 1) PRINT 53                                    07AP1
          IF (KOFFSE .EQ. 1) PRINT 54                                    07AP1
 8000     CONTINUE                                                       18NO0
      RETURN                                                             25MR0
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      END                                                               25MR0
C
C     *****************************************************************
C                                SUBROUTINE
C     *****************************************************************
C
      OVERLAY(JTCORD,1,0)                                               OVERLAY
      PROGRAM JTCORD                                                    OVERLAY
COMMENT - REPLACE THE OVERLAY CARDS BY THE NONOVER CARD UNLESS THE CDC  OVERLAY
COMMENT - OVERLAY SYSTEM IS USED                                        OVERLAY
C     SUBROUTINE JTCORD                                                 NONOVER
COMMENT - SUBROUTINE JTCORD INPUTS JOINT GEOMETRY DATA (TABLE 2)        24AP0
COMMENT - CHECKS FOR BAD DATA, COMPUTES JOINT COORDINATES,ECHO PRINTS   24AP0
COMMENT - DATA AND PRINTS COMPUTED JOINT COORDINATES                    24AP0
      DIMENSION J2( 7 )                                                 26JA0
      COMMON /BLOCK1/ X( 20),     Y( 20),     QXX( 20),    QYY( 20),    13FE0
     2    QZZ( 20),   SXX( 20),   SYY( 20),   SZZ( 20),    DXX( 20),    13FE0
     3    DYY( 20),   DZZ( 20),   RXX( 20),   RYY( 20),    RZZ( 20),    13FE0
     4    ERXX( 20),  ERYY( 20),  ERZZ( 20),  QMJ( 20),    WMJ( 20),    08AG0
     5    NSXX( 20),  NSYY( 20),  NSZZ( 20),  IMJ( 20),    NSXP( 20),   20MYI
     6    NSYP( 20),  ISTJR( 20)                                        20MY1
      COMMON /BLK1/  KEEP2, KEEP3, KEEP4A,KEEP5A,KEEP6, KEEP7,          26JA0
     2         ITYPE, NCD2,  NCD3,  NCD4A, NCD5A, NCD6,  NCD7,          26JA0
     3         IABAN, IFORM, NM,    NJT,   NST,   NLT,   TOL,           26JA0
     4         M,     MP1,   MP2,   ISTT,  LTT,   ITYPEL,IDJ,           12FE0
     5         NSTL,  IP8,   IP9,   IP10,  KEEP4B,KEEP4C,NCD4B,         05AG0
     6         NCD4C, KEEP5B,KEEP5C,KEEP5D,NCD5B, NCD5C, NCD5D          05AG0
      COMMON /BLK3/ MNJT,MNST,MNLT,MNM,MNC5,MNC6,MDJT,MNJS,MNE,MNCS,    11JU1
     2    MNPCS,MNSS,MNQWM                                              11JU1
    9 FORMAT (        35H      TABLE 2 - FRAME GEOMETRY DATA ,///)      26JA0
   10 FORMAT (10X,I5,5X,I5,5X,2E10.3,10X,E10.3)                         26JA0
   11 FORMAT (        32H      NUMBER OF JOINTS IN FRAME =,I5,/,        26JA0
     2         30H      REFERENCE JOINT IS JOINT ,I5,    5H  AT ,       26JA0
     3          5H X  =,E12.3,10H AND Y =   ,E10.3,/ ,3X,               26JA0
     4         25H  JOINT TOLERANCE IS     ,E10.3,///)                  26JA0
   12 FORMAT (10X,I5,5X,2E10.3,5X,7I5)                                  26JA0
   13 FORMAT ( 10X,I5,5X,2E11.3,5X,7I5)                                 26JA0
   14 FORMAT ( 25X,  23H INPUT OF JOINT OFFSETS ,//,                    26JA0
     2         10X,   35H FROM       X-OFFSET   Y-OFFSET    ,3X,        26JA0
     3                35H  TO    TO    TO    TO    TO    TO    TO ,/,   30MR0
     4    10X,   5HJOINT, 32X, 5HJOINT ,/)                              30MR0
   15 FORMAT ( 47X,7I5)                                                 26JA0
   16 FORMAT ( 10X,I5)                                                  26JA0
   17 FORMAT      (48H      HOLDING DATA FROM THE PREVIOUS PROBLEM PLUS, 26JA0
     2             15H THE FOLLOWING , //)                              26JA0
   18 FORMAT      ( 33H     NUMBER OF JOINTS IN FRAME = , I5,///)       26JA0
   19 FORMAT ( 3(/),10X,     26HCOMPUTED JOINT COORDINATES, //, 10X,    30MR0
     2                   25HJOINT      X             Y    ,/)           26JA0
   20 FORMAT (    45H      JOINT NUMBERS MUST BE POSITIVE          )    26JA0
   21 FORMAT ( 10X,I5,2E11.3)                                           26JA0
   22 FORMAT (    18H      JOINT NUMBERS, I5,12H NOT LOCATED )          29AP0
   23 FORMAT (    10H      NONE )                                       26JA0
   30 FORMAT (    40H      NO DATA HELD OR READ IN TABLE 2      )       26JA0
   31 FORMAT (    50H      NUMBER OF CARDS IN TABLE 2 MAY NOT EQUAL 1  ) 09MY0
   50 FORMAT (    43H      JOINT NUMBER ABOVE GREATER THAN NUMBER,      26JA0
     2            20H OF JOINTS IN FRAME )                              26JA0
   60 FORMAT (    43H      NUMBER OF JOINTS IN FRAME GREATER THAN,      26JA0
     2            15H STORAGE ALLOWS)                                   26JA0
   70 FORMAT (    35H          X AND Y OFFSETS FOR JOINT, I7,           26JA0
     2            15H  ARE BOTH ZERO)                                   26JA0
   80 FORMAT (    10H      JOINT, I5,  30H  HAS NOT PREVIOUSLY BEEN SPEC, 26JA0
     2            5HIFIED)                                              26JA0
   90 FORMAT (    32H      ERROR IN LOCATION OF JOINT , I5,             26JA0
     2            40H  EXCEEDS THE TOLERANCE SPECIFIED ABOVE ,/,4X,     26JA0
     3            30H THE ERROR IN X DIRECTION IS    ,E10.3,/,4X,       26JA0
     4            30H THE ERROR IN Y DIRECTION IS  ,E10.3)              26JA0
      PRINT 9                                                           26JA0
         IF (NCD2 .EQ. 1) GO TO 8100                                    09MY0
         IF ( NCD2 .LE. 0 .AND.   KEEP2 .LE. 0 ) GO TO 8300             26JA0
         IF(NCD2 .NE. 0) GO TO 1150                                     26JA0
COMMENT - NO NEW DATA                                                   29AP0
      PRINT 17                                                          26JA0
      PRINT 23                                                          26JA0
         GO TO 9800                                                     13FE0
 1150    CONTINUE                                                       26JA0
            JNTL = 0                                                    26JA0
         IF (KEEP2 .EQ. 1) GO TO 1230                                   26JA0
COMMENT - ALL NEW DATA - SET COORDINATES EQUAL TO 1.01E50               29AP0
         DO 1200 I = 1,MNJT                                             26JA0
            X(I) = 1.01E50                                              24JL1
 1200       Y(I) = 1.01E50                                              24JL1
COMMENT - READ FIRST CARD OF TABLE 2                                    29AP0
      READ  10,NJT,J1,DX,DY,TOL                                         26JA0
      PRINT 11,NJT,J1,DX,DY,TOL                                         26JA0
         IF (J1 .LE. 0) GO TO 8200                                      26JA0
COMMENT - COMPUTE COORDINATES OF REFERENCE JOINT                        29AP0
         IF (J1 .GT. NJT) GO TO 8500                                    26JA0
            X(J1) = DX                                                  26JA0
            Y(J1) = DY                                                  26JA0
         GO TO 1240                                                     26JA0
COMMENT - HOLDING DATA                                                  29AP0
COMMENT - READ FIRST CARD OF TABLE 2                                    29AP0
 1230 READ 16,NJT                                                       26JA0
      PRINT 17                                                          26JA0
      PRINT 18,NJT                                                      26JA0
 1240    CONTINUE                                                       26JA0
         IF (NJT .GT. MNJT) GO TO 8600                                  26JA0
      PRINT 14                                                          26JA0
            N2M1 = NCD2 - 1                                             26JA0
COMMENT - DO FOR SECOND AND SUCCEEDING CARDS OF TABLE 2                 29AP0
         DO 4900 JJ = 1,N2M1                                            26JA0
      READ  12,J1,DX ,DY ,(J2(II),II=1,7)                               26JA0
         IF (J1 .GT. NJT)    JNTL = 1                                   26JA0
            NJNZ = 0                                                    26JA0
         DO 1270 II = 1,7                                               26JA0
         IF (J2(II) .GT. NJT) JNTL = 1                                  26JA0
 1270    IF (J2(II) .NE. 0) NJNZ = NJNZ + 1                             26JA0
      PRINT 13,J1,DX ,DY ,(J2(II),II=1,NJNZ)                            26JA0
         IF (J1 .LE. 0  .OR. J2(1) .LE. 0)   GO TO 8200                 26JA0
COMMENT - CHECK IF FROM JOINT HAS BEEN LOCATED                          29AP0
 1300    IF (X(J1) .GT. 1.0E50) GO TO 8800                              26JA0
         IF ( DX  .EQ. 0.0 .AND. DY  .EQ. 0.0 ) GO TO 8700              26JA0
         IF (JNTL .EQ. 1) GO TO 8500                                    26JA0
COMMENT - DO FOR ALL JOINTS SPECIFIED ON THIS CARD                      29AP0
         DO 4600 II= 1,NJNZ                                             26JA0
COMMENT - COMPUTE TEMPORARY VALUES OF COORDINATES                       29AP0
 3250       XT = X(J1) + DX                                             26JA0
            YT = Y(J1) + DY                                             26JA0
            J2II = J2(II)                                               26JA0
         IF (J2II .LE. 0) GO TO 8200                                    26JA0
         IF (X(J2II)  .GT. 1.00E50) GO TO 4000                          26JA0
COMMENT - JOINT PREVIOUSLY LOCATED COMPUTE DIFFERENCE BETWEEN OLD       29AP0
COMMENT - LOCATION AND NEW LOCATION ERX AND ERY                         29AP0
            ERX = ABS(X(J2II)  - XT)                                    26JA0
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         ERY = ABS(Y(J2II)  - YT)                                       26JA0
      IF ( ERX .GT. TOL .OR. ERY .GT. TOL) GO TO 8900                   26JA0
COMMENT - AVERAGE OLD AND NEW COORDINATES                               29AP0
         X(J2II)  = 0.5*(X(J2II)  + XT)                                 26JA0
         Y(J2II)  = 0.5*(Y(J2II)  + YT)                                 26JA0
      GO TO 4500                                                        26JA0
COMMENT - JOINT NOT PREVIOUSLY LOCATED                                  29AP0
 4000    X(J2II)  = XT                                                  26JA0
         Y(J2II)  = YT                                                  26JA0
 4500 CONTINUE                                                          26JA0
         JI = J2II                                                      26JA0
 4600 CONTINUE                                                          26JA0
 4900 CONTINUE                                                          26JA0
      GO TO 9800                                                        26JA0
 8100 PRINT 31                                                          09MY0
      GO TO 9700                                                        09MY0
 8200 PRINT 20                                                          26JA0
      GO TO 9700                                                        26JA0
 8300 PRINT 30                                                          26JA0
      GO TO 9700                                                        26JA0
 8500 PRINT 50                                                          26JA0
      GO TO 9700                                                        26JA0
 8600 PRINT 60                                                          26JA0
      GO TO 9700                                                        26JA0
 8700 PRINT 70, J1                                                      26JA0
      GO TO 9700                                                        26JA0
 8800 PRINT 80,J1                                                       26JA0
      GO TO 9700                                                        26JA0
 8900 PRINT 90, J2II,ERX,ERY                                            26JA0
 9700    IABAN = 1                                                      26JA0
      GO TO 9900                                                        26JA0
 9800 CONTINUE                                                          26JA0
      PRINT 19                                                          26JA0
COMMENT - PRINT JOINT COORDINATES AND CHECK FOR JOINT NOT SPECIFIED     29AP0
      DO 9850 I = 1,NJT                                                 26JA0
      IF (X(I) .GT. 1.0E50 .OR. Y(I) .GT. 1.0E50) GO TO 9840            26JA0
 9830 PRINT 21,I,X(I),Y(I)                                              26JA0
      GO TO 9845                                                        26JA0
 9840 PRINT 22,I                                                        26JA0
         IABAN = 1                                                      26JA0
 9845 CONTINUE                                                          26JA0
 9850 CONTINUE                                                          26JA0
 9900 CONTINUE                                                          26JA0
      RETURN                                                            26JA0
      END                                                               26JA0
C
C     ****************************************************************
C                              SUBROUTINE
C     ****************************************************************
C
      OVERLAY(MEMLOC,2,0)                                               OVERLAY
      PROGRAM MEMLOC                                                    OVERLAY
COMMENT - REPLACE THE OVERLAY CARDS BY THE NONOVER CARD UNLESS THE CDC  OVERLAY
COMMENT - OVERLAY SYSTEM IS USED                                        OVERLAY
C     SUBROUTINE MEMLOC                                                 NONOVER
COMMENT - SUBROUTINE  MEMLOC  INPUTS LOCATION OF STIFFNESS AND LOAD     24AP0
COMMENT - TYPES IN FRAME (TABLE 3),CHECKS FOR BAD DATA,COMPUTES MEMBER  24AP0
COMMENT - NUMBERS,LENGTHS OFFSETS AND DIRECTION COSINES,ECHO PRINTS DATA24AP0
COMMENT - AND PRINTS COMPUTED MEMBER NUMBERS,LENGTHS AND OFFSETS        24AP0
      DIMENSION J2( 10 )                                                26JA0
      COMMON /BLOCK1/ X( 20),     Y( 20),     QXX( 20),   QYY( 20),     13FE0
     2    QZZ( 20),   SXX( 20),   SYY( 20),   SZZ( 20),   DXX( 20),     13FE0
     3    DYY( 20),   DZZ( 20),   RXX( 20),   RYY( 20),   RZZ( 20),     13FE0
     4    ERXX( 20),  ERYY( 20),  ERZZ( 20),  QMJ( 20),   WMJ( 20),     08AG0
     5    NSXX( 20),  NSYY( 20),  NSZZ( 20),  IMJ( 20),   NSXP( 20),    20MY1
     6    NSYP( 20),  ISTJR( 20)                                        20MY1
      COMMON /BLOCK2/ DXS( 25),   DYS( 25),   ZLS( 25),   DC1S( 25),    26JA0
     2    DC2S( 25),  PRF( 25),   PRAE( 25),  NCDS( 25),  IAXOPS( 25),  26JA0
     3    IOPOP( 25), IPINL( 25), IPINR( 25), NC5I( 25),  INLOP( 25),   17OC0
     4    NAL( 25),   NSXL( 25),  NSYL( 25),  NSZL( 25),  NAR( 25),     17OC0
     5    NSXR( 25),  NSYR( 25),  NSZR( 25),  QM( 25),    WM( 25)       17OC0
      COMMON /BLOCK3/ DXL( 25),   DYL( 25),   ZLL( 25),   DC1L( 25),    26JA0
     2    DC2L( 25),  UQX( 25),   UQY( 25),   NCDL( 25),  IAXOPL( 25),  26JA0
     3    NC61( 25)                                                     26JA0
      COMMON /BLOCK4/ JT1( 40),   JT2( 40),   IST( 40),   LT( 40),      26JA0
     2    FOMM( 40,6), SMC( 40,21), NITM( 40), IMM( 40),  IMC( 40)      01JL1
      COMMON /BLK1/  KEEP2, KEEP3, KEEP4A,KEEP5A,KEEP6, KEEP7,          26JA0
     2         ITYPE, NCD2,  NCD3,  NCD4A, NCD5A, NCD6,  NCD7,          26JA0
     3         IABAN, IFORM, NM,    NJT,   NST,   NLT,   TOL,           26JA0
     4         M,     MP1,   MP2,   ISTT,  LTT,   ITYPEL,IOJ,           12FE0
     5         NSTL,  IP8,   IP9,   IP10,  KEEP4B,KEEP4C,NCD4B,         05AG0
     6         NCD4C, KEEP5B,KEEP5C,KEEP5D,NCD5B, NCD5C, NCD5D          05AG0
      COMMON /BLK3/ MNJT,MNST,MNLT,MNM,MNC5,MNC6,MDJT,MNJS,MNE,MNCS,    11JU1
     2    MNPCS,MNSS,MNQWM                                              11JU1
    6 FORMAT (5X,  3(I5,1X), 2X, 2I5)                                   30MR0
    7 FORMAT (5X,  3(I5,1X), 2X, 2I5, 3E11.3)                           30MR0
    8 FORMAT  ( ///,10X,    40H COMPUTED MEMBER NUMBERS,LENGTHS,AND OFF, 30MR0
     2 4HSETS,//,46H     MEMBER  FROM     TO     STIFF LOAD   LENGTH  ,  30MR0
     3          25H  X-OFFSET    Y-OFFSET    ,/,                        30MR0
     4          35H      NUMB  JOINT  JOINT   TYPE TYPE,//)             30MR0
    9 FORMAT (   40H      TABLE 3 - MEMBER LOCATION DATA      ,///)     26JA0
   10 FORMAT (10X,I5,5X,I5,5X,I5)                                       26JA0
   11 FORMAT (   40H      NUMBER OF MEMBER STIFFNESS TYPES  =,I5,/,     26JA0
     2          40H      NUMBER OF MEMBER LOAD TYPES   =     ,I5,/,     26JA0
     3          40H      NUMBER OF ELEMENTS PER MEMBER =     ,I5,///)   26JA0
   12 FORMAT ( 5X,I5,5X,2I5,5X,10I5)                                    26JA0
   13 FORMAT ( 5X,I5,5X,2I5,5X,10I5)                                    26JA0
   14 FORMAT (25X,     26H INPUT OF MEMBER LOCATIONS ,//,               26JA0
     2          50H       FROM      STIFF LOAD        TO     TO     TO     TO ,26JA0
     3          30H  TO    TO    TO    TO    TO , /,                    26JA0
     4          35H      JOINT        TYPE TYPE        JOINT,//)        30MR0
   17 FORMAT      (48H      HOLDING DATA FROM THE PREVIOUS PROBLEM PLUS, 26JA0
     2          15H THE FOLLOWING , //)                                 26JA0
   18 FORMAT (//,47H *** COMPUTED MEMBER NUMBERS MAY NOT AGREE WITH ,   01MY0
     2          20H LAST PROBLEM ***    )                               01MY0
   19 FORMAT (//,50H *** COMPUTED MEMBER NUMBERS AGREE WITH LAST PROBL, 01MY0
     2          10HEM ***       )                                       01MY0
   20 FORMAT (   45H      JOINT NUMBERS MUST BE POSITIVE           )    26JA0
   23 FORMAT (   10H      NONE )                                        26JA0
   25 FORMAT (   32H      MEMBER WITH STIFFNESS TYPE ,I5, 9H AND LOAD,  26JA0
     2           5H TYPE,I5,/,32H      WAS SPECIFIED AS GOING FROM,     26JA0
     3           7H JOINT ,I5, 9H TO JOINT,I5,/,17H      PROGRAM DOES,  26JA0
     4          36H NOT ALLOW THIS ORDER TO BE REVERSED)                26JA0
   30 FORMAT (   40H      NO DATA HELD OR READ IN TABLE 3     )         26JA0
   31 FORMAT (   50H      NUMBER OF CARDS IN TABLE 3 MAY NOT EQUAL 1    ) 09MY0
   50 FORMAT (   43H      JOINT NUMBER ABOVE GREATER THAN NUMBER,       26JA0
     2          20H OF JOINTS IN FRAME )                                26JA0
   61 FORMAT (   51H      NUMBER OF STIFFNESS TYPES GREATER THAN STORAGE,26JA0
     2           7H ALLOWS)                                             26JA0
   62 FORMAT (   46H      NUMBER OF LOAD TYPES GREATER THAN STORAGE,    26JA0
     2           7H ALLOWS)                                             26JA0
   63 FORMAT (   50H      NUMBER OF ELEMENTS MUST BE BETWEEN 4 AND 40   ) 09JU1
   71 FORMAT (   46H      STIFFNESS AND LOAD TYPES MUST BE POSITIVE,    26JA0
     2           8 NUMBERS)                                             26JA0
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   72 FORMAT (    51H    STIFFNESS OR LOAD TYPE ABOVE GREATER THAN TOTAL,26JA0
      2           50H NUMBER OF STIFFNESS OR LOAD TYPES SPECIFIED ABOVE) 26JA0
   73 FORMAT (    51H     YOU CANNOT HOLD UP THE LOAD WITHOUT SOME STIFF,26JA0
      2           50HNESS - IF STIFF TYPE = 0 - LOAD TYPE MUST = 0     ) 26JA0
   74 FORMAT (    45H      MAXIMUM BAND WIDTH OF EQUATIONS EXCEEDED, /,  28NO0
      2           45H      RENUMBER JOINTS OR REDIMENSION DRIVER    )    28NO0
   91 FORMAT (    50H      ERROR IN OFFSETS FOR MEMBER OF STIFFNESS TYPE, 26JA0
      2        I5,/,47H      THE X AND Y OFFSETS FOR THE MEMBER BETWEEN,  26JA0
      3              7H JOINTS,I5, 5H AND ,I5,/,                         26JA0
      4           49H      DO NOT AGREE WITH PREVIOUSLY DEFINED OFFSETS,  26JA0
      5           46H FOR A MEMBER OF THIS TYPE, WITHIN THE ALLOWED,/,   26JA0
      6           51H      ERROR OF TWO TIMES THE JOINT LOCATION TOLERANC,26JA0
      7              1HE)                                                26JA0
   92 FORMAT (    45H      ERROR IN OFFSETS FOR MEMBER OF LOAD TYPE,      26JA0
      2        I5,/,47H      THE X AND Y OFFSETS FOR THE MEMBER BETWEEN,  26JA0
      3              7H JOINTS,I5, 5H AND ,I5,/,                         26JA0
      4           49H      DO NOT AGREE WITH PREVIOUSLY DEFINED OFFSETS,  26JA0
      5           46H FOR A MEMBER OF THIS TYPE, WITHIN THE ALLOWED,/,   26JA0
      6           51H      ERROR OF TWO TIMES THE JOINT LOCATION TOLERANC,26JA0
      7              1HE)                                                26JA0
COMMENT - PRINT TABLE HEADING                                            01MY0
      PRINT 9                                                            26JA0
         IF (NCD3 .EQ. 1) GO TO 8100                                     09MY0
         IF (NCD3 .LE. 0  .AND. KEEP3 .LE. 0 ) GO TO 8300                26JA0
            TTOL = 2.0*TOL                                               26JA0
COMMENT - SET OFFSETS FOR STIFF TYPES                                    01MY0
         DO 1100  I = 1, MNST                                            03AP0
            DXS(I) = 1.01E50                                             24JL1
 1100       DYS(I) = 1.01E50                                             24JL1
COMMENT - SET OFFSETS FOR LOAD TYPES                                     01MY0
         DO 1110  I = 1, MNLT                                            03AP0
            DXL(I) = 1.01E50                                             24JL1
 1110       DYL(I) = 1.01E50                                             24JL1
         IF (KEEP3 .NE. 1) GO TO 1150                                    25AP0
      PRINT 17                                                           26JA0
         GO TO 1160                                                      09JU1
 1150       NM = 0                                                       09JU1
 1160    CONTINUE                                                        25AP0
         IF (NCD3 .NE. 0) GO TO 1180                                     03AP0
      PRINT 23                                                           26JA0
         GO TO  6000                                                     03AP0
 1180       JNTL = 0                                                     26JA0
 1250    CONTINUE                                                        26JA0
COMMENT - READ FIRST CARD IN TABLE 3                                     01MY0
      READ 10,NST,NLT,M                                                  26JA0
         IF (M .LE. 0) M = MNE                                           15AP1
      PRINT 11, NST,NLT,M                                                26JA0
            MP1 = M + 1                                                  26JA0
            MP2 = M + 2                                                  26JA0
         IF (NST .GT. MNST) GO TO 8610                                   26JA0
         IF (NLT .GT. MNLT) GO TO 8620                                   26JA0
         IF (M .LT. 4) GO TO 8630                                        09JU1
         IF (M .GT. MNE) GO TO 8630                                      09JU1
      PRINT 14                                                           26JA0
            N3M1 = NCD3 - 1                                              26JA0
         DO 4900 JJ = 1,N3M1                                             26JA0
COMMENT - READ 2ND AND SUCCEEDING CARDS IN TABLE 3                       01MY0
      READ 12,J1,ISTT,LTT,(J2(II),II = 1,10)                             26JA0
         IF (J1 .GT. NJT) JNTL = 1                                       26JA0
            NJNZ = 0                                                     26JA0
         DO 1270 II = 1,10                                               26JA0
         IF (J2(II) .GT. NJT) JNTL = 1                                   26JA0
         IF (J2(II) .NE. 0) NJNZ = NJNZ + 1                              30AP0
 1270    CONTINUE                                                        30AP0
COMMENT - PRINT 2ND AND SUCCEEDING CARDS IN TABLE 3                      01MY0
      PRINT 13,J1,ISTT,LTT, (J2(II),II = 1,NJNZ )                        26JA0
         IF (J1 .LE. 0) GO TO 8200                                       30AP0
         IF (JNTL .EQ. 1)  GO TO 8500                                    26JA0
      IF (ISTT .LT. 0 .OR. LTT .LT. 0) GO TO 8710                        26JA0
      IF (ISTT .GT. NST .OR. LTT .GT. NLT) GO TO 8720                    26JA0
         IF (ISTT .EQ. 0 .AND. LTT .NE. 0) GO TO 8730                    26JA0
COMMENT - NUMBER MEMBERS AND ASSIGN STIFFNESS AND LOAD TYPES             09JU1
COMMENT - DO FOR NUMBER OF MEMBERS SPECIFIED ON ONE CARD                 01MY0
         DO 4500  II = 1,NJNZ                                            26JA0
            J2II = J2(II)                                                26JA0
         IF (J2II .LE. 0) GO TO 8200                                     30AP0
         IF (KEEP3 .NE. 1) GO TO 4425                                    06MY0
COMMENT - DO FOR EACH MEMBER                                             01MY0
         DO 4400 K = 1,NM                                                26JA0
         IF (J1 .EQ. JT1(K) .AND. J2II .EQ. JT2(K) ) GO TO 4410          26JA0
         IF (J1 .EQ. JT2(K) .AND. J2II .EQ. JT1(K) ) GO TO 8250          26JA0
 4400    CONTINUE                                                        26JA0
         GO TO 4425                                                      26JA0
COMMENT - OLD MEMBER (PREVIOUSLY GIVEN STIFF AND LOAD TYPE)              01MY0
 4410    IST(K) = ISTT                                                   26JA0
         LT(K) = LTT                                                     26JA0
         GO TO 4450                                                      26JA0
COMMENT - NEW MEMBER INCREASE NM                                         01MY0
 4425       NM = NM + 1                                                  26JA0
            JT1(NM) = J1                                                 26JA0
            JT2(NM) = J2II                                               26JA0
            IST(NM) = ISTT                                               26JA0
            LT(NM) = LTT                                                 26JA0
 4450    CONTINUE                                                        26JA0
            J1 = J2II                                                    26JA0
 4500    CONTINUE                                                        26JA0
 4900    CONTINUE                                                        26JA0
 6000    CONTINUE                                                        03AP0
         DO 6600  I = 1,NM                                               03AP0
            ISTT = IST(I)                                                03AP0
            LTT  =  LT(I)                                                03AP0
            J2I  = JT2(I)                                                03AP0
            J1   = JT1(I)                                                03AP0
COMMENT - COMPUTE OFFSETS                                                03AP0
            DX   = X(J2I)   - X(J1)                                      03AP0
            DY   = Y(J2I)   - Y(J1)                                      03AP0
         IF (ISTT .EQ. 0) GO TO 6100                                     03AP0
         IF (DXS(ISTT) .GT. 1.0E50) GO TO 6050                           03AP0
COMMENT - CHECK FOR TWO MEMBERS WITH SAME STIFFNESS TYPE BUT DIFFERENT   01MY0
COMMENT - ORIENTATIONS                                                   01MY0
            ERX = ABS(DXS(ISTT) - DX )                                   26JA0
            ERY = ABS(DYS(ISTT) - DY )                                   26JA0
         IF (ERX  .GT. TTOL .OR.  ERY  .GT. TTOL) GO TO 8910             26JA0
            DXS(ISTT)   = 0.5*(DXS(ISTT) + DX)                           26JA0
            DYS(ISTT)   = 0.5*(DYS(ISTT) + DY)                           26JA0
         GO TO 6100                                                      03AP0
 6050    CONTINUE                                                        03AP0
            DXS(ISTT)   = DX                                             26JA0
            DYS(ISTT)   = DY                                             26JA0
 6100    CONTINUE                                                        03AP0
         IF ( LTT .EQ. 0) GO TO 6300                                     03AP0
         IF (DXL(LTT) .GT. 1.0E50) GO TO 6200                            03AP0
COMMENT - CHECK FOR TWO MEMBERS WITH SAME LOAD TYPE BUT DIFFERENT        01MY0
COMMENT - ORIENTATIONS                                                   01MY0
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            ERX = ABS(DXL(LTT) - DX)                                     26JA0
            ERY = ABS(DYL(LTT) - DY)                                     26JA0
        IF (ERX .GT. TTOL .OR. ERY .GT. TTOL) GO TO 8920                 26JA0
            DXL(LTT) = 0.5*(DXL(LTT) + DX)                               26JA0
            DYL(LTT) = 0.5*(DYL(LTT) + DY)                               26JA0
        GO TO 6300                                                       03AP0
 6200   CONTINUE                                                         03AP0
            DXL(LTT) = DX                                                26JA0
            DYL(LTT) = DY                                                26JA0
 6300   CONTINUE                                                         03AP0
 6600   CONTINUE                                                         03AP0
        DO 7400 I = 1,NST                                                03AP0
COMMENT - COMPUTE LENGTHS AND DIRECTION COSINES FOR STIFFNESS TYPES      01MY0
            ZLS(I) = (DXS(I)*DXS(I) + DYS(I)*DYS(I) ) **0.5              26JA0
            DC1S(I) = DXS(I)/ZLS(I)                                      26JA0
 7400       DC2S(I) = DYS(I)/ZLS(I)                                      03AP0
        IF ( NLT  .EQ. 0 )         GO TO  7600                           13NO2
        DO 7500 I = 1,NLT                                                03AP0
COMMENT - COMPUTE LENGTHS AND DIRECTION COSINES FOR LOAD TYPES           01MY0
            ZLL(I) = (DXL(I)*DXL(I) + DYL(I)*DYL(I) )**0.5               26JA0
            DC1L(I) = DXL(I)/ZLL(I)                                      26JA0
 7500       DC2L(I) = DYL(I)/ZLL(I)                                      03AP0
 7600   CONTINUE                                                         13NO2
            IDJT = 0                                                     26JA0
            IDJ  = 0                                                     26JA0
COMMENT - COMPUTE HALF BAND WIDTH OF FRAME                               01MY0
        DO 7700 I = 1,NM                                                 03AP0
            IDJT = IABS (JT1(I) - JT2(I))                                29JA0
        IF (IDJT .GT. IDJ)   IDJ = IDJT                                  26JA0
 7700   CONTINUE                                                         03AP0
        IF (IDJ .GT. MDJT)  GO TO 8740                                   26JA0
        GO TO 9800                                                       26JA0
 8100 PRINT 31                                                           09MY0
        GO TO 9700                                                       09MY0
 8200 PRINT 20                                                           26JA0
        GO TO 9700                                                       26JA0
 8250 PRINT 25, ISTT,J2II,J1                                             26JA0
        GO TO 9700                                                       26JA0
 8300 PRINT 30                                                           26JA0
        GO TO 9700                                                       26JA0
 8500 PRINT 50                                                           26JA0
        GO TO 9700                                                       26JA0
 8610 PRINT 61                                                           26JA0
        GO TO 9700                                                       26JA0
 8620 PRINT 62                                                           26JA0
        GO TO 9700                                                       26JA0
 8630 PRINT 63                                                           09JU1
        GO TO 9700                                                       09JU1
 8710 PRINT 71                                                           26JA0
        GO TO 9700                                                       26JA0
 8720 PRINT 72                                                           26JA0
        GO TO 9700                                                       26JA0
 8730 PRINT 73                                                           26JA0
        GO TO 9700                                                       26JA0
 8740 PRINT 74                                                           26JA0
        GO TO 9700                                                       26JA0
 8910 PRINT 91,ISTT,J1,J2I                                               06MR0
        GO TO 9700                                                       26JA0
 8920 PRINT 92,LTT, J1,J2I                                               06MR0
        GO TO 9700                                                       26JA0
 9700 IABAN = 1                                                          26JA0
        GO TO 9900                                                       26JA0
 9800   CONTINUE                                                         26JA0
      PRINT 8                                                            26JA0
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COMMENT - PRINT MEMBER NUMBERS,FROM AND TO JOINTS,LENGTHS AND OFFSETS   01MY0
          DO 9875 I = 1,NM                                               26JA0
              ISTT = IST(I)                                              26JA0
      IF (ISTT .EQ. 0) GO TO 9860                                        26JA0
      PRINT 7, I, JT1(I), JT2(I), IST(I), LT(I), ZLS(ISTT), DXS(ISTT),   30MR0
     2    DYS(ISTT)                                                      30MR0
          GO TO 9875                                                     26JA0
 9860 PRINT 6, I, JT1(I), JT2(I), IST(I), LT(I)                          30MR0
 9875     CONTINUE                                                       26JA0
          IF (KEEP3 .EQ. 1 ) GO TO 9880                                  11MY0
      PRINT 18                                                           01MY0
          GO TO 9900                                                     01MY0
 9880 PRINT 19                                                           01MY0
 9900     CONTINUE                                                       26JA0
      RETURN                                                             26JA0
      END                                                                26JA0
C
C         ****************************************************************
C                                    SUBROUTINE
C         ****************************************************************
C
      OVERLAY(JNTDAT,3,0)                                                OVERLAY
      PROGRAM JNTDAT                                                     OVERLAY
COMMENT - REPLACE THE OVERLAY CARDS BY THE NONOVER CARD UNLESS THE CDC  OVERLAY
COMMENT - OVERLAY SYSTEM IS USED                                         OVERLAY
C     SUBROUTINE JNTDAT                                                  NONOVER
COMMENT - SUBROUTINE JNTDAT INPUTS JOINT LOADS AND RESTRAINTS            24AP0
COMMENT - (TABLE 4),CHECKS FOR BAD DATA,ACCUMULATES JOINT LOADS AND      24AP0
COMMENT - RESTRAINTS,ECHO PRINTS DATA AND PRINTS ACCUMULATED DATA        24AP0
COMMENT - EQUILIBRIUM ERRORS ARE SET EQUAL TO NET JOINT LOADS            09JU1
      COMMON /BLOCK1/ X( 20),     Y( 20),     QXX( 20),   QYY( 20),      13FE0
     2    QZZ( 20),   SXX( 20),   SYY( 20),   SZZ( 20),   DXX( 20),      13FE0
     3    DYY( 20),   DZZ( 20),   RXX( 20),   RYY( 20),   RZZ( 20),      13FE0
     4    ERXX( 20),  ERYY( 20),  ERZZ( 20),  QMJ( 20),   WMJ( 20),      08AG0
     5    NSXX( 20),  NSYY( 20),  NSZZ( 20),  IMJ( 20),   NSXP( 20),     20MY1
     6    NSYP( 20),  ISTJR( 20)                                         20MY1
      COMMON /BLOCK8/ NPT( 20),   ISJ( 20),   NQJ( 20,11),NWJ( 20,11),   08AG0
     2    NQJT(11),   NWJT(11)                                           08AG0
      COMMON /BLK1/  KEEP2, KEEP3, KEEP4A,KEEP5A,KEEP6, KEEP7,           26JA0
     2        ITYPE, NCD2,  NCD3,  NCD4A, NCD5A, NCD6,  NCD7,            26JA0
     3        IABAN, IFORM, NM,    NJT,   NST,   NLT,   TOL,             26JA0
     4        M,     MP1,   MP2,   ISTT,  LTT,   ITYPEL,IDJ,             12FE0
     5        NSTL,  IP8,   IP9,   IP10,  KEEP4B,KEEP4C,NCD4B,           05AG0
     6        NCD4C, KEEP5B,KEEP5C,KEEP5D,NCD5B, NCD5C, NCD5D            05AG0
      COMMON /BLK3/ MNJT,MNST,MNLT,MNM,MNC5,MNC6,MDJT,MNJS,MNE,MNCS,     11JU1
     2    MNPCS,MNSS,MNQWM                                               11JU1
    7 FORMAT (5X,35H     SAME AS INPUT FOR THIS PROBLEM)                 06FE0
    9 FORMAT ( 49H    TABLE 4A - JOINT LOADS AND LINEAR RESTRAINTS.//)   05AG0
   10 FORMAT (//,45H     TABLE 4B - JOINT SUPPORT CURVE NUMBERS   ,//)   08AG0
   11 FORMAT (//,40H     TABLE 4C - JOINT SUPPORT CURVES     ,//)        08AG0
   12 FORMAT ( 5X,I5,6E10.3)                                             26JA0
   13 FORMAT ( 5X,I5,6E11.3)                                             26JA0
   14 FORMAT  ( 25X,20H INPUT OF JOINT DATA,/)                           26JA0
   15 FORMAT  (5X, 38HJOINT  FORCE(X)   FORCE(Y)  MOMENT(Z) ,            26JA0
     2                   33H SPRING(X)  SPRING(Y)  SPRING(Z) ,//)        26JA0
   16 FORMAT ( //,25X,23H ACCUMULATED JOINT DATA,//)                     26JA0
   17 FORMAT ( 48H     HOLDING DATA FROM THE PREVIOUS PROBLEM PLUS,      26JA0
     2         15H THE FOLLOWING ,//)                                    26JA0
   20 FORMAT ( 35H     JOINT NUMBERS MUST BE POSITIVE)                   26JA0
   23 FORMAT (    10H      NONE )                                        26JA0
   30 FORMAT  (   15H      NO DATA    )                                  02MY0
   32     FORMAT (5X,I5,2E10.3,10X,5I5,10X,I5)                           20MY1
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 33     FORMAT (5X,I5,2E11.3, 7X,5I5,10X,I5)                            20MY1
 35 FORMAT (    30H      JOINT     Q-MULT     W-MULT,10X,    9HNSXX NSYY,  31MY1
   2                30H NSZZ NSXP NSYP            STIFF,/)              20MY1
 42 FORMAT (5X,3I5,5X,11I5,/,25X,11I5)                                 08AG0
 43 FORMAT (/,5X,3I5 ,/, 6H     Q,19X,11I5)                            10AG0
 44 FORMAT (            6H     W,19X,11I5)                             10AG0
 45 FORMAT (//,30H      CURVE NUMB SYMT (1 = YES,,/,                   08AG0
   2          30H      NUMB  PTS  OPT   0 = NO))                       10AG0
 50 FORMAT ( 43H      JOINT NUMBER ABOVE GREATER THAN NUMBER,          26JA0
   2        20H OF JOINTS IN FRAME )                                   26JA0
 60 FORMAT (    40H      NUMBER OF CARDS IN TABLE 4C MUST BE,          08AG0
   2          20H A MULTIPLE OF TWO  )                                 08AG0
 70 FORMAT (    50H JOINT CURVE NUMBER TO LARGE OR NO JOINT CURVE NUM, 11JU1
   2          15HBER SPECIFIED  )                                      11JU1
 71 FORMAT (    51H      STIFF TYPE ABOVE NOT ONE OF MEMBER STIFF TYPES,08JU1
   2          51H      STIFF TYPE REQUIRED TO REFERENCE JOINT SPRINGS)08JU1
 72 FORMAT (    17H      CURVE NUMBER,I5, 25H  NOT DEFINED IN TABLE 4C) 08JU1
 73 FORMAT (    48H      NUMBER OF POINTS ON CURVE MUST BE BETWEEN 2,  11JU1
   2           7H AND 11)                                              11JU1
 74 FORMAT (    35H      SYMMETRY OPTION MUST BE 1 OR 0)               11JU1
 75 FORMAT   (  17H      CURVE NUMBER, I5,25H DOES NOT HAVE DISPLACEME, 24JL1
   2          32HNTS IN ASCENDING ALGEBRAIC ORDER,/,   9H     WHEN,    24JL1
   3          50H INPUT VALUES ARE MULTIPLIED BY DISPLACEMENT MULTI,  24JL1
   4          14HPLIER AT JOINT)                                       24JL1
 76 FORMAT   (  50H      IF SYMMETRY OPTION = 1, FIRST POINT ON CURVE , 24JL1
   2          13HMUST BE 0 - 0 )                                       24JL1
COMMENT - INPUT TABLE 4A                                               08AG0
      PRINT 9                                                          26JA0
        IF (ITYPE .NE. 2) GO TO 1120                                   06MY0
        DO 1110  I = 1,NJT                                             02MY0
              ERXX(I) = QXX(I)                                         06MY0
              ERYY(I) = QYY(I)                                         06MY0
              ERZZ(I) = QZZ(I)                                         06MY0
 1110   CONTINUE                                                       02MY0
 1120   CONTINUE                                                       02MY0
        IF (KEEP4A .EQ. 1) GO TO 1230                                  05AG0
COMMENT - ZERO JOINT DATA                                              04MY0
        DO 1200 I = 1, MNJT                                            26JA0
              QXX(I) = 0.0                                             24JL1
              QYY(I) = 0.0                                             24JL1
              QZZ(I) = 0.0                                             24JL1
              SXX(I) = 0.0                                             24JL1
              SYY(I) = 0.0                                             24JL1
 1200         SZZ(I) = 0.0                                             24JL1
        IF (NCD4A .NE. 0) GO TO 1240                                   05AG0
      PRINT 30                                                         02MY0
        GO TO 3000                                                     02MY0
COMMENT - HOLDING DATA                                                 04MY0
 1230 PRINT 17                                                         26JA0
        IF (NCD4A .NE. 0) GO TO 1240                                   05AG0
      PRINT 23                                                         02MY0
        GO TO 3000                                                     06MY0
 1240   CONTINUE                                                       26JA0
      PRINT 14                                                         26JA0
      PRINT 15                                                         26JA0
        DO 2900  II = 1, NCD4A                                         26JA0
COMMENT - READ AND PRINT ONE DATA CARD                                 04MY0
      READ  12, I,QXXT,QYYT,QZZT,SXXT,SYYT,SZZT                        26JA0
      PRINT 13, I,QXXT,QYYT,QZZT,SXXT,SYYT,SZZT                        26JA0
        IF (I .GT. NJT) GO TO  8500                                    26JA0
        IF (I .LE. 0 ) GO TO  8200                                     26JA0
COMMENT - ACCUMULATE DATA                                              04MY0
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              QXX(I) = QXX(I) + QXXT                                   26JA0
              QYY(I) = QYY(I) + QYYT                                   26JA0
              QZZ(I) = QZZ(I) + QZZT                                   26JA0
              SXX(I) = SXX(I) + SXXT                                   26JA0
              SYY(I) = SYY(I) + SYYT                                   26JA0
              SZZ(I) = SZZ(I) + SZZT                                   26JA0
 2900   CONTINUE                                                       26JA0
 3000   CONTINUE                                                       02MY0
        IF (ITYPE .NE. 2) GO TO 3800                                   06MY0
        DO 3600  I = 1,NJT                                             06MY0
              ERXX(I) = QXX(I) - ERXX(I)                               06MY0
              ERYY(I) = QYY(I) - ERYY(I)                               06MY0
              ERZZ(I) = QZZ(I) - ERZZ(I)                               06MY0
 3600   CONTINUE                                                       06MY0
        GO TO 4000                                                     07MY0
 3800   CONTINUE                                                       06MY0
        DO 3900 I =  1,NJT                                             06MY0
              ERXX(I) = QXX(I)                                         06MY0
              ERYY(I) = QYY(I)                                         06MY0
              ERZZ(I) = QZZ(I)                                         06MY0
 3900   CONTINUE                                                       06MY0
 4000   CONTINUE                                                       02MY0
COMMENT - PRINT ACCUMULATED JOINT DATA UNLESS IT IS THE SAME AS INPUT  04MY0
COMMENT - FOR THIS PROBLEM                                             04MY0
        IF (KEEP4A .EQ. 1) GO TO 4820                                  05AG0
        IF (NCD4A .EQ. 0) GO TO 4865                                   05AG0
      PRINT 16                                                         26JA0
      PRINT 7                                                          26JA0
        GO TO 4865                                                     07MY0
 4820   CONTINUE                                                       26JA0
      PRINT 16                                                         26JA0
      PRINT 15                                                         23AP0
        DO 4860 I = 1, NJT                                             26JA0
        IF (QXX(I) .NE. 0) GO TO 4850                                  26JA0
        IF (QYY(I) .NE. 0) GO TO 4850                                  26JA0
        IF (QZZ(I) .NE. 0) GO TO 4850                                  26JA0
        IF (SXX(I) .NE. 0) GO TO 4850                                  26JA0
        IF (SYY(I) .NE. 0) GO TO 4850                                  26JA0
        IF (SZZ(I) .NE. 0) GO TO 4850                                  26JA0
        GO TO 4860                                                     26JA0
 4850 PRINT 13, I,QXX(I),QYY(I),QZZ(I),SXX(I),SYY(I),SZZ(I)             26JA0
 4860   CONTINUE                                                       26JA0
 4865   CONTINUE                                                       05AG0
COMMENT - INPUT TABLE 4B                                               08AG0
      PRINT 10                                                         08AG0
        IF (KEEP4B .EQ. 1) GO TO 5230                                  08AG0
COMMENT - ZERO CURVE NUMBERS                                           08AG0
        DO 5200 I = 1, MNJT                                            08AG0
              NSXX(I) = 0.0                                            24JL1
              NSYY(I) = 0.0                                            24JL1
              NSZZ(I) = 0.0                                            24JL1
              NSXP(I) = 0.0                                            24JL1
 5200         NSYP(I) = 0.0                                            24JL1
        IF (NCD4B .NE. 0) GO TO 5240                                   08AG0
      PRINT 30                                                         02MY0
      GO TO 6000                                                       08AG0
COMMENT - HOLDING DATA                                                 04MY0
 5230 PRINT 17                                                         08AG0
        IF (NCD4B .NE. 0) GO TO 5240                                   08AG0
      PRINT 23                                                         02MY0
      GO TO 6000                                                       08AG0
 5240 CONTINUE                                                         08AG0
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      PRINT 14                                                          26JA0
      PRINT 35                                                          08AG0
         DO 5900  II = 1, NCD4B                                         08AG0
COMMENT - READ AND PRINT ONE DATA CARD                                  04MY0
         READ 32,I,QMJ(I),WMJ(I),NSXX(I),NSYY(I),NSZZ(I),NSXP(I),       20MY1
     2    NSYP(I),ISTJR(I)                                              20MY1
         PRINT 33,I,QMJ(I),WMJ(I),NSXX(I),NSYY(I),NSZZ(I),NSXP(I),      20MY1
     2    NSYP(I),ISTJR(I)                                              20MY1
         IF (I .GT. NJT) GO TO  8500                                    26JA0
         IF (I .LE. 0 ) GO TO  8200                                     26JA0
         IF (NSXX(I) .GT. MNJS .OR. NSXX(I) .LT. 0) GO TO 8700          08JU1
         IF (NSYY(I) .GT. MNJS .OR. NSYY(I) .LT. 0) GO TO 8700          08JU1
         IF (NSZZ(I) .GT. MNJS .OR. NSZZ(I) .LT. 0) GO TO 8700          08JU1
         IF (NSXP(I) .GT. MNJS .OR. NSXP(I) .LT. 0) GO TO 8700          08JU1
         IF (NSYP(I) .GT. MNJS .OR. NSYP(I) .LT. 0) GO TO 8700          08JU1
         IF (NSXP(I) + NSYP(I) .EQ. 0)  GO TO 5800                      10JU1
         IF (ISTJR(I) .LE. 0 .OR. ISTJR(I) .GT. NST) GO TO 8710         08JU1
 5800    CONTINUE                                                       08JU1
 5900    CONTINUE                                                       08AG0
 6000    CONTINUE                                                       08AG0
COMMENT - PRINT ACCUMULATED JOINT DATA UNLESS IT IS THE SAME AS INPUT   04MY0
COMMENT - FOR THIS PROBLEM                                              04MY0
         IF (KEEP4B .EQ. 1) GO TO 6820                                  08AG0
         IF (NCD4B .EQ. 0) GO TO 6865                                   08AG0
      PRINT 16                                                          26JA0
      PRINT 7                                                           26JA0
      GO TO 6865                                                        08AG0
 6820    CONTINUE                                                       08AG0
      PRINT 16                                                          08AG0
      PRINT 35                                                          08AG0
         DO 6860  I = 1,NJT                                             08AG0
         IF (NSXX(I) .NE. 0) GO TO 6850                                 08AG0
         IF (NSYY(I) .NE. 0) GO TO 6850                                 08AG0
         IF (NSZZ(I) .NE. 0) GO TO 6850                                 08AG0
         IF (NSXP(I) .NE. 0) GO TO 6850                                 21MY1
         IF (NSYP(I) .NE. 0) GO TO 6850                                 21MY1
         GO TO 6860                                                     08AG0
 6850    PRINT 33,I,QMJ(I),WMJ(I),NSXX(I),NSYY(I),NSZZ(I),NSXP(I),      20MY1
     2    NSYP(I),ISTJR(I)                                              20MY1
 6860    CONTINUE                                                       08AG0
 6865    CONTINUE                                                       08AG0
COMMENT - INPUT TABLE 4C                                                08AG0
      PRINT 11                                                          08AG0
         IF (KEEP4C .EQ. 1) GO TO 7230                                  08AG0
COMMENT - INITIALIZE NUMBER OF POINTS ON CURVE                          09JU1
         DO 7200  J = 1,MNJS                                            09JU1
 7200          NPT(J) = -1                                              09JU1
         IF (NCD4C .NE. 0) GO TO 7240                                   08AG0
      PRINT 30                                                          08AG0
         GO TO 7500                                                     08AG0
COMMENT - HOLDING DATA                                                  08AG0
 7230 PRINT 17                                                          08AG0
         IF (NCD4C .NE. 0) GO TO 7240                                   08AG0
      PRINT 23                                                          08AG0
         GO TO 7500                                                     08AG0
 7240    CONTINUE                                                       08AG0
      PRINT 14                                                          08AG0
      PRINT 45                                                          08AG0
               NCD4C2 = NCD4C/2                                         08AG0
         IF (NCD4C2*2 .NE. NCD4C) GO TO 8600                            08AG0
      DO 7350  II = 1,NCD4C2                                            08AG0
      READ 42, NC,NPTT,ISJT,(NQJT(I), I = 1,11),(NWJT(I), I = 1,11)     08AG0
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```
         DO 7310  I = 1,NPTT                                            08AG0
               NQJ(NC,I) = NQJT(I)                                      08AG0
               NWJ(NC,I) = NWJT(I)                                      08AG0
 7310    CONTINUE                                                       08AG0
               NPT(NC) = NPTT                                           08AG0
               ISJ(NC) = ISJT                                           08AG0
      PRINT 43, NC,NPT(NC),ISJ(NC),(NQJ(NC,I), I = 1,NPTT)              08AG0
      PRINT 44, (NWJ(NC,I), I = 1,NPTT)                                 08AG0
         IF (ISJT .EQ. 1 .AND. NQJT(1) .NE. 0) GO TO 8760               24JL1
         IF ( ISJT .EQ. 1 .AND. NWJT(1) .NE. 0)  GO TO 8760             24JL1
         IF (NC .LT. 0 .OR. NC .GT. MNJS)  GO TO 8700                   11JU1
         IF (NPTT .LT. 2 .OR. NPTT .GT. 11) GO TO 8730                  11JU1
         IF (ISJT .NE. 0 .AND. ISJT .NE. 1) GO TO 8740                  11JU1
 7350    CONTINUE                                                       08AG0
 7500    CONTINUE                                                       08AG0
COMMENT - CHECK FOR CURVE REFERENCED IN TABLE 4B BUT NOT IN TABLE 4C    09JU1
COMMENT - AND FOR DISPLACEMENT VALUES NOT IN ASCENDING ALGEBRAIC ORDER  24JL1
         DO 7700 I = 1,NJT                                              09JU1
         IF (NSXX(I) .EQ. 0) GO TO 7510                                 09JU1
               NC = NSXX(I)                                             09JU1
         IF (NPT(NC) .EQ. -1) GO TO 8720                                09JU1
               NPTT = NPT(NC)                                           24JU1
         DO 7505  II = 2,NPTT                                           24JU1
         IF ( QMJ(I)*(NWJ(NC,II) - NWJ(NC,II - 1)) .LE. 0.0)) GO TO 875024JU1
 7505    CONTINUE                                                       24JU1
 7510    IF (NSYY(I) .EQ. 0) GO TO 7520                                 09JU1
               NC = NSYY(I)                                             09JU1
         IF (NPT(NC) .EQ. -1) GO TO 8720                                09JU1
               NPTT = NPT(NC)                                           24JU1
         DO 7515  II = 2,NPTT                                           24JU1
         IF ( QMJ(I)*(NWJ(NC,II) - NWJ(NC,II - 1)) .LE. 0.0)) GO TO 875024JU1
 7515    CONTINUE                                                       24JU1
 7520    IF (NSZZ(I) .EQ. 0) GO TO 7530                                 09JU1
               NC = NSZZ(I)                                             09JU1
         IF (NPT(NC) .EQ. -1) GO TO 8720                                09JU1
               NPTT = NPT(NC)                                           24JU1
         DO 7525  II = 2,NPTT                                           24JU1
         IF ( QMJ(I)*(NWJ(NC,II) - NWJ(NC,II - 1)) .LE. 0.0)) GO TO 875024JU1
 7525    CONTINUE                                                       24JU1
 7530    IF (NSXP(I) .EQ. 0) GO TO 7540                                 09JU1
               NC = NSXP(I)                                             09JU1
         IF (NPT(NC) .EQ. -1) GO TO 8720                                09JU1
               NPTT = NPT(NC)                                           24JU1
         DO 7535  II = 2,NPTT                                           24JU1
         IF ( QMJ(I)*(NWJ(NC,II) - NWJ(NC,II - 1)) .LE. 0.0)) GO TO 875024JU1
 7535    CONTINUE                                                       24JU1
 7540    IF ( NSYP(I) .EQ. 0) GO TO 7700                                09JU1
               NC = NSYP(I)                                             09JU1
         IF (NPT(NC) .EQ. -1) GO TO 8720                                09JU1
               NPTT = NPT(NC)                                           24JU1
         DO 7545  II = 2,NPTT                                           24JU1
         IF ( QMJ(I)*(NWJ(NC,II) - NWJ(NC,II - 1)) .LE. 0.0)) GO TO 875024JU1
 7545    CONTINUE                                                       24JU1
 7700    CONTINUE                                                       09JU1
         GO TO 9900                                                     05AG0
 8200 PRINT 20                                                          26JA0
         GO TO 9700                                                     26JA0
 8500 PRINT 50                                                          26JA0
         GO TO 9700                                                     08AG0
 8600 PRINT 60                                                          08AG0
         GO TO 9700                                                     09JU1
 8700 PRINT 70                                                          09JU1
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          GO TO 9700                                                      09JU1
 8710 PRINT 71                                                            09JU1
          GO TO 9700                                                      09JU1
 8720 PRINT 72,NC                                                         09JU1
          GO TO 9700                                                      11JU1
 8730 PRINT 73                                                            11JU1
          GO TO 9700                                                      11JU1
 8740 PRINT 74                                                            11JU1
          GO TO 9700                                                      24JL1
 8750 PRINT 75, NC                                                        24JL1
          GO TO 9700                                                      24JL1
 8760     PRINT 76                                                        24JL1
 9700          IABAN = 1                                                  26JA0
 9900     CONTINUE                                                        26JA0
      RETURN                                                              26JA0
      END                                                                 26JA0
C
C         ****************************************************************
C                                 SURROUTINE
C         ****************************************************************
C
      OVERLAY(RDMST,4,0)                                                  OVERLAY
      PROGRAM RDMST                                                       OVERLAY
COMMENT - REPLACE THE OVERLAY CARDS BY THE NONOVER CARD UNLESS THE CDC    OVERLAY
COMMENT - OVERLAY SYSTEM IS USED                                          OVERLAY
C     SUBROUTINE RDMST                                                    NONOVER
COMMENT - SUBROUTINE RDMST  INPUTS MEMBER STIFFNESS DATA (TABLE 5),       24AP0
COMMENT - CHECKS FOR BAD DATA,CONVERTS INPUT DISTANCES TO MEMBER          24AP0
COMMENT - COORDINATES AND ECHO PRINTS DATA                                24AP0
      COMMON /BLOCK2/ DXS( 25),   DYS( 25),   ZLS( 25),   DC1S( 25),      26JA0
     2    DC2S( 25),  PRF( 25),   PRAE( 25),  NCDS( 25),  IAXOPS( 25),    26JA0
     3    IOPOP( 25), IPINL( 25), IPINR( 25), NC51( 25),  INLOP( 25),     170C0
     4    NAL( 25),   NSXL( 25),  NSYL( 25),  NSZL( 25),  NAR( 25),       170C0
     5    NSXR( 25),  NSYR( 25),  NSZR( 25),  QM( 25),    WM( 25)         170C0
      COMMON /BLOCK5/ XLS( 50),   XRS( 50),   FL( 50),    AEL( 50),       26JA0
     2    SXL( 50),   SYL( 50),   SZL( 50)                                26JA0
      COMMON /BLOC12/ NA(20),     NCDA(20),   BI(20,10),  D1(20,10),      190C0
     2    Y1(20,10),  NSS(20,10), SM(20,10),  EM(20,10), IRECT(20,10)     17MYI
      COMMON /BLOC13/ NPTS( 08),   ISS( 08),  NSIG(08,11),NEPS(08,11),    05NO0
     2    NSIT(11),   NEPT(11)                                            240C0
      COMMON /BLOC14/ NPTM( 20),   ISM( 20),  NQM(20,11), NWM(20,11),     240C0
     2    NQMT(11),   NWMT(11)                                            240C0
      COMMON /BLK1/  KEEP2, KEEP3, KEEP4A,KEEP5A,KEEP6, KEEP7,            26JA0
     2         ITYPE, NCD2,  NCD3,  NCD4A, NCD5A, NCD6,  NCD7,            26JA0
     3         IABAN, IFORM, NM,    NJT,   NST,   NLT,   TOL,             26JA0
     4         M,     MP1,   MP2,   ISTT,  LTT,   ITYPEL,IDJ,             12FE0
     5         NSTL,  IP8,   IP9,   IP10,  KEEP4B,KEEP4C,NCD4B,           05AG0
     6         NCD4C, KEEP5B,KEEP5C,KEEP5D,NCD5B, NCD5C, NCD5D            05AG0
      COMMON /BLK3/ MNJT,MNST,MNLT,MNM,MNC5,MNC6,MDJT,MNJS,MNE,MNCS,      11JU1
     2    MNPCS,MNSS,MNQWM                                                11JU1
    6 FORMAT (3/,42H      TABLE 5D - SUPPORT CURVES FOR MEMBERS,/)        290C0
    7 FORMAT (3/,36H      TABLE 5C - STRESS STRAIN CURVES,/)              10MY1
    8 FORMAT (3/,35H      TABLE 5B - CROSS SECTION DATA ,/)               10MY1
    9 FORMAT  (  40H      TABLE 5A - MEMBER STIFFNESS DATA    ,///)       190C0
   12 FORMAT ( 5X,I5,E10.3,10X,2E10.3,   615)                             30MR0
   13 FORMAT ( 5X,15,     3E10.3,4I5,5X,2I5)                              30MR0
   14 FORMAT (//,45H      STIFF  MOD OF   PRISMATIC PRISMATIC  NON,       170C0
     2             30H NUMB AXIS  OUTPUT   PIN  PIN , /,                  30MR0
     3             45H      TYPE  ELAST        I         A       LIN,     30MR0
     4             30H CROS  OPT   OPT    FROM   TO ,//)                  30MR0
   15 FORMAT (10X,7E10.3)                                                 26JA0
   16 FORMAT ( 5X,7E11.3)                                                 26JA0
   17 FORMAT (   48H      HOLDING DATA FROM THE PREVIOUS PROBLEM PLUS,    26JA0
     2             15H THE FOLLOWING ,//)                                 26JA0
   18 FORMAT ( /,20H             STIFF TYPE, I5,6H CONTD,5X,/,            04MY0
     2       3X, 47H      FROM          TO            I           A     , 02MY0
     3           30H    SX             SY             SZ,/)               02MY0
   19 FORMAT  (10X,4I5,5X,4I5,5X,2E10.3)                                  190C0
   20 FORMAT  (/,15H      STIFF TYPE, I5,6H CONT ,/,                      190C0
     2 45H           FROM JOINT                   TO JOINT ,/,            190C0
     3 50H         NA  NSX  NSY  NSZ          NA  NSX  NSY  NSZ,          190C0
     4 26H        Q - MULT   W - MULT,/, 5X,4I5,5X,4I5,5X,2E11.3)         190C0
   23 FORMAT (   10H      NONE )                                          26JA0
   30 FORMAT  (  25H      NO DATA IN TABLE     )                          31MR0
   31 FORMAT  (  51H      NUMBER OF CARDS TO FOLLOW MUST NOT BE NEGATIVE)04AP0
   32 FORMAT  (  35H      OUTPUT OPTION MUST BE 0 OR 1  )                 04MY0
   33 FORMAT (   45H      PIN OPTION MUST NOT BE GREATER THAN ONE )       110E0
   34 FORMAT (   40H      NON LINEAR OPTION MUST BE 0 OR 1    )           170C0
   35 FORMAT (   48H      CROSS-SECTION NUMBER TOO LARGE OR NO CROSS-,    11JU1
     2           25HSECTION NUMBER SPECIFIED )                            11JU1
   41 FORMAT (//,30H      INPUT OF CROSS SECTIONS    )                    190C0
   42 FORMAT (5X,2I5)                                                     190C0
   43 FORMAT (   51H      CROSS NUMB WIDTH OR  DEPTH OR   Y-CENT  RECT=0,19MY1
     2           28H SIG-EP   SIG-MULT   EP-MULT,/,5X,   10HSECT  CROS, 17MY1
     3           20H  O-DIAM   THICKNESS,10X,12HPIPE=1  NUMB,/)           17MY1
   44 FORMAT (5X,2I5)                                                     190C0
   45 FORMAT (10X,3E10.3,2I5,2E10.3)                                      17MY1
   46 FORMAT (15X,3E10.3,2I5,5X,2E10.3)                                   17MY1
   51 FORMAT  (  35H      STIFF DATA MUST START AT 0.0  )                 31MR0
   52 FORMAT  (  40H      STIFF DATA MUST STOP AT END OF MEMB)            31MR0
   53 FORMAT  (  50H      STIFF SEQUENCE MUST BE LONGER THAN 1/M *SPAN ) 31MR0
   54 FORMAT  (  50H      STIFF DATA MUST BE SPECIFIED CONTINUOUSLY,IE , 31MR0
     2           35H FROM DIST MUST EQUAL LAST TO DIST )                  31MR0
   55 FORMAT  (  48H      NO CARDS IN TABLE 5 BUT STIFF TYPES NOT ALL,    29AP0
     2           10H SPECIFIED)                                           29AP0
   56 FORMAT  (  49H      ALL CARDS SPECIFIED FOR TABLE 5 READ BUT ALL,   29AP0
     2           26H STIFF TYPES NOT SPECIFIED,/,                         30AP0
     3           47H      CHECK CARD COUNT AND NUMBER OF STIFF TYPES)     30AP0
   57 FORMAT  (  48H      ALL STIFF TYPES SPECIFIED BUT ALL CARDS NOT,    30AP0
     2            5H READ,/,                                              30AP0
     3           47H      CHECK CARD COUNT AND NUMBER OF STIFF TYPES)     30AP0
   58 FORMAT  (  35H      AXIS OPTION MUST EQUAL 1 OR 2 )                 30AP0
   60 FORMAT  (  50H      NEGATIVE VALUES OF A       I ARE NOT PERMITTED) 02MY0
   65 FORMAT  (  45H      STIFF TYPES MUST BE IN ASCENDING ORDER  )       31MR0
   67 FORMAT  (  50H      IF 2ND CARD USED FOR STIFF TYPE, PRISMATIC I , 02MY0
     2           20H AND A  MUST BE 0.0 )                                 02MY0
   61 FORMAT (   50H      IF NONLINEAR OPTION = 1, TABLE 5B MUST HAVE   , 230C0
     2           10HSOME DATA )                                           230C0
   71 FORMAT  (  40H      STIFF TYPES MUST NOT BE NEGATIVE    )           31MR0
   72 FORMAT  (  40H      STIFF TYPE GREATER THAN TOTAL NUMBER OF STIFF, 31MR0
     2           20H TYPES SPECIFIED     )                                31MR0
   73 FORMAT (   47H      NUMBER OF CARDS IN THIS TABLE MUST BE EVEN)     240C0
   74 FORMAT (   48H      NON LINEAR OPTION MAY NOT BE 1 IF NUMBER OF,    11JU1
     2           25H CARDS THAT FOLLOWS IS 0 )                            11JU1
   75 FORMAT (   50H      TOO LARGE A NUMBER FOR Q-W CURVE NUMBER OR NO, 11JU1
     2           24H CURVE NUMBER SPECIFIED)                              11JU1
   76 FORMAT (   31H      AREA OPTION MUST BE 1 OR 0)                     11JU1
   77 FORMAT (   50H      TOO LARGE A NUMBER FOR STRESS-STRAIN CURVE NU, 11JU1
     2           35HMBER OR NO CURVE NUMBER SPECIFIED  )                  11JU1
   78 FORMAT (   48H      NUMBER OF PIECES OF CROSS SECTION TO LARGE ,    11JU1
     2           25H OR NO PIECES SPECIFIED  )                            11JU1
   79 FORMAT (   48H      NUMBER OF POINTS ON CURVE MUST BE BETWEEN 2,    11JU1
     2            7H AND 11)                                              11JU1
   80 FORMAT (   40H      SYMMETRY OPTION MUST BE 1 OR 0      )           11JU1
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 81 FORMAT (//,30H     CURVE NUMB SYMT (1 = YES,,/,                       230C0
  2           30H     NUMB  PTS  OPT   0 = NO) )                          230C0
 82 FORMAT (5X,3I5,5X,11I5,/,25X,11I5)                                    240C0
 83 FORMAT (/,5X,3I5,/,8H      SIG,17X,11I5)                              240C0
 84 FORMAT (/,         8H      EPS,17X,11I5)                              240C0
 85 FORMAT (/,5X,3I5,/,8H        Q,17X,11I5)                              240C0
 86 FORMAT (/,         8H        W,17X,11I5)                              240C0
 90 FORMAT (   16H     AREA NUMBER, I5,  10H NOT INPUT)                   11JU1
 92 FORMAT (   16H     AREA NUMBER,I5,  16H AND AREA NUMBER,I5,           11JU1
  2           40H SHOULD HAVE THE SAME NUMBER OF PIECES   ,/,5X,          11JU1
  3           45H SINCE THEY ARE BOTH ON MEMBERS OF STIFF TYPE,I5 )       11JU1
 93 FORMAT (   31H     STRESS-STRAIN CURVE NUMBER,I5,  10H NOT INPUT)     11JU1
 95 FORMAT (   32H     STRESS-STRAIN CURVE NUMBERS,I5,  4H AND,I5,        11JU1
  2           38H SHOULD HAVE THE SAME NUMBER OF POINTS,/,5X,             11JU1
  3           36H SINCE THEY ARE BOTH ON PIECE NUMBER,I5,                 11JU1
  4           16H OF AREA NUMBERS,I5,   4H AND,I5, /,5X,                  11JU1
  5           35H WHICH ARE ON MEMBERS OF STIFF TYPE ,I5  )               11JU1
 96 FORMAT (   13H PIECE NUMBER,I5,     15H ON AREA NUMBER,I5,            11JU1
  2            4H AND,I5,    24H WHICH ARE ON STIFF TYPE,I5,/,5X,         11JU1
  3           40H CANNOT BE BOTH A PIPE AND A RECTANGLE  )                11JU1
 97 FORMAT (   24H MEMBER Q-W CURVE NUMBER,I5,     10H NOT INPUT)         11JU1
 98 FORMAT ( 5H 98      )                                                 11JU1
991 FORMAT (   28H     MEMBER Q-W CURVE NUMBER,I5,10H NOT INPUT)          11JU1
993 FORMAT (   29H     MEMBER Q-W CURVE NUMBERS,I5,4H AND,I5,             11JU1
  2           38H SHOULD HAVE THE SAME NUMBER OF POINTS,/,5X,             11JU1
  3           44H SINCE THEY ARE ON MEMBERS OF STIFFNESS TYPE,I5)         11JU1
994 FORMAT  (  27H STRESS-STRAIN CURVE NUMBER,I5, 16H ACTING ON PIECE,24JL1
  2     I5,   10H OF AREA  ,I5,   11H STIFF TYPE, I5,                     24JL1
  3           51H NOT INPUT WITH FINAL VALUES OF STRAIN IN ASCENDING,24JL1
  4           16H ALGEBRAIC ORDER )                                       24JL1
996 FORMAT (   49H     IF SYMMETRY OPTION = 1, FIRST POINT ON CURVE,      24JL1
  2           21H     MUST EQUAL 0 - 0 )                                  24JL1
997 FORMAT (   32H     MEMBER SUPPORT CURVE NUMBER,I5,  9H ON STIFF,      24JL1
  2            5H TYPE,I5,/, 35H     NOT INPUT WITH FINAL VALUES OF,      24JL1
  3           43H DISPLACEMENTS IN ASCENDING ALGEBRAIC ORDER)             24JL1
      PRINT 9                                                             26JA0
           IF (KEEP5A .EQ.0) NSTL = 0                                     24AP0
COMMENT - FRAME MUST HAVE AT LEAST ONE STIFFNESS TYPE                     04MY0
           IF (NCD5A .LE. 0 .AND. KEEP5A .LE. 0) GO TO 8300               26JA0
           IF (NCD5A .NE. 0) GO TO 1150                                   26JA0
           IF (NST .NE. NSTL) GO TO 8550                                  29AP0
                NCR5 = 0                                                  06MR1
      PRINT 17                                                            26JA0
      PRINT 23                                                            26JA0
      GO TO 6100                                                          21FE1
 1150      CONTINUE                                                       26JA0
           IF (KEEP5A .EQ. 1) GO TO 1240                                  26JA0
COMMENT - INITILIZE CONTROLS FOR ALL NEW DATA                             04MY0
           DO 1200 I=1,MNST                                               26JA0
                NC51(I) = -1                                              26JA0
 1200           NCDS(I)= - 1                                              26JA0
                NC5 = 0                                                   26JA0
           GO TO 1250                                                     26JA0
 1240 PRINT 17                                                            26JA0
 1250      CONTINUE                                                       26JA0
      PRINT 14                                                            26JA0
                NCR5 = 0                                                  29AP0
COMMENT - DO FOR EACH STIFF TYPE                                          04MY0
           DO 5900  JJ = 1,NST                                            10MY1
COMMENT - SKIP FOR STIFF TYPE PREVIOUSLY DEFINED                          04MY0
           IF (NCDS(JJ) .NE. - 1) GO TO 5900                              19OC0
           IF (JJ .EQ. 1) GO TO 1300                                      26JA0
           IF (JJ .EQ. NSTL + 1) GO TO 1300                               24AP0
COMMENT - PRINT NEW HEADING FOR FIRST STIFF TYPE OF PROBLEM AND AFTER     04MY0
COMMENT - EVERY NON PRISMATIC STIFF TYPE                                  04MY0
           IF (NCDS(JJ - 1) .GT. 0) PRINT 14                              26JA0
 1300      CONTINUE                                                       04MY0
           IF (NCR5 .EQ. NCD5A) GO TO 8560                                29AP0
COMMENT - READ AND PRINT 1ST CARD FOR STIFF TYPE                          04MY0
      READ  12, ISTT,E,PRIT,PRAT,INLOPT,NCDST,IAXOPT,IOPOPT,IPINLT,       17OC0
     2     IPINRT                                                         17OC0
      PRINT  13,ISTT,E,PRIT,PRAT,INLOPT,NCDST,IAXOPT,IOPOPT,IPINLT,       17OC0
     2     IPINRT                                                         17OC0
           IF (IAXOPT .LT. 1  .OR. IAXOPT .GT. 2) GO TO 8580              30AP0
           IF (NCDST .LT. 0) GO TO 8310                                   04MY0
           IF (IOPOPT .LT. 0  .OR. IOPOPT .GT. 1) GO TO 8320              04MY0
           IF (IPINLT .GT. 1) GO TO 8330                                  11DE0
           IF (IPINRT .GT. 1) GO TO 8330                                  11DE0
           IF (INLOPT .LT. 0 .OR. INLOPT .GT. 1) GO TO 8340               17OC0
                NCR5 = NCR5 + 1                                           29AP0
           IF (JJ .NE. ISTT) GO TO 8650                                   26JA0
           IF (ISTT .GT. NST) GO TO 8720                                  26JA0
           IF (ISTT .LT. 0) GO TO 8710                                    26JA0
COMMENT - MULTIPLY A AND I BY E                                           04MY0
                PRFT = E*PRIT                                             30MR0
                PRAET = E*PRAT                                            30MR0
           IF (NCDST .GT. 0) GO TO 2400                                   26JA0
           IF (INLOPT .EQ. 1)  GO TO 8740                                 11JU1
COMMENT - PRISMATIC MEMBER - NO CARDS FOLLOW                              04MY0
           IF (PRFT .LE. 0.0  .OR. PRAET .LE. 0.0) GO TO 8660             10AP0
COMMENT - STORE TEMPORARY READ IN VALUES                                  04MY0
                PRF(ISTT) = PRFT                                          26JA0
                PRAE(ISTT) = PRAET                                        26JA0
                NCDS(ISTT) = 0                                            26JA0
                IAXOPS(ISTT) = IAXOPT                                     26JA0
                IOPOP(ISTT) = IOPOPT                                      26JA0
                IPINL(ISTT) = IPINLT                                      26JA0
                IPINR(ISTT) = IPINRT                                      26JA0
                INLOP(ISTT) = INLOPT                                      07OC0
           GO TO 5900                                                     10MY1
 2400      CONTINUE                                                       26JA0
           IF (PRFT .GT. 0.0  .OR. PRAET .GT. 0.0) GO TO 8670             10AP0
                NCDS(ISTT) = NCDST                                        26JA0
                IAXOPS(ISTT) = IAXOPT                                     26JA0
                IOPOP(ISTT)  = IOPOPT                                     26JA0
                IPINL(ISTT) = IPINLT                                      26JA0
                IPINR(ISTT) = IPINRT                                      26JA0
                INLOP(ISTT) = INLOPT                                      07OC0
           IF (INLOPT .EQ. 1) GO TO 5100                                  17OC0
COMMENT - NON PRISMATIC MEMBER - NCDST CARDS FOLLOW                       04MY0
COMMENT - STORE TEMPORARY READ IN VALUES                                  04MY0
      PRINT 18,ISTT                                                       26JA0
COMMENT - DO FOR EACH ADDITIONAL DATA CARD FOR THIS STIFF TYPE            04MY0
           DO 4500  II = 1,NCDST                                          26JA0
                NC5 = NC5 + 1                                             26JA0
           IF (II .EQ. 1) NC51(ISTT) = NC5                                26JA0
           IF (NCR5 .EQ. NCD5A) GO TO 8560                                29AP0
COMMENT - READ AND PRINT NON PRISMATIC STIFFNESS VALUES                   04MY0
      READ 15, XLS(NC5),XRS(NC5),FL(NC5),AEL(NC5),SXL(NC5),SYL(NC5),      26JA0
     2     SZL(NC5)                                                       26JA0
      PRINT 16,XLS(NC5),XRS(NC5),FL(NC5),AEL(NC5),SXL(NC5),SYL(NC5),      26JA0
     2     SZL(NC5)                                                       26JA0
                NCR5 = NCR5 + 1                                           29AP0
           IF (AEL(NC5) .LE. 0.0 .OR. FL(NC5) .LE. 0.0) GO TO 8660        04MY0
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COMMENT - MULTIPLY A AND I BY E                                         04MY0
             FL(NC5) = E*FL(NC5)                                        30MR0
             AEL(NC5) = E*AEL(NC5)                                      30MR0
COMMENT - CHECK FOR BAD DATA                                            04MY0
             TH = ZLS(ISTT)/M                                           26JA0
          IF  (II .EQ. 1) GO TO 3200                                    14AP0
          IF  (XLS(NC5) .NE. XRS(NC5 - 1)) GO TO 8540                   14AP0
          IF  (XLS(NC5) .NE. 0.0) GO TO 3300                            14AP0
          IF (XLS(NC5 - 1) + TH .GE. XRS(NC5) ) GO TO 8530              20AP0
          GO TO 4000                                                    14AP0
 3200     IF (XLS(NC5) .NE. 0.0) GO TO 8510                             14AP0
 3300     IF (XRS(NC5) .EQ. 0.0) GO TO 4000                             20AP0
          IF (XLS(NC5) + TH .GE. XRS(NC5)) GO TO 8530                   14AP0
 4000     CONTINUE                                                      14AP0
 4500     CONTINUE                                                      26JA0
COMMENT - CHECK FOR STIFF NOT STOPING AT END OF MEMBER                  04MY0
             ERRLN = ABS (ZLS(ISTT) - XRS(NC5))                         26JA0
          IF (ERRLN .GT. 0.1*TH) GO TO 8520                             23AP0
             XRS(NC5) = ZLS(ISTT)                                       26JA0
          GO TO 5900                                                    10MY1
 5100     CONTINUE                                                      17OC0
COMMENT - INPUT NONLINEAR SUPPORT CURVE AND CROSS-SECTION NUMBERS       19OC0
      READ  19, NAL(ISTT),NSXL(ISTT),NSYL(ISTT),NSZL(ISTT),NAR(ISTT),   19OC0
     2    NSXR(ISTT),NSYR(ISTT),NSZR(ISTT),QM(ISTT),WM(ISTT)            19OC0
             NCR5 = NCR5 + 1                                            26OC0
      PRINT 20,ISTT,NAL(ISTT),NSXL(ISTT),NSYL(ISTT),NSZL(ISTT),         19OC0
     2    NAR(ISTT),NSXR(ISTT),NSYR(ISTT),NSZR(ISTT),QM(ISTT),WM(ISTT)  19OC0
          IF (NAL(ISTT) .LE. 0 .OR. NAR(ISTT) .LE. 0) GO TO 8350        11JU1
          IF (NAL(ISTT) .GT. MNCS .OR. NAR(ISTT) .GT. MNCS) GO TO 8350  11JU1
          IF (NSXL(ISTT) .LT. 0 .OR. NSXL(ISTT) .GT. MNQWM) GO TO 8750  11JU1
          IF (NSYL(ISTT) .LT. 0 .OR. NSYL(ISTT) .GT. MNQWM) GO TO 8750  11JU1
          IF (NSZL(ISTT) .LT. 0 .OR. NSZL(ISTT) .GT. MNQWM) GO TO 8750  11JU1
          IF (NSXR(ISTT) .LT. 0 .OR. NSXR(ISTT) .GT. MNQWM) GO TO 8750  11JU1
          IF (NSYR(ISTT) .LT. 0 .OR. NSYR(ISTT) .GT. MNQWM) GO TO 8750  11JU1
          IF (NSZR(ISTT) .LT. 0 .OR. NSZR(ISTT) .GT. MNQWM) GO TO 8750  11JU1
 5900     CONTINUE                                                      10MY1
          IF (NCR5 .LT. NCD5A) GO TO 8570                               30AP0
 6100     CONTINUE                                                      19OC0
COMMENT - INPUT TABLE 5B                                                26OC0
      PRINT 8                                                           10MY1
          IF (NCD5B .GT. 0 .OR. KEEP5B .GT. 0) GO TO 6170               02NO0
          IF (INLOPT .EQ. 1) GO TO 8610                                 02NO0
      PRINT 30                                                          02NO0
          GO TO 6900                                                    02NO0
 6170     CONTINUE                                                      02NO0
          IF (NCD5B .NE. 0) GO TO 6200                                  19OC0
      PRINT 17                                                          19OC0
      PRINT 23                                                          19OC0
          GO TO 6900                                                    23OC0
 6200     IF (KEEP5B .EQ. 1) GO TO 6250                                 11JU1
          DO 6220 I = 1,MNCS                                            11JU1
 6220        NCDA(I) = -1                                               11JU1
          GO TO 6275                                                    12JU1
 6250 PRINT 17                                                          11JU1
 6275 PRINT 41                                                          19OC0
      PRINT 43                                                          19OC0
 6300     CONTINUE                                                      23OC0
COMMENT - READ FIRST CARD OF TABLE 5B                                   11JU1
      READ  42, NAT,NCDAT                                               19OC0
             NCDA(NAT) = NCDAT                                          07NO0
             NCR5 = NCR5 + 1                                            23OC0
      PRINT 44, NAT,NCDA(NAT)                                           07NO0
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          IF (NAT .LE. 0 .OR. NAT .GT. MNCS) GO TO 8350                 11JU1
          IF (NCDAT .LE. 0 .OR. NCDAT .GT. MNPCS) GO TO 8780            11JU1
COMMENT - DO FOR REMAINDER OF CARDS                                     11JU1
          DO 6400 II = 1,NCDAT                                          19OC0
      READ 45, BI(NAT,II),DI(NAT,II),YI(NAT,II),IRECT(NAT,II),NSS(NAT,  17MY1
     2    II),SM(NAT,II),EM(NAT,II)                                     17MB1
             NCR5 = NCR5 + 1                                            23OC0
      PRINT 46,BI(NAT,II),DI(NAT,II),YI(NAT,II),IRECT(NAT,II),NSS(NAT,  17MY1
     2    II),SM(NAT,II),EM(NAT,II)                                     17MB1
          IF (IRECT(NAT,II) .NE. 1 .AND. IRECT(NAT,II) .NE. 0)          11JU1
     2    GO TO 8760                                                    11JU1
          IF (NSS(NAT,II) .LE. 0 .OR. NSS(NAT,II) .GT. MNSS) GO TO 8770 11JU1
 6400     CONTINUE                                                      19OC0
          IF (NCR5 .LT. (NCD5A + NCD5B)) GO TO 6300                     23OC0
 6900     CONTINUE                                                      19OC0
COMMENT - INPUT TABLE 5C                                                26OC0
      PRINT 7                                                           10MY1
          IF (NCD5C .GT. 0 .OR. KEEP5C .GT. 0) GO TO 7200               23OC0
      PRINT 30                                                          23OC0
          GO TO 7500                                                    23OC0
 7200     IF (NCD5C .NE. 0) GO TO 7250                                  26OC0
      PRINT 17                                                          23OC0
      PRINT 23                                                          23OC0
          GO TO 7500                                                    23OC0
 7250     IF (KEEP5C .EQ. 1) GO TO 7280                                 11JU1
          DO 7270  I = 1,MNSS                                           11JU1
 7270        NPTS(I) = -1                                               11JU1
      GO TO 7300                                                        12JU1
 7280 PRINT 17                                                          11JU1
 7300     CONTINUE                                                      23OC0
      PRINT 81                                                          23OC0
             NCD5C2 = NCD5C/2                                           23OC0
          IF (NCD5C2*2 .NE. NCD5C  ) GO TO 8730                         26OC0
COMMENT - INPUT STRESS-STRAIN CURVE ON TWO CARDS                        11JU1
          DO 7350  II = 1,NCD5C2                                        26OC0
      READ 82, NC,NPTT,ISJT, (NSIT(I), I = 1,11), (NEPT(I), I = 1,11)   26OC0
          DO 7310  I = 1, NPTT                                          26OC0
             NSIG(NC,I) = NSIT(I)                                       26OC0
             NEPS(NC,I) = NEPT(I)                                       26OC0
 7310     CONTINUE                                                      26OC0
             NPTS(NC) = NPTT                                            26OC0
             ISS(NC) = ISJT                                             26OC0
      PRINT 83, NC,NPTS(NC),ISS(NC), (NSIG(NC,I), I = 1,NPTT)           26OC0
      PRINT 84, (NEPS(NC,I), I = 1,NPTT)                                26OC0
          IF (ISJT .EQ. 1 .AND. NSIT(1) .NE. 0) GO TO 8996              24JL1
          IF (ISJT .EQ. 1 .AND. NEPT(1) .NE. 0) GO TO 8996              24JL1
          IF (ISJT .NE. 1 .AND. ISJT .NE. 0) GO TO 8800                 11JU1
          IF (NPTT .LT. 2 .OR. NPTT .GT. 11) GO TO 8790                 11JU1
          IF (NC .LT.0 .OR. NC .GT. MNSS) GO TO 8770                    11JU1
 7350     CONTINUE                                                      26OC0
 7500     CONTINUE                                                      24OC0
COMMENT - INPUT TABLE 5D                                                26OC0
      PRINT 6                                                           10MY1
          IF (NCD5D .GT. 0 .OR. KEEP5D .GT. 0) GO TO 7700               26OC0
      PRINT 30                                                          26OC0
          GO TO 8000                                                    26OC0
 7700     IF (NCD5D .NE. 0) GO TO 7750                                  26OC0
      PRINT 17                                                          26OC0
      PRINT 23                                                          26OC0
          GO TO 8000                                                    26OC0
 7750     IF (KEEP5D .EQ. 1) GO TO 7780                                 11JU1
          DO 7770  I = 1,MNQWM                                          11JU1
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7770          NPTM(I) = -1                                          11JU1
        GO TO 7800                                                  11JU1
 7780 PRINT 17                                                      11JU1
 7800   CONTINUE                                                    26OC0
      PRINT 81                                                      26OC0
           NCDSD2 = NCDSD/2                                         26OC0
        IF (NCDSD2*2 .NE. NCDSD  ) GO TO 8730                       26OC0
COMMENT - INPUT MEMBER Q-W CURVE ON TWO CARDS                       11JU1
        DO 7850  II = 1,NCDSD2                                      26OC0
      READ 82, NC,NPTT,ISJT, (NQMT(I), I = 1,11),(NWMT(I), I = 1,11)  26OC0
        DO 7810  I = 1,NPTT                                         26OC0
           NQM(NC,I) = NQMT(I)                                      26OC0
           NWM(NC,I) = NWMT(I)                                      26OC0
 7810   CONTINUE                                                    26OC0
           NPTM(NC) = NPTT                                          26OC0
           ISM(NC) = ISJT                                           26OC0
      PRINT 85, NC,NPTM(NC),ISM(NC), (NQM(NC,I), I = 1,NPTT)        26OC0
      PRINT 86, (NWM(NC,I), I = 1,NPTT)                             26OC0
        IF (ISJT .EQ. 1 .AND. NQMT(1) .NE. 0) GO TO 8996            24JL1
        IF (ISJT .EQ. 1 .AND. NWMT(1) .NE. 0) GO TO 8996            24JL1
        IF (ISJT .NE. 1 .AND. ISJT .NE. 0) GO TO 8800               11JU1
        IF (NPTT .LT. 2 .OR. NPTT .GT. 11) GO TO 8790               11JU1
        IF (NC .LT.0 .OR. NC .GT. MNQWM) GO TO 8750                 11JU1
 7850   CONTINUE                                                    26OC0
 8000   CONTINUE                                                    26OC0
COMMENT - CHECK FOR INCOMPATIBLE DATA ON CROSS-SECTION AND STRESS-STRAIN11JU1
COMMENT - CURVES ON SAME MEMBER                                     11JU1
        DO 8100  I = 1,NST                                          24JL1
           ISTT = I                                                 24JL1
        IF (INLOP (ISTT) .EQ. 0) GO TO 8100                         11JU1
           NALT = NAL(ISTT)                                         11JU1
           NART = NAR(ISTT)                                         11JU1
        IF (NCDA(NALT) .EQ. -1) GO TO 8900                          11JU1
        IF (NCDA(NART) .EQ. -1) GO TO 8910                          11JU1
        IF (NCDA(NALT) .NE. NCDA(NART)) GO TO 8920                  11JU1
           NCDAT = NCDA(NALT)                                       11JU1
        DO 8050  K = 1,NCDAT                                        11JU1
           KJ = K                                                   24JL1
           NSSLT = NSS(NALT,K)                                      11JU1
           NSSRT = NSS(NART,K)                                      11JU1
        IF (NPTS(NSSLT) .EQ. -1) GO TO 8930                         11JU1
        IF (NPTS(NSSRT) .EQ. -1) GO TO 8940                         11JU1
        IF (NPTS(NSSLT) .NE. NPTS(NSSRT)) GO TO 8950                11JU1
        IF (IRECT(NALT,K) .NE. IRECT(NART,K)) GO TO 8960            11JU1
           NPTT = NPTS(NSSLT)                                       24JL1
        DO 8030  KK = 2,NPTT                                        24JL1
        IF (EM(NALT,K)*(NEPS(NSSLT,KK) - NEPS(NSSLT,KK - 1)) .LE. 0.0)24JL1
    2   GO TO 8994                                                  24JL1
 8030   CONTINUE                                                    24JL1
           NPTT = NPTS(NSSRT)                                       24JL1
        DO 8040  KK = 2,NPTT                                        24JL1
        IF (EM(NART,K)*(NEPS(NSSRT,KK) - NEPS(NSSRT,KK - 1)) .LE. 0.0)24JL1
    2   GO TO 8995                                                  24JL1
 8040   CONTINUE                                                    24JL1
 8050   CONTINUE                                                    12JU1
 8100   CONTINUE                                                    11JU1
COMMENT - CHECK FOR INCOMPATIBLE DATA ON MEMBER Q-W CURVES          11JU1
        DO 8200  I = 1,NST                                          24ML1
           ISTT = I                                                 24ML1
        IF (INLOP (ISTT) .EQ. 0) GO TO 8200                         11JU1
           K = 1                                                    11JU1
           NSLT = NSXL(ISTT)                                        11JU1
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           NSRT = NSXR(ISTT)                                        11JU1
        GO TO 8120                                                  11JU1
 8105      K = 2                                                    11JU1
           NSLT = NSYL(ISTT)                                        11JU1
           NSRT = NSYR(ISTT)                                        11JU1
        GO TO 8120                                                  11JU1
 8110      K = 3                                                    11JU1
           NSLT = NSZL(ISTT)                                        11JU1
           NSRT = NSZR(ISTT)                                        11JU1
 8120   CONTINUE                                                    11JU1
        IF (NSLT .EQ. 0 .AND. NSRT .NE. 0) GO TO 8993               11JU1
        IF (NSLT .EQ. 0) GO TO 8200                                 11JU1
        IF (NPTM(NSLT) .EQ. -1) GO TO 8991                          11JU1
        IF (NPTM(NSRT) .EQ. -1) GO TO 8992                          11JU1
        IF (NPTM(NSLT) .NE. NPTM(NSRT)) GO TO 8993                  11JU1
           NPTT = NPTM(NSLT)                                        24JL1
        DO 8160  II = 2,NPTT                                        24JL1
        IF (WM(ISTT)*(NWM(NSLT,II) - NWM(NSLT,II - 1)) .LE. 0.0)    24JL1
    2   GO TO 8997                                                  24JL1
 8160   CONTINUE                                                    24JL1
           NPTT = NPTM(NSRT)                                        24JL1
        DO 8170  II = 2,NPTT                                        24JL1
        IF (WM(ISTT)*(NWM(NSRT,II) - NWM(NSRT,II - 1)) .LE. 0.0)    24JL1
    2   GO TO 8998                                                  24JL1
 8170   CONTINUE                                                    24JL1
        GO TO (8105,8110,8200) K                                    11JU1
 8200   CONTINUE                                                    11JU1
        GO TO 9900                                                  26JA0
 8300 PRINT 30                                                      26JA0
        GO TO 9700                                                  26JA0
 8310 PRINT 31                                                      04MY0
        GO TO 9700                                                  04MY0
 8320 PRINT 32                                                      04MY0
        GO TO 9700                                                  04MY0
 8330 PRINT 33                                                      04MY0
        GO TO 9700                                                  04MY0
 8340 PRINT 34                                                      17OC0
        GO TO 9700                                                  17OC0
 8350 PRINT 35                                                      19OC0
        GO TO 9700                                                  19OC0
 8510 PRINT 51                                                      26JA0
        GO TO 9700                                                  26JA0
 8520 PRINT 52                                                      26JA0
        GO TO 9700                                                  26JA0
 8530 PRINT 53                                                      26JA0
        GO TO 9700                                                  26JA0
 8540 PRINT 54                                                      26JA0
        GO TO 9700                                                  26JA0
 8550 PRINT 55                                                      29AP0
        GO TO 9700                                                  29AP0
 8560 PRINT 56                                                      29AP0
        GO TO 9700                                                  29AP0
 8570 PRINT 57                                                      30AP0
        GO TO 9700                                                  30AP0
 8580 PRINT 58                                                      30AP0
        GO TO 9700                                                  30AP0
 8610 PRINT 61                                                      23OC0
        GO TO 9700                                                  23OC0
 8650 PRINT 65                                                      26JA0
        GO TO 9700                                                  26JA0
 8660 PRINT 60                                                      26JA0
        GO TO 9700                                                  26JA0
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8670 PRINT 67                                                           26JA0
         GO TO 9700                                                     26JA0
8710 PRINT 71                                                           26JA0
         GO TO 9700                                                     26JA0
8720 PRINT 72                                                           26JA0
         GO TO 9700                                                     24OC0
8730 PRINT 73                                                           24OC0
         GO TO 9700                                                     11JU1
8740 PRINT 74                                                           11JU1
         GO TO 9700                                                     11JU1
8750 PRINT 75                                                           11JU1
         GO TO 9700                                                     11JU1
8760 PRINT 76                                                           11JU1
         GO TO 9700                                                     11JU1
8770 PRINT 77                                                           11JU1
         GO TO 9700                                                     11JU1
8780 PRINT 78                                                           11JU1
         GO TO 9700                                                     11JU1
8790 PRINT 79                                                           11JU1
         GO TO 9700                                                     11JU1
8800 PRINT 80                                                           11JU1
         GO TO 9700                                                     11JU1
8900 PRINT 90, NALT                                                     11JU1
         GO TO 9700                                                     11JU1
8910 PRINT 90, NART                                                     11JU1
         GO TO 9700                                                     11JU1
8920 PRINT 92, NALT, NART, ISTT                                         11JU1
         GO TO 9700                                                     11JU1
8930 PRINT 93, NSSLT                                                    11JU1
         GO TO 9700                                                     11JU1
8940 PRINT 93, NSSRT                                                    11JU1
         GO TO 9700                                                     11JU1
8950 PRINT 95, NSSLT, NSSRT,KJ, NALT, NART, ISTT                        11JU1
         GO TO 9700                                                     11JU1
8960 PRINT 96,KJ, NALT, NART, ISTT                                      11JU1
         GO TO 9700                                                     11JU1
8970 PRINT 97, NSLT                                                     11JU1
         GO TO 9700                                                     11JU1
8980 PRINT 98, NSLT, NSRT, ISTT                                         11JU1
         GO TO 9700                                                     11JU1
8991 PRINT 991, NSLT                                                    11JU1
         GO TO 9700                                                     11JU1
8992 PRINT 991, NSRT                                                    11JU1
         GO TO 9700                                                     11JU1
8993 PRINT 993, NSLT, NSRT, ISTT                                        11JU1
         GO TO 9700                                                     24JL1
8994 PRINT 994, NSSLT,KJ, NALT, ISTT                                    24JL1
         GO TO 9700                                                     24JL1
8995 PRINT 994, NSSRT,KJ, NART, ISTT                                    24JL1
         GO TO 9700                                                     24JL1
8996     PRINT 996                                                      24JL1
         GO TO 9700                                                     24ML1
8997 PRINT 997, NSLT,ISTT                                               24JL1
         GO TO 9700                                                     24ML1
8998 PRINT 997, NSRT,ISTT                                               24JL1
9700          IABAN = 1                                                 26JA0
9900     CONTINUE                                                       26JA0
              NSTL = NST                                                24AP0
      RETURN                                                            26JA0
      END                                                               26JA0
C
C         ****************************************************************
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C                                SUBROUTINE
C         ****************************************************************
C
      OVERLAY(RDMLD,5,0)                                                OVERLAY
      PROGRAM RDMLD                                                     OVERLAY
COMMENT - REPLACE THE OVERLAY CARDS BY THE NONOVER CARD UNLESS THE CDC  OVERLAY
COMMENT - OVERLAY SYSTEM IS USED                                        OVERLAY
C     SUBROUTINE RDMLD                                                  NONOVER
COMMENT - SUBROUTINE RDMLD  INPUTS MEMBER LOAD DATA (TABLE 6) CHECKS    24AP0
COMMENT - FOR BAD DATA, CONVERTS LOADS AND DISTANCES TO MEMBER          24AP0
COMMENT - COORDINATES AND ECHO PRINTS DATA                              24AP0
      COMMON /BLOCK3/ DXL( 25),   DYL( 25),   ZLL( 25),   DC1L( 25),    26JA0
     2    DC2L( 25),  UQX( 25),   UQY( 25),   NCDL( 25),  IAXOPL( 25),  26JA0
     3    NC61( 25)                                                     26JA0
      COMMON /BLOCK6/ XLL( 75),   XRL( 75),   QXL( 75),   QYL( 75),     26JA0
     2    QZL( 75)                                                      26JA0
      COMMON /BLK1/  KEEP2, KEEP3, KEEP4A,KEEP5A,KEEP6, KEEP7,          26JA0
     2         ITYPE, NCD2,  NCD3,  NCD4A, NCD5A, NCD6,  NCD7,          26JA0
     3         IABAN, IFORM, NM,    NJT,   NST,   NLT,   TOL,           26JA0
     4         M,     MP1,   MP2,   ISTT,  LTT,   ITYPEL,IDJ,           12FE0
     5         NSTL,  IP8,   IP9,   IP10,  KEEP4B,KEEP4C,NCD4B,         05AG0
     6         NCD4C, KEEP5B,KEEP5C,KEEP5D,NCD5B, NCD5C, NCD5D          05AG0
      COMMON /BLK3/ MNJT,MNST,MNLT,MNM,MNC5,MNC6,MDJT,MNJS,MNE,MNCS,    11JU1
     2    MNPCS,MNSS,MNQ,M                                              11JU1
      COMMON /BLK8/ NLTL                                                12FE1
    9 FORMAT (   40H      TABLE 6 - MEMBER LOAD DATA            ,////)  26JA0
   10 FORMAT  (  49H      LOAD TYPES INCREASED BY PERCENTAGE OVER LAST, 08MY0
     2           10H PROBLEM  ,//,5X,15H LOAD  PERCENT ,/,5X,           08MY0
     3                               15H TYPE   CHANGE ,//)             08MY0
   12 FORMAT ( 5X, I5, 20X, 2E10.3,  5X,2I5 )                           17MR0
   13 FORMAT ( 5X, I5,       2E11.3,     2I5 )                          25MR0
   14 FORMAT (//,50H       LOAD  UNIFORM    UNIFORM     NO   AXIS     , 26JA0
     2        /, 50H       TYPE      QX         QY       CARDS  OPT    , 26JA0
     3        //)                                                       26JA0
   15 FORMAT (10X,5E10.3)                                               26JA0
   16 FORMAT ( 5X,5E11.3)                                               26JA0
   17 FORMAT (    48H      HOLDING DATA FROM THE PREVIOUS PROBLEM PLUS, 26JA0
     2           15H THE FOLLOWING ,//)                                 26JA0
   18 FORMAT (//,20H            LOAD TYPE ,I5,6H CONTD,/,2X,            02MY0
     2           49H         FROM         TO          QX          QY  , 26JA0
     3           30H    QZ                         , //)                26JA0
   21 FORMAT  ( 5X,I5,E10.3)                                            08MY0
   22 FORMAT  ( 5X,I5,E11.3)                                            08MY0
   23 FORMAT (   10H      NONE )                                        26JA0
   24 FORMAT (   20H      NO DATA           )                           04FE0
   52 FORMAT   (  50H     LOAD SPECIFIED BEYOND THE END OF MEMBER      ) 31MR0
   53 FORMAT   (  50H     LOAD SEQUENCE MUST BE LONGER THAN 1/M *SPAN  ) 31MR0
   54 FORMAT   (  51H     LOAD SPECIFIED AT NEGATIVE DISTANCE ALONG MEMB)31MR0
   55 FORMAT   (  49H     TO DISTANCE OF ZERO IMPLIES THAT IT IS FIRST, 21AP0
     2 55H CARD OF TWO CARD SEQUENCE AND NEXT CARD WILL HAVE FROM,/,    21AP0
     3 20H DISTANCE OF ZERO    )                                        21AP0
   56 FORMAT   (  50H     ALL CARDS SPECIFIED FOR TABLE 6 READ BUT ALL , 29AP0
     2            25HLOAD TYPES NOT SPECIFIED ,/,                       30AP0
     3            46H     CHECK CARD COUNT AND NUMBER OF LOAD TYPES)    30AP0
   57 FORMAT   (  48H     NO CARDS IN TABLE 6  BUT ALL LOAD TYPES NOT,  29AP0
     2            10H SPECIFIED)                                        29AP0
   58 FORMAT   (  51H     ALL LOAD TYPES SPECIFIED BUT ALL CADS NOT READ 30AP0
     2     ,/,    46H     CHECK CARD COUNT AND NUMBER OF LOAD TYPES)    30AP0
   59 FORMAT   (  40H     AXIS OPTION MUST BE 1,2,3, OR 4     )         30AP0
   60 FORMAT   (  51H     NUMBER OF CARDS TO FOLLOW MUST NOT BE NEGATIVE)04AP0
   61 FORMAT   (  48H     CONCENTRATED LOADS AT 0.0 ARE NOT PERMITTED)  04MY0
   62 FORMAT   (  50H     LOADS CAN NOT BE INCREASED IF NO LOADS HELD  ) 08MY0
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   65 FORMAT  (  45H      LOAD TYPES MUST BE IN ASCENDING ORDER    )        31MR0
   67 FORMAT  (  50H      IF 2ND CARO USEO FOR LOAD TYPE, UNIFORM LOAO ,   31MR0
     2           20HVALUES MUST BE 0.0   )                                  31MR0
   71 FORMAT  (  36H      LOAD TYPES MUST NOT BE NEGATIVE)                  31MR0
   72 FORMAT  (  48H      LOAD TYPE GREATER THAN TOTAL NUMBER OF LOAD,     31MR0
     2           16H TYPES SPECIFIED)                                       31MR0
COMMENT - PRINT TABLE HEADING                                               05MY0
      PRINT 9                                                               26JA0
          IF (KEEP6 .NE. 2) GO TO 1101                                      08MY0
          IF (NLTL .EQ. 0) GO TO 8620                                       08MY0
      PRINT 17                                                              08MY0
                NC6 = 0                                                     08MY0
                NCR6 = 0                                                    08MY0
COMMENT - DO FOR EACH OLD LOAD TYPE                                         10JU1
          OO 1080 JJ = I,NLTL                                               08MY0
          IF (NCR6 .EQ. NCD6) GO TO 8560                                    08MY0
      PRINT 10                                                              08MY0
COMMENT - READ LOAD TYPE AND PERCENT INCREASE                               10JU1
      READ  21, LTT,PER                                                     08MY0
      PRINT 22, LTT,PER                                                     08MY0
                NCR6 = NCR6 + 1                                             08MY0
          IF (JJ .NE. LTT) GO TO 8650                                       08MY0
                FAC = 1.0 + PER/100.0                                       12MY0
                NCDLT = NCDL(LTT)                                           08MY0
          IF (NCDLT .EQ. 0) GO TO 1040                                      08MY0
COMMENT - INCREASE GENERAL LOADS                                            10JU1
          DO 1030 II = I,NCDLT                                              08MY0
                NC6 = NC6 + 1                                               08MY0
                QXL(NC6) = QXL(NC6)*FAC                                     08MY0
                QYL(NC6) = QYL(NC6)*FAC                                     08MY0
                QZL(NC6) = QZL(NC6)*FAC                                     08MY0
 1030     CONTINUE                                                          08MY0
          GO TO 1080                                                        08MY0
 1040     CONTINUE                                                          08MY0
COMMENT - INCREASE UNIFORM LOADS                                            10JU1
                UQX(LTT) = UQX(LTT)*FAC                                     08MY0
                UQY(LTT) = UQY(LTT)*FAC                                     08MY0
 1080     CONTINUE                                                          08MY0
          IF  (NLT .NE. NLTL) GO TO 1260                                    08MY0
          IF  (NCR6 .LT. NCD6) GO TO 8580                                   08MY0
          GO TO 9900                                                        08MY0
 1101     IF (KEEP6 .EQ. 0) NLTL = 0                                        08MY0
          IF (NCD6 .EQ. 0 .AND. KEEP6 .EQ. 0) GO TO 1110                    04FE0
          GO TO 1120                                                        04FE0
 1110 PRINT 24                                                              04FF0
          IF (NLT .NE. 0) GO TO 8570                                        29AP0
          GO TO 9900                                                        04FE0
 1120     IF (NCD6 .NE. 0) GO TO 1150                                       04FE0
          IF (NLT .NE. NLTL) GO TO 8570                                     29AP0
      PRINT 17                                                              26JA0
      PRINT 23                                                              26JA0
          GO TO 9900                                                        26JA0
 1150     CONTINUE                                                          26JA0
          IF (KEEP6 .EQ. 1) GO TO 1240                                      26JA0
COMMENT - INITILIZE CONTROL CONSTANTS                                       05MY0
 1160     DO 1200  I = 1,MNLT                                               06MY0
                NC61(I) = -1                                                26JA0
 1200           NCDL(I)= - 1                                                26JA0
                NC6 = 0                                                     26JA0
          GO TO 1250                                                        26JA0
 1240 PRINT 17                                                              26JA0
          IF (NLTL .EQ. 0) GO TO 1160                                       06MY0
 1250     CONTINUE                                                          26JA0
                NCR6 = 0                                                    29AP0
 1260     CONTINUE                                                          08MY0
      PRINT 14                                                              26JA0
COMMENT - DO FOR EACH LOAO TYPE                                             05MY0
          DO 4900 JJ =1,NLT                                                 26JA0
COMMENT - SKIP FOR LOAD TYPES HELD FROM PREVIOUS PROBLEM                    05MY0
         IF (NCDL(JJ) .NE. -1) GO TO 4900                                   26JA0
          IF (JJ .EQ. 1) GO TO 1300                                         26JA0
          IF (JJ .EQ. NLTL + 1) GO TO 1300                                  24AP0
          IF (NCOL(JJ - 1) .GT. 0) PRINT 14                                 26JA0
 1300     CONTINUE                                                          04MY0
          IF (NCR6 .EQ. NCD6) GO TO 8560                                    29AP0
COMMENT - READ AND PRINT FIRST CARD FOR LOAD TYPE                           05MY0
      READ  12, LTT,UQXT,UQYT,NCDLT,IAXOPT                                  04MY0
      PRINT 13, LTT,UQXT,UQYT,NCDLT,IAXOPT                                  26JA0
          IF (IAXOPT .LT.1  .OR. IAXOPT .GT. 4) GO TO 8590                  30AP0
                NCR6 = NCR6 + 1                                             29AP0
          IF (LTT .GT. NLT) GO TO 8720                                      26JA0
          IF ( LTT .LT. 0) GO TO 8710                                       26JA0
          IF (JJ .NE.  LTT) GO TO 8650                                      26JA0
          IF (NCDLT .LT. 0) GO TO 8600                                      04MY0
          IF (NCDLT .GT. 0) GO TO 2400                                      26JA0
COMMENT - UNIFORM LOADS ONLY                                                05MY0
          IF (IAXOPT .EQ. 1) GO TO 1500                                     17MR0
          IF (IAXOPT .EQ. 2) GO TO 1400                                     17MR0
COMMENT - AXIS OPTION 3 OR 4 - CONVERT UNIFORM LOADS TO DIRECTIONS          05MY0
COMMENT - AND INTENSITY OF MEMBER AXES                                      05MY0
                TEMP1 = ABS(DC1L(LTT))                                      26JA0
                TEMP2 = ABS(DC2L(LTT))                                      26JA0
                UQX(LTT) =  UQXT*DC1L(LTT)*TEMP2 +                          26JA0
     2                      UQYT*DC2L(LTT)*TEMP1                            26JA0
                UQY(LTT) = -UQXT*DC2L(LTT)*TEMP2 +                          26JA0
     2                      UQYT*DC1L(LTT)*TEMP1                            26JA0
          GO TO 1600                                                        26JA0
COMMENT - AXIS OPTION 2 - CONVERT UNIFORM LOADS TO DIRECTIONS OF            09JN1
COMMENT - MEMBER AXES                                                       05MY0
 1400           UQX(LTT) = UQXT*DC1L(LTT) + UQYT*DC2L(LTT)                  26JA0
                UQY(LTT) = - UQXT*DC2L(LTT) + UQYT*DC1L(LTT)                26JA0
          GO TO 1600                                                        26JA0
COMMENT - AXIS OPTION 1 - LOADS ALLREADY IN MEMBER AXES                     05MY0
 1500           UQX(LTT) = UQXT                                             26JA0
                UQY(LTT) = UQYT                                             26JA0
 1600           NCDL(LTT) = 0                                               26JA0
                IAXOPL(LTT) = IAXOPT                                        26JA0
          GO TO 4900                                                        26JA0
COMMENT - VARIABLE LOADING                                                  05MY0
 2400     CONTINUE                                                          26JA0
          IF (UQXT .NE. 0 .OR.  UQYT .NE. 0) GO TO 8670                     26JA0
                NCDL(LTT) = NCDLT                                           26JA0
                IAXOPL(LTT) = IAXOPT                                        26JA0
      PRINT 18, LTT                                                         26JA0
COMMENT - DO FOR EACH ADDITIONAL CARD OF LOAD TYPE                           5MY0
          DO 4500  II = 1,NCDLT                                             26JA0
                NC6 = NC6 + 1                                               26JA0
          IF (II .EQ. 1) NC61(LTT) = NC6                                    26JA0
          IF (NCR6.EQ. NCD6) GO TO 8560                                     29AP0
COMMENT - READ AND PRINT NONUNIFORM LOAD DATA                               05MY0
      READ  15, XLL(NC6),XRL(NC6),QXLT,QYLT,QZL(NC6)                        26JA0
      PRINT 16, XLL(NC6),XRL(NC6),QXLT,QYLT,QZL(NC6)                        26JA0
                NCR6 = NCR6 + 1                                             29AP0
                TH = ZLL(LTT)/M                                             26JA0
```

```
COMMENT - CONVERT DISTANCES TO MEMBER COORDINATES                      05MY0
      GO TO  (2800,2800,2700,2600), IAXOPT                             21AP0
 2600        XLL(NC6) = XLL(NC6)/DC2L(LTT)                             26JA0
             XRL(NC6) = XRL(NC6)/DC2L(LTT)                             26JA0
      GO TO 2800                                                       26JA0
 2700        XLL(NC6) = XLL(NC6)/DC1L(LTT)                             26JA0
             XRL(NC6) = XRL(NC6)/DC1L(LTT)                             26JA0
 2800 CONTINUE                                                         26JA0
COMMENT - CHECK FOR ILLEGAL DATA                                       05MY0
      IF (XLL(NC6) .LT. 0.0) GO TO 8540                                21AP0
      IF (XRL(NC6) .GT. ZLL(LTT) + 0.1*TH) GO TO 8520                  21AP0
      IF (XRL(NC6) .EQ. 0.0) GO TO 2838                                21AP0
      IF (II .EQ. 1) GO TO 2820                                        04MY0
      IF (XRL(NC6 - 1) .NE. 0.0) GO TO 2820                            21AP0
      IF (XLL(NC6) .NE. 0.0) GO TO 8550                                21AP0
             DEL = XRL(NC6) - XLL(NC6 - 1)                             21AP0
      GO TO 2830                                                       21AP0
 2820        DEL = XRL(NC6) - XLL(NC6)                                 21AP0
      IF (DEL .EQ. 0.0) GO TO 2840                                     21AP0
 2830 IF (DEL .LE. TH) GO TO 8530                                      21AP0
      GO TO 2840                                                       21AP0
 2838        DEL = 1.0                                                 21AP0
      IF (II .EQ. 1) GO TO 2840                                        04MY0
      IF (XLL(NC6) .EQ. 0.0 .AND. XRL(NC6 - 1) .EQ. 0.0) GO TO 8610    04MY0
 2840 CONTINUE                                                         21AP0
      IF (IAXOPT .EQ. 1) GO TO 2900                                    21AP0
      IF (IAXOPT .EQ. 2 .OR. DEL .EQ. 0.0) GO TO 2850                  21AP0
COMMENT - AXIS APTIONS 3 OR 4 - CONVERT DISTRIBUTED LOADS TO DIRECTIONS 05MY0
COMMENT - AND INTENSITY OF MEMBER AXES                                 05MY0
             TEMP1 = ABS(DC1L(LTT))                                    26JA0
             TEMP2 = ABS(DC2L(LTT))                                    26JA0
             QXL(NC6) =  QXLT*DC1L(LTT)*TEMP2 +                        26JA0
     2                   QYLT*DC2L(LTT)*TEMP1                          26JA0
             QYL(NC6) = -QXLT*DC2L(LTT)*TEMP2 +                        26JA0
     2                   QYLT*DC1L(LTT)*TEMP1                          26JA0
      GO TO 2950                                                       26JA0
 2850 CONTINUE                                                         26JA0
COMMENT - AXIS OPTION 2 OR CONCENTRATED LOADS - CONVERT DISTRIBUTED    05MY0
COMMENT - AND CONCENTRATED LOADS TO DIRECTIONS OF MEMBER AXES          05MY0
             QXL(NC6) = QXLT*DC1L(LTT) + QYLT*DC2L(LTT)                26JA0
             QYL(NC6) = -QXLT*DC2L(LTT) + QYLT*DC1L(LTT)               26JA0
      GO TO 2950                                                       26JA0
 2900 CONTINUE                                                         26JA0
COMMENT - AXIS OPTION 1 - LOADS ALLREADY IN MEMBER AXES                05MY0
             QXL(NC6) = QXLT                                           26JA0
             QYL(NC6) = QYLT                                           26JA0
 2950 CONTINUE                                                         21AP0
 4500 CONTINUE                                                         26JA0
 4900 CONTINUE                                                         26JA0
      IF (NCR6 .LT. NCD6) GO TO 8580                                   01MY0
      GO TO 9900                                                       26JA0
 8520 PRINT 52                                                         26JA0
      GO TO 9700                                                       09FE0
 8530 PRINT 53                                                         26JA0
      GO TO 9700                                                       26JA0
 8540 PRINT 54                                                         09FE0
      GO TO 9700                                                       26JA0
 8550 PRINT 55                                                         21AP0
      GO TO 9700                                                       21AP0
 8560 PRINT 56                                                         29AP0
      GO TO 9700                                                       29AP0
 8570 PRINT 57                                                         29AP0
      GO TO 9700                                                       29AP0
 8580 PRINT 58                                                         30AP0
      GO TO 9700                                                       30AP0
 8590 PRINT 59                                                         30AP0
      GO TO 9700                                                       30AP0
 8600 PRINT 60                                                         04MY0
      GO TO 9700                                                       04MY0
 8610 PRINT 61                                                         04MY0
      GO TO 9700                                                       04MY0
 8620 PRINT 62                                                         08MY0
      GO TO 9700                                                       08MY0
 8650 PRINT 65                                                         26JA0
      GO TO 9700                                                       26JA0
 8670 PRINT 67                                                         26JA0
      GO TO 9700                                                       26JA0
 8710 PRINT 71                                                         26JA0
      GO TO 9700                                                       26JA0
 8720 PRINT 72                                                         26JA0
 9700        IABAN = 1                                                 26JA0
 9900 CONTINUE                                                         26JA0
             NLTL = NLT                                                24AP0
      RETURN                                                           26JA0
      END                                                              26JA0
C
C       ****************************************************************
C                              SUBROUTINE
C       ****************************************************************
C
      OVERLAY(ITCONT,6,0)                                              OVERLAY
      PROGRAM ITCONT                                                   OVERLAY
COMMENT - REPLACE THE OVERLAY CARDS BY THE NONOVER CARD UNLESS THE CDC OVERLAY
COMMENT - OVERLAY SYSTEM IS USED                                       OVERLAY
C     SUBROUTINE ITCONT                                                NONOVER
COMMENT - SUBROUTINE ITCONT INPUTS ITERATION CONTROL DATA, CHECKS FOR  09JU1
COMMENT - BAD DATA AND ECHO PRINTS DATA                                09JU1
      COMMON /BLOCK1/ X( 20),     Y( 20),     QXX( 20),   QYY( 20),    13FE0
     2     QZZ( 20),   SXX( 20),   SYY( 20),   SZZ( 20),   DXX( 20),   13FE0
     3     DYY( 20),   DZZ( 20),   RXX( 20),   RYY( 20),   RZZ( 20),   13FE0
     4     ERXX( 20),  ERYY( 20),  ERZZ( 20),  QMJ( 20),   WMJ( 20),   08AG0
     5     NSXX( 20),  NSYY( 20),  NSZZ( 20),  IMJ( 20),   NSXP( 20),  20MY1
     6     NSYP( 20),  ISTJR( 20)                                      20MY1
      COMMON /BLOCK4/ JT1( 40),   JT2( 40),   IST( 40),   LT( 40),     26JA0
     2     FORM( 40,6), SMC( 40,21), NITM( 40), IMM( 40),  IMC( 40)    01JL1
      COMMON /BLK1/  KEEP2, KEEP3, KEEP4A,KEEP5A,KEEP6, KEEP7,         26JA0
     2        ITYPE, NCD2,  NCD3,  NCD4A, NCD5A, NCD6,  NCD7,          26JA0
     3        IABAN, IFORM, NM,    NJT,   NST,   NLT,   TOL,           26JA0
     4        M,     MP1,   MP2,   ISTT,  LTT,   ITYPEL,IDJ,           12FE0
     5        NSTL,  IP8,   IP9,   IP10,  KEEP4B,KEEP4C,NCD4B,         05AG0
     6        NCD4C, KEEP5B,KEEP5C,KEEP5D,NCD5B, NCD5C, NCD5D          05AG0
      COMMON /ITC/ MNITF,ERR1,ERR2,MNITM,ER1,ER2,MM(5),MJ(5)           07AP1
    9 FORMAT (   40H      TABLE 7 -  ITERATION CONTROL        ,///)   10MY1
   14 FORMAT (10X,I5,5X,2E10.3,10X,5I5)                                10MY1
   17 FORMAT (   43H     HOLDING DATA FROM THE PREVIOUS PROBLEM,///)   10MY1
   18 FORMAT (   30H            FRAME SOLUTION , //,                   10MY1
     2          40H           NUMB       FORCE     MOMENT  ,/,         10MY1
     3          40H          ITER        ERROR      ERROR  , 15X,      10MY1
     4          16H  MONITOR JOINTS,/)                                 10MY1
   19 FORMAT (///30H          MEMBER SOLUTIONS,//,                     10MY1
     2          40H           NUMB       FORCE     MOMENT  ,/,         10MY1
     3          40H          ITER        ERROR      ERROR  , 15X,      10MY1
     4          17H  MONITOR MEMBERS,/)                                10MY1
   71 FORMAT (   45H MAXIMUN NUMBER OF ITERATIONS PERMITTED IS 20)     11JU1
```

```
   72 FORMAT (    43H MONITOR JOINT NUMBER TOO LARGE OR NEGATIVE )        11JUl
   73 FORMAT (    45H MONITOR MEMBER NUMBER TOO LARGE OR NEGATIVE )       11JU1
   87 FORMAT (    45H      IF TABLE 7 IS HELD NO CARDS MAY BE ADDED)      10MY1
COMMENT - PRINT TABLE HEADING                                             10MY1
        PRINT 9                                                           10MY1
           IF (KEEP7 .EQ. 1  .AND. NCD7 .NE. 0) GO TO 8700                10MY1
           IF (KEEP7 .EQ. 1) GO TO 2010                                   10MY1
        READ 14, MNITF,ERR1,ERR2 ,(MJ(I),I = 1,5)                         10MY1
        READ 14, MNITM,ER1,ER2, (MM(I), I = 1,5)                          10MY1
           GO TO 2100                                                     10MY1
 2010 PRINT 17                                                            10MY1
 2100 PRINT 18                                                            10MY1
        PRINT 14,MNITF,ERR1,ERR2,(MJ(I), I = 1,5)                         10MY1
           IF (MNITF .GT. 20)  GO TO 8710                                 11JU1
           DO 2200 I = 1, 5                                               11JU1
 2200      IF (MJ(I) .GT. NJT .OR. MJ(I) .LT. 0)  GO TO 8720              11JU1
        PRINT 19                                                          10MY1
        PRINT 14,MNITM,ER1,ER2,(MM(I),I = 1,5)                            10MY1
           IF (MNITM .GT. 20)  GO TO 8710                                 11JU1
           DO 2300 I = 1, 5                                               11JU1
 2300      IF (MM(I) .GT. NM .OR. MM(I) .LT. 0)  GO TO 8730               11JU1
           IF (KEEP7 .EQ. 1) GO TO 9900                                   10MY1
COMMENT - SET JOINT SWITCH EQUAL TO 1 FOR MONITOR JOINTS                  11JU1
           DO 3600  I = 1,NJT                                             10MY1
               IMJ(I) = 0                                                 10MY1
           DO 3600  J = 1,5                                               10MY1
           IF (I .EQ. MJ(J)) IMJ(I) = 1                                   10MY1
 3600      CONTINUE                                                       10MY1
COMMENT - SET MEMBER SWITCH EQUAL TO 1 FOR MONITOR MEMBERS                11JU1
           DO 3800  I = 1,NM                                              10MY1
               IMM(I) = 0                                                 10MY1
           DO 3800  J = 1,5                                               10MY1
           IF (I .EQ. MM(J))  IMM(I) = 1                                  10MY1
 3800      CONTINUE                                                       10MY1
           GO TO 9900                                                     10MY1
 8700 PRINT 87                                                            10MY1
           GO TO 9700                                                     11JU1
 8710 PRINT 71                                                            11JU1
           GO TO 9700                                                     11JU1
 8720 PRINT 72                                                            11JU1
           GO TO 9700                                                     11JU1
 8730 PRINT 73                                                            11JU1
 9700          IABAN = 1                                                  10MY1
 9900      CONTINUE                                                       10MY1
        RETURN                                                            10MY1
        END                                                               10MY1
```

APPENDIX I

SAMPLE INPUT

```
         EXAMPLE PROBLEMS - CHAPTER 5
         3 BAY 2 STORY FRAME - CODED 24 MAY 71 / CDH
501      ANALYSIS FOR DESIGN LIVE + DEAD + WIND LOADS
        1
          15    21    12     2    2    18    20     2     0    25    2
          20           1          0.0          0.0                0.3
           1      450.0                               6    11    16
           1                   355.45                 2
           2                   292.55                 3
           2      450.0                               7    12    17
          17      120.0       4.55                   19
           3      450.0       18.75                   8    13    18
          18      120.0       5.0                    20
           2      120.0       4.55                    4
           4      210.0                               5
           7      120.0       4.55                    9
           9      210.0                              10
          12      120.0       4.55                   14
          14      210.0                              15
          20    -1470.0     -709.3                    1
          10         11         20
        1         1     1        2
        6         1     2        7
       11         1     2       12
       16         1     2       17
        2         2     3        3
        7         3     4        8
       12         4     5       13
       17         5     6       18
        3         6     7        8    13    18
       18         7     8       20
        2         8     9        4
        4         9    10        5
        5        10    11        7
        7         8     9        9
        9         9    10       10
       10        10    11       12
       12         8     9       14
       14         9    10       15
       15        10    11       17
       17         8     9       19
        2        -17.0
        7        -17.0
       12        -17.0
       17        -17.0
        3        -12.0
        8        -12.0
       13        -12.0
       18        -12.0
        1                                  1.000E+20 1.000E+20 1.000E+20
        6                                            1.000E+20
       11                                            1.000E+20
       16                                  1.000E+20 1.000E+20
        6 1.0      0.01                        1
       11 1.0      0.01                        1
        1    5     1        0    -5   -10   -15   -15
                            0    25   100   300  1000
        1                                                1     1     1
             1                         1
        2                                                1     1     1
             2                         2
```

```
3                                               1     1     1     1
     2                           2
4                                               1     1     1     1
     2                           2
5                                               1     1     1     1
     2                           2
6 3.000E-04          3266.7      27.65          0     0     1
7 3.000E-04          3266.7      27.65          0     0     1
8                                               1     1     1
     4                           5
9                                               1     1     1
     3                           3
10                                              1     1     1
     5                           4
1    3
  15.55      1.188      6.906              1 1.0      1.000E-04
  15.55      1.188     -6.906              1 1.0      1.000E-04
  0.730      12.62                         1 1.0      1.000E-04
2    3
  12.02      0.778      6.70               1 1.0      1.000E-04
  12.02      0.778     -6.70               1 1.0      1.000E-04
   0.451     12.62                         1 1.0      1.000E-04
3    3
  9.99       0.747      13.08              1 1.0      1.000E-04
  9.99       0.747     -13.08              1 1.0      1.000E-04
  0.49       25.42                         1 1.0      1.000E-04
4    3
  10.0       0.75       17.625             1 1.0      1.000E-04
  10.0       0.75      -17.625             1 1.0      1.000E-04
  0.75       34.5                          1 1.0      1.000E-04
5    3
  10.0       0.75       13.08              1 1.0      1.000E-04
  10.0       0.75      -13.08              1 1.0      1.000E-04
  1.0        24.41                         1 1.0      1.000E-04
1    2    1           0   24
                      0    8
1                      -0.013     -0.0833         0     1
2                      -0.013                     0     1
3                      -0.007     -0.0833         0     1
4                      -0.007                     0     1
5                      -0.007                     0     1
6                      -0.007                     0     1
7                                                 5     2
  90.07      90.07                -12.0
  180.1      180.1                -12.0
  270.2      270.2                -12.0
  360.3      360.3                -12.0
  0.0        450.4                -0.2
8                                                 2     2
  90.07      90.07                -12.0
     0.0       120.1                -0.2
9                                                 2     3
  90.0       90.0                 -17.0
  0.0        120.0                -0.25
10                                                3     3
  60.0       60.0                 -17.0
  150.0      150.0                -17.0
  0.0        210.0                -0.25
11                                                2     3
  30.0       30.0                 -17.0
  0.0        120.0                -0.25
     10      0.02      10.0                 1     2     3     6    11
```

```
        10      0.002     1.0                       1    4    9
502      501 WITH COLUMNS RIGID WITHIN JOINTS
       2    1    1    1    1    1    0    1    1        1    1
                                     18
       1                                            1    1    1             -10
            1                         1
       2                                            1    1    1        -10   -10
            2                         2
       3                                            1    1    1    1   -10   -10
            2                         2
       4                                            1    1    1    1   -10   -10
            2                         2
       5                                            1    1    1    1   -10   -10
            2                         2
       6 3.000E+04          3266.7      27.65       0    0    1
       7 3.000E+04          3266.7      27.65       0    0    1
       8                                            1    1    1
            4                         5
       9                                            1    1    1
            3                         3
      10                                            1    1    1
            5                         4
CEASE
```

```
      SOIL SUPPORTED BENT - GALATI RUMANIA
      THREE BATTERED PILES
901   Q =  0 KIPS
     1
        15    15     1     0     0    20     9     4    12    10     2
        15           1                                              0.001
         1       55.8                                 2
         2       62.5                                 3
         1      -7.3       -29.7                      4
         4      -46.0      -184.0                     7
         7      -31.0      -124.0                    10
        10      -82.5      -330.0                    13
         2       4.867     -29.7                      5
         5       30.67     -184.0                     8
         8       20.67     -124.0                    11
        11       56.85     -341.0                    14
         3       4.867     -29.7                      6
         6       30.67     -184.0                     9
         9       20.67     -124.0                    12
        12       56.85     -341.0                    15
        10         10         10
     1         1    1          2
     2         2    2          3
     1         3    3          4
     4         5    5          7
     7         7    7         10
    10         9    9         13
     2         4    4          5
     3         4    4          6
     5         6    6          8
     6         6    6          9
     8         8    8         11
     9         8    8         12
    11        10   10         14
    12        10   10         15
     2        -15.2       -43.6
     1                                          1     1     1
          1                        1
     2                                          1     1     1
          1                        1
     3                                          1     1     1        -40
          2                        2
     4                                          1     1     1        -40
          2                        2
     5                                          1     1     1
          2    1    4              2    2    5          -0.0001    0.001
     6                                          1     1     1
          2    1    4              2    2    5          -0.0001    0.001
     7                                          1     1     1
          2    2    5              2    3    6          -0.0001    0.001
     8                                          1     1     1
          2    2    5              2    3    6          -0.0001    0.001
     9                                          1     1     1
          2    3    6              2    3    6          -0.0001    0.001
    10                                          1     1     1
          2    3    6              2    3    6          -0.0001    0.001
     1    3
      31.5       35.4       0.0               1 1.000E-02 1.000E-05
      1.22       1.0        13.7              2 1.0       1.000E-05
      1.22       1.0       -13.7              2 1.0       1.000E-05
     2    4
      15.75      15.75      0.0               1 1.000E-02 1.000E-05
      2.286      1.0        6.695             2 1.0       1.000E-05
      2.286      1.0       -6.695             2 1.0       1.000E-05
      1.524      1.0        0.0               2 1.0       1.000E-05
     1   10    0      -257 -302 -283 -227 -132    0   28   14    0    0
                      -400 -192 -144  -96  -48    0   10   30  200 2000
     2    3    1         0   54   54
                         0  183 1830
     1    8    1         0  184  353  507  614  768  798  798
                         0   25   50   75  100  150  200  250
     2    8    1         0  219  405  569  712  876  909  909
                         0   25   50   75  100  150  200  250
     3    8    1           2276 3986 4380 4073 3635 3635 3635
                         0   25   50   75  100  150  200  250
     4    9    1         0  372  469  590  743  850 1008 1179 1179
                         0   10   20   39   79  118  197  315 3150
     5    9    1         0 1074 1356 1705 2149 2458 2916 3410 3410
                         0   10   20   39   79  118  197  315 3150
     6    9    1         0 3178 4011 5045 6357 7275 86271009010090
                         0   10   20   39   79  118  197  315 3150
     1                               -0.097                 2
     2                               -0.097                 2
     3                               -.021                  2
     4                               -.021                  2
     5                               -.021                  2
     6                               -.021                  2
     7                               -.021                  2
     8                               -.021                  2
     9                               -.021                  2
    10                               -.021                  2
       10         0.1        10.0               1    4    7   10   13
       10         0.01       1.0                1    3    6    9   12
902   Q = 80 KIPS
     2    1    1    1              1    1    1    1    1    1
                    1
     3-80.0               -904.0
CEASE
```

APPENDIX J

SAMPLE OUTPUT

```
PROGRAM  FRAME 51 - MASTER DECK - MATLOCK-HAYS  REVISION DATE = 24 JULY 71

     EXAMPLE PROBLEMS - CHAPTER 5
     3 BAY 2 STORY FRAME - CODED 24 MAY 71 / COH
```

EXAMPLE PROBLEMS - CHAPTER 5
3 BAY 2 STORY FRAME - CODED 24 MAY 71 / COH

PROB

501 ANALYSIS FOR DESIGN LIVE + DEAD + WIND LOADS

TABLE 1 - PROGRAM CONTROL DATA
PROBLEM TYPE 1

INPUT TABLES

TABLE NUMBER	HOLD DATA FROM LAST PROBLEM (1 = YES,0 = NO)	NUMBER OF CARDS ADDED FOR THIS PROBLEM
2	-0	15
3	-0	21
4A	-0	12
4B	-0	2
4C	-0	2
5A	-0	18
5B	-0	20
5C	-0	2
5D	-0	0
6	-0	25
7	-0	2

OUTPUT TABLES

TABLE NUMBER	SUPPRESS OUTPUT (1 = YES,0 = NO)
8	-0
9	-0
10	-0

PROB (CONTD)
501 ANALYSIS FOR DESIGN LIVE + DEAD + WIND LOADS

TABLE 2 - FRAME GEOMETRY DATA

NUMBER OF JOINTS IN FRAME = 20
REFERENCE JOINT IS JOINT 1 AT X = 0. AND Y = 0.
JOINT TOLERANCE IS 3.000E-01

INPUT OF JOINT OFFSETS

FROM JOINT	X-OFFSET	Y-OFFSET	TO JOINT	TO	TO	TO	TO	TO	TO
1	4.500E+02	-0.	6	11	16				
1	-0.	3.555E+02	2						
2	-0.	2.925E+02	3						
2	4.500E+02	-0.	7	12	17				
17	1.200E+02	4.550E+00	19						
3	4.500E+02	1.875E+01	8	13	18				
18	1.200E+02	5.000E+00	20						
2	1.200E+02	4.550E+00	4						
4	2.100E+02	-0.	5						
7	1.200E+02	4.550E+00	9						
9	2.100E+02	-0.	10						
12	1.200E+02	4.550E+00	14						
14	2.100E+02	-0.	15						
20	-1.470E+03	-7.093E+02	1						

COMPUTED JOINT COORDINATES

JOINT	X	Y
1	0.	-2.500E-02
2	0.	3.555E+02
3	0.	6.480E+02
4	1.200E+02	3.600E+02
5	3.300E+02	3.600E+02
6	4.500E+02	0.
7	4.500E+02	3.555E+02
8	4.500E+02	6.667E+02
9	5.700E+02	3.600E+02
10	7.800E+02	3.600E+02
11	9.000E+02	0.
12	9.000E+02	3.555E+02
13	9.000E+02	6.855E+02
14	1.020E+03	3.600E+02
15	1.230E+03	3.600E+02
16	1.350E+03	0.
17	1.350E+03	3.555E+02
18	1.350E+03	7.042E+02

19	1.470E+03	3.600E+02
20	1.470E+03	7.092E+02

PROB (CONTD)
501 ANALYSIS FOR DESIGN LIVE + DEAD + WIND LOADS

TABLE 3 - MEMBER LOCATION DATA

NUMBER OF MEMBER STIFFNESS TYPES = 10
NUMBER OF MEMBER LOAD TYPES = 11
NUMBER OF ELEMENTS PER MEMBER = 20

INPUT OF MEMBER LOCATIONS

FROM JOINT	STIFF TYPE	LOAD TYPE	TO JOINT	TO	TO	TO	TO	TO	TO	TO	TO	TO
1	1	1	2									
6	1	2	7									
11	1	2	12									
16	1	2	17									
2	2	3	3									
7	3	4	8									
12	4	5	13									
17	5	6	18									
3	6	7	8	13	18							
18	7	8	20									
2	8	9	4									
4	9	10	5									
5	10	11	7									
7	8	9	9									
9	9	10	10									
10	10	11	12									
12	8	9	14									
14	9	10	15									
15	10	11	17									
17	8	9	19									

COMPUTED MEMBER NUMBERS,LENGTHS,AND OFFSETS

MEMBER NUMB	FROM JOINT	TO JOINT	STIFF TYPE	LOAD TYPE	LENGTH	X-OFFSET	Y-OFFSET
1	1	2	1	1	3.555E+02	0.	3.555E+02
2	6	7	1	2	3.555E+02	0.	3.555E+02
3	11	12	1	2	3.555E+02	0.	3.555E+02
4	16	17	1	2	3.555E+02	0.	3.555E+02
5	2	3	2	3	2.925E+02	0.	2.925E+02
6	7	8	3	4	3.113E+02	0.	3.113E+02
7	12	13	4	5	3.300E+02	0.	3.300E+02
8	17	18	5	6	3.488E+02	0.	3.488E+02

9	3	8	6	7	4.504E+02	4.500E+02	1.875E+01
10	8	13	6	7	4.504E+02	4.500E+02	1.875E+01
11	13	18	6	7	4.504E+02	4.500E+02	1.875E+01
12	18	20	7	8	1.201E+02	1.200E+02	5.000E+00
13	2	4	8	9	1.201E+02	1.200E+02	4.550E+00
14	4	5	9	10	2.100E+02	2.100E+02	0.
15	5	7	10	11	1.201E+02	1.200E+02	-4.550E+00
16	7	9	8	9	1.201E+02	1.200E+02	4.550E+00
17	9	10	9	10	2.100E+02	2.100E+02	0.
18	10	12	10	11	1.201E+02	1.200E+02	-4.550E+00
19	12	14	8	9	1.201E+02	1.200E+02	4.550E+00
20	14	15	9	10	2.100E+02	2.100E+02	0.
21	15	17	10	11	1.201E+02	1.200E+02	-4.550E+00
22	17	19	8	9	1.201E+02	1.200E+02	4.550E+00

*** COMPUTED MEMBER NUMBERS MAY NOT AGREE WITH LAST PROBLEM ***

PROB (CONTD)
501 ANALYSIS FOR DESIGN LIVE + DEAD + WIND LOADS

TABLE 4A - JOINT LOADS AND LINEAR RESTRAINTS

INPUT OF JOINT DATA

JOINT	FORCE(X)	FORCE(Y)	MOMENT(Z)	SPRING(X)	SPRING(Y)	SPRING(Z)
2	-0.	-1.700E+01	-0.	-0.	-0.	-0.
7	-0.	-1.700E+01	-0.	-0.	-0.	-0.
12	-0.	-1.700E+01	-0.	-0.	-0.	-0.
17	-0.	-1.700E+01	-0.	-0.	-0.	-0.
3	-0.	-1.200E+01	-0.	-0.	-0.	-0.
8	-0.	-1.200E+01	-0.	-0.	-0.	-0.
13	-0.	-1.200E+01	-0.	-0.	-0.	-0.
18	-0.	-1.200E+01	-0.	-0.	-0.	-0.
1	-0.	-0.	-0.	1.000E+20	1.000E+20	1.000E+20
6	-0.	-0.	-0.	-0.	1.000E+20	-0.
11	-0.	-0.	-0.	-0.	1.000E+20	-0.
16	-0.	-0.	-0.	1.000E+20	1.000E+20	-0.

ACCUMULATED JOINT DATA

SAME AS INPUT FOR THIS PROBLEM

TABLE 4B - JOINT SUPPORT CURVE NUMBERS

INPUT OF JOINT DATA

JOINT	Q-MULT	W-MULT	NSXX	NSYY	NSZZ	NSXP	NSYP	STIFF
6	1.000E+00	1.000E-02	1	-0	-0	-0	-0	-0
11	1.000E+00	1.000E-02	1	-0	-0	-0	-0	-0

ACCUMULATED JOINT DATA

SAME AS INPUT FOR THIS PROBLEM

TABLE 4C - JOINT SUPPORT CURVES

INPUT OF JOINT DATA

CURVE NUMB	NUMB PTS	SYMT OPT (1 = YES, 0 = NO)					
1	5	1					
Q			0	-5	-10	-15	-15
W			0	25	100	300	1000

PROB (CONTD)
501 ANALYSIS FOR DESIGN LIVE • DEAD • WIND LOADS

TABLE 5A - MEMBER STIFFNESS DATA

STIFF TYPE	MOD OF ELAST	PRISMATIC I	PRISMATIC A	NON LIN	NUMB CRDS	AXIS OPT	OUTPUT OPT	PIN FROM	PIN TO
1	-0.	-0.	-0.	1	1	1	-0	-0	-0

STIFF TYPE 1 CONT

FROM JOINT NA	NSX	NSY	NSZ	TO JOINT NA	NSX	NSY	NSZ	Q - MULT	W - MULT
1	-0	-0	-0	1	-0	-0	-0	-0.	-0.

STIFF TYPE	MOD OF ELAST	PRISMATIC I	PRISMATIC A	NON LIN	NUMB CRDS	AXIS OPT	OUTPUT OPT	PIN FROM	PIN TO
2	-0.	-0.	-0.	1	1	1	-0	-0	-0

STIFF TYPE 2 CONT

FROM JOINT NA	NSX	NSY	NSZ	TO JOINT NA	NSX	NSY	NSZ	Q - MULT	W - MULT
2	-0	-0	-0	2	-0	-0	-0	-0.	-0.

STIFF TYPE	MOD OF ELAST	PRISMATIC I	PRISMATIC A	NON LIN	NUMB CRDS	AXIS OPT	OUTPUT OPT	PIN FROM	PIN TO
3	-0.	-0.	-0.	1	1	1	1	-0	-0

STIFF TYPE 3 CONT

FROM JOINT NA	NSX	NSY	NSZ	TO JOINT NA	NSX	NSY	NSZ	Q - MULT	W - MULT
2	-0	-0	-0	2	-0	-0	-0	-0.	-0.

STIFF TYPE	MOD OF ELAST	PRISMATIC I	PRISMATIC A	NON LIN	NUMB CRDS	AXIS OPT	OUTPUT OPT	PIN FROM	PIN TO
4	-0.	-0.	-0.	1	1	1	1	-0	-0

STIFF TYPE 4 CONT

FROM JOINT NA	NSX	NSY	NSZ	TO JOINT NA	NSX	NSY	NSZ	Q - MULT	W - MULT
2	-0	-0	-0	2	-0	-0	-0	-0.	-0.

```
STIFF  MOD OF    PRISMATIC PRISMATIC  NON NUMB AXIS  OUTPUT   PIN  PIN
 TYPE  ELAST         I          A      LIN CRDS  OPT   OPT    FROM   TO

    5-0.       -0.        -0.            1    1    1    1        -0   -0

STIFF TYPE    5 CONT
     FROM JOINT                   TO JOINT
   NA  NSX  NSY  NSZ          NA  NSX  NSY  NSZ        Q - MULT   W - MULT
    2   -0   -0   -0           2   -0   -0   -0      -0.         -0.

STIFF  MOD OF    PRISMATIC PRISMATIC  NON NUMB AXIS  OUTPUT   PIN  PIN
 TYPE  ELAST         I          A      LIN CRDS  OPT   OPT    FROM   TO

    6 3.000E+04 3.267E+03 2.765E+01    0    0    1   -0        -0   -0
    7 3.000E+04 3.267E+03 2.765E+01    0    0    1   -0        -0   -0
    8-0.       -0.        -0.          1    1    1   -0        -0   -0

STIFF TYPE    8 CONT
     FROM JOINT                   TO JOINT
   NA  NSX  NSY  NSZ          NA  NSX  NSY  NSZ        Q - MULT   W - MULT
    4   -0   -0   -0           5   -0   -0   -0      -0.         -0.

STIFF  MOD OF    PRISMATIC PRISMATIC  NON NUMB AXIS  OUTPUT   PIN  PIN
 TYPE  ELAST         I          A      LIN CRDS  OPT   OPT    FROM   TO

    9-0.       -0.        -0.          1    1    1   -0        -0   -0

STIFF TYPE    9 CONT
     FROM JOINT                   TO JOINT
   NA  NSX  NSY  NSZ          NA  NSX  NSY  NSZ        Q - MULT   W - MULT
    3   -0   -0   -0           3   -0   -0   -0      -0.         -0.

STIFF  MOD OF    PRISMATIC PRISMATIC  NON NUMB AXIS  OUTPUT   PIN  PIN
 TYPE  ELAST         I          A      LIN CRDS  OPT   OPT    FROM   TO

   10-0.       -0.        -0.          1    1    1   -0        -0   -0

STIFF TYPE   10 CONT
     FROM JOINT                   TO JOINT
   NA  NSX  NSY  NSZ          NA  NSX  NSY  NSZ        Q - MULT   W - MULT
    5   -0   -0   -0           4   -0   -0   -0      -0.         -0.


TABLE 5B - CROSS SECTION DATA


INPUT OF CROSS SECTIONS
CROSS NUMB WIDTH OR  DEPTH OR    Y-CENT  RECT=0 SIG-EP   SIG-MULT   EP-MULT

SECT  CRDS  O-DIAM   THICKNESS           PIPE=1  NUMB

    1    3
             1.555E+01 1.188E+00 6.906E+00    -0     1        1.000E+00 1.000E-04
             1.555E+01 1.188E+00-6.906E+00    -0     1        1.000E+00 1.000E-04
             7.300E-01 1.262E+01-0.           -0     1        1.000E+00 1.000E-04
    2    3
             1.202E+01 7.780E-01 6.700E+00    -0     1        1.000E+00 1.000E-04
             1.202E+01 7.780E-01-6.700E+00    -0     1        1.000E+00 1.000E-04
             4.510E-01 1.262E+01-0.           -0     1        1.000E+00 1.000E-04
    3    3
             9.990E+00 7.470E-01 1.308E+01    -0     1        1.000E+00 1.000E-04
             9.990E+00 7.470E-01-1.308E+01    -0     1        1.000E+00 1.000E-04
             4.900E-01 2.542E+01-0.           -0     1        1.000E+00 1.000E-04
    4    3
             1.000E+01 7.500E-01 1.762E+01    -0     1        1.000E+00 1.000E-04
             1.000E+01 7.500E-01-1.762E+01    -0     1        1.000E+00 1.000E-04
             7.500E-01 3.450E+01-0.           -0     1        1.000E+00 1.000E-04
    5    3
             1.000E+01 7.500E-01 1.308E+01    -0     1        1.000E+00 1.000E-04
             1.000E+01 7.500E-01-1.308E+01    -0     1        1.000E+00 1.000E-04
             1.000E+00 2.441E+01-0.           -0     1        1.000E+00 1.000E-04


TABLE 5C - STRESS STRAIN CURVES


CURVE NUMB SYMT (1 = YES,
NUMB  PTS  OPT   0 = NO)

     1    2    1
SIG                       0    24

EPS                       0     8


TABLE 5D - SUPPORT CURVES FOR MEMBERS

NO DATA IN TABLE
```

PROB (CONTD)
S01 ANALYSIS FOR DESIGN LIVE + DEAD + WIND LOADS

TABLE 6 - MEMBER LOAD DATA

LOAD TYPE	UNIFORM QX	UNIFORM QY	NO CARDS	AXIS OPT
1	-1.300E-02	-8.330E-02	0	1
2	-1.300E-02	-0.	0	1
3	-7.000E-03	-8.330E-02	0	1
4	-7.000E-03	-0.	0	1
5	-7.000E-03	-0.	0	1
6	-7.000E-03	-0.	0	1
7	-0.	-0.	5	2

LOAD TYPE 7 CONTD

FROM	TO	QX	QY	QZ
9.007E+01	9.007E+01	-0.	-1.200E+01	-0.
1.801E+02	1.801E+02	-0.	-1.200E+01	-0.
2.702E+02	2.702E+02	-0.	-1.200E+01	-0.
3.603E+02	3.603E+02	-0.	-1.200E+01	-0.
0.	4.504E+02	-0.	-2.000E-01	-0.

LOAD TYPE	UNIFORM QX	UNIFORM QY	NO CARDS	AXIS OPT
8	-0.	-0.	2	2

LOAD TYPE 8 CONTD

FROM	TO	QX	QY	QZ
9.007E+01	9.007E+01	-0.	-1.200E+01	-0.
0.	1.201E+02	-0.	-2.000E-01	-0.

LOAD TYPE	UNIFORM QX	UNIFORM QY	NO CARDS	AXIS OPT
9	-0.	-0.	2	3

LOAD TYPE 9 CONTD

FROM	TO	QX	QY	QZ
9.000E+01	9.000E+01	-0.	-1.700E+01	-0.
0.	1.200E+02	-0.	-2.500E-01	-0.

LOAD TYPE	UNIFORM QX	UNIFORM QY	NO CARDS	AXIS OPT
10	-0.	-0.	3	3

LOAD TYPE 10 CONTD

FROM	TO	QX	QY	QZ
6.000E+01	6.000E+01	-0.	-1.700E+01	-0.
1.500E+02	1.500E+02	-0.	-1.700E+01	-0.
0.	2.100E+02	-0.	-2.500E-01	-0.

LOAD TYPE	UNIFORM QX	UNIFORM QY	NO CARDS	AXIS OPT
11	-0.	-0.	2	3

LOAD TYPE 11 CONTD

FROM	TO	QX	QY	QZ
3.000E+01	3.000E+01	-0.	-1.700E+01	-0.
0.	1.200E+02	-0.	-2.500E-01	-0.

```
PROB (CONTD)
 501     ANALYSIS FOR DESIGN LIVE + DEAD + WIND LOADS


TABLE 7 -  ITERATION CONTROL


         FRAME SOLUTION

       NUMB      FORCE    MOMENT
      ITER       ERROR     ERROR                        MONITOR JOINTS

        10      2.000E-02 1.000E+01             1    2    3    6   11


        MEMBER SOLUTIONS

        NUMB     FORCE    MOMENT
        ITER     ERROR     ERROR                        MONITOR MEMBERS

        10      2.000E-03 1.000E+00             1    4    9   -0   -0


***** FRAME ITERATION NO      1 *****

 MEMB MEMB          MEMBER DISPLACEMENTS                     MEMBER EQULIBRIUM ERRORS
  NO  ITER       AXIAL  LATERAL  ROTATIONAL           AXIAL       LATERAL    ROTATIONAL

    1    1
FROM JOINT   -2.030E-03 -1.271E-02 -1.409E-03  2.458E+00 -2.222E-01 -8.105E+00
CENTERLINE   -2.017E-02 -8.792E-01 -7.724E-03  2.026E+00 -2.048E-02 -3.656E+01
 TO JOINT    -3.807E-02 -2.097E+00 -6.808E-03 -2.624E+00  3.786E-02 -3.324E+01

    1    2
FROM JOINT   -1.654E-03 -1.263E-02 -1.401E-03  5.061E-05 -1.759E-04 -8.481E-03
CENTERLINE   -1.895E-02 -8.780E-01 -7.730E-03  2.357E-05 -3.558E-05 -1.851E-03
 TO JOINT    -3.806E-02 -2.097E+00 -6.810E-03 -9.222E-06  9.477E-07 -9.014E-05

MEMBER     1 CONVERGED AFTER ITERATION    2


MEMBER     2 CONVERGED AFTER ITERATION    2


MEMBER     3 CONVERGED AFTER ITERATION    2


    4    1
FROM JOINT   -3.570E-03 -1.775E-01 -9.968E-03 -7.382E-01  1.423E-02 -8.531E+01
CENTERLINE   -3.557E-02 -1.617E+00 -7.314E-03 -5.411E+00  1.378E-01 -6.771E+01
 TO JOINT    -6.733E-02 -2.285E+00 -3.159E-04 -4.120E-01  2.997E-01 -3.169E+00

    4    2
FROM JOINT   -3.999E-03 -1.776E-01 -9.986E-03  3.756E-04 -5.483E-04 -1.623E-02
CENTERLINE   -3.845E-02 -1.623E+00 -7.321E-03 -1.483E-04  1.747E-05 -6.591E-04
 TO JOINT    -6.779E-02 -2.285E+00 -2.919E-04 -5.407E-04  7.617E-04 -3.104E-02

MEMBER     4 CONVERGED AFTER ITERATION    2


MEMBER     5 CONVERGED AFTER ITERATION    2


MEMBER     6 CONVERGED AFTER ITERATION    2


MEMBER     7 CONVERGED AFTER ITERATION    2


MEMBER     8 CONVERGED AFTER ITERATION    2


    9    1
FROM JOINT    3.022E+00 -3.018E-01 -4.886E-03  6.882E-01 -1.428E-03 -7.620E+00
CENTERLINE    3.016E+00 -8.831E-01  7.374E-04  5.119E-01  5.281E-02  1.363E+00
 TO JOINT     3.011E+00 -3.161E-01  1.731E-03 -1.517E+00 -5.829E-02  2.696E+00

    9    2
FROM JOINT    3.022E+00 -3.018E-01 -4.888E-03  2.181E-06 -2.485E-05 -6.774E-04
CENTERLINE    3.016E+00 -8.836E-01  7.380E-04  5.533E-07 -9.568E-06 -1.530E-04
 TO JOINT     3.011E+00 -3.162E-01  1.733E-03 -1.117E-06  3.732E-06 -2.217E-04

MEMBER     9 CONVERGED AFTER ITERATION    2


MEMBER    10 CONVERGED AFTER ITERATION    2


MEMBER    11 CONVERGED AFTER ITERATION    2


MEMBER    12 CONVERGED AFTER ITERATION    2


MEMBER    13 CONVERGED AFTER ITERATION    2


MEMBER    14 CONVERGED AFTER ITERATION    2


MEMBER    15 CONVERGED AFTER ITERATION    2
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```
MEMBER   16 CONVERGED AFTER ITERATION    2

MEMBER   17 CONVERGED AFTER ITERATION    2

MEMBER   18 CONVERGED AFTER ITERATION    2

MEMBER   19 CONVERGED AFTER ITERATION    2

MEMBER   20 CONVERGED AFTER ITERATION    2

MEMBER   21 CONVERGED AFTER ITERATION    2

MEMBER   22 CONVERGED AFTER ITERATION    2


   20 JOINTS NOT CONVERGED AT END OF FRAME ITERATION    1


***** FRAME ITERATION NO     2 *****

 MEMB MEMB          MEMBER DISPLACEMENTS                      MEMBER EQULIBRIUM ERRORS
  NO  ITER       AXIAL   LATERAL  ROTATIONAL           AXIAL       LATERAL     ROTATIONAL

    1    1
FROM JOINT    -2.004E-03 -1.522E-02 -1.689E-03  1.053E-01 -8.229E-03 -2.864E-01
CENTERLINE    -2.355E-02 -1.067E+00 -9.406E-03  7.043E-02 -1.732E-03 -1.586E+00
 TO JOINT     -4.754E-02 -2.516E+00 -7.636E-03 -2.461E-01  8.026E-03 -8.117E-01
** LIMIT OF MEMBERS STRESS-STRAIN CURVE EXCEEDED ON PRECEEDING ITERATION

    1    2
FROM JOINT    -1.989E-03 -1.522E-02 -1.689E-03  2.980E-08 -1.904E-07 -9.579E-06
CENTERLINE    -2.352E-02 -1.067E+00 -9.407E-03  2.431E-08 -5.034E-08 -6.894E-06
 TO JOINT     -4.755E-02 -2.516E+00 -7.636E-03 -3.224E-10 -8.090E-09 -2.952E-06
** LIMIT OF MEMBERS STRESS-STRAIN CURVE EXCEEDED ON PRECEEDING ITERATION

MEMBER    1 CONVERGED AFTER ITERATION    2

MEMBER    2 CONVERGED AFTER ITERATION    2

MEMBER    3 CONVERGED AFTER ITERATION    2

    4    1
FROM JOINT    -4.807E-03 -2.104E-01 -1.182E-02 -6.922E-02  1.797E-03 -2.427E+00
CENTERLINE    -4.594E-02 -1.914E+00 -8.632E-03 -1.589E-01  5.214E-03 -1.769E+00
 TO JOINT     -8.025E-02 -2.712E+00 -6.052E-04 -5.595E-02  5.296E-03 -4.319E-01

    4    2
FROM JOINT    -4.822E-03 -2.104E-01 -1.182E-02  1.511E-07 -3.826E-07 -9.981E-06
CENTERLINE    -4.603E-02 -1.915E+00 -8.632E-03 -5.399E-08 -1.470E-08 -2.407E-07
 TO JOINT     -8.027E-02 -2.712E+00 -6.048E-04 -1.697E-07  4.113E-07 -1.814E-05

MEMBER    4 CONVERGED AFTER ITERATION    2

MEMBER    5 CONVERGED AFTER ITERATION    2

MEMBER    6 CONVERGED AFTER ITERATION    2

MEMBER    7 CONVERGED AFTER ITERATION    2

MEMBER    8 CONVERGED AFTER ITERATION    2

    9    1
FROM JOINT     3.534E+00 -3.352E-01 -4.904E-03 -1.270E-04  1.110E-04 -5.962E-03
CENTERLINE     3.527E+00 -9.149E-01  7.605E-04 -1.546E-05 -9.796E-06  8.305E-03
 TO JOINT      3.521E+00 -3.470E-01  1.698E-03  3.554E-04 -1.447E-04 -1.297E-02

MEMBER    9 CONVERGED AFTER ITERATION    1

MEMBER   10 CONVERGED AFTER ITERATION    1

MEMBER   11 CONVERGED AFTER ITERATION    1

MEMBER   12 CONVERGED AFTER ITERATION    1

MEMBER   13 CONVERGED AFTER ITERATION    2

MEMBER   14 CONVERGED AFTER ITERATION    2
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MEMBER   15 CONVERGED AFTER ITERATION     1

MEMBER   16 CONVERGED AFTER ITERATION     1

MEMBER   17 CONVERGED AFTER ITERATION     1

MEMBER   18 CONVERGED AFTER ITERATION     1

MEMBER   19 CONVERGED AFTER ITERATION     2

MEMBER   20 CONVERGED AFTER ITERATION     1

MEMBER   21 CONVERGED AFTER ITERATION     2

MEMBER   22 CONVERGED AFTER ITERATION     1


   14 JOINTS NOT CONVERGED AT END OF FRAME ITERATION     2


***** FRAME ITERATION NO      3 *****

 MEMB MEMB          MEMBER DISPLACEMENTS                  MEMBER EQULIBRIUM ERRORS
  NO  ITER       AXIAL  LATERAL  ROTATIONAL          AXIAL      LATERAL     ROTATIONAL

   1    1
FROM JOINT   -2.003E-03 -1.531E-02 -1.699E-03  1.226E-04 -1.101E-05 -3.828E-04
CENTERLINE   -2.371E-02 -1.073E+00 -9.463E-03  6.391E-05 -2.016E-06 -2.184E-03
 TO JOINT    -4.792E-02 -2.530E+00 -7.660E-03 -2.605E-04  1.116E-05 -9.398E-04
** LIMIT OF MEMBERS STRESS-STRAIN CURVE EXCEEDED ON PRECEEDING ITERATION

MEMBER    1 CONVERGED AFTER ITERATION     1

MEMBER    2 CONVERGED AFTER ITERATION     1

MEMBER    3 CONVERGED AFTER ITERATION     1

   4    1
FROM JOINT   -4.850E-03 -2.115E-01 -1.188E-02 -4.900E-05  1.522E-06 -2.494E-03
CENTERLINE   -4.628E-02 -1.924E+00 -8.676E-03 -1.391E-04  5.004E-06 -1.898E-03
 TO JOINT    -8.069E-02 -2.726E+00 -6.214E-04 -7.820E-05  4.656E-06 -7.307E-04

MEMBER    4 CONVERGED AFTER ITERATION     1

MEMBER    5 CONVERGED AFTER ITERATION     1

MEMBER    6 CONVERGED AFTER ITERATION     1

MEMBER    7 CONVERGED AFTER ITERATION     1

MEMBER    8 CONVERGED AFTER ITERATION     1


   9    1
FROM JOINT    3.550E+00 -3.363E-01 -4.904E-03 -6.264E-08 -5.828E-09  8.172E-07
CENTERLINE    3.543E+00 -9.159E-01  7.604E-04  5.197E-09 -1.352E-09 -1.881E-07
 TO JOINT     3.537E+00 -3.480E-01  1.697E-03 -7.834E-11  2.342E-09 -7.552E-08

MEMBER    9 CONVERGED AFTER ITERATION     1

MEMBER   10 CONVERGED AFTER ITERATION     1

MEMBER   11 CONVERGED AFTER ITERATION     1

MEMBER   12 CONVERGED AFTER ITERATION     1

MEMBER   13 CONVERGED AFTER ITERATION     1

MEMBER   14 CONVERGED AFTER ITERATION     1

MEMBER   15 CONVERGED AFTER ITERATION     1

MEMBER   16 CONVERGED AFTER ITERATION     1

MEMBER   17 CONVERGED AFTER ITERATION     1
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MEMBER   18 CONVERGED AFTER ITERATION    1

MEMBER   19 CONVERGED AFTER ITERATION    1

MEMBER   20 CONVERGED AFTER ITERATION    1

MEMBER   21 CONVERGED AFTER ITERATION    1

MEMBER   22 CONVERGED AFTER ITERATION    1


   1 JOINTS NOT CONVERGED AT END OF FRAME ITERATION    3

***** FRAME ITERATION NO     4 *****

 MEMB MEMB          MEMBER DISPLACEMENTS                  MEMBER EQULIBRIUM ERRORS
  NO  ITER       AXIAL  LATERAL  ROTATIONAL          AXIAL      LATERAL     ROTATIONAL

    1    1
FROM JOINT    -2.003E-03 -1.530E-02 -1.698E-03  3.363E-07  2.601E-09  1.248E-07
CENTERLINE    -2.370E-02 -1.073E+00 -9.460E-03  9.142E-08 -8.913E-10  9.392E-07
 TO JOINT     -4.792E-02 -2.530E+00 -7.659E-03 -5.543E-07  1.430E-09  2.280E-07
** LIMIT OF MEMBERS STRESS-STRAIN CURVE EXCEEDED ON PRECEEDING ITERATION

MEMBER    1 CONVERGED AFTER ITERATION    1

MEMBER    2 CONVERGED AFTER ITERATION    1

MEMBER    3 CONVERGED AFTER ITERATION    1

    4    1
FROM JOINT    -4.849E-03 -2.114E-01 -1.188E-02 -6.780E-08  1.170E-09 -8.604E-08
CENTERLINE    -4.627E-02 -1.923E+00 -8.673E-03 -3.632E-07  5.222E-09 -1.437E-07
 TO JOINT     -8.068E-02 -2.726E+00 -6.207E-04 -1.932E-07 -1.086E-10 -7.874E-08

MEMBER    4 CONVERGED AFTER ITERATION    1

MEMBER    5 CONVERGED AFTER ITERATION    1

MEMBER    6 CONVERGED AFTER ITERATION    1

MEMBER    7 CONVERGED AFTER ITERATION    1

MEMBER    8 CONVERGED AFTER ITERATION    1

    9    1
FROM JOINT     3.549E+00 -3.362E-01 -4.904E-03 -6.338E-09 -3.735E-10 -1.979E-09
CENTERLINE     3.542E+00 -9.158E-01  7.604E-04 -9.140E-10  4.633E-12 -3.129E-09
 TO JOINT      3.536E+00 -3.480E-01  1.697E-03  4.155E-09 -2.331E-10 -2.910E-10

MEMBER    9 CONVERGED AFTER ITERATION    1

MEMBER   10 CONVERGED AFTER ITERATION    1

MEMBER   11 CONVERGED AFTER ITERATION    1

MEMBER   12 CONVERGED AFTER ITERATION    1

MEMBER   13 CONVERGED AFTER ITERATION    1

MEMBER   14 CONVERGED AFTER ITERATION    1

MEMBER   15 CONVERGED AFTER ITERATION    1

MEMBER   16 CONVERGED AFTER ITERATION    1

MEMBER   17 CONVERGED AFTER ITERATION    1

MEMBER   18 CONVERGED AFTER ITERATION    1

MEMBER   19 CONVERGED AFTER ITERATION    1
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MEMBER 20 CONVERGED AFTER ITERATION 1

MEMBER 21 CONVERGED AFTER ITERATION 1

MEMBER 22 CONVERGED AFTER ITERATION 1

ALL JOINTS CONVERGED AT END OF ITERATION 4

SUMMARY OF FRAME ITERATIONS

JOINT	FRAME	JOINT DISPLACEMENTS			JOINT EQULIBRIUM ERRORS		
NO	ITER	DISP(X)	DISP(Y)	ROTATION(Z)	ERR(X)	ERR(Y)	ERR(Z)
1	1	3.082E-19	-1.583E-18	-4.760E-17	-8.559E-01	2.981E+01	3.281E+01
1	2	3.454E-19	-1.556E-18	-5.686E-17	-2.840E-02	1.155E+00	9.799E-01
1	3	3.467E-19	-1.555E-18	-5.718E-17	5.622E-06	2.471E-05	-7.485E-05
1	4	3.466E-19	-1.555E-18	-5.716E-17	-4.441E-05	1.244E-03	1.367E-03
2	1	2.216E+00	-4.004E-02	-6.522E-03	2.095E+01	-2.539E+01	-1.723E+01
2	2	2.647E+00	-4.996E-02	-7.115E-03	1.257E-01	-1.107E+00	2.685E-01
2	3	2.662E+00	-5.035E-02	-7.131E-03	1.229E-04	-1.358E-04	-1.974E-04
2	4	2.661E+00	-5.034E-02	-7.130E-03	-2.553E-05	-1.117E-03	9.368E-04
3	1	3.028E+00	-6.881E-02	-4.577E-03	4.261E+00	-3.579E+00	-9.148E+00
3	2	3.542E+00	-8.042E-02	-4.603E-03	1.072E-03	-3.893E-02	4.078E-02
3	3	3.557E+00	-8.083E-02	-4.602E-03	-5.202E-05	2.008E-04	-5.354E-04
3	4	3.556E+00	-8.083E-02	-4.602E-03	-1.363E-07	-1.452E-05	1.154E-05
6	1	3.919E-01	-3.863E-18	-8.157E-03	-9.504E-02	2.383E+01	-7.792E+01
6	2	4.551E-01	-3.883E-18	-9.899E-03	-2.199E-02	9.460E-01	-1.018E+00
6	3	4.545E-01	-3.885E-18	-9.962E-03	9.926E-05	2.762E-03	-1.245E-03
6	4	4.544E-01	-3.885E-18	-9.960E-03	-1.360E-04	-1.325E-03	-3.172E-05
11	1	2.853E-01	-3.593E-18	-7.679E-03	-1.445E+00	2.392E+01	-5.308E+01
11	2	1.895E-01	-3.583E-18	-9.936E-03	7.843E-01	1.794E+00	-8.872E-01
11	3	2.258E-01	-3.583E-18	-9.851E-03	-1.137E-04	4.986E-03	2.777E-03
11	4	2.257E-01	-3.582E-18	-9.849E-03	2.483E-04	-2.054E-03	9.680E-04

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TABLE 8 - JOINT DISPLACEMENTS AND REACTIONS

	DISPLACEMENTS			REACTIONS		
JOINT	DISP(X)	DISP(Y)	ROTATION(Z)	REACT(X)	REACT(Y)	REACT(Z)
1	3.466E-19	-1.555E-18	-5.716E-17	-3.466E+01	1.555E+02	5.716E+03
2	2.661E+00	-5.034E-02	-7.130E-03	0.	0.	0.
3	3.556E+00	-8.083E-02	-4.602E-03	0.	0.	0.
4	2.687E+00	-7.886E-01	-4.220E-03	0.	0.	0.
5	2.687E+00	-4.972E-01	4.780E-03	0.	0.	0.
6	4.544E-01	-3.885E-18	-9.960E-03	-6.363E+00	3.885E+02	0.
7	2.701E+00	-1.080E-01	6.340E-04	0.	0.	0.
8	3.546E+00	-1.776E-01	2.885E-04	0.	0.	0.
9	2.704E+00	-2.085E-01	-1.525E-03	0.	0.	0.
10	2.704E+00	-1.607E-01	1.669E-03	0.	0.	0.
11	2.257E-01	-3.582E-18	-9.849E-03	-4.514E+00	3.582E+02	0.
12	2.706E+00	-1.011E-01	-1.477E-03	0.	0.	0.
13	3.538E+00	-1.724E-01	-9.079E-04	0.	0.	0.
14	2.717E+00	-4.045E-01	-2.704E-03	0.	0.	0.
15	2.717E+00	-3.447E-01	2.912E-03	0.	0.	0.
16	8.442E-20	-2.801E-18	-1.191E-02	-8.442E+00	2.801E+02	0.
17	2.726E+00	-8.422E-02	5.349E-04	0.	0.	0.
18	3.530E+00	-1.405E-01	1.977E-03	0.	0.	0.
19	2.726E+00	-8.603E-02	-2.204E-04	0.	0.	0.
20	3.524E+00	-9.916E-04	8.911E-04	0.	0.	0.

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TABLE 9 - MEMBER RESULTS

MEMBER NUMBER 1 STIFF TYPE 1 LOAD TYPE 1
LENGTH = 3.555E+02 ALPHA = 0. BETA = 1.000E+00
GOES FROM JOINT 1 TO JOINT 2

OUTPUT DISTANCES ARE FROM JOINT 1 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	-1.555E-18	-3.466E-19	-5.716E-17	-1.555E+02	3.466E+01	-5.716E+03
1.777E+01	-2.003E-03	-1.530E-02	-1.698E-03	-1.552E+02	3.318E+01	-5.111E+03
3.555E+01	-4.050E-03	-5.912E-02	-3.210E-03	-1.550E+02	3.170E+01	-4.528E+03
5.332E+01	-6.172E-03	-1.282E-01	-4.543E-03	-1.548E+02	3.022E+01	-3.967E+03
7.109E+01	-8.391E-03	-2.194E-01	-5.703E-03	-1.545E+02	2.874E+01	-3.429E+03
8.886E+01	-1.071E-02	-3.298E-01	-6.698E-03	-1.543E+02	2.726E+01	-2.915E+03
1.066E+02	-1.314E-02	-4.564E-01	-7.535E-03	-1.541E+02	2.578E+01	-2.424E+03
1.244E+02	-1.567E-02	-5.966E-01	-8.222E-03	-1.538E+02	2.430E+01	-1.957E+03
1.422E+02	-1.828E-02	-7.477E-01	-8.767E-03	-1.536E+02	2.282E+01	-1.515E+03
1.600E+02	-2.097E-02	-9.073E-01	-9.177E-03	-1.534E+02	2.134E+01	-1.099E+03
1.777E+02	-2.370E-02	-1.073E+00	-9.460E-03	-1.532E+02	1.986E+01	-7.073E+02
1.955E+02	-2.648E-02	-1.243E+00	-9.625E-03	-1.529E+02	1.838E+01	-3.416E+02
2.133E+02	-2.926E-02	-1.414E+00	-9.679E-03	-1.527E+02	1.689E+01	-2.035E+00
2.310E+02	-3.205E-02	-1.586E+00	-9.630E-03	-1.525E+02	1.541E+01	3.112E+02
2.488E+02	-3.482E-02	-1.756E+00	-9.488E-03	-1.522E+02	1.393E+01	5.979E+02
2.666E+02	-3.755E-02	-1.923E+00	-9.259E-03	-1.520E+02	1.245E+01	8.577E+02
2.844E+02	-4.023E-02	-2.085E+00	-8.954E-03	-1.518E+02	1.097E+01	1.090E+03
3.021E+02	-4.286E-02	-2.240E+00	-8.579E-03	-1.515E+02	9.492E+00	1.296E+03
3.199E+02	-4.543E-02	-2.389E+00	-8.145E-03	-1.513E+02	8.012E+00	1.474E+03
3.377E+02	-4.792E-02	-2.530E+00	-7.659E-03	-1.511E+02	6.532E+00	1.624E+03
3.555E+02	-5.034E-02	-2.661E+00	-7.130E-03	-1.508E+02	5.051E+00	1.747E+03

** LIMIT OF MEMBERS STRESS-STRAIN CURVE EXCEEDED ON THIS PROBLEM

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501 ANALYSIS FOR DESIGN LIVE + DEAD + WIND LOADS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 2 STIFF TYPE 1 LOAD TYPE 2
LENGTH = 3.555E+02 ALPHA = 0. BETA = 1.000E+00
GOES FROM JOINT 6 TO JOINT 7

OUTPUT DISTANCES ARE FROM JOINT 6 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	-3.885E-18	-4.544E-01	-9.960E-03	-3.885E+02	6.363E+00	-3.172E-05
1.777E+01	-5.862E-03	-6.312E-01	-9.932E-03	-3.882E+02	6.363E+00	1.817E+02
3.555E+01	-1.171E-02	-8.069E-01	-9.846E-03	-3.880E+02	6.363E+00	3.629E+02
5.332E+01	-1.754E-02	-9.807E-01	-9.704E-03	-3.878E+02	6.363E+00	5.434E+02
7.109E+01	-2.333E-02	-1.151E+00	-9.505E-03	-3.875E+02	6.363E+00	7.226E+02
8.886E+01	-2.909E-02	-1.318E+00	-9.251E-03	-3.873E+02	6.363E+00	9.002E+02
1.066E+02	-3.479E-02	-1.480E+00	-8.941E-03	-3.871E+02	6.363E+00	1.076E+03
1.244E+02	-4.044E-02	-1.635E+00	-8.576E-03	-3.868E+02	6.363E+00	1.249E+03
1.422E+02	-4.602E-02	-1.784E+00	-8.157E-03	-3.866E+02	6.363E+00	1.420E+03
1.600E+02	-5.154E-02	-1.925E+00	-7.686E-03	-3.864E+02	6.363E+00	1.587E+03
1.777E+02	-5.699E-02	-2.057E+00	-7.162E-03	-3.861E+02	6.363E+00	1.751E+03
1.955E+02	-6.236E-02	-2.179E+00	-6.587E-03	-3.859E+02	6.363E+00	1.911E+03
2.133E+02	-6.766E-02	-2.291E+00	-5.963E-03	-3.857E+02	6.363E+00	2.067E+03
2.310E+02	-7.289E-02	-2.391E+00	-5.291E-03	-3.855E+02	6.363E+00	2.219E+03
2.488E+02	-7.806E-02	-2.478E+00	-4.571E-03	-3.852E+02	6.363E+00	2.366E+03
2.666E+02	-8.315E-02	-2.553E+00	-3.807E-03	-3.850E+02	6.363E+00	2.508E+03
2.844E+02	-8.820E-02	-2.613E+00	-2.999E-03	-3.848E+02	6.363E+00	2.644E+03
3.021E+02	-9.319E-02	-2.659E+00	-2.149E-03	-3.845E+02	6.363E+00	2.775E+03
3.199E+02	-9.815E-02	-2.689E+00	-1.259E-03	-3.843E+02	6.363E+00	2.899E+03
3.377E+02	-1.031E-01	-2.704E+00	-3.304E-04	-3.841E+02	6.363E+00	3.018E+03
3.555E+02	-1.080E-01	-2.701E+00	6.340E-04	-3.838E+02	6.363E+00	3.130E+03

PRUB (CONTD)
501 ANALYSIS FOR DESIGN LIVE + DEAD + WIND LOADS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 3 STIFF TYPE 1 LOAD TYPE 2
LENGTH = 3.555E+02 ALPHA = 0. BETA = 1.000E+00
GOES FROM JOINT 11 TO JOINT 12

OUTPUT DISTANCES ARE FROM JOINT 11 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	-3.582E-18	-2.257E-01	-9.849E-03	-3.582E+02	4.514E+00	9.680E-04
1.777E+01	-5.456E-03	-4.006E-01	-9.826E-03	-3.580E+02	4.514E+00	1.428E+02
3.555E+01	-1.090E-02	-5.746E-01	-9.759E-03	-3.578E+02	4.514E+00	2.853E+02
5.332E+01	-1.633E-02	-7.471E-01	-9.647E-03	-3.575E+02	4.514E+00	4.272E+02
7.109E+01	-2.173E-02	-9.171E-01	-9.491E-03	-3.573E+02	4.514E+00	5.682E+02
8.886E+01	-2.710E-02	-1.084E+00	-9.291E-03	-3.571E+02	4.514E+00	7.080E+02
1.066E+02	-3.242E-02	-1.247E+00	-9.047E-03	-3.569E+02	4.514E+00	8.464E+02
1.244E+02	-3.771E-02	-1.405E+00	-8.760E-03	-3.566E+02	4.514E+00	9.831E+02
1.422E+02	-4.294E-02	-1.558E+00	-8.431E-03	-3.564E+02	4.514E+00	1.118E+03
1.600E+02	-4.811E-02	-1.705E+00	-8.059E-03	-3.562E+02	4.514E+00	1.250E+03
1.777E+02	-5.323E-02	-1.844E+00	-7.647E-03	-3.559E+02	4.514E+00	1.380E+03
1.955E+02	-5.829E-02	-1.976E+00	-7.194E-03	-3.557E+02	4.514E+00	1.507E+03
2.133E+02	-6.328E-02	-2.100E+00	-6.701E-03	-3.555E+02	4.514E+00	1.631E+03
2.310E+02	-6.821E-02	-2.214E+00	-6.171E-03	-3.552E+02	4.514E+00	1.752E+03
2.488E+02	-7.307E-02	-2.319E+00	-5.602E-03	-3.550E+02	4.514E+00	1.870E+03
2.666E+02	-7.788E-02	-2.413E+00	-4.998E-03	-3.548E+02	4.514E+00	1.983E+03
2.844E+02	-8.263E-02	-2.496E+00	-4.359E-03	-3.545E+02	4.514E+00	2.093E+03
3.021E+02	-8.732E-02	-2.567E+00	-3.685E-03	-3.543E+02	4.514E+00	2.198E+03
3.199E+02	-9.196E-02	-2.627E+00	-2.980E-03	-3.541E+02	4.514E+00	2.300E+03
3.377E+02	-9.657E-02	-2.673E+00	-2.243E-03	-3.539E+02	4.514E+00	2.396E+03
3.555E+02	-1.011E-01	-2.706E+00	-1.477E-03	-3.536E+02	4.514E+00	2.488E+03

PROB (CONTD)
501 ANALYSIS FOR DESIGN LIVE + DEAD + WIND LOADS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 4 STIFF TYPE 1 LOAD TYPE 2
LENGTH = 3.555E+02 ALPHA = 0. BETA = 1.000E+00
GOES FROM JOINT 16 TO JOINT 17

OUTPUT DISTANCES ARE FROM JOINT 16 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	-2.801E-18	-8.442E-20	-1.191E-02	-2.801E+02	8.441E+00	2.146E-04
1.777E+01	-4.849E-03	-2.114E-01	-1.188E-02	-2.798E+02	8.441E+00	2.092E+02
3.555E+01	-9.681E-03	-4.217E-01	-1.178E-02	-2.796E+02	8.441E+00	4.180E+02
5.332E+01	-1.448E-02	-6.296E-01	-1.162E-02	-2.794E+02	8.441E+00	6.261E+02
7.109E+01	-1.924E-02	-8.340E-01	-1.139E-02	-2.791E+02	8.441E+00	8.331E+02
8.886E+01	-2.394E-02	-1.034E+00	-1.109E-02	-2.789E+02	8.441E+00	1.039E+03
1.066E+02	-2.858E-02	-1.228E+00	-1.074E-02	-2.787E+02	8.441E+00	1.243E+03
1.244E+02	-3.314E-02	-1.415E+00	-1.031E-02	-2.784E+02	8.441E+00	1.445E+03
1.422E+02	-3.761E-02	-1.594E+00	-9.829E-03	-2.782E+02	8.441E+00	1.645E+03
1.600E+02	-4.199E-02	-1.764E+00	-9.282E-03	-2.780E+02	8.441E+00	1.842E+03
1.777E+02	-4.627E-02	-1.923E+00	-8.673E-03	-2.777E+02	8.441E+00	2.036E+03
1.955E+02	-5.045E-02	-2.072E+00	-8.005E-03	-2.775E+02	8.441E+00	2.228E+03
2.133E+02	-5.453E-02	-2.207E+00	-7.276E-03	-2.773E+02	8.441E+00	2.415E+03
2.310E+02	-5.851E-02	-2.330E+00	-6.490E-03	-2.770E+02	8.441E+00	2.599E+03
2.488E+02	-6.239E-02	-2.438E+00	-5.646E-03	-2.768E+02	8.441E+00	2.779E+03
2.666E+02	-6.619E-02	-2.530E+00	-4.747E-03	-2.766E+02	8.441E+00	2.955E+03
2.844E+02	-6.990E-02	-2.606E+00	-3.793E-03	-2.764E+02	8.441E+00	3.126E+03
3.021E+02	-7.354E-02	-2.664E+00	-2.786E-03	-2.761E+02	8.441E+00	3.292E+03
3.199E+02	-7.713E-02	-2.705E+00	-1.728E-03	-2.759E+02	8.441E+00	3.453E+03
3.377E+02	-8.068E-02	-2.726E+00	-6.207E-04	-2.757E+02	8.441E+00	3.609E+03
3.555E+02	-8.422E-02	-2.726E+00	5.349E-04	-2.754E+02	8.441E+00	3.759E+03

PROB (CONTD)
501 ANALYSIS FOR DESIGN LIVE • DEAD • WIND LOADS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 5 STIFF TYPE 2 LOAD TYPE 3
LENGTH = 2.925E+02 ALPHA = 0. BETA = 1.000E+00
GOES FROM JOINT 2 TO JOINT 3

OUTPUT DISTANCES ARE FROM JOINT 2 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	-5.034E-02	-2.661E+00	-7.130E-03	-7.278E+01	1.188E+00	1.214E+03
1.463E+01	-5.214E-02	-2.761E+00	-6.480E-03	-7.267E+01	-3.069E-02	1.230E+03
2.925E+01	-5.387E-02	-2.851E+00	-5.826E-03	-7.257E+01	-1.249E+00	1.227E+03
4.388E+01	-5.554E-02	-2.931E+00	-5.178E-03	-7.247E+01	-2.468E+00	1.206E+03
5.851E+01	-5.716E-02	-3.002E+00	-4.547E-03	-7.237E+01	-3.686E+00	1.166E+03
7.314E+01	-5.874E-02	-3.064E+00	-3.942E-03	-7.226E+01	-4.905E+00	1.108E+03
8.776E+01	-6.028E-02	-3.118E+00	-3.373E-03	-7.216E+01	-6.123E+00	1.031E+03
1.024E+02	-6.179E-02	-3.163E+00	-2.849E-03	-7.206E+01	-7.342E+00	9.356E+02
1.170E+02	-6.328E-02	-3.201E+00	-2.382E-03	-7.196E+01	-8.560E+00	8.221E+02
1.316E+02	-6.475E-02	-3.233E+00	-1.979E-03	-7.185E+01	-9.778E+00	6.903E+02
1.463E+02	-6.621E-02	-3.260E+00	-1.652E-03	-7.175E+01	-1.100E+01	5.402E+02
1.609E+02	-6.766E-02	-3.282E+00	-1.409E-03	-7.165E+01	-1.222E+01	3.721E+02
1.755E+02	-6.911E-02	-3.301E+00	-1.260E-03	-7.155E+01	-1.343E+01	1.859E+02
1.902E+02	-7.055E-02	-3.319E+00	-1.216E-03	-7.144E+01	-1.465E+01	-1.821E+01
2.048E+02	-7.199E-02	-3.337E+00	-1.284E-03	-7.134E+01	-1.587E+01	-2.401E+02
2.194E+02	-7.342E-02	-3.358E+00	-1.476E-03	-7.124E+01	-1.709E+01	-4.797E+02
2.340E+02	-7.487E-02	-3.381E+00	-1.800E-03	-7.114E+01	-1.831E+01	-7.369E+02
2.487E+02	-7.632E-02	-3.411E+00	-2.265E-03	-7.103E+01	-1.953E+01	-1.011E+03
2.633E+02	-7.779E-02	-3.448E+00	-2.881E-03	-7.093E+01	-2.074E+01	-1.303E+03
2.779E+02	-7.928E-02	-3.496E+00	-3.657E-03	-7.083E+01	-2.196E+01	-1.612E+03
2.925E+02	-8.083E-02	-3.556E+00	-4.602E-03	-7.073E+01	-2.318E+01	-1.938E+03

PROB (CONTD)
501 ANALYSIS FOR DESIGN LIVE • DEAD • WIND LOADS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 6 STIFF TYPE 3 LOAD TYPE 4
LENGTH = 3.113E+02 ALPHA = 0. BETA = 1.000E+00
GOES FROM JOINT 7 TO JOINT 8

ALL OUTPUT FORCES ARE WITH RESPECT TO THE MEMBER AXES

AT JOINT 7		AT JOINT 8	
AXIAL FORCE =	-1.612E+02	AXIAL FORCE =	-1.591E+02
SHEAR =	1.028E+01	SHEAR =	1.028E+01
MOMENT =	-1.696E+03	MOMENT =	1.638E+03

MEMBER NUMBER 7 STIFF TYPE 4 LOAD TYPE 5
LENGTH = 3.300E+02 ALPHA = 0. BETA = 1.000E+00
GOES FROM JOINT 12 TO JOINT 13

ALL OUTPUT FORCES ARE WITH RESPECT TO THE MEMBER AXES

AT JOINT 12		AT JOINT 13	
AXIAL FORCE =	-1.568E+02	AXIAL FORCE =	-1.545E+02
SHEAR =	3.592E+00	SHEAR =	3.592E+00
MOMENT =	-6.126E+02	MOMENT =	7.021E+02

MEMBER NUMBER 8 STIFF TYPE 5 LOAD TYPE 6
LENGTH = 3.488E+02 ALPHA = 0. BETA = 1.000E+00
GOES FROM JOINT 17 TO JOINT 18

ALL OUTPUT FORCES ARE WITH RESPECT TO THE MEMBER AXES

AT JOINT 17		AT JOINT 18	
AXIAL FORCE =	-1.164E+02	AXIAL FORCE =	-1.140E+02
SHEAR =	9.311E+00	SHEAR =	9.311E+00
MOMENT =	-1.561 +03	MOMENT =	1.779E+03

PROB (CONTD)
501 ANALYSIS FOR DESIGN LIVE + DEAD + WIND LOADS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 9 STIFF TYPE 6 LOAD TYPE 7
LENGTH = 4.504E+02 ALPHA = 9.991E-01 BETA = 4.163E-02
GOES FROM JOINT 3 TO JOINT 8

OUTPUT DISTANCES ARE FROM JOINT 3 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	3.550E+00	-2.288E-01	-4.602E-03	-2.561E+01	5.771E+01	-1.938E+03
2.252E+01	3.549E+00	-3.362E-01	-4.904E-03	-2.542E+01	5.321E+01	-6.865E+02
4.504E+01	3.548E+00	-4.473E-01	-4.929E-03	-2.523E+01	4.871E+01	4.639E+02
6.756E+01	3.547E+00	-5.561E-01	-4.702E-03	-2.504E+01	4.421E+01	1.513E+03
9.008E+01	3.546E+00	-6.572E-01	-4.246E-03	-2.461E+01	3.371E+01	2.460E+03
1.126E+02	3.545E+00	-7.458E-01	-3.614E-03	-2.417E+01	2.322E+01	3.036E+03
1.351E+02	3.545E+00	-8.189E-01	-2.862E-03	-2.398E+01	1.872E+01	3.510E+03
1.576E+02	3.544E+00	-8.739E-01	-2.013E-03	-2.379E+01	1.421E+01	3.882E+03
1.802E+02	3.543E+00	-9.089E-01	-1.089E-03	-2.336E+01	3.712E+00	4.152E+03
2.027E+02	3.543E+00	-9.228E-01	-1.470E-04	-2.292E+01	-6.768E+00	4.051E+03
2.252E+02	3.542E+00	-9.158E-01	7.604E-04	-2.273E+01	-1.127E+01	3.847E+03
2.477E+02	3.541E+00	-8.891E-01	1.609E-03	-2.254E+01	-1.578E+01	3.542E+03
2.702E+02	3.541E+00	-8.440E-01	2.377E-03	-2.211E+01	-2.627E+01	3.135E+03
2.928E+02	3.540E+00	-7.832E-01	3.008E-03	-2.167E+01	-3.676E+01	2.357E+03
3.153E+02	3.539E+00	-7.102E-01	3.448E-03	-2.148E+01	-4.126E+01	1.477E+03
3.378E+02	3.539E+00	-6.297E-01	3.675E-03	-2.130E+01	-4.576E+01	4.954E+02
3.603E+02	3.538E+00	-5.467E-01	3.664E-03	-2.086E+01	-5.626E+01	-5.876E+02
3.828E+02	3.537E+00	-4.671E-01	3.362E-03	-2.042E+01	-6.675E+01	-2.042E+03
4.054E+02	3.536E+00	-3.982E-01	2.714E-03	-2.023E+01	-7.125E+01	-3.597E+03
4.279E+02	3.536E+00	-3.480E-01	1.697E-03	-2.005E+01	-7.575E+01	-5.253E+03
4.504E+02	3.535E+00	-3.251E-01	2.885E-04	-1.986E+01	-8.025E+01	-7.010E+03

PROB (CONTD)
501 ANALYSIS FOR DESIGN LIVE + DEAD + WIND LOADS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 10 STIFF TYPE 6 LOAD TYPE 7
LENGTH = 4.504E+02 ALPHA = 9.991E-01 BETA = 4.163E-02
GOES FROM JOINT 8 TO JOINT 13

OUTPUT DISTANCES ARE FROM JOINT 8 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	3.535E+00	-3.251E-01	2.885E-04	-1.571E+01	6.712E+01	-5.372E+03
2.252E+01	3.535E+00	-3.310E-01	-7.780E-04	-1.552E+01	6.262E+01	-3.911E+03
4.504E+01	3.534E+00	-3.574E-01	-1.520E-03	-1.534E+01	5.812E+01	-2.551E+03
6.756E+01	3.534E+00	-3.970E-01	-1.962E-03	-1.515E+01	5.361E+01	-1.292E+03
9.008E+01	3.534E+00	-4.434E-01	-2.126E-03	-1.471E+01	4.312E+01	-1.351E+02
1.126E+02	3.533E+00	-4.908E-01	-2.067E-03	-1.427E+01	3.263E+01	6.509E+02
1.351E+02	3.533E+00	-5.350E-01	-1.839E-03	-1.409E+01	2.813E+01	1.336E+03
1.576E+02	3.532E+00	-5.724E-01	-1.465E-03	-1.390E+01	2.361E+01	1.919E+03
1.802E+02	3.532E+00	-6.000E-01	-9.684E-04	-1.346E+01	1.312E+01	2.400E+03
2.027E+02	3.532E+00	-6.155E-01	-4.043E-04	-1.302E+01	2.636E+00	2.510E+03
2.252E+02	3.531E+00	-6.181E-01	1.735E-04	-1.284E+01	-1.864E+00	2.519E+03
2.477E+02	3.531E+00	-6.077E-01	7.417E-04	-1.265E+01	-6.373E+00	2.426E+03
2.702E+02	3.530E+00	-5.849E-01	1.277E-03	-1.221E+01	-1.687E+01	2.231E+03
2.928E+02	3.530E+00	-5.510E-01	1.725E-03	-1.177E+01	-2.735E+01	1.666E+03
3.153E+02	3.530E+00	-5.085E-01	2.031E-03	-1.159E+01	-3.185E+01	9.986E+02
3.378E+02	3.529E+00	-4.609E-01	2.172E-03	-1.140E+01	-3.636E+01	2.300E+02
3.603E+02	3.529E+00	-4.122E-01	2.125E-03	-1.096E+01	-4.685E+01	-6.400E+02
3.828E+02	3.529E+00	-3.672E-01	1.835E-03	-1.052E+01	-5.734E+01	-1.881E+03
4.054E+02	3.528E+00	-3.321E-01	1.249E-03	-1.034E+01	-6.184E+01	-3.223E+03
4.279E+02	3.528E+00	-3.137E-01	3.420E-04	-1.015E+01	-6.634E+01	-4.667E+03
4.504E+02	3.528E+00	-3.196E-01	-9.079E-04	-9.962E+00	-7.084E+01	-6.212E+03

PROB (CONTD)
501 ANALYSIS FOR DESIGN LIVE + DEAD + WIND LOADS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 11 STIFF TYPE 6 LOAD TYPE 7
LENGTH = 4.504E+02 ALPHA = 9.991E-01 BETA = 4.163E-02
GOES FROM JOINT 13 TO JOINT 18

OUTPUT DISTANCES ARE FROM JOINT 13 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	3.528E+00	-3.196E-01	-9.079E-04	-1.231E+01	7.167E+01	-5.509E+03
2.252E+01	3.527E+00	-3.528E-01	-1.994E-03	-1.212E+01	6.717E+01	-3.946E+03
4.504E+01	3.527E+00	-4.065E-01	-2.733E-03	-1.193E+01	6.267E+01	-2.483E+03
6.756E+01	3.527E+00	-4.731E-01	-3.147E-03	-1.174E+01	5.816E+01	-1.122E+03
9.008E+01	3.526E+00	-5.457E-01	-3.260E-03	-1.131E+01	4.767E+01	1.378E+02
1.126E+02	3.526E+00	-6.179E-01	-3.127E-03	-1.087E+01	3.718E+01	1.026E+03
1.351E+02	3.525E+00	-6.848E-01	-2.800E-03	-1.068E+01	3.268E+01	1.814E+03
1.576E+02	3.525E+00	-7.425E-01	-2.305E-03	-1.049E+01	2.816E+01	2.499E+03
1.802E+02	3.525E+00	-7.874E-01	-1.663E-03	-1.006E+01	1.767E+01	3.083E+03
2.027E+02	3.524E+00	-8.167E-01	-9.304E-04	-9.619E+00	7.186E+00	3.296E+03
2.252E+02	3.524E+00	-8.290E-01	-1.602E-04	-9.431E+00	2.686E+00	3.407E+03
2.477E+02	3.524E+00	-8.238E-01	6.238E-04	-9.243E+00	-1.823E+00	3.417E+03
2.702E+02	3.524E+00	-8.010E-01	1.398E-03	-8.806E+00	-1.232E+01	3.325E+03
2.928E+02	3.523E+00	-7.613E-01	2.109E-03	-8.369E+00	-2.280E+01	2.862E+03
3.153E+02	3.523E+00	-7.070E-01	2.702E-03	-8.181E+00	-2.730E+01	2.297E+03
3.378E+02	3.523E+00	-6.409E-01	3.153E-03	-7.994E+00	-3.181E+01	1.631E+03
3.603E+02	3.523E+00	-5.664E-01	3.440E-03	-7.557E+00	-4.230E+01	8.632E+02
3.828E+02	3.522E+00	-4.878E-01	3.507E-03	-7.119E+00	-5.279E+01	-2.755E+02
4.054E+02	3.522E+00	-4.107E-01	3.301E-03	-6.932E+00	-5.729E+01	-1.516E+03
4.279E+02	3.522E+00	-3.416E-01	2.799E-03	-6.744E+00	-6.179E+01	-2.857E+03
4.504E+02	3.521E+00	-2.874E-01	1.977E-03	-6.557E+00	-6.630E+01	-4.300E+03

PROB (CONTD)
501 ANALYSIS FOR DESIGN LIVE + DEAD + WIND LOADS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 12 STIFF TYPE 7 LOAD TYPE 8
LENGTH = 1.201E+02 ALPHA = 9.991E-01 BETA = 4.163E-02
GOES FROM JOINT 18 TO JOINT 20

OUTPUT DISTANCES ARE FROM JOINT 18 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	3.521E+00	-2.874E-01	1.977E-03	-1.500E+00	3.599E+01	-2.521E+03
6.005E+00	3.521E+00	-2.759E-01	1.829E-03	-1.450E+00	3.479E+01	-2.308E+03
1.201E+01	3.521E+00	-2.654E-01	1.694E-03	-1.400E+00	3.359E+01	-2.103E+03
1.802E+01	3.521E+00	-2.556E-01	1.571E-03	-1.350E+00	3.239E+01	-1.905E+03
2.402E+01	3.521E+00	-2.465E-01	1.460E-03	-1.300E+00	3.119E+01	-1.714E+03
3.003E+01	3.521E+00	-2.380E-01	1.361E-03	-1.250E+00	2.999E+01	-1.530E+03
3.603E+01	3.521E+00	-2.301E-01	1.272E-03	-1.200E+00	2.879E+01	-1.354E+03
4.204E+01	3.521E+00	-2.227E-01	1.194E-03	-1.150E+00	2.759E+01	-1.185E+03
4.804E+01	3.521E+00	-2.157E-01	1.127E-03	-1.100E+00	2.639E+01	-1.023E+03
5.405E+01	3.521E+00	-2.092E-01	1.069E-03	-1.050E+00	2.519E+01	-8.678E+02
6.005E+01	3.521E+00	-2.029E-01	1.020E-03	-9.995E-01	2.399E+01	-7.201E+02
6.606E+01	3.521E+00	-1.969E-01	9.803E-04	-9.495E-01	2.279E+01	-5.797E+02
7.206E+01	3.521E+00	-1.911E-01	9.489E-04	-8.995E-01	2.159E+01	-4.464E+02
7.807E+01	3.521E+00	-1.855E-01	9.254E-04	-8.495E-01	2.039E+01	-3.204E+02
8.407E+01	3.521E+00	-1.800E-01	9.094E-04	-7.992E-01	1.918E+01	-2.016E+02
9.008E+01	3.521E+00	-1.745E-01	9.005E-04	-4.994E-01	1.199E+01	-9.005E+01
9.608E+01	3.521E+00	-1.691E-01	8.959E-04	-2.000E-01	4.799E+00	-5.763E+01
1.021E+02	3.521E+00	-1.638E-01	8.932E-04	-1.500E-01	3.599E+00	-3.241E+01
1.081E+02	3.521E+00	-1.584E-01	8.917E-04	-9.997E-02	2.399E+00	-1.440E+01
1.141E+02	3.521E+00	-1.531E-01	8.912E-04	-4.997E-02	1.199E+00	-3.598E+00
1.201E+02	3.521E+00	-1.477E-01	8.911E-04	1.053E-08	7.175E-08	2.063E-07

PROB (CONTD)
501 ANALYSIS FOR DESIGN LIVE + DEAD + WIND LOADS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 13 STIFF TYPE 8 LOAD TYPE 9
LENGTH = 1.201E+02 ALPHA = 9.993E-01 BETA = 3.789E-02
GOES FROM JOINT 2 TO JOINT 4

OUTPUT DISTANCES ARE FROM JOINT 2 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	2.657E+00	-1.511E-01	-7.130E-03	1.547E+00	6.117E+01	5.329E+02
6.004E+00	2.657E+00	-1.939E-01	-7.110E-03	1.603E+00	5.967E+01	8.956E+02
1.201E+01	2.657E+00	-2.365E-01	-7.079E-03	1.660E+00	5.817E+01	1.249E+03
1.801E+01	2.657E+00	-2.789E-01	-7.037E-03	1.717E+00	5.667E+01	1.594E+03
2.402E+01	2.657E+00	-3.210E-01	-6.983E-03	1.774E+00	5.518E+01	1.930E+03
3.002E+01	2.656E+00	-3.627E-01	-6.918E-03	1.831E+00	5.368E+01	2.256E+03
3.603E+01	2.656E+00	-4.040E-01	-6.840E-03	1.888E+00	5.218E+01	2.574E+03
4.203E+01	2.656E+00	-4.448E-01	-6.749E-03	1.944E+00	5.068E+01	2.883E+03
4.803E+01	2.656E+00	-4.850E-01	-6.645E-03	2.001E+00	4.918E+01	3.183E+03
5.404E+01	2.656E+00	-5.246E-01	-6.528E-03	2.058E+00	4.768E+01	3.473E+03
6.004E+01	2.656E+00	-5.634E-01	-6.396E-03	2.115E+00	4.618E+01	3.755E+03
6.605E+01	2.656E+00	-6.013E-01	-6.249E-03	2.172E+00	4.468E+01	4.028E+03
7.205E+01	2.656E+00	-6.384E-01	-6.087E-03	2.229E+00	4.318E+01	4.291E+03
7.806E+01	2.656E+00	-6.744E-01	-5.909E-03	2.285E+00	4.169E+01	4.546E+03
8.406E+01	2.655E+00	-7.093E-01	-5.715E-03	2.342E+00	4.019E+01	4.792E+03
9.006E+01	2.655E+00	-7.430E-01	-5.503E-03	2.721E+00	3.019E+01	5.029E+03
9.607E+01	2.655E+00	-7.753E-01	-5.276E-03	3.100E+00	2.020E+01	5.154E+03
1.021E+02	2.655E+00	-8.063E-01	-5.034E-03	3.157E+00	1.870E+01	5.271E+03
1.081E+02	2.655E+00	-8.358E-01	-4.778E-03	3.214E+00	1.720E+01	5.379E+03
1.141E+02	2.655E+00	-8.636E-01	-4.507E-03	3.271E+00	1.570E+01	5.477E+03
1.201E+02	2.655E+00	-8.898E-01	-4.220E-03	3.327E+00	1.421E+01	5.567E+03

PROB (CONTD)
501 ANALYSIS FOR DESIGN LIVE + DEAD + WIND LOADS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 14 STIFF TYPE 9 LOAD TYPE 10
LENGTH = 2.100E+02 ALPHA = 1.000E+00 BETA = 0.
GOES FROM JOINT 4 TO JOINT 5

OUTPUT DISTANCES ARE FROM JOINT 4 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	2.687E+00	-7.886E-01	-4.220E-03	3.863E+00	1.407E+01	5.567E+03
1.050E+01	2.687E+00	-8.297E-01	-3.608E-03	3.863E+00	1.144E+01	5.701E+03
2.100E+01	2.687E+00	-8.643E-01	-2.984E-03	3.863E+00	8.819E+00	5.807E+03
3.150E+01	2.687E+00	-8.923E-01	-2.349E-03	3.863E+00	6.194E+00	5.886E+03
4.200E+01	2.687E+00	-9.136E-01	-1.708E-03	3.863E+00	3.569E+00	5.937E+03
5.250E+01	2.687E+00	-9.282E-01	-1.062E-03	3.863E+00	-1.485E+00	5.961E+03
6.300E+01	2.687E+00	-9.359E-01	-4.182E-04	3.863E+00	-1.261E+01	5.906E+03
7.350E+01	2.687E+00	-9.370E-01	2.113E-04	3.863E+00	-2.131E+01	5.696E+03
8.400E+01	2.687E+00	-9.316E-01	8.166E-04	3.863E+00	-2.393E+01	5.458E+03
9.450E+01	2.687E+00	-9.200E-01	1.395E-03	3.863E+00	-2.656E+01	5.193E+03
1.050E+02	2.687E+00	-9.024E-01	1.942E-03	3.863E+00	-2.918E+01	4.901E+03
1.155E+02	2.687E+00	-8.793E-01	2.457E-03	3.863E+00	-3.181E+01	4.581E+03
1.260E+02	2.687E+00	-8.510E-01	2.935E-03	3.863E+00	-3.443E+01	4.233E+03
1.365E+02	2.687E+00	-8.178E-01	3.374E-03	3.863E+00	-3.706E+01	3.858E+03
1.470E+02	2.687E+00	-7.803E-01	3.771E-03	3.863E+00	-4.575E+01	3.455E+03
1.575E+02	2.687E+00	-7.388E-01	4.116E-03	3.863E+00	-5.688E+01	2.897E+03
1.680E+02	2.687E+00	-6.941E-01	4.396E-03	3.863E+00	-6.193E+01	2.261E+03
1.785E+02	2.687E+00	-6.468E-01	4.605E-03	3.863E+00	-6.456E+01	1.597E+03
1.890E+02	2.687E+00	-5.977E-01	4.741E-03	3.863E+00	-6.718E+01	9.056E+02
1.995E+02	2.687E+00	-5.476E-01	4.800E-03	3.863E+00	-6.981E+01	1.867E+02
2.100E+02	2.687E+00	-4.972E-01	4.780E-03	3.863E+00	-7.243E+01	-5.599E+02

** LIMIT OF MEMBERS STRESS-STRAIN CURVE EXCEEDED ON THIS PROBLEM

PROB (CONTD)
501 ANALYSIS FOR DESIGN LIVE + DEAD + WIND LOADS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 15 STIFF TYPE 10 LOAD TYPE 11
LENGTH = 1.201E+02 ALPHA = 9.993E-01 BETA = -3.789E-02
GOES FROM JOINT 5 TO JOINT 7

OUTPUT DISTANCES ARE FROM JOINT 5 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	2.704E+00	-3.950E-01	4.780E-03	1.116E+00	-7.253E+01	-5.599E+02
6.004E+00	2.704E+00	-3.665E-01	4.739E-03	1.059E+00	-7.402E+01	-9.998E+02
1.201E+01	2.704E+00	-3.382E-01	4.678E-03	1.002E+00	-7.552E+01	-1.449E+03
1.801E+01	2.704E+00	-3.103E-01	4.597E-03	9.456E-01	-7.702E+01	-1.907E+03
2.402E+01	2.704E+00	-2.830E-01	4.498E-03	8.887E-01	-7.852E+01	-2.374E+03
3.002E+01	2.703E+00	-2.563E-01	4.381E-03	5.098E-01	-8.851E+01	-2.850E+03
3.603E+01	2.703E+00	-2.304E-01	4.246E-03	1.309E-01	-9.851E+01	-3.437E+03
4.203E+01	2.703E+00	-2.054E-01	4.090E-03	7.410E-02	-1.000E+02	-4.032E+03
4.803E+01	2.703E+00	-1.814E-01	3.916E-03	1.727E-02	-1.015E+02	-4.637E+03
5.404E+01	2.703E+00	-1.584E-01	3.723E-03	-3.957E-02	-1.030E+02	-5.251E+03
6.004E+01	2.703E+00	-1.367E-01	3.514E-03	-9.640E-02	-1.045E+02	-5.874E+03
6.605E+01	2.703E+00	-1.162E-01	3.288E-03	-1.532E-01	-1.060E+02	-6.506E+03
7.205E+01	2.703E+00	-9.722E-02	3.047E-03	-2.101E-01	-1.075E+02	-7.147E+03
7.806E+01	2.703E+00	-7.968E-02	2.791E-03	-2.669E-01	-1.090E+02	-7.797E+03
8.406E+01	2.703E+00	-6.373E-02	2.520E-03	-3.237E-01	-1.105E+02	-8.456E+03
9.006E+01	2.703E+00	-4.944E-02	2.237E-03	-3.806E-01	-1.120E+02	-9.124E+03
9.607E+01	2.703E+00	-3.689E-02	1.940E-03	-4.374E-01	-1.135E+02	-9.801E+03
1.021E+02	2.703E+00	-2.616E-02	1.631E-03	-4.942E-01	-1.150E+02	-1.049E+04
1.081E+02	2.703E+00	-1.733E-02	1.310E-03	-5.511E-01	-1.165E+02	-1.118E+04
1.141E+02	2.703E+00	-1.045E-02	9.776E-04	-6.079E-01	-1.180E+02	-1.189E+04
1.201E+02	2.703E+00	-5.606E-03	6.340E-04	-6.647E-01	-1.195E+02	-1.260E+04

** LIMIT OF MEMBERS STRESS-STRAIN CURVE EXCEEDED ON THIS PROBLEM

PROB (CONTD)
501 ANALYSIS FOR DESIGN LIVE + DEAD + WIND LOADS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 16 STIFF TYPE 8 LOAD TYPE 9
LENGTH = 1.201E+02 ALPHA = 9.993E-01 BETA = 3.789E-02
GOES FROM JOINT 7 TO JOINT 9

OUTPUT DISTANCES ARE FROM JOINT 7 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	2.695E+00	-2.103E-01	6.340E-04	-3.318E+00	8.610E+01	-7.773E+03
6.004E+00	2.695E+00	-2.071E-01	4.231E-04	-3.261E+00	8.460E+01	-7.260E+03
1.201E+01	2.695E+00	-2.052E-01	2.211E-04	-3.204E+00	8.310E+01	-6.757E+03
1.801E+01	2.695E+00	-2.044E-01	2.820E-05	-3.147E+00	8.161E+01	-6.262E+03
2.402E+01	2.695E+00	-2.048E-01	-1.552E-04	-3.091E+00	8.011E+01	-5.777E+03
3.002E+01	2.695E+00	-2.063E-01	-3.288E-04	-3.034E+00	7.861E+01	-5.300E+03
3.603E+01	2.695E+00	-2.088E-01	-4.923E-04	-2.977E+00	7.711E+01	-4.833E+03
4.203E+01	2.695E+00	-2.122E-01	-6.454E-04	-2.920E+00	7.561E+01	-4.374E+03
4.803E+01	2.695E+00	-2.165E-01	-7.876E-04	-2.863E+00	7.411E+01	-3.925E+03
5.404E+01	2.695E+00	-2.216E-01	-9.185E-04	-2.806E+00	7.261E+01	-3.484E+03
6.004E+01	2.695E+00	-2.275E-01	-1.038E-03	-2.750E+00	7.111E+01	-3.053E+03
6.605E+01	2.695E+00	-2.341E-01	-1.145E-03	-2.693E+00	6.961E+01	-2.630E+03
7.205E+01	2.695E+00	-2.412E-01	-1.239E-03	-2.636E+00	6.812E+01	-2.217E+03
7.806E+01	2.695E+00	-2.489E-01	-1.320E-03	-2.579E+00	6.662E+01	-1.812E+03
8.406E+01	2.695E+00	-2.570E-01	-1.388E-03	-2.522E+00	6.512E+01	-1.417E+03
9.006E+01	2.695E+00	-2.655E-01	-1.440E-03	-2.143E+00	5.512E+01	-1.030E+03
9.607E+01	2.695E+00	-2.743E-01	-1.480E-03	-1.764E+00	4.513E+01	-7.550E+02
1.021E+02	2.695E+00	-2.833E-01	-1.509E-03	-1.708E+00	4.363E+01	-4.885E+02
1.081E+02	2.695E+00	-2.924E-01	-1.526E-03	-1.651E+00	4.213E+01	-2.310E+02
1.141E+02	2.695E+00	-3.016E-01	-1.532E-03	-1.594E+00	4.063E+01	1.754E+01
1.201E+02	2.695E+00	-3.108E-01	-1.525E-03	-1.537E+00	3.914E+01	2.570E+02

PROB (CONTD)
501 ANALYSIS FOR DESIGN LIVE + DEAD + WIND LOADS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 17 STIFF TYPE 9 LOAD TYPE 10
LENGTH = 2.100E+02 ALPHA = 1.000E+00 BETA = 0.
GOES FROM JOINT 9 TO JOINT 10

OUTPUT DISTANCES ARE FROM JOINT 9 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	2.704E+00	-2.085E-01	-1.525E-03	-5.313E-02	3.917E+01	2.570E+02
1.050E+01	2.704E+00	-2.242E-01	-1.475E-03	-5.313E-02	3.654E+01	6.545E+02
2.100E+01	2.704E+00	-2.393E-01	-1.384E-03	-5.313E-02	3.392E+01	1.024E+03
3.150E+01	2.704E+00	-2.531E-01	-1.254E-03	-5.313E-02	3.129E+01	1.367E+03
4.200E+01	2.704E+00	-2.655E-01	-1.089E-03	-5.313E-02	2.867E+01	1.682E+03
5.250E+01	2.704E+00	-2.759E-01	-8.907E-04	-5.313E-02	2.361E+01	1.969E+03
6.300E+01	2.704E+00	-2.841E-01	-6.657E-04	-5.313E-02	1.249E+01	2.177E+03
7.350E+01	2.704E+00	-2.898E-01	-4.265E-04	-5.313E-02	3.791E+00	2.231E+03
8.400E+01	2.704E+00	-2.930E-01	-1.830E-04	-5.313E-02	1.166E+00	2.257E+03
9.450E+01	2.704E+00	-2.936E-01	6.189E-05	-5.313E-02	-1.459E+00	2.255E+03
1.050E+02	2.704E+00	-2.917E-01	3.051E-04	-5.313E-02	-4.084E+00	2.226E+03
1.155E+02	2.704E+00	-2.872E-01	5.437E-04	-5.313E-02	-6.709E+00	2.170E+03
1.260E+02	2.704E+00	-2.803E-01	7.746E-04	-5.313E-02	-9.334E+00	2.085E+03
1.365E+02	2.704E+00	-2.710E-01	9.948E-04	-5.313E-02	-1.196E+01	1.974E+03
1.470E+02	2.704E+00	-2.595E-01	1.201E-03	-5.313E-02	-2.066E+01	1.834E+03
1.575E+02	2.704E+00	-2.459E-01	1.385E-03	-5.313E-02	-3.178E+01	1.540E+03
1.680E+02	2.704E+00	-2.305E-01	1.531E-03	-5.313E-02	-3.683E+01	1.167E+03
1.785E+02	2.704E+00	-2.139E-01	1.636E-03	-5.313E-02	-3.946E+01	7.664E+02
1.890E+02	2.704E+00	-1.964E-01	1.696E-03	-5.313E-02	-4.208E+01	3.383E+02
1.995E+02	2.704E+00	-1.785E-01	1.708E-03	-5.313E-02	-4.471E+01	-1.174E+02
2.100E+02	2.704E+00	-1.607E-01	1.669E-03	-5.313E-02	-4.733E+01	-6.006E+02

PROB (CONTD)
501 ANALYSIS FOR DESIGN LIVE + DEAD + WIND LOADS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 18 STIFF TYPE 10 LOAD TYPE 11
LENGTH = 1.201E+02 ALPHA = 9.993E-01 BETA = -3.789E-02
GOES FROM JOINT 10 TO JOINT 12

OUTPUT DISTANCES ARE FROM JOINT 10 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	2.708E+00	-5.811E-02	1.669E-03	-1.847E+00	-4.730E+01	-6.006E+02
6.004E+00	2.708E+00	-4.820E-02	1.631E-03	-1.903E+00	-4.880E+01	-8.891E+02
1.201E+01	2.708E+00	-3.856E-02	1.579E-03	-1.960E+00	-5.030E+01	-1.187E+03
1.801E+01	2.708E+00	-2.926E-02	1.514E-03	-2.017E+00	-5.179E+01	-1.493E+03
2.402E+01	2.708E+00	-2.040E-02	1.438E-03	-2.074E+00	-5.329E+01	-1.809E+03
3.002E+01	2.708E+00	-1.202E-02	1.350E-03	-2.453E+00	-6.329E+01	-2.133E+03
3.603E+01	2.708E+00	-4.215E-03	1.248E-03	-2.832E+00	-7.328E+01	-2.569E+03
4.203E+01	2.708E+00	2.938E-03	1.132E-03	-2.888E+00	-7.478E+01	-3.013E+03
4.803E+01	2.708E+00	9.351E-03	1.002E-03	-2.945E+00	-7.628E+01	-3.467E+03
5.404E+01	2.708E+00	1.494E-02	8.577E-04	-3.002E+00	-7.778E+01	-3.929E+03
6.004E+01	2.708E+00	1.962E-02	7.008E-04	-3.059E+00	-7.928E+01	-4.401E+03
6.605E+01	2.708E+00	2.333E-02	5.315E-04	-3.116E+00	-8.077E+01	-4.881E+03
7.205E+01	2.708E+00	2.598E-02	3.503E-04	-3.173E+00	-8.227E+01	-5.371E+03
7.806E+01	2.708E+00	2.752E-02	1.577E-04	-3.229E+00	-8.377E+01	-5.869E+03
8.406E+01	2.708E+00	2.786E-02	-4.583E-05	-3.286E+00	-8.527E+01	-6.377E+03
9.006E+01	2.708E+00	2.695E-02	-2.600E-04	-3.343E+00	-8.677E+01	-6.893E+03
9.607E+01	2.708E+00	2.472E-02	-4.843E-04	-3.400E+00	-8.827E+01	-7.419E+03
1.021E+02	2.708E+00	2.111E-02	-7.184E-04	-3.457E+00	-8.977E+01	-7.953E+03
1.081E+02	2.708E+00	1.607E-02	-9.621E-04	-3.514E+00	-9.127E+01	-8.497E+03
1.141E+02	2.708E+00	9.545E-03	-1.215E-03	-3.570E+00	-9.277E+01	-9.049E+03
1.201E+02	2.708E+00	1.470E-03	-1.477E-03	-3.627E+00	-9.426E+01	-9.611E+03

PROB (CONTD)
501 ANALYSIS FOR DESIGN LIVE + DEAD + WIND LOADS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 19 STIFF TYPE 8 LOAD TYPE 9
LENGTH = 1.201E+02 ALPHA = 9.993E-01 BETA = 3.789E-02
GOES FROM JOINT 12 TO JOINT 14

OUTPUT DISTANCES ARE FROM JOINT 12 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	2.700E+00	-2.036E-01	-1.477E-03	-2.370E+00	8.547E+01	-6.510E+03
6.004E+00	2.700E+00	-2.130E-01	-1.652E-03	-2.314E+00	8.397E+01	-6.001E+03
1.201E+01	2.700E+00	-2.234E-01	-1.818E-03	-2.257E+00	8.247E+01	-5.501E+03
1.801E+01	2.700E+00	-2.348E-01	-1.974E-03	-2.200E+00	8.097E+01	-5.011E+03
2.402E+01	2.700E+00	-2.471E-01	-2.119E-03	-2.143E+00	7.947E+01	-4.529E+03
3.002E+01	2.700E+00	-2.602E-01	-2.254E-03	-2.086E+00	7.797E+01	-4.056E+03
3.603E+01	2.700E+00	-2.742E-01	-2.377E-03	-2.029E+00	7.647E+01	-3.593E+03
4.203E+01	2.700E+00	-2.888E-01	-2.489E-03	-1.973E+00	7.497E+01	-3.138E+03
4.803E+01	2.700E+00	-3.040E-01	-2.589E-03	-1.916E+00	7.347E+01	-2.692E+03
5.404E+01	2.700E+00	-3.198E-01	-2.676E-03	-1.859E+00	7.197E+01	-2.256E+03
6.004E+01	2.700E+00	-3.361E-01	-2.751E-03	-1.802E+00	7.048E+01	-1.828E+03
6.605E+01	2.700E+00	-3.528E-01	-2.812E-03	-1.745E+00	6.898E+01	-1.409E+03
7.205E+01	2.700E+00	-3.699E-01	-2.859E-03	-1.688E+00	6.748E+01	-9.995E+02
7.806E+01	2.700E+00	-3.871E-01	-2.891E-03	-1.632E+00	6.598E+01	-5.988E+02
8.406E+01	2.700E+00	-4.045E-01	-2.908E-03	-1.575E+00	6.448E+01	-2.071E+02
9.006E+01	2.700E+00	-4.220E-01	-2.908E-03	-1.196E+00	5.449E+01	1.756E+02
9.607E+01	2.700E+00	-4.394E-01	-2.894E-03	-8.169E-01	4.449E+01	4.472E+02
1.021E+02	2.700E+00	-4.567E-01	-2.868E-03	-7.601E-01	4.300E+01	7.099E+02
1.081E+02	2.700E+00	-4.738E-01	-2.827E-03	-7.032E-01	4.150E+01	9.636E+02
1.141E+02	2.700E+00	-4.907E-01	-2.773E-03	-6.464E-01	4.000E+01	1.208E+03
1.201E+02	2.700E+00	-5.071E-01	-2.704E-03	-5.896E-01	3.850E+01	1.444E+03

PROB (CONTD)
501 ANALYSIS FOR DESIGN LIVE + DEAD + WIND LOADS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 20 STIFF TYPE 9 LOAD TYPE 10
LENGTH = 2.100E+02 ALPHA = 1.000E+00 BETA = 0.
GOES FROM JOINT 14 TO JOINT 15

OUTPUT DISTANCES ARE FROM JOINT 14 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	2.717E+00	-4.045E-01	-2.704E-03	8.695E-01	3.849E+01	1.444E+03
1.050E+01	2.717E+00	-4.319E-01	-2.526E-03	8.695E-01	3.587E+01	1.834E+03
2.100E+01	2.717E+00	-4.573E-01	-2.308E-03	8.695E-01	3.324E+01	2.197E+03
3.150E+01	2.717E+00	-4.803E-01	-2.051E-03	8.695E-01	3.062E+01	2.532E+03
4.200E+01	2.717E+00	-5.003E-01	-1.759E-03	8.695E-01	2.799E+01	2.840E+03
5.250E+01	2.717E+00	-5.171E-01	-1.436E-03	8.695E-01	2.294E+01	3.120E+03
6.300E+01	2.717E+00	-5.303E-01	-1.086E-03	8.695E-01	1.182E+01	3.322E+03
7.350E+01	2.717E+00	-5.398E-01	-7.234E-04	8.695E-01	3.119E+00	3.368E+03
8.400E+01	2.717E+00	-5.455E-01	-3.568E-04	8.695E-01	4.937E-01	3.387E+03
9.450E+01	2.717E+00	-5.473E-01	1.038E-05	8.695E-01	-2.131E+00	3.379E+03
1.050E+02	2.717E+00	-5.453E-01	3.751E-04	8.695E-01	-4.756E+00	3.343E+03
1.155E+02	2.717E+00	-5.395E-01	7.344E-04	8.695E-01	-7.381E+00	3.279E+03
1.260E+02	2.717E+00	-5.299E-01	1.085E-03	8.695E-01	-1.001E+01	3.188E+03
1.365E+02	2.717E+00	-5.167E-01	1.425E-03	8.695E-01	-1.263E+01	3.069E+03
1.470E+02	2.717E+00	-5.000E-01	1.750E-03	8.695E-01	-2.133E+01	2.922E+03
1.575E+02	2.717E+00	-4.801E-01	2.051E-03	8.695E-01	-3.245E+01	2.621E+03
1.680E+02	2.717E+00	-4.571E-01	2.315E-03	8.695E-01	-3.751E+01	2.241E+03
1.785E+02	2.717E+00	-4.316E-01	2.536E-03	8.695E-01	-4.013E+01	1.833E+03
1.890E+02	2.717E+00	-4.041E-01	2.711E-03	8.695E-01	-4.276E+01	1.398E+03
1.995E+02	2.717E+00	-3.749E-01	2.838E-03	8.695E-01	-4.538E+01	9.354E+02
2.100E+02	2.717E+00	-3.447E-01	2.912E-03	8.695E-01	-4.801E+01	4.451E+02

PROB (CONTD)
501 ANALYSIS FOR DESIGN LIVE + DEAD + WIND LOADS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 21 STIFF TYPE 10 LOAD TYPE 11
LENGTH = 1.201E+02 ALPHA = 9.993E-01 BETA = -3.789E-02
GOES FROM JOINT 15 TO JOINT 17

OUTPUT DISTANCES ARE FROM JOINT 15 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	2.728E+00	-2.415E-01	2.912E-03	-9.500E-01	-4.800E+01	4.451E+02
6.004E+00	2.728E+00	-2.239E-01	2.928E-03	-1.007E+00	-4.950E+01	1.524E+02
1.201E+01	2.728E+00	-2.064E-01	2.928E-03	-1.064E+00	-5.100E+01	-1.494E+02
1.801E+01	2.728E+00	-1.888E-01	2.913E-03	-1.121E+00	-5.250E+01	-4.601E+02
2.402E+01	2.728E+00	-1.714E-01	2.885E-03	-1.177E+00	-5.400E+01	-7.799E+02
3.002E+01	2.728E+00	-1.542E-01	2.842E-03	-1.556E+00	-6.399E+01	-1.109E+03
3.603E+01	2.728E+00	-1.373E-01	2.785E-03	-1.935E+00	-7.399E+01	-1.548E+03
4.203E+01	2.728E+00	-1.208E-01	2.711E-03	-1.992E+00	-7.549E+01	-1.997E+03
4.803E+01	2.728E+00	-1.048E-01	2.622E-03	-2.049E+00	-7.698E+01	-2.455E+03
5.404E+01	2.728E+00	-8.934E-02	2.517E-03	-2.106E+00	-7.848E+01	-2.922E+03
6.004E+01	2.728E+00	-7.457E-02	2.398E-03	-2.162E+00	-7.998E+01	-3.397E+03
6.605E+01	2.728E+00	-6.057E-02	2.265E-03	-2.219E+00	-8.148E+01	-3.882E+03
7.205E+01	2.728E+00	-4.740E-02	2.119E-03	-2.276E+00	-8.298E+01	-4.376E+03
7.806E+01	2.728E+00	-3.514E-02	1.961E-03	-2.333E+00	-8.448E+01	-4.879E+03
8.406E+01	2.728E+00	-2.387E-02	1.790E-03	-2.390E+00	-8.598E+01	-5.390E+03
9.006E+01	2.728E+00	-1.367E-02	1.608E-03	-2.447E+00	-8.748E+01	-5.911E+03
9.607E+01	2.728E+00	-4.589E-03	1.414E-03	-2.503E+00	-8.898E+01	-6.441E+03
1.021E+02	2.728E+00	3.294E-03	1.210E-03	-2.560E+00	-9.047E+01	-6.980E+03
1.081E+02	2.728E+00	9.918E-03	9.947E-04	-2.617E+00	-9.197E+01	-7.528E+03
1.141E+02	2.728E+00	1.522E-02	7.697E-04	-2.674E+00	-9.347E+01	-8.084E+03
1.201E+02	2.728E+00	1.914E-02	5.349E-04	-2.731E+00	-9.497E+01	-8.650E+03

PROB (CONTD)
501 ANALYSIS FOR DESIGN LIVE + DEAD + WIND LOADS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 22 STIFF TYPE 8 LOAD TYPE 9
LENGTH = 1.201E+02 ALPHA = 9.993E-01 BETA = 3.789E-02
GOES FROM JOINT 17 TO JOINT 19

OUTPUT DISTANCES ARE FROM JOINT 17 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	2.721E+00	-1.875E-01	5.349E-04	-1.781E+00	4.697E+01	-3.330E+03
6.004E+00	2.721E+00	-1.845E-01	4.454E-04	-1.724E+00	4.547E+01	-3.052E+03
1.201E+01	2.721E+00	-1.821E-01	3.612E-04	-1.667E+00	4.397E+01	-2.784E+03
1.801E+01	2.721E+00	-1.802E-01	2.826E-04	-1.610E+00	4.247E+01	-2.524E+03
2.402E+01	2.721E+00	-1.787E-01	2.095E-04	-1.553E+00	4.097E+01	-2.274E+03
3.002E+01	2.721E+00	-1.776E-01	1.420E-04	-1.497E+00	3.947E+01	-2.033E+03
3.603E+01	2.721E+00	-1.770E-01	8.016E-05	-1.440E+00	3.797E+01	-1.800E+03
4.203E+01	2.721E+00	-1.767E-01	2.403E-05	-1.383E+00	3.647E+01	-1.577E+03
4.803E+01	2.721E+00	-1.767E-01	-2.632E-05	-1.326E+00	3.497E+01	-1.362E+03
5.404E+01	2.721E+00	-1.770E-01	-7.083E-05	-1.269E+00	3.348E+01	-1.157E+03
6.004E+01	2.721E+00	-1.775E-01	-1.094E-04	-1.212E+00	3.198E+01	-9.600E+02
6.605E+01	2.721E+00	-1.783E-01	-1.421E-04	-1.156E+00	3.048E+01	-7.725E+02
7.205E+01	2.721E+00	-1.792E-01	-1.687E-04	-1.099E+00	2.898E+01	-5.940E+02
7.806E+01	2.721E+00	-1.803E-01	-1.892E-04	-1.042E+00	2.748E+01	-4.245E+02
8.406E+01	2.721E+00	-1.815E-01	-2.035E-04	-9.851E-01	2.598E+01	-2.640E+02
9.006E+01	2.721E+00	-1.827E-01	-2.116E-04	-6.062E-01	1.599E+01	-1.125E+02
9.607E+01	2.721E+00	-1.840E-01	-2.157E-04	-2.273E-01	5.996E+00	-7.200E+01
1.021E+02	2.721E+00	-1.853E-01	-2.184E-04	-1.705E-01	4.497E+00	-4.050E+01
1.081E+02	2.721E+00	-1.866E-01	-2.198E-04	-1.137E-01	2.998E+00	-1.800E+01
1.141E+02	2.721E+00	-1.879E-01	-2.203E-04	-5.683E-02	1.499E+00	-4.500E+00
1.201E+02	2.721E+00	-1.893E-01	-2.204E-04	2.878E-06	-1.082E-05	-3.157E-05

PROB (CONTD)
501 ANALYSIS FOR DESIGN LIVE + DEAD + WIND LOADS

TABLE 10 - JOINT EQUILIBRIUM ERRORS

JOINT	ERR(X) FORCE	ERR(Y) FORCE	ERR(Z) MOMENT
1	-4.441E-05	1.244E-03	1.367E-03
2	-2.553E-05	-1.117E-03	9.368E-04
3	-1.363E-07	-1.452E-05	1.154E-05
4	-4.376E-05	1.735E-06	-8.072E-06
5	-8.976E-06	6.300E-06	9.460E-05
6	-1.360E-04	-1.325E-03	-3.172E-05
7	5.942E-05	-1.397E-03	1.527E-03
8	2.891E-07	-4.639E-06	2.627E-06
9	-7.595E-06	1.561E-05	-1.063E-04
10	4.039E-05	1.707E-05	9.865E-05
11	2.483E-04	-2.054E-03	9.680E-04
12	-1.576E-04	-2.862E-03	-5.693E-03
13	1.139E-07	-1.120E-05	-3.861E-06
14	-4.302E-05	-3.806E-06	2.581E-05
15	4.870E-05	-3.748E-06	-2.832E-05
16	-1.389E-04	-9.868E-04	2.146E-04
17	8.898E-05	-1.114E-03	1.573E-03
18	1.887E-07	-9.499E-06	3.262E-06
19	-2.465E-06	-1.092E-05	3.157E-05
20	-1.351E-08	7.125E-08	-2.063E-07

PROB

502 501 WITH COLUMNS RIGID WITHIN JOINTS

TABLE 1 - PROGRAM CONTROL DATA
PROBLEM TYPE 2

INPUT TABLES

TABLE NUMBER	HOLD DATA FROM LAST PROBLEM (1 = YES,0 = NO)	NUMBER OF CARDS ADDED FOR THIS PROBLEM
2	1	-0
3	1	-0
4A	1	-0
4B	1	-0
4C	1	-0
5A	0	18
5B	1	-0
5C	1	-0
5D	-0	-0
6	1	-0
7	1	-0

OUTPUT TABLES

TABLE NUMBER	SUPPRESS OUTPUT (1 = YES,0 = NO)
8	-0
9	-0
10	-0

PROB (CONTD)
502 501 WITH COLUMNS RIGID WITHIN JOINTS

TABLE 2 - FRAME GEOMETRY DATA

HOLDING DATA FROM THE PREVIOUS PROBLEM PLUS THE FOLLOWING

NONE

COMPUTED JOINT COORDINATES

JOINT	X	Y
1	0.	-2.500E-02
2	0.	3.555E+02
3	0.	6.480E+02
4	1.200E+02	3.600E+02
5	3.300E+02	3.600E+02
6	4.500E+02	0.
7	4.500E+02	3.555E+02
8	4.500E+02	6.667E+02
9	5.700E+02	3.600E+02
10	7.800E+02	3.600E+02
11	9.000E+02	0.
12	9.000E+02	3.555E+02
13	9.000E+02	6.855E+02
14	1.020E+03	3.600E+02
15	1.230E+03	3.600E+02
16	1.350E+03	0.
17	1.350E+03	3.555E+02
18	1.350E+03	7.042E+02
19	1.470E+03	3.600E+02
20	1.470E+03	7.092E+02

PROB (CONTD)
502 501 WITH COLUMNS RIGID WITHIN JOINTS

TABLE 3 - MEMBER LOCATION DATA

HOLDING DATA FROM THE PREVIOUS PROBLEM PLUS THE FOLLOWING

NONE

COMPUTED MEMBER NUMBERS,LENGTHS, ND OFFSETS

MEMBER NUMB	FROM JOINT	TO JOINT	STIFF TYPE	LOAD TYPE	LENGTH	X-OFFSET	Y-OFFSET
1	1	2	1	1	3.555E+02	0.	3.555E+02
2	6	7	1	2	3.555E+02	0.	3.555E+02
3	11	12	1	2	3.555E+02	0.	3.555E+02
4	16	17	1	2	3.555E+02	0.	3.555E+02
5	2	3	2	3	2.925E+02	0.	2.925E+02
6	7	8	3	4	3.113E+02	0.	3.113E+02
7	12	13	4	5	3.300E+02	0.	3.300E+02
8	17	18	5	6	3.488E+02	0.	3.488E+02
9	3	8	6	7	4.504E+02	4.500E+02	1.875E+01
10	8	13	6	7	4.504E+02	4.500E+02	1.875E+01
11	13	18	6	7	4.504E+02	4.500E+02	1.875E+01
12	18	20	7	8	1.201E+02	1.200E+02	5.000E+00
13	2	4	8	9	1.201E+02	1.200E+02	4.550E+00
14	4	5	9	10	2.100E+02	2.100E+02	0.
15	5	7	10	11	1.201E+02	1.200E+02	-4.550E+00
16	7	9	8	9	1.201E+02	1.200E+02	4.550E+00
17	9	10	9	10	2.100E+02	2.100E+02	0.
18	10	12	10	11	1.201E+02	1.200E+02	-4.550E+00
19	12	14	8	9	1.201E+02	1.200E+02	4.550E+00
20	14	15	9	10	2.100E+02	2.100E+02	0.
21	15	17	10	11	1.201E+02	1.200E+02	-4.550E+00
22	17	19	8	9	1.201E+02	1.200E+02	4.550E+00

*** COMPUTED MEMBER NUMBERS AGREE WITH LAST PROBLEM ***

PROB (CONTD)
502 501 WITH COLUMNS RIGID WITHIN JOINTS

TABLE 4A - JOINT LOADS AND LINEAR RESTRAINTS

HOLDING DATA FROM THE PREVIOUS PROBLEM PLUS THE FOLLOWING

NONE

ACCUMULATED JOINT DATA

JOINT	FORCE(X)	FORCE(Y)	MOMENT(Z)	SPRING(X)	SPRING(Y)	SPRING(Z)
1	0.	0.	0.	1.000E+20	1.000E+20	1.000E+20
2	0.	-1.700E+01	0.	0.	0.	0.
3	0.	-1.200E+01	0.	0.	0.	0.
6	0.	0.	0.	0.	1.000E+20	0.
7	0.	-1.700E+01	0.	0.	0.	0.
8	0.	-1.200E+01	0.	0.	0.	0.
11	0.	0.	0.	0.	1.000E+20	0.
12	0.	-1.700E+01	0.	0.	0.	0.
13	0.	-1.200E+01	0.	0.	0.	0.
16	0.	0.	0.	1.000E+20	1.000E+20	0.
17	0.	-1.700E+01	0.	0.	0.	0.
18	0.	-1.200E+01	0.	0.	0.	0.

TABLE 4B - JOINT SUPPORT CURVE NUMBERS

HOLDING DATA FROM THE PREVIOUS PROBLEM PLUS THE FOLLOWING

NONE

ACCUMULATED JOINT DATA

JOINT	Q-MULT	W-MULT	NSXX	NSYY	NSZZ	NSXP	NSYP	STIFF
6	1.000E+00	1.000E-02	1	-0	-0	-0	-0	-0
11	1.000E+00	1.000E-02	1	-0	-0	-0	-0	-0

TABLE 4C - JOINT SUPPORT CURVES

HOLDING DATA FROM THE PREVIOUS PROBLEM PLUS THE FOLLOWING

NONE

PROB (CONTD)
502 501 WITH COLUMNS RIGID WITHIN JOINTS

TABLE 5A - MEMBER STIFFNESS DATA

STIFF TYPE	MOD OF ELAST	PRISMATIC I	PRISMATIC A	NON LIN	NUMB CRDS	AXIS OPT	OUTPUT OPT	PIN FROM	PIN TO
1	-0.	-0.	-0.	1	1	1	-0	-0	-10

STIFF TYPE 1 CONT

FROM JOINT NA	NSX	NSY	NSZ	TO JOINT NA	NSX	NSY	NSZ	Q - MULT	W - MULT
1	-0	-0	-0	1	-0	-0	-0	-0.	-0.

STIFF TYPE	MOD OF ELAST	PRISMATIC I	PRISMATIC A	NON LIN	NUMB CRDS	AXIS OPT	OUTPUT OPT	PIN FROM	PIN TO
2	-0.	-0.	-0.	1	1	1	-0	-10	-10

STIFF TYPE 2 CONT

FROM JOINT NA	NSX	NSY	NSZ	TO JOINT NA	NSX	NSY	NSZ	Q - MULT	W - MULT
2	-0	-0	-0	2	-0	-0	-0	-0.	-0.

STIFF TYPE	MOD OF ELAST	PRISMATIC I	PRISMATIC A	NON LIN	NUMB CRDS	AXIS OPT	OUTPUT OPT	PIN FROM	PIN TO
3	-0.	-0.	-0.	1	1	1	1	-10	-10

STIFF TYPE 3 CONT

FROM JOINT NA	NSX	NSY	NSZ	TO JOINT NA	NSX	NSY	NSZ	Q - MULT	W - MULT
2	-0	-0	-0	2	-0	-0	-0	-0.	-0.

STIFF TYPE	MOD OF ELAST	PRISMATIC I	PRISMATIC A	NON LIN	NUMB CRDS	AXIS OPT	OUTPUT OPT	PIN FROM	PIN TO
4	-0.	-0.	-0.	1	1	1	1	-10	-10

STIFF TYPE 4 CONT

FROM JOINT NA	NSX	NSY	NSZ	TO JOINT NA	NSX	NSY	NSZ	Q - MULT	W - MULT
2	-0	-0	-0	2	-0	-0	-0	-0.	-0.

STIFF TYPE	MOD OF ELAST	PRISMATIC I	PRISMATIC A	NON LIN	NUMB CRDS	AXIS OPT	OUTPUT OPT	PIN FROM	PIN TO
5	-0.	-0.	-0.	1	1	1	1	-10	-10

STIFF TYPE 5 CONT

FROM JOINT NA	NSX	NSY	NSZ	TO JOINT NA	NSX	NSY	NSZ	Q - MULT	W - MULT
2	-0	-0	-0	2	-0	-0	-0	-0.	-0.

STIFF TYPE	MOD OF ELAST	PRISMATIC I	PRISMATIC A	NON LIN	NUMB CRDS	AXIS OPT	OUTPUT OPT	PIN FROM	PIN TO
6	3.000E+04	3.267E+03	2.765E+01	0	0	1	-0	-0	-0
7	3.000E+04	3.267E+03	2.765E+01	0	0	1	-0	-0	-0
8	-0.	-0.	-0.	1	1	1	-0	-0	-0

STIFF TYPE 8 CONT

FROM JOINT NA	NSX	NSY	NSZ	TO JOINT NA	NSX	NSY	NSZ	Q - MULT	W - MULT
4	-0	-0	-0	5	-0	-0	-0	-0.	-0.

STIFF TYPE	MOD OF ELAST	PRISMATIC I	PRISMATIC A	NON LIN	NUMB CRDS	AXIS OPT	OUTPUT OPT	PIN FROM	PIN TO
9	-0.	-0.	-0.	1	1	1	-0	-0	-0

STIFF TYPE 9 CONT

FROM JOINT NA	NSX	NSY	NSZ	TO JOINT NA	NSX	NSY	NSZ	Q - MULT	W - MULT
3	-0	-0	-0	3	-0	-0	-0	-0.	-0.

STIFF TYPE	MOD OF ELAST	PRISMATIC I	PRISMATIC A	NON LIN	NUMB CRDS	AXIS OPT	OUTPUT OPT	PIN FROM	PIN TO
10	-0.	-0.	-0.	1	1	1	-0	-0	-0

STIFF TYPE 10 CONT

FROM JOINT NA	NSX	NSY	NSZ	TO JOINT NA	NSX	NSY	NSZ	Q - MULT	W - MULT
5	-0	-0	-0	4	-0	-0	-0	-0.	-0.

TABLE 5B - CROSS SECTION DATA

HOLDING DATA FROM THE PREVIOUS PROBLEM PLUS THE FOLLOWING

NONE

TABLE 5C - STRESS STRAIN CURVES

HOLDING DATA FROM THE PREVIOUS PROBLEM PLUS THE FOLLOWING

NONE

TABLE 5D - SUPPORT CURVES FOR MEMBERS

NO DATA IN TABLE

PROB (CONTD)
  502   501 WITH COLUMNS RIGID WITHIN JOINTS

TABLE 6 - MEMBER LOAD DATA

HOLDING DATA FROM THE PREVIOUS PROBLEM PLUS THE FOLLOWING

NONE

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PROB (CONTD)
  502      501 WITH COLUMNS RIGID WITHIN JOINTS


TABLE 7 -  ITERATION CONTROL


HOLDING DATA FROM THE PREVIOUS PROBLEM


          FRAME SOLUTION

        NUMB       FORCE    MOMENT
       ITER        ERROR     ERROR                    MONITOR JOINTS

        10      2.000E-02 1.000E+01            1    2    3    6   11


         MEMBER SOLUTIONS

        NUMB       FORCE    MOMENT
        ITER       ERROR     ERROR                    MONITOR MEMBERS

        10      2.000E-03 1.000E+00            1    4    9   -0   -0


***** FRAME ITERATION NO       1 *****

 MEMB MEMB         MEMBER DISPLACEMENTS              MEMBER EQUILIBRIUM ERRORS
  NO  ITER      AXIAL  LATERAL  ROTATIONAL        AXIAL      LATERAL     ROTATIONAL

    1    1
FROM JOINT    -2.030E-03 -1.441E-02 -1.599E-03  1.299E-02  1.832E-04  7.699E-03
CENTERLINE    -2.342E-02 -9.985E-01 -8.714E-03  4.773E-02 -4.462E-04  5.271E-02
 TO JOINT     -4.662E-02 -2.315E+00 -6.734E-03  2.836E+00 -1.042E+00 -1.873E+01
** LIMIT OF MEMBERS STRESS-STRAIN CURVE EXCEEDED ON PRECEEDING ITERATION

    1    2
FROM JOINT    -2.025E-03 -1.441E-02 -1.599E-03  3.223E-09  1.265E-09  1.417E-07
CENTERLINE    -2.340E-02 -9.984E-01 -8.714E-03 -1.927E-09  6.407E-09  1.310E-07
 TO JOINT     -4.662E-02 -2.315E+00 -6.734E-03  2.975E-07  2.694E-07 -6.578E-06
** LIMIT OF MEMBERS STRESS-STRAIN CURVE EXCEEDED ON PRECEEDING ITERATION

MEMBER     1 CONVERGED AFTER ITERATION     2


MEMBER     2 CONVERGED AFTER ITERATION     2


MEMBER     3 CONVERGED AFTER ITERATION     2

    4    1
FROM JOINT    -4.739E-03 -2.010E-01 -1.129E-02  1.003E-03  4.985E-06  2.050E-02
CENTERLINE    -4.525E-02 -1.815E+00 -8.026E-03  1.075E-02  1.036E-04  2.186E-02
 TO JOINT     -7.923E-02 -2.503E+00  1.772E-04  1.030E+00 -7.843E-01 -1.876E+01

    4    2
FROM JOINT    -4.738E-03 -2.010E-01 -1.129E-02  1.800E-08 -4.079E-09 -1.525E-07
CENTERLINE    -4.524E-02 -1.815E+00 -8.026E-03 -1.263E-08  1.617E-09 -6.007E-08
 TO JOINT     -7.923E-02 -2.503E+00  1.769E-04  4.285E-07  3.461E-09 -4.264E-06

MEMBER     4 CONVERGED AFTER ITERATION     2


MEMBER     5 CONVERGED AFTER ITERATION     2


MEMBER     6 CONVERGED AFTER ITERATION     2


MEMBER     7 CONVERGED AFTER ITERATION     2


MEMBER     8 CONVERGED AFTER ITERATION     2


    9    1
FROM JOINT     3.219E+00 -3.044E-01 -4.391E-03 -3.661E-02 -4.422E-04  1.110E-01
CENTERLINE     3.212E+00 -8.449E-01  6.983E-04  2.076E-03 -2.973E-04 -1.358E-02
 TO JOINT      3.205E+00 -3.149E-01  1.451E-03 -2.483E-04 -2.145E-05 -5.421E-02

    9    2
FROM JOINT     3.219E+00 -3.044E-01 -4.391E-03  2.538E-09  2.689E-09  1.102E-07
CENTERLINE     3.212E+00 -8.449E-01  6.983E-04  8.117E-10  6.461E-10  9.342E-09
 TO JOINT      3.205E+00 -3.149E-01  1.451E-03  5.439E-09 -2.031E-10  8.440E-10

MEMBER     9 CONVERGED AFTER ITERATION     2


MEMBER    10 CONVERGED AFTER ITERATION     2


MEMBER    11 CONVERGED AFTER ITERATION     2


MEMBER    12 CONVERGED AFTER ITERATION     1


MEMBER    13 CONVERGED AFTER ITERATION     2
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MEMBER   14 CONVERGED AFTER ITERATION    2


MEMBER   15 CONVERGED AFTER ITERATION    1


MEMBER   16 CONVERGED AFTER ITERATION    1


MEMBER   17 CONVERGED AFTER ITERATION    1


MEMBER   18 CONVERGED AFTER ITERATION    1


MEMBER   19 CONVERGED AFTER ITERATION    1


MEMBER   20 CONVERGED AFTER ITERATION    1


MEMBER   21 CONVERGED AFTER ITERATION    1


MEMBER   22 CONVERGED AFTER ITERATION    1



   15 JOINTS NOT CONVERGED AT END OF FRAME ITERATION    1


***** FRAME ITERATION NO    2 *****

 MEMB MEMB          MEMBER DISPLACEMENTS                  MEMBER EQULIBRIUM ERRORS
  NO  ITER       AXIAL  LATERAL  ROTATIONAL          AXIAL      LATERAL     ROTATIONAL

    1    1
FROM JOINT   -2.029E-03 -1.442E-02 -1.599E-03  2.515E-07 -1.317E-07 -4.409E-06
CENTERLINE   -2.344E-02 -9.989E-01 -8.719E-03  3.310E-06 -1.825E-07 -4.890E-05
 TO JOINT    -4.670E-02 -2.316E+00 -6.743E-03  5.440E-04 -3.711E-06 -9.463E-05
** LIMIT OF MEMBERS STRESS-STRAIN CURVE EXCEEDED ON PRECEEDING ITERATION

MEMBER    1 CONVERGED AFTER ITERATION    1


MEMBER    2 CONVERGED AFTER ITERATION    1


MEMBER    3 CONVERGED AFTER ITERATION    1



    4    1
FROM JOINT   -4.744E-03 -2.010E-01 -1.129E-02  3.621E-07 -3.283E-08 -5.583E-05
CENTERLINE   -4.530E-02 -1.816E+00 -8.030E-03  6.904E-07 -4.272E-08 -6.685E-05
 TO JOINT    -7.933E-02 -2.505E+00  1.708E-04  2.295E-04  3.743E-08 -8.799E-05

MEMBER    4 CONVERGED AFTER ITERATION    1


MEMBER    5 CONVERGED AFTER ITERATION    1


MEMBER    6 CONVERGED AFTER ITERATION    1


MEMBER    7 CONVERGED AFTER ITERATION    1


MEMBER    8 CONVERGED AFTER ITERATION    1


    9    1
FROM JOINT    3.222E+00 -3.047E-01 -4.392E-03 -5.134E-07  3.793E-08 -3.121E-06
CENTERLINE    3.215E+00 -8.452E-01  6.991E-04  8.038E-10  5.312E-11  1.925E-06
 TO JOINT     3.208E+00 -3.151E-01  1.450E-03  4.919E-07 -3.683E-08 -3.023E-06

MEMBER    9 CONVERGED AFTER ITERATION    1


MEMBER   10 CONVERGED AFTER ITERATION    1


MEMBER   11 CONVERGED AFTER ITERATION    1


MEMBER   12 CONVERGED AFTER ITERATION    1


MEMBER   13 CONVERGED AFTER ITERATION    1


MEMBER   14 CONVERGED AFTER ITERATION    1


MEMBER   15 CONVERGED AFTER ITERATION    1


MEMBER   16 CONVERGED AFTER ITERATION    1
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MEMBER 17 CONVERGED AFTER ITERATION 1

MEMBER 18 CONVERGED AFTER ITERATION 1

MEMBER 19 CONVERGED AFTER ITERATION 1

MEMBER 20 CONVERGED AFTER ITERATION 1

MEMBER 21 CONVERGED AFTER ITERATION 1

MEMBER 22 CONVERGED AFTER ITERATION 1

ALL JOINTS CONVERGED AT END OF ITERATION 2

SUMMARY OF FRAME ITERATIONS

JOINT	FRAME	JOINT DISPLACEMENTS			JOINT EQULIBRIUM ERRORS		
NO	ITER	DISP(X)	DISP(Y)	ROTATION(Z)	ERR(X)	ERR(Y)	ERR(Z)
1	1	3.371E-19	-1.576E-18	-5.391E-17	3.122E-03	3.505E-01	-6.132E-02
1	2	3.371E-19	-1.575E-18	-5.392E-17	6.258E-08	5.713E-08	-6.050E-07
2	1	2.434E+00	-4.721E-02	-6.682E-03	6.366E-02	-2.719E-01	-1.781E+01
2	2	2.436E+00	-4.729E-02	-6.692E-03	4.925E-05	-3.245E-04	-2.026E-04
3	1	3.226E+00	-7.524E-02	-4.001E-03	2.616E-02	-7.471E-02	-1.798E+00
3	2	3.229E+00	-7.535E-02	-4.003E-03	7.665E-07	-1.201E-05	-4.310E-06
6	1	4.849E-01	-3.855E-18	-9.165E-03	-1.220E-03	3.949E-01	2.349E-01
6	2	4.846E-01	-3.855E-18	-9.171E-03	3.234E-06	3.172E-05	-5.036E-05
11	1	2.443E-01	-3.579E-18	-9.189E-03	7.766E-04	3.479E-01	2.582E-01
11	2	2.440E-01	-3.579E-18	-9.193E-03	1.521E-06	1.084E-05	-2.439E-05

PROB (CONTD)
502 501 WITH COLUMNS RIGID WITHIN JOINTS

TABLE 8 - JOINT DISPLACEMENTS AND REACTIONS

	DISPLACEMENTS			REACTIONS		
JOINT	DISP(X)	DISP(Y)	ROTATION(Z)	REACT(X)	REACT(Y)	REACT(Z)
1	3.371E-19	-1.575E-18	-5.392E-17	-3.371E+01	1.575E+02	5.392E+03
2	2.436E+00	-4.729E-02	-6.692E-03	0.	0.	0.
3	3.229E+00	-7.535E-02	-4.003E-03	0.	0.	0.
4	2.461E+00	-7.477E-01	-4.040E-03	0.	0.	0.
5	2.461E+00	-4.660E-01	4.587E-03	0.	0.	0.
6	4.846E-01	-3.855E-18	-9.171E-03	-6.564E+00	3.855E+02	0.
7	2.475E+00	-1.012E-01	4.352E-04	0.	0.	0.
8	3.217E+00	-1.639E-01	4.444E-05	0.	0.	0.
9	2.479E+00	-2.188E-01	-1.605E-03	0.	0.	0.
10	2.479E+00	-1.662E-01	1.759E-03	0.	0.	0.
11	2.440E-01	-3.579E-18	-9.193E-03	-4.880E+00	3.579E+02	0.
12	2.481E+00	-9.537E-02	-1.387E-03	0.	0.	0.
13	3.209E+00	-1.601E-01	-8.218E-04	0.	0.	0.
14	2.492E+00	-3.864E-01	-2.599E-03	0.	0.	0.
15	2.492E+00	-3.195E-01	2.821E-03	0.	0.	0.
16	8.810E-20	-2.812E-18	-1.133E-02	-8.810E+00	2.812E+02	0.
17	2.501E+00	-7.969E-02	2.885E-04	0.	0.	0.
18	3.201E+00	-1.311E-01	1.699E-03	0.	0.	0.
19	2.502E+00	-1.111E-01	-4.669E-04	0.	0.	0.
20	3.196E+00	-2.493E-02	6.129E-04	0.	0.	0.

PROB (CONTD)
502 501 WITH COLUMNS RIGID WITHIN JOINTS

TABLE 9 - MEMBER RESULTS

MEMBER NUMBER 1 STIFF TYPE 1 LOAD TYPE 1
LENGTH = 3.555E+02 ALPHA = 0. BETA = 1.000E+00
GOES FROM JOINT 1 TO JOINT 2

OUTPUT DISTANCES ARE FROM JOINT 1 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	-1.575E-18	-3.371E-19	-5.392E-17	-1.575E+02	3.371E+01	-5.392E+03
1.777E+01	-2.029E-03	-1.442E-02	-1.599E-03	-1.573E+02	3.223E+01	-4.804E+03
3.555E+01	-4.095E-03	-5.564E-02	-3.018E-03	-1.571E+02	3.075E+01	-4.238E+03
5.332E+01	-6.228E-03	-1.205E-01	-4.262E-03	-1.568E+02	2.927E+01	-3.695E+03
7.109E+01	-8.445E-03	-2.060E-01	-5.339E-03	-1.566E+02	2.779E+01	-3.174E+03
8.886E+01	-1.075E-02	-3.092E-01	-6.257E-03	-1.564E+02	2.631E+01	-2.677E+03
1.066E+02	-1.315E-02	-4.274E-01	-7.023E-03	-1.562E+02	2.483E+01	-2.205E+03
1.244E+02	-1.563E-02	-5.578E-01	-7.644E-03	-1.559E+02	2.335E+01	-1.756E+03
1.422E+02	-1.818E-02	-6.981E-01	-8.129E-03	-1.557E+02	2.187E+01	-1.332E+03
1.600E+02	-2.079E-02	-8.459E-01	-8.484E-03	-1.555E+02	2.039E+01	-9.340E+02
1.777E+02	-2.344E-02	-9.989E-01	-8.719E-03	-1.552E+02	1.891E+01	-5.611E+02
1.955E+02	-2.611E-02	-1.155E+00	-8.840E-03	-1.550E+02	1.743E+01	-2.141E+02
2.133E+02	-2.880E-02	-1.312E+00	-8.857E-03	-1.548E+02	1.595E+01	1.068E+02
2.310E+02	-3.147E-02	-1.469E+00	-8.777E-03	-1.545E+02	1.447E+01	4.013E+02
2.488E+02	-3.412E-02	-1.624E+00	-8.609E-03	-1.543E+02	1.299E+01	6.691E+02
2.666E+02	-3.674E-02	-1.775E+00	-8.362E-03	-1.541E+02	1.151E+01	9.100E+02
2.844E+02	-3.931E-02	-1.920E+00	-8.043E-03	-1.538E+02	1.003E+01	1.124E+03
3.021E+02	-4.183E-02	-2.060E+00	-7.661E-03	-1.536E+02	8.545E+00	1.310E+03
3.199E+02	-4.430E-02	-2.192E+00	-7.225E-03	-1.534E+02	7.064E+00	1.469E+03
3.377E+02	-4.670E-02	-2.316E+00	-6.743E-03	-1.531E+02	5.584E+00	1.601E+03
3.555E+02	-4.729E-02	-2.436E+00	-6.692E-03	-1.529E+02	4.104E+00	1.705E+03

** LIMIT OF MEMBERS STRESS-STRAIN CURVE EXCEEDED ON THIS PROBLEM

PROB (CONTD)
502 501 WITH COLUMNS RIGID WITHIN JOINTS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 2 STIFF TYPE 1 LOAD TYPE 2
LENGTH = 3.555E+02 ALPHA = 0. BETA = 1.000E+00
GOES FROM JOINT 6 TO JOINT 7

OUTPUT DISTANCES ARE FROM JOINT 6 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	-3.855E-18	-4.846E-01	-9.171E-03	-3.855E+02	6.564E+00	-5.036E-05
1.777E+01	-5.691E-03	-6.474E-01	-9.143E-03	-3.853E+02	6.564E+00	1.794E+02
3.555E+01	-1.137E-02	-8.091E-01	-9.059E-03	-3.851E+02	6.564E+00	3.583E+02
5.332E+01	-1.703E-02	-9.689E-01	-8.919E-03	-3.848E+02	6.564E+00	5.364E+02
7.109E+01	-2.266E-02	-1.126E+00	-8.723E-03	-3.846E+02	6.564E+00	7.133E+02
8.886E+01	-2.825E-02	-1.278E+00	-8.471E-03	-3.844E+02	6.564E+00	8.887E+02
1.066E+02	-3.379E-02	-1.426E+00	-8.165E-03	-3.841E+02	6.564E+00	1.062E+03
1.244E+02	-3.929E-02	-1.568E+00	-7.805E-03	-3.839E+02	6.564E+00	1.233E+03
1.422E+02	-4.473E-02	-1.703E+00	-7.392E-03	-3.837E+02	6.564E+00	1.402E+03
1.600E+02	-5.010E-02	-1.831E+00	-6.926E-03	-3.834E+02	6.564E+00	1.567E+03
1.777E+02	-5.542E-02	-1.949E+00	-6.409E-03	-3.832E+02	6.564E+00	1.729E+03
1.955E+02	-6.067E-02	-2.058E+00	-5.841E-03	-3.830E+02	6.564E+00	1.888E+03
2.133E+02	-6.585E-02	-2.156E+00	-5.225E-03	-3.827E+02	6.564E+00	2.042E+03
2.310E+02	-7.098E-02	-2.243E+00	-4.561E-03	-3.825E+02	6.564E+00	2.192E+03
2.488E+02	-7.604E-02	-2.318E+00	-3.850E-03	-3.823E+02	6.564E+00	2.337E+03
2.666E+02	-8.106E-02	-2.380E+00	-3.095E-03	-3.821E+02	6.564E+00	2.477E+03
2.844E+02	-8.602E-02	-2.428E+00	-2.297E-03	-3.818E+02	6.564E+00	2.612E+03
3.021E+02	-9.095E-02	-2.461E+00	-1.457E-03	-3.816E+02	6.564E+00	2.742E+03
3.199E+02	-9.586E-02	-2.479E+00	-5.775E-04	-3.814E+02	6.564E+00	2.865E+03
3.377E+02	-1.008E-01	-2.481E+00	3.399E-04	-3.811E+02	6.564E+00	2.983E+03
3.555E+02	-1.012E-01	-2.475E+00	4.352E-04	-3.809E+02	6.564E+00	3.097E+03

PROB (CONTD)
502 501 WITH COLUMNS RIGID WITHIN JOINTS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 3 STIFF TYPE 1 LOAD TYPE 2
LENGTH = 3.555E+02 ALPHA = 0. BETA = 1.000E+00
GOES FROM JOINT 11 TO JOINT 12

OUTPUT DISTANCES ARE FROM JOINT 11 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	-3.579E-18	-2.440E-01	-9.193E-03	-3.579E+02	4.880E+00	-2.439E-05
1.777E+01	-5.341E-03	-4.072E-01	-9.170E-03	-3.577E+02	4.880E+00	1.451E+02
3.555E+01	-1.067E-02	-5.696E-01	-9.102E-03	-3.575E+02	4.880E+00	2.899E+02
5.332E+01	-1.598E-02	-7.303E-01	-8.988E-03	-3.572E+02	4.880E+00	4.340E+02
7.109E+01	-2.127E-02	-8.887E-01	-8.830E-03	-3.570E+02	4.880E+00	5.773E+02
8.886E+01	-2.653E-02	-1.044E+00	-8.626E-03	-3.568E+02	4.880E+00	7.193E+02
1.066E+02	-3.175E-02	-1.195E+00	-8.379E-03	-3.565E+02	4.880E+00	8.599E+02
1.244E+02	-3.693E-02	-1.341E+00	-8.087E-03	-3.563E+02	4.880E+00	9.988E+02
1.422E+02	-4.205E-02	-1.482E+00	-7.752E-03	-3.561E+02	4.880E+00	1.136E+03
1.600E+02	-4.713E-02	-1.616E+00	-7.375E-03	-3.559E+02	4.880E+00	1.270E+03
1.777E+02	-5.215E-02	-1.744E+00	-6.956E-03	-3.556E+02	4.880E+00	1.402E+03
1.955E+02	-5.712E-02	-1.863E+00	-6.495E-03	-3.554E+02	4.880E+00	1.531E+03
2.133E+02	-6.202E-02	-1.974E+00	-5.995E-03	-3.552E+02	4.880E+00	1.658E+03
2.310E+02	-6.687E-02	-2.076E+00	-5.456E-03	-3.549E+02	4.880E+00	1.780E+03
2.488E+02	-7.166E-02	-2.168E+00	-4.878E-03	-3.547E+02	4.880E+00	1.900E+03
2.666E+02	-7.640E-02	-2.249E+00	-4.264E-03	-3.545E+02	4.880E+00	2.015E+03
2.844E+02	-8.108E-02	-2.319E+00	-3.615E-03	-3.542E+02	4.880E+00	2.127E+03
3.021E+02	-8.573E-02	-2.377E+00	-2.930E-03	-3.540E+02	4.880E+00	2.234E+03
3.199E+02	-9.033E-02	-2.423E+00	-2.213E-03	-3.538E+02	4.880E+00	2.337E+03
3.377E+02	-9.490E-02	-2.456E+00	-1.465E-03	-3.535E+02	4.880E+00	2.435E+03
3.555E+02	-9.537E-02	-2.481E+00	-1.387E-03	-3.533E+02	4.880E+00	2.531E+03

PROB (CONTD)
502 501 WITH COLUMNS RIGID WITHIN JOINTS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 4 STIFF TYPE 1 LOAD TYPE 2
LENGTH = 3.555E+02 ALPHA = 0. BETA = 1.000E+00
GOES FROM JOINT 16 TO JOINT 17

OUTPUT DISTANCES ARE FROM JOINT 16 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	-2.812E-18	-8.810E-20	-1.133E-02	-2.812E+02	8.810E+00	-2.751E-05
1.777E+01	-4.744E-03	-2.010E-01	-1.129E-02	-2.810E+02	8.810E+00	2.131E+02
3.555E+01	-9.472E-03	-4.009E-01	-1.119E-02	-2.808E+02	8.810E+00	4.257E+02
5.332E+01	-1.417E-02	-5.984E-01	-1.103E-02	-2.805E+02	8.810E+00	6.377E+02
7.109E+01	-1.883E-02	-7.923E-01	-1.079E-02	-2.803E+02	8.810E+00	8.486E+02
8.886E+01	-2.343E-02	-9.815E-01	-1.049E-02	-2.801E+02	8.810E+00	1.058E+03
1.066E+02	-2.797E-02	-1.165E+00	-1.013E-02	-2.799E+02	8.810E+00	1.266E+03
1.244E+02	-3.243E-02	-1.341E+00	-9.701E-03	-2.796E+02	8.810E+00	1.472E+03
1.422E+02	-3.681E-02	-1.509E+00	-9.207E-03	-2.794E+02	8.810E+00	1.675E+03
1.600E+02	-4.110E-02	-1.668E+00	-8.650E-03	-2.792E+02	8.810E+00	1.876E+03
1.777E+02	-4.530E-02	-1.816E+00	-8.030E-03	-2.789E+02	8.810E+00	2.074E+03
1.955E+02	-4.941E-02	-1.953E+00	-7.349E-03	-2.787E+02	8.810E+00	2.269E+03
2.133E+02	-5.341E-02	-2.077E+00	-6.607E-03	-2.785E+02	8.810E+00	2.460E+03
2.310E+02	-5.733E-02	-2.187E+00	-5.806E-03	-2.782E+02	8.810E+00	2.647E+03
2.488E+02	-6.116E-02	-2.283E+00	-4.947E-03	-2.780E+02	8.810E+00	2.830E+03
2.666E+02	-6.490E-02	-2.363E+00	-4.031E-03	-2.778E+02	8.810E+00	3.009E+03
2.844E+02	-6.858E-02	-2.426E+00	-3.060E-03	-2.775E+02	8.810E+00	3.183E+03
3.021E+02	-7.220E-02	-2.471E+00	-2.034E-03	-2.773E+02	8.810E+00	3.352E+03
3.199E+02	-7.578E-02	-2.498E+00	-9.571E-04	-2.771E+02	8.810E+00	3.516E+03
3.377E+02	-7.933E-02	-2.505E+00	1.708E-04	-2.769E+02	8.810E+00	3.675E+03
3.555E+02	-7.969E-02	-2.501E+00	2.885E-04	-2.766E+02	8.810E+00	3.830E+03

PROB (CONTD)
502 501 WITH COLUMNS RIGID WITHIN JOINTS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 5 STIFF TYPE 2 LOAD TYPE 3
LENGTH = 2.925E+02 ALPHA = 0. BETA = 1.000E+00
GOES FROM JOINT 2 TO JOINT 3

OUTPUT DISTANCES ARE FROM JOINT 2 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	-4.729E-02	-2.436E+00	-6.692E-03	-7.381E+01	-1.392E+00	1.584E+03
1.463E+01	-4.777E-02	-2.533E+00	-6.608E-03	-7.370E+01	-2.611E+00	1.562E+03
2.925E+01	-4.952E-02	-2.624E+00	-5.787E-03	-7.360E+01	-3.829E+00	1.522E+03
4.388E+01	-5.120E-02	-2.703E+00	-4.993E-03	-7.350E+01	-5.047E+00	1.462E+03
5.851E+01	-5.283E-02	-2.770E+00	-4.235E-03	-7.340E+01	-6.266E+00	1.385E+03
7.314E+01	-5.440E-02	-2.827E+00	-3.524E-03	-7.329E+01	-7.484E+00	1.288E+03
8.776E+01	-5.594E-02	-2.873E+00	-2.869E-03	-7.319E+01	-8.703E+00	1.173E+03
1.024E+02	-5.745E-02	-2.911E+00	-2.280E-03	-7.309E+01	-9.921E+00	1.040E+03
1.170E+02	-5.894E-02	-2.941E+00	-1.767E-03	-7.299E+01	-1.114E+01	8.880E+02
1.316E+02	-6.042E-02	-2.963E+00	-1.339E-03	-7.289E+01	-1.236E+01	7.178E+02
1.463E+02	-6.189E-02	-2.980E+00	-1.007E-03	-7.278E+01	-1.358E+01	5.294E+02
1.609E+02	-6.335E-02	-2.993E+00	-7.804E-04	-7.268E+01	-1.480E+01	3.229E+02
1.755E+02	-6.480E-02	-3.004E+00	-6.683E-04	-7.258E+01	-1.601E+01	9.831E+01
1.902E+02	-6.625E-02	-3.013E+00	-6.805E-04	-7.248E+01	-1.723E+01	-1.441E+02
2.048E+02	-6.771E-02	-3.024E+00	-8.264E-04	-7.237E+01	-1.845E+01	-4.043E+02
2.194E+02	-6.916E-02	-3.038E+00	-1.116E-03	-7.227E+01	-1.967E+01	-6.820E+02
2.340E+02	-7.062E-02	-3.058E+00	-1.557E-03	-7.217E+01	-2.089E+01	-9.772E+02
2.487E+02	-7.208E-02	-3.085E+00	-2.160E-03	-7.207E+01	-2.211E+01	-1.290E+03
2.633E+02	-7.357E-02	-3.122E+00	-2.935E-03	-7.196E+01	-2.332E+01	-1.619E+03
2.779E+02	-7.510E-02	-3.172E+00	-3.889E-03	-7.186E+01	-2.454E+01	-1.966E+03
2.925E+02	-7.535E-02	-3.229E+00	-4.003E-03	-7.176E+01	-2.576E+01	-2.329E+03

PROB (CONTD)
502 501 WITH COLUMNS RIGID WITHIN JOINTS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 6 STIFF TYPE 3 LOAD TYPE 4
LENGTH = 3.113E+02 ALPHA = 0. BETA = 1.000E+00
GOES FROM JOINT 7 TO JOINT 8

ALL OUTPUT FORCES ARE WITH RESPECT TO THE MEMBER AXES

	AT JOINT 7		AT JOINT 8
AXIAL FORCE =	-1.598E+02	AXIAL FORCE =	1.132E+01
SHEAR =	-1.857E+03	SHEAR =	-1.577E+02
MOMENT =	1.132E+01	MOMENT =	1.785E+03

MEMBER NUMBER 7 STIFF TYPE 4 LOAD TYPE 5
LENGTH = 3.300E+02 ALPHA = 0. BETA = 1.000E+00
GOES FROM JOINT 12 TO JOINT 13

ALL OUTPUT FORCES ARE WITH RESPECT TO THE MEMBER AXES

	AT JOINT 12		AT JOINT 13
AXIAL FORCE =	-1.567E+02	AXIAL FORCE =	4.014E+00
SHEAR =	-6.702E+02	SHEAR =	-1.544E+02
MOMENT =	4.014E+00	MOMENT =	7.676E+02

MEMBER NUMBER 8 STIFF TYPE 5 LOAD TYPE 6
LENGTH = 3.488E+02 ALPHA = 0. BETA = 1.000E+00
GOES FROM JOINT 17 TO JOINT 18

ALL OUTPUT FORCES ARE WITH RESPECT TO THE MEMBER AXES

	AT JOINT 17		AT JOINT 18
AXIAL FORCE =	-1.169E+02	AXIAL FORCE =	1.043E+01
SHEAR =	-1.742E+03	SHEAR =	-1.145E+02
MOMENT =	1.043E+01	MOMENT =	1.975E+03

PROB (CONTD)
502 501 WITH COLUMNS RIGID WITHIN JOINTS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 9 STIFF TYPE 6 LOAD TYPE 7
LENGTH = 4.504E+02 ALPHA = 9.991E-01 BETA = 4.163E-02
GOES FROM JOINT 3 TO JOINT 8

OUTPUT DISTANCES ARE FROM JOINT 3 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	3.223E+00	-2.097E-01	-4.003E-03	-2.823E+01	5.863E+01	-2.329E+03
2.252E+01	3.222E+00	-3.047E-01	-4.392E-03	-2.804E+01	5.413E+01	-1.057E+03
4.504E+01	3.221E+00	-4.052E-01	-4.501E-03	-2.785E+01	4.963E+01	1.141E+02
6.756E+01	3.221E+00	-5.052E-01	-4.351E-03	-2.766E+01	4.513E+01	1.184E+03
9.008E+01	3.220E+00	-5.992E-01	-3.968E-03	-2.723E+01	3.464E+01	2.152E+03
1.126E+02	3.219E+00	-6.824E-01	-3.405E-03	-2.679E+01	2.414E+01	2.749E+03
1.351E+02	3.218E+00	-7.515E-01	-2.717E-03	-2.660E+01	1.964E+01	3.244E+03
1.576E+02	3.217E+00	-8.039E-01	-1.926E-03	-2.641E+01	1.513E+01	3.637E+03
1.802E+02	3.216E+00	-8.376E-01	-1.057E-03	-2.598E+01	4.635E+00	3.927E+03
2.027E+02	3.216E+00	-8.513E-01	-1.639E-04	-2.554E+01	-5.845E+00	3.847E+03
2.252E+02	3.215E+00	-8.452E-01	6.991E-04	-2.535E+01	-1.034E+01	3.664E+03
2.477E+02	3.214E+00	-8.202E-01	1.508E-03	-2.516E+01	-1.485E+01	3.380E+03
2.702E+02	3.214E+00	-7.779E-01	2.241E-03	-2.473E+01	-2.535E+01	2.994E+03
2.928E+02	3.213E+00	-7.204E-01	2.842E-03	-2.429E+01	-3.583E+01	2.236E+03
3.153E+02	3.212E+00	-6.515E-01	3.257E-03	-2.410E+01	-4.033E+01	1.377E+03
3.378E+02	3.211E+00	-5.755E-01	3.463E-03	-2.392E+01	-4.484E+01	4.158E+02
3.603E+02	3.210E+00	-4.975E-01	3.436E-03	-2.348E+01	-5.533E+01	-6.465E+02
3.828E+02	3.210E+00	-4.232E-01	3.123E-03	-2.304E+01	-6.582E+01	-2.080E+03
4.054E+02	3.209E+00	-3.597E-01	2.469E-03	-2.285E+01	-7.032E+01	-3.614E+03
4.279E+02	3.208E+00	-3.151E-01	1.450E-03	-2.267E+01	-7.482E+01	-5.250E+03
4.504E+02	3.208E+00	-2.977E-01	4.444E-05	-2.248E+01	-7.933E+01	-6.986E+03

PROB (CONTD)
502 501 WITH COLUMNS RIGID WITHIN JOINTS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 10 STIFF TYPE 6 LOAD TYPE 7
LENGTH = 4.504E+02 ALPHA = 9.991E-01 BETA = 4.163E-02
GOES FROM JOINT 8 TO JOINT 13

OUTPUT DISTANCES ARE FROM JOINT 8 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	3.208E+00	-2.977E-01	4.444E-05	-1.723E+01	6.667E+01	-5.201E+03
2.252E+01	3.207E+00	-3.088E-01	-9.839E-04	-1.704E+01	6.217E+01	-3.750E+03
4.504E+01	3.207E+00	-3.393E-01	-1.691E-03	-1.686E+01	5.767E+01	-2.400E+03
6.756E+01	3.206E+00	-3.824E-01	-2.099E-03	-1.667E+01	5.317E+01	-1.151E+03
9.008E+01	3.206E+00	-4.315E-01	-2.231E-03	-1.623E+01	4.268E+01	-3.618E+00
1.126E+02	3.205E+00	-4.810E-01	-2.143E-03	-1.579E+01	3.218E+01	7.726E+02
1.351E+02	3.205E+00	-5.266E-01	-1.888E-03	-1.561E+01	2.768E+01	1.447E+03
1.576E+02	3.204E+00	-5.648E-01	-1.489E-03	-1.542E+01	2.317E+01	2.021E+03
1.802E+02	3.204E+00	-5.927E-01	-9.708E-04	-1.498E+01	1.267E+01	2.492E+03
2.027E+02	3.204E+00	-6.080E-01	-3.867E-04	-1.454E+01	2.195E+00	2.592E+03
2.252E+02	3.203E+00	-6.100E-01	2.089E-04	-1.436E+01	-2.305E+00	2.591E+03
2.477E+02	3.203E+00	-5.987E-01	7.925E-04	-1.417E+01	-6.815E+00	2.488E+03
2.702E+02	3.202E+00	-5.746E-01	1.341E-03	-1.373E+01	-1.731E+01	2.284E+03
2.928E+02	3.202E+00	-5.390E-01	1.799E-03	-1.329E+01	-2.779E+01	1.708E+03
3.153E+02	3.202E+00	-4.948E-01	2.114E-03	-1.311E+01	-3.229E+01	1.031E+03
3.378E+02	3.201E+00	-4.452E-01	2.261E-03	-1.292E+01	-3.680E+01	2.521E+02
3.603E+02	3.201E+00	-3.945E-01	2.218E-03	-1.248E+01	-4.729E+01	-6.279E+02
3.828E+02	3.200E+00	-3.474E-01	1.930E-03	-1.204E+01	-5.778E+01	-1.879E+03
4.054E+02	3.200E+00	-3.101E-01	1.343E-03	-1.186E+01	-6.228E+01	-3.231E+03
4.279E+02	3.200E+00	-2.896E-01	4.334E-04	-1.167E+01	-6.678E+01	-4.685E+03
4.504E+02	3.199E+00	-2.935E-01	-8.218E-04	-1.148E+01	-7.129E+01	-6.240E+03

PROB (CONTD)
502 501 WITH COLUMNS RIGID WITHIN JOINTS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 11 STIFF TYPE 6 LOAD TYPE 7
LENGTH = 4.504E+02 ALPHA = 9.991E-01 BETA = 4.163E-02
GOES FROM JOINT 13 TO JOINT 18

OUTPUT DISTANCES ARE FROM JOINT 13 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	3.199E+00	-2.935E-01	-8.218E-04	-1.340E+01	7.115E+01	-5.472E+03
2.252E+01	3.199E+00	-3.247E-01	-1.901E-03	-1.321E+01	6.665E+01	-3.920E+03
4.504E+01	3.199E+00	-3.762E-01	-2.635E-03	-1.302E+01	6.215E+01	-2.469E+03
6.756E+01	3.198E+00	-4.406E-01	-3.047E-03	-1.284E+01	5.764E+01	-1.120E+03
9.008E+01	3.198E+00	-5.109E-01	-3.161E-03	-1.240E+01	4.715E+01	1.287E+02
1.126E+02	3.197E+00	-5.809E-01	-3.031E-03	-1.196E+01	3.666E+01	1.006E+03
1.351E+02	3.197E+00	-6.458E-01	-2.711E-03	-1.177E+01	3.216E+01	1.781E+03
1.576E+02	3.196E+00	-7.016E-01	-2.224E-03	-1.159E+01	2.764E+01	2.455E+03
1.802E+02	3.196E+00	-7.448E-01	-1.594E-03	-1.115E+01	1.715E+01	3.027E+03
2.027E+02	3.196E+00	-7.727E-01	-8.751E-04	-1.071E+01	6.667E+00	3.228E+03
2.252E+02	3.196E+00	-7.839E-01	-1.218E-04	-1.053E+01	2.167E+00	3.328E+03
2.477E+02	3.195E+00	-7.780E-01	6.427E-04	-1.034E+01	-2.342E+00	3.326E+03
2.702E+02	3.195E+00	-7.551E-01	1.395E-03	-9.900E+00	-1.284E+01	3.222E+03
2.928E+02	3.195E+00	-7.158E-01	2.081E-03	-9.463E+00	-2.332E+01	2.747E+03
3.153E+02	3.194E+00	-6.624E-01	2.646E-03	-9.276E+00	-2.782E+01	2.171E+03
3.378E+02	3.194E+00	-5.978E-01	3.067E-03	-9.088E+00	-3.233E+01	1.493E+03
3.603E+02	3.194E+00	-5.256E-01	3.320E-03	-8.651E+00	-4.282E+01	7.137E+02
3.828E+02	3.193E+00	-4.501E-01	3.352E-03	-8.214E+00	-5.331E+01	-4.368E+02
4.054E+02	3.193E+00	-3.770E-01	3.108E-03	-8.026E+00	-5.781E+01	-1.689E+03
4.279E+02	3.193E+00	-3.127E-01	2.565E-03	-7.839E+00	-6.231E+01	-3.042E+03
4.504E+02	3.192E+00	-2.642E-01	1.699E-03	-7.651E+00	-6.681E+01	-4.496E+03

PROB (CONTD)
502 501 WITH COLUMNS RIGID WITHIN JOINTS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 12 STIFF TYPE 7 LOAD TYPE 8
LENGTH = 1.201E+02 ALPHA = 9.991E-01 BETA = 4.163E-02
GOES FROM JOINT 18 TO JOINT 20

OUTPUT DISTANCES ARE FROM JOINT 18 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	3.192E+00	-2.642E-01	1.699E-03	-1.500E+00	3.599E+01	-2.521E+03
6.005E+00	3.192E+00	-2.545E-01	1.551E-03	-1.450E+00	3.479E+01	-2.308E+03
1.201E+01	3.192E+00	-2.456E-01	1.415E-03	-1.400E+00	3.359E+01	-2.103E+03
1.802E+01	3.192E+00	-2.374E-01	1.293E-03	-1.350E+00	3.239E+01	-1.905E+03
2.402E+01	3.192E+00	-2.300E-01	1.182E-03	-1.300E+00	3.119E+01	-1.714E+03
3.003E+01	3.192E+00	-2.232E-01	1.082E-03	-1.250E+00	2.999E+01	-1.531E+03
3.603E+01	3.192E+00	-2.170E-01	9.940E-04	-1.200E+00	2.879E+01	-1.354E+03
4.204E+01	3.192E+00	-2.113E-01	9.162E-04	-1.150E+00	2.759E+01	-1.185E+03
4.804E+01	3.192E+00	-2.060E-01	8.486E-04	-1.100E+00	2.639E+01	-1.023E+03
5.405E+01	3.192E+00	-2.010E-01	7.906E-04	-1.050E+00	2.519E+01	-8.678E+02
6.005E+01	3.192E+00	-1.964E-01	7.420E-04	-9.995E-01	2.399E+01	-7.202E+02
6.606E+01	3.192E+00	-1.921E-01	7.022E-04	-9.495E-01	2.279E+01	-5.797E+02
7.206E+01	3.192E+00	-1.880E-01	6.707E-04	-8.995E-01	2.159E+01	-4.465E+02
7.807E+01	3.192E+00	-1.840E-01	6.472E-04	-8.495E-01	2.039E+01	-3.204E+02
8.407E+01	3.192E+00	-1.802E-01	6.312E-04	-7.992E-01	1.918E+01	-2.016E+02
9.008E+01	3.192E+00	-1.764E-01	6.223E-04	-4.994E-01	1.199E+01	-9.006E+01
9.608E+01	3.192E+00	-1.727E-01	6.178E-04	-2.000E-01	4.799E+00	-5.764E+01
1.021E+02	3.192E+00	-1.690E-01	6.150E-04	-1.500E-01	3.599E+00	-3.242E+01
1.081E+02	3.192E+00	-1.653E-01	6.136E-04	-9.996E-02	2.399E+00	-1.441E+01
1.141E+02	3.192E+00	-1.616E-01	6.130E-04	-4.996E-02	1.199E+00	-3.599E+00
1.201E+02	3.192E+00	-1.580E-01	6.129E-04	3.293E-06	3.016E-04	6.775E-04

PROB (CONTD)
502 501 WITH COLUMNS RIGID WITHIN JOINTS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 13 STIFF TYPE 8 LOAD TYPE 9
LENGTH = 1.201E+02 ALPHA = 9.993E-01 BETA = 3.789E-02
GOES FROM JOINT 2 TO JOINT 4

OUTPUT DISTANCES ARE FROM JOINT 2 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	2.432E+00	-1.396E-01	-6.692E-03	3.138E+00	6.227E+01	1.209E+02
6.004E+00	2.432E+00	-1.797E-01	-6.683E-03	3.195E+00	6.077E+01	4.902E+02
1.201E+01	2.432E+00	-2.198E-01	-6.664E-03	3.252E+00	5.928E+01	8.504E+02
1.801E+01	2.432E+00	-2.597E-01	-6.633E-03	3.309E+00	5.778E+01	1.202E+03
2.402E+01	2.432E+00	-2.994E-01	-6.591E-03	3.366E+00	5.628E+01	1.544E+03
3.002E+01	2.432E+00	-3.388E-01	-6.538E-03	3.423E+00	5.478E+01	1.877E+03
3.603E+01	2.432E+00	-3.779E-01	-6.472E-03	3.479E+00	5.328E+01	2.201E+03
4.203E+01	2.432E+00	-4.165E-01	-6.394E-03	3.536E+00	5.178E+01	2.517E+03
4.803E+01	2.431E+00	-4.546E-01	-6.302E-03	3.593E+00	5.028E+01	2.823E+03
5.404E+01	2.431E+00	-4.922E-01	-6.197E-03	3.650E+00	4.878E+01	3.120E+03
6.004E+01	2.431E+00	-5.290E-01	-6.078E-03	3.707E+00	4.728E+01	3.409E+03
6.605E+01	2.431E+00	-5.651E-01	-5.944E-03	3.764E+00	4.578E+01	3.688E+03
7.205E+01	2.431E+00	-6.004E-01	-5.796E-03	3.820E+00	4.429E+01	3.958E+03
7.806E+01	2.431E+00	-6.347E-01	-5.631E-03	3.877E+00	4.279E+01	4.219E+03
8.406E+01	2.431E+00	-6.680E-01	-5.450E-03	3.934E+00	4.129E+01	4.472E+03
9.006E+01	2.431E+00	-7.001E-01	-5.252E-03	4.313E+00	3.130E+01	4.715E+03
9.607E+01	2.431E+00	-7.310E-01	-5.038E-03	4.692E+00	2.130E+01	4.847E+03
1.021E+02	2.431E+00	-7.605E-01	-4.811E-03	4.749E+00	1.980E+01	4.970E+03
1.081E+02	2.431E+00	-7.887E-01	-4.569E-03	4.805E+00	1.830E+01	5.085E+03
1.141E+02	2.431E+00	-8.154E-01	-4.312E-03	4.862E+00	1.681E+01	5.190E+03
1.201E+02	2.431E+00	-8.404E-01	-4.040E-03	4.919E+00	1.531E+01	5.286E+03

PROB (CONTD)
502 501 WITH COLUMNS RIGID WITHIN JOINTS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 14 STIFF TYPE 9 LOAD TYPE 10
LENGTH = 2.100E+02 ALPHA = 1.000E+00 BETA = 0.
GOES FROM JOINT 4 TO JOINT 5

OUTPUT DISTANCES ARE FROM JOINT 4 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	2.461E+00	-7.477E-01	-4.040E-03	5.496E+00	1.511E+01	5.286E+03
1.050E+01	2.461E+00	-7.871E-01	-3.458E-03	5.496E+00	1.248E+01	5.431E+03
2.100E+01	2.461E+00	-8.203E-01	-2.863E-03	5.496E+00	9.859E+00	5.548E+03
3.150E+01	2.461E+00	-8.472E-01	-2.256E-03	5.496E+00	7.234E+00	5.638E+03
4.200E+01	2.461E+00	-8.677E-01	-1.640E-03	5.496E+00	4.609E+00	5.700E+03
5.250E+01	2.461E+00	-8.816E-01	-1.020E-03	5.496E+00	-4.441E-01	5.734E+03
6.300E+01	2.461E+00	-8.891E-01	-4.000E-04	5.496E+00	-1.157E+01	5.690E+03
7.350E+01	2.461E+00	-8.901E-01	2.068E-04	5.496E+00	-2.027E+01	5.491E+03
8.400E+01	2.461E+00	-8.848E-01	7.905E-04	5.496E+00	-2.289E+01	5.265E+03
9.450E+01	2.461E+00	-8.736E-01	1.348E-03	5.496E+00	-2.552E+01	5.011E+03
1.050E+02	2.461E+00	-8.566E-01	1.877E-03	5.496E+00	-2.814E+01	4.729E+03
1.155E+02	2.461E+00	-8.343E-01	2.373E-03	5.496E+00	-3.077E+01	4.420E+03
1.260E+02	2.461E+00	-8.069E-01	2.834E-03	5.496E+00	-3.339E+01	4.083E+03
1.365E+02	2.461E+00	-7.749E-01	3.258E-03	5.496E+00	-3.602E+01	3.719E+03
1.470E+02	2.461E+00	-7.387E-01	3.640E-03	5.496E+00	-4.471E+01	3.327E+03
1.575E+02	2.461E+00	-6.987E-01	3.972E-03	5.496E+00	-5.584E+01	2.781E+03
1.680E+02	2.461E+00	-6.555E-01	4.240E-03	5.496E+00	-6.089E+01	2.155E+03
1.785E+02	2.461E+00	-6.099E-01	4.438E-03	5.496E+00	-6.352E+01	1.502E+03
1.890E+02	2.461E+00	-5.626E-01	4.564E-03	5.496E+00	-6.614E+01	8.219E+02
1.995E+02	2.461E+00	-5.144E-01	4.615E-03	5.496E+00	-6.877E+01	1.139E+02
2.100E+02	2.461E+00	-4.660E-01	4.587E-03	5.496E+00	-7.139E+01	-6.217E+02

** LIMIT OF MEMBERS STRESS-STRAIN CURVE EXCEEDED ON THIS PROBLEM

PROB (CONTD)
502 501 WITH COLUMNS RIGID WITHIN JOINTS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 15 STIFF TYPE 10 LOAD TYPE 11
LENGTH = 1.201E+02 ALPHA = 9.993E-01 BETA = -3.789E-02
GOES FROM JOINT 5 TO JOINT 7

OUTPUT DISTANCES ARE FROM JOINT 5 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	2.477E+00	-3.724E-01	4.587E-03	2.789E+00	-7.153E+01	-6.217E+02
6.004E+00	2.477E+00	-3.450E-01	4.544E-03	2.732E+00	-7.303E+01	-1.056E+03
1.201E+01	2.477E+00	-3.179E-01	4.480E-03	2.675E+00	-7.453E+01	-1.499E+03
1.801E+01	2.477E+00	-2.912E-01	4.397E-03	2.619E+00	-7.603E+01	-1.951E+03
2.402E+01	2.477E+00	-2.651E-01	4.296E-03	2.562E+00	-7.753E+01	-2.411E+03
3.002E+01	2.477E+00	-2.397E-01	4.178E-03	2.183E+00	-8.752E+01	-2.881E+03
3.603E+01	2.477E+00	-2.150E-01	4.041E-03	1.804E+00	-9.751E+01	-3.462E+03
4.203E+01	2.477E+00	-1.912E-01	3.884E-03	1.747E+00	-9.901E+01	-4.052E+03
4.803E+01	2.477E+00	-1.684E-01	3.709E-03	1.690E+00	-1.005E+02	-4.651E+03
5.404E+01	2.477E+00	-1.467E-01	3.516E-03	1.633E+00	-1.020E+02	-5.259E+03
6.004E+01	2.477E+00	-1.262E-01	3.306E-03	1.577E+00	-1.035E+02	-5.876E+03
6.605E+01	2.477E+00	-1.070E-01	3.081E-03	1.520E+00	-1.050E+02	-6.502E+03
7.205E+01	2.477E+00	-8.924E-02	2.840E-03	1.463E+00	-1.065E+02	-7.137E+03
7.806E+01	2.477E+00	-7.294E-02	2.584E-03	1.406E+00	-1.080E+02	-7.781E+03
8.406E+01	2.477E+00	-5.823E-02	2.314E-03	1.349E+00	-1.095E+02	-8.434E+03
9.006E+01	2.477E+00	-4.517E-02	2.032E-03	1.292E+00	-1.110E+02	-9.096E+03
9.607E+01	2.477E+00	-3.386E-02	1.736E-03	1.236E+00	-1.125E+02	-9.767E+03
1.021E+02	2.477E+00	-2.435E-02	1.428E-03	1.179E+00	-1.140E+02	-1.045E+04
1.081E+02	2.477E+00	-1.673E-02	1.108E-03	1.122E+00	-1.155E+02	-1.114E+04
1.141E+02	2.477E+00	-1.106E-02	7.772E-04	1.065E+00	-1.170E+02	-1.183E+04
1.201E+02	2.477E+00	-7.411E-03	4.352E-04	1.008E+00	-1.185E+02	-1.254E+04

** LIMIT OF MEMBERS STRESS-STRAIN CURVE EXCEEDED ON THIS PROBLEM

PROB (CONTD)
502 501 WITH COLUMNS RIGID WITHIN JOINTS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 16 STIFF TYPE 8 LOAD TYPE 9
LENGTH = 1.201E+02 ALPHA = 9.993E-01 BETA = 3.789E-02
GOES FROM JOINT 7 TO JOINT 9

OUTPUT DISTANCES ARE FROM JOINT 7 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	2.469E+00	-1.949E-01	4.352E-04	-2.517E+00	8.565E+01	-7.588E+03
6.004E+00	2.469E+00	-1.929E-01	2.294E-04	-2.460E+00	8.415E+01	-7.078E+03
1.201E+01	2.469E+00	-1.922E-01	3.261E-05	-2.403E+00	8.265E+01	-6.577E+03
1.801E+01	2.469E+00	-1.925E-01	-1.550E-04	-2.347E+00	8.115E+01	-6.086E+03
2.402E+01	2.469E+00	-1.940E-01	-3.330E-04	-2.290E+00	7.965E+01	-5.603E+03
3.002E+01	2.469E+00	-1.965E-01	-5.012E-04	-2.233E+00	7.815E+01	-5.129E+03
3.603E+01	2.469E+00	-2.000E-01	-6.593E-04	-2.176E+00	7.665E+01	-4.664E+03
4.203E+01	2.469E+00	-2.044E-01	-8.068E-04	-2.119E+00	7.515E+01	-4.209E+03
4.803E+01	2.469E+00	-2.097E-01	-9.433E-04	-2.062E+00	7.365E+01	-3.762E+03
5.404E+01	2.469E+00	-2.157E-01	-1.069E-03	-2.006E+00	7.216E+01	-3.324E+03
6.004E+01	2.469E+00	-2.225E-01	-1.182E-03	-1.949E+00	7.066E+01	-2.895E+03
6.605E+01	2.469E+00	-2.299E-01	-1.283E-03	-1.892E+00	6.916E+01	-2.476E+03
7.205E+01	2.469E+00	-2.379E-01	-1.372E-03	-1.835E+00	6.766E+01	-2.065E+03
7.806E+01	2.469E+00	-2.463E-01	-1.447E-03	-1.778E+00	6.616E+01	-1.663E+03
8.406E+01	2.469E+00	-2.552E-01	-1.508E-03	-1.721E+00	6.466E+01	-1.270E+03
9.006E+01	2.469E+00	-2.644E-01	-1.554E-03	-1.342E+00	5.467E+01	-8.866E+02
9.607E+01	2.469E+00	-2.738E-01	-1.588E-03	-9.636E-01	4.467E+01	-6.139E+02
1.021E+02	2.469E+00	-2.834E-01	-1.610E-03	-9.067E-01	4.318E+01	-3.501E+02
1.081E+02	2.469E+00	-2.931E-01	-1.621E-03	-8.499E-01	4.168E+01	-9.535E+01
1.141E+02	2.469E+00	-3.029E-01	-1.619E-03	-7.931E-01	4.018E+01	1.504E+02
1.201E+02	2.469E+00	-3.126E-01	-1.605E-03	-7.362E-01	3.868E+01	3.872E+02

PROB (CONTD)
502 501 WITH COLUMNS RIGID WITHIN JOINTS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 17 STIFF TYPE 9 LOAD TYPE 10
LENGTH = 2.100E+02 ALPHA = 1.000E+00 BETA = 0.
GOES FROM JOINT 9 TO JOINT 10

OUTPUT DISTANCES ARE FROM JOINT 9 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	2.479E+00	-2.188E-01	-1.605E-03	7.200E-01	3.868E+01	3.871E+02
1.050E+01	2.479E+00	-2.354E-01	-1.542E-03	7.200E-01	3.605E+01	7.795E+02
2.100E+01	2.479E+00	-2.510E-01	-1.438E-03	7.200E-01	3.343E+01	1.144E+03
3.150E+01	2.479E+00	-2.654E-01	-1.295E-03	7.200E-01	3.080E+01	1.481E+03
4.200E+01	2.479E+00	-2.781E-01	-1.118E-03	7.200E-01	2.818E+01	1.791E+03
5.250E+01	2.479E+00	-2.887E-01	-9.080E-04	7.200E-01	2.312E+01	2.073E+03
6.300E+01	2.479E+00	-2.971E-01	-6.720E-04	7.200E-01	1.200E+01	2.277E+03
7.350E+01	2.479E+00	-3.028E-01	-4.222E-04	7.200E-01	3.303E+00	2.325E+03
8.400E+01	2.479E+00	-3.059E-01	-1.688E-04	7.200E-01	6.776E-01	2.346E+03
9.450E+01	2.479E+00	-3.063E-01	8.548E-05	7.200E-01	-1.947E+00	2.339E+03
1.050E+02	2.479E+00	-3.041E-01	3.375E-04	7.200E-01	-4.572E+00	2.305E+03
1.155E+02	2.479E+00	-2.993E-01	5.843E-04	7.200E-01	-7.197E+00	2.243E+03
1.260E+02	2.479E+00	-2.919E-01	8.230E-04	7.200E-01	-9.822E+00	2.154E+03
1.365E+02	2.479E+00	-2.820E-01	1.050E-03	7.200E-01	-1.245E+01	2.037E+03
1.470E+02	2.479E+00	-2.699E-01	1.264E-03	7.200E-01	-2.114E+01	1.893E+03
1.575E+02	2.479E+00	-2.556E-01	1.453E-03	7.200E-01	-3.227E+01	1.593E+03
1.680E+02	2.479E+00	-2.395E-01	1.605E-03	7.200E-01	-3.732E+01	1.215E+03
1.785E+02	2.479E+00	-2.221E-01	1.715E-03	7.200E-01	-3.995E+01	8.093E+02
1.890E+02	2.479E+00	-2.037E-01	1.779E-03	7.200E-01	-4.257E+01	3.761E+02
1.995E+02	2.479E+00	-1.849E-01	1.795E-03	7.200E-01	-4.520E+01	-8.469F+01
2.100E+02	2.479E+00	-1.662E-01	1.759E-03	7.200E-01	-4.782E+01	-5.730E+02

PROB (CONTD)
502 501 WITH COLUMNS RIGID WITHIN JOINTS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 18 STIFF TYPE 10 LOAD TYPE 11
LENGTH = 1.201E+02 ALPHA = 9.993E-01 BETA = -3.789E-02
GOES FROM JOINT 10 TO JOINT 12

OUTPUT DISTANCES ARE FROM JOINT 10 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	2.483E+00	-7.214E-02	1.759E-03	-1.090E+00	-4.782E+01	-5.730E+02
6.004E+00	2.483E+00	-6.169E-02	1.722E-03	-1.146E+00	-4.932E+01	-8.646E+02
1.201E+01	2.483E+00	-5.149E-02	1.671E-03	-1.203E+00	-5.082E+01	-1.165E+03
1.801E+01	2.483E+00	-4.164E-02	1.608E-03	-1.260E+00	-5.231E+01	-1.475E+03
2.402E+01	2.483E+00	-3.221E-02	1.532E-03	-1.317E+00	-5.381E+01	-1.793E+03
3.002E+01	2.483E+00	-2.327E-02	1.445E-03	-1.696E+00	-6.381E+01	-2.121E+03
3.603E+01	2.483E+00	-1.489E-02	1.344E-03	-2.075E+00	-7.380E+01	-2.560E+03
4.203E+01	2.483E+00	-7.163E-03	1.228E-03	-2.132E+00	-7.530E+01	-3.007E+03
4.803E+01	2.483E+00	-1.751E-04	1.098E-03	-2.188E+00	-7.680E+01	-3.464E+03
5.404E+01	2.483E+00	5.989E-03	9.536E-04	-2.245E+00	-7.830E+01	-3.930E+03
6.004E+01	2.483E+00	1.125E-02	7.966E-04	-2.302E+00	-7.979E+01	-4.404E+03
6.605E+01	2.483E+00	1.553E-02	6.271E-04	-2.359E+00	-8.129E+01	-4.888E+03
7.205E+01	2.483E+00	1.876E-02	4.457E-04	-2.416E+00	-8.279E+01	-5.380E+03
7.806E+01	2.483E+00	2.086E-02	2.527E-04	-2.473E+00	-8.429E+01	-5.882E+03
8.406E+01	2.483E+00	2.177E-02	4.866E-05	-2.529E+00	-8.579E+01	-6.393E+03
9.006E+01	2.483E+00	2.143E-02	-1.660E-04	-2.586E+00	-8.729E+01	-6.912E+03
9.607E+01	2.483E+00	1.976E-02	-3.910E-04	-2.643E+00	-8.879E+01	-7.441E+03
1.021E+02	2.483E+00	1.671E-02	-6.259E-04	-2.700E+00	-9.029E+01	-7.979E+03
1.081E+02	2.483E+00	1.223E-02	-8.704E-04	-2.757E+00	-9.179E+01	-8.525E+03
1.141E+02	2.483E+00	6.246E-03	-1.124E-03	-2.814E+00	-9.328E+01	-9.081E+03
1.201E+02	2.483E+00	-1.286E-03	-1.387E-03	-2.870E+00	-9.478E+01	-9.645E+03

PROB (CONTD)
502 501 WITH COLUMNS RIGID WITHIN JOINTS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 19 STIFF TYPE 8 LOAD TYPE 9
LENGTH = 1.201E+02 ALPHA = 9.993E-01 BETA = 3.789E-02
GOES FROM JOINT 12 TO JOINT 14

OUTPUT DISTANCES ARE FROM JOINT 12 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	2.476E+00	-1.893E-01	-1.387E-03	-1.624E+00	8.478E+01	-6.444E+03
6.004E+00	2.476E+00	-1.982E-01	-1.561E-03	-1.567E+00	8.329E+01	-5.940E+03
1.201E+01	2.476E+00	-2.080E-01	-1.725E-03	-1.511E+00	8.179E+01	-5.444E+03
1.801E+01	2.476E+00	-2.189E-01	-1.879E-03	-1.454E+00	8.029E+01	-4.957E+03
2.402E+01	2.476E+00	-2.306E-01	-2.023E-03	-1.397E+00	7.879E+01	-4.480E+03
3.002E+01	2.476E+00	-2.431E-01	-2.156E-03	-1.340E+00	7.729E+01	-4.011E+03
3.603E+01	2.476E+00	-2.564E-01	-2.278E-03	-1.283E+00	7.579E+01	-3.552E+03
4.203E+01	2.476E+00	-2.705E-01	-2.388E-03	-1.226E+00	7.429E+01	-3.101E+03
4.803E+01	2.476E+00	-2.851E-01	-2.487E-03	-1.170E+00	7.279E+01	-2.659E+03
5.404E+01	2.476E+00	-3.003E-01	-2.573E-03	-1.113E+00	7.129E+01	-2.227E+03
6.004E+01	2.476E+00	-3.160E-01	-2.647E-03	-1.056E+00	6.980E+01	-1.803E+03
6.605E+01	2.476E+00	-3.320E-01	-2.707E-03	-9.991E-01	6.830E+01	-1.389E+03
7.205E+01	2.476E+00	-3.484E-01	-2.753E-03	-9.422E-01	6.680E+01	-9.831E+02
7.806E+01	2.476E+00	-3.651E-01	-2.785E-03	-8.854E-01	6.530E+01	-5.865E+02
8.406E+01	2.476E+00	-3.819E-01	-2.801E-03	-8.286E-01	6.380E+01	-1.989E+02
9.006E+01	2.476E+00	-3.987E-01	-2.801E-03	-4.497E-01	5.381E+01	1.797E+02
9.607E+01	2.476E+00	-4.155E-01	-2.787E-03	-7.079E-02	4.381E+01	4.473E+02
1.021E+02	2.475E+00	-4.321E-01	-2.761E-03	-1.396E-02	4.232E+01	7.058E+02
1.081E+02	2.475E+00	-4.486E-01	-2.721E-03	4.288E-02	4.082E+01	9.554E+02
1.141E+02	2.475E+00	-4.648E-01	-2.667E-03	9.971E-02	3.932E+01	1.196E+03
1.201E+02	2.475E+00	-4.806E-01	-2.599E-03	1.565E-01	3.782E+01	1.428E+03

PROB (CONTD)
502 501 WITH COLUMNS RIGID WITHIN JOINTS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 20 STIFF TYPE 9 LOAD TYPE 10
LENGTH = 2.100E+02 ALPHA = 1.000E+00 BETA = 0.
GOES FROM JOINT 14 TO JOINT 15

OUTPUT DISTANCES ARE FROM JOINT 14 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	2.492E+00	-3.864E-01	-2.599E-03	1.587E+00	3.779E+01	1.428E+03
1.050E+01	2.492E+00	-4.128E-01	-2.423E-03	1.587E+00	3.516E+01	1.811E+03
2.100E+01	2.492E+00	-4.372E-01	-2.207E-03	1.587E+00	3.254E+01	2.166E+03
3.150E+01	2.492E+00	-4.590E-01	-1.955E-03	1.587E+00	2.991E+01	2.494E+03
4.200E+01	2.492E+00	-4.781E-01	-1.668E-03	1.587E+00	2.729E+01	2.794E+03
5.250E+01	2.492E+00	-4.939E-01	-1.350E-03	1.587E+00	2.223E+01	3.067E+03
6.300E+01	2.492E+00	-5.063E-01	-1.006E-03	1.587E+00	1.111E+01	3.261E+03
7.350E+01	2.492E+00	-5.150E-01	-6.502E-04	1.587E+00	2.413E+00	3.300E+03
8.400E+01	2.492E+00	-5.200E-01	-2.914E-04	1.587E+00	-2.122E-01	3.312E+03
9.450E+01	2.492E+00	-5.211E-01	6.712E-05	1.587E+00	-2.837E+00	3.296E+03
1.050E+02	2.492E+00	-5.186E-01	4.224E-04	1.587E+00	-5.462E+00	3.252E+03
1.155E+02	2.492E+00	-5.123E-01	7.715E-04	1.587E+00	-8.087E+00	3.181E+03
1.260E+02	2.492E+00	-5.024E-01	1.111E-03	1.587E+00	-1.071E+01	3.082E+03
1.365E+02	2.492E+00	-4.890E-01	1.439E-03	1.587E+00	-1.334E+01	2.956E+03
1.470E+02	2.492E+00	-4.722E-01	1.751E-03	1.587E+00	-2.203E+01	2.802E+03
1.575E+02	2.492E+00	-4.523E-01	2.039E-03	1.587E+00	-3.316E+01	2.493E+03
1.680E+02	2.492E+00	-4.296E-01	2.288E-03	1.587E+00	-3.821E+01	2.106E+03
1.785E+02	2.492E+00	-4.044E-01	2.494E-03	1.587E+00	-4.084E+01	1.691E+03
1.890E+02	2.492E+00	-3.774E-01	2.654E-03	1.587E+00	-4.346E+01	1.248E+03
1.995E+02	2.492E+00	-3.489E-01	2.764E-03	1.587E+00	-4.609E+01	7.783E+02
2.100E+02	2.492E+00	-3.195E-01	2.821E-03	1.587E+00	-4.871E+01	2.806E+02

PROB (CONTD)
502 501 WITH COLUMNS RIGID WITHIN JOINTS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 21 STIFF TYPE 10 LOAD TYPE 11
LENGTH = 1.201E+02 ALPHA = 9.993E-01 BETA = -3.789E-02
GOES FROM JOINT 15 TO JOINT 17

OUTPUT DISTANCES ARE FROM JOINT 15 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	2.502E+00	-2.249E-01	2.821E-03	-2.459E-01	-4.874E+01	2.806E+02
6.004E+00	2.502E+00	-2.079E-01	2.828E-03	-3.027E-01	-5.023E+01	-1.653E+01
1.201E+01	2.502E+00	-1.910E-01	2.820E-03	-3.595E-01	-5.173E+01	-3.227E+02
1.801E+01	2.502E+00	-1.741E-01	2.797E-03	-4.164E-01	-5.323E+01	-6.378E+02
2.402E+01	2.502E+00	-1.574E-01	2.760E-03	-4.732E-01	-5.473E+01	-9.619E+02
3.002E+01	2.502E+00	-1.410E-01	2.709E-03	-8.521E-01	-6.472E+01	-1.295E+03
3.603E+01	2.502E+00	-1.249E-01	2.644E-03	-1.231E+00	-7.472E+01	-1.739E+03
4.203E+01	2.502E+00	-1.093E-01	2.562E-03	-1.288E+00	-7.622E+01	-2.192E+03
4.803E+01	2.502E+00	-9.418E-02	2.464E-03	-1.345E+00	-7.771E+01	-2.654E+03
5.404E+01	2.502E+00	-7.972E-02	2.352E-03	-1.401E+00	-7.921E+01	-3.126E+03
6.004E+01	2.502E+00	-6.597E-02	2.225E-03	-1.458E+00	-8.071E+01	-3.606E+03
6.605E+01	2.502E+00	-5.303E-02	2.085E-03	-1.515E+00	-8.221E+01	-4.095E+03
7.205E+01	2.502E+00	-4.096E-02	1.931E-03	-1.572E+00	-8.371E+01	-4.593E+03
7.806E+01	2.502E+00	-2.986E-02	1.765E-03	-1.629E+00	-8.521E+01	-5.100E+03
8.406E+01	2.502E+00	-1.979E-02	1.587E-03	-1.686E+00	-8.671E+01	-5.616E+03
9.006E+01	2.502E+00	-1.083E-02	1.397E-03	-1.742E+00	-8.821E+01	-6.141E+03
9.607E+01	2.502E+00	-3.039E-03	1.196E-03	-1.799E+00	-8.971E+01	-6.676E+03
1.021E+02	2.502E+00	3.514E-03	9.845E-04	-1.856E+00	-9.120E+01	-7.219E+03
1.081E+02	2.502E+00	8.764E-03	7.624E-04	-1.913E+00	-9.270E+01	-7.771E+03
1.141E+02	2.502E+00	1.265E-02	5.303E-04	-1.970E+00	-9.420E+01	-8.332E+03
1.201E+02	2.502E+00	1.512E-02	2.885E-04	-2.027E+00	-9.570E+01	-8.902E+03

PROB (CONTD)
502 501 WITH COLUMNS RIGID WITHIN JOINTS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 22 STIFF TYPE 8 LOAD TYPE 9
LENGTH = 1.201E+02 ALPHA = 9.993E-01 BETA = 3.789E-02
GOES FROM JOINT 17 TO JOINT 19

OUTPUT DISTANCES ARE FROM JOINT 17 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	2.496E+00	-1.744E-01	2.885E-04	-1.780E+00	4.697E+01	-3.330E+03
6.004E+00	2.496E+00	-1.729E-01	1.990E-04	-1.723E+00	4.547E+01	-3.053E+03
1.201E+01	2.496E+00	-1.720E-01	1.148E-04	-1.666E+00	4.397E+01	-2.784E+03
1.801E+01	2.496E+00	-1.715E-01	3.619E-05	-1.609E+00	4.247E+01	-2.525E+03
2.402E+01	2.496E+00	-1.715E-01	-3.690E-05	-1.553E+00	4.097E+01	-2.274E+03
3.002E+01	2.496E+00	-1.720E-01	-1.044E-04	-1.496E+00	3.947E+01	-2.033E+03
3.603E+01	2.496E+00	-1.728E-01	-1.662E-04	-1.439E+00	3.797E+01	-1.800E+03
4.203E+01	2.496E+00	-1.739E-01	-2.224E-04	-1.382E+00	3.647E+01	-1.577E+03
4.803E+01	2.496E+00	-1.754E-01	-2.727E-04	-1.325E+00	3.498E+01	-1.362E+03
5.404E+01	2.496E+00	-1.772E-01	-3.172E-04	-1.268E+00	3.348E+01	-1.157E+03
6.004E+01	2.496E+00	-1.792E-01	-3.558E-04	-1.212E+00	3.198E+01	-9.600E+02
6.605E+01	2.496E+00	-1.815E-01	-3.885E-04	-1.155E+00	3.048E+01	-7.725E+02
7.205E+01	2.496E+00	-1.839E-01	-4.151E-04	-1.098E+00	2.898E+01	-5.940E+02
7.806E+01	2.496E+00	-1.864E-01	-4.356E-04	-1.041E+00	2.748E+01	-4.245E+02
8.406E+01	2.496E+00	-1.891E-01	-4.499E-04	-9.842E-01	2.598E+01	-2.640E+02
9.006E+01	2.496E+00	-1.918E-01	-4.580E-04	-6.053E-01	1.599E+01	-1.125E+02
9.607E+01	2.496E+00	-1.946E-01	-4.622E-04	-2.264E-01	5.996E+00	-7.201E+01
1.021E+02	2.496E+00	-1.974E-01	-4.648E-04	-1.696E-01	4.497E+00	-4.050E+01
1.081E+02	2.496E+00	-2.002E-01	-4.662E-04	-1.127E-01	2.998E+00	-1.800E+01
1.141E+02	2.496E+00	-2.030E-01	-4.667E-04	-5.590E-02	1.499E+00	-4.501E+00
1.201E+02	2.496E+00	-2.058E-01	-4.669E-04	9.309E-04	2.422E-04	5.543E-04

SOIL SUPPORTED BENT - GALATI RUMANIA
THREE BATTERED PILES

PROB (CONTD)
502 501 WITH COLUMNS RIGID WITHIN JOINTS

TABLE 10 - JOINT EQUILIBRIUM ERRORS

JOINT	ERR(X) FORCE	ERR(Y) FORCE	ERR(Z) MOMENT
1	6.258E-08	5.713E-08	-6.050E-07
2	4.925E-05	-3.245E-04	-2.026E-04
3	7.665E-07	-1.201E-05	-4.310E-06
4	-7.028E-07	2.731E-06	-8.782E-06
5	1.787E-03	-1.424E-02	-4.143E-02
6	3.234E-06	3.172E-05	-5.036E-05
7	-9.927E-03	1.219E-02	-1.087E-01
8	-1.498E-07	-1.149E-05	-3.770E-06
9	-9.872E-03	1.813E-03	-1.188E-02
10	2.982E-03	1.922E-03	1.301E-02
11	1.521E-06	1.084E-05	-2.439E-05
12	4.311E-04	-3.906E-04	3.442E-02
13	-1.897E-07	-1.949E-05	-2.237E-06
14	-2.650E-03	-2.226E-03	1.489E-02
15	1.416E-02	-2.532E-03	-1.255E-02
16	1.713E-06	9.819E-06	-2.751E-05
17	1.617E-02	1.172E-02	-3.947E-02
18	2.327E-05	-5.074E-04	-1.727E-03
19	-9.394E-04	2.067E-04	-5.543E-04
20	-1.585E-05	3.012E-04	-6.775E-04

SOIL SUPPORTED BENT - GALATI RUMANIA
THREE BATTERED PILES

PROB

901 Q = 0 KIPS

TABLE 1 - PROGRAM CONTROL DATA
PROBLEM TYPE 1

INPUT TABLES

TABLE NUMBER	HOLD DATA FROM LAST PROBLEM (1 = YES,0 = NO)	NUMBER OF CARDS ADDED FOR THIS PROBLEM
2	-0	15
3	-0	15
4A	-0	1
4B	-0	0
4C	-0	0
5A	-0	20
5B	-0	9
5C	-0	4
5D	-0	12
6	-0	10
7	-0	2

OUTPUT TABLES

TABLE NUMBER	SUPPRESS OUTPUT (1 = YES,0 = NO)
8	-0
9	-0
10	-0

PROB (CONTD)
901 Q = 0 KIPS

TABLE 2 - FRAME GEOMETRY DATA

NUMBER OF JOINTS IN FRAME = 15
REFERENCE JOINT IS JOINT 1 AT X = -0. AND Y = -0.
JOINT TOLERANCE IS 1.000E-03

INPUT OF JOINT OFFSETS

FROM JOINT	X-OFFSET	Y-OFFSET	TO JOINT	TO	TO	TO	TO	TO	TO
1	5.580E+01	-0.	2						
2	6.250E+01	-0.	3						
1	-7.300E+00	-2.970E+01	4						
4	-4.600E+01	-1.840E+02	7						
7	-3.100E+01	-1.240E+02	10						
10	-8.250E+01	-3.300E+02	13						
2	4.867E+00	-2.970E+01	5						
5	3.067E+01	-1.840E+02	8						
8	2.067E+01	-1.240E+02	11						
11	5.685E+01	-3.410E+02	14						
3	4.867E+00	-2.970E+01	6						
6	3.067E+01	-1.840E+02	9						
9	2.067E+01	-1.240E+02	12						
12	5.685E+01	-3.410E+02	15						

COMPUTED JOINT COORDINATES

JOINT	X	Y
1	-0.	-0.
2	5.580E+01	0.
3	1.183E+02	0.
4	-7.300E+00	-2.970E+01
5	6.067E+01	-2.970E+01
6	1.232E+02	-2.970E+01
7	-5.330E+01	-2.137E+02
8	9.134E+01	-2.137E+02
9	1.538E+02	-2.137E+02
10	-8.430E+01	-3.377E+02
11	1.120E+02	-3.377E+02
12	1.745E+02	-3.377E+02
13	-1.668E+02	-6.677E+02
14	1.689E+02	-6.787E+02
15	2.314E+02	-6.787E+02

*** COMPUTED MEMBER NUMBERS MAY NOT AGREE WITH LAST PROBLEM ***

PROB (CONTD)
901 Q = 0 KIPS

TABLE 3 - MEMBER LOCATION DATA

NUMBER OF MEMBER STIFFNESS TYPES = 10
NUMBER OF MEMBER LOAD TYPES = 10
NUMBER OF ELEMENTS PER MEMBER = 10

INPUT OF MEMBER LOCATIONS

FROM JOINT	STIFF TYPE	LOAD TYPE	TO JOINT	TO	TO	TO	TO	TO	TO	TO	TO	TO
1	1	1	2									
2	2	2	3									
1	3	3	4									
4	5	5	7									
7	7	7	10									
10	9	9	13									
2	4	4	5									
3	4	4	6									
5	6	6	8									
6	6	6	9									
8	8	8	11									
9	8	8	12									
11	10	10	14									
12	10	10	15									

COMPUTED MEMBER NUMBERS,LENGTHS,AND OFFSETS

MEMBER NUMB	FROM JOINT	TO JOINT	STIFF TYPE	LOAD TYPE	LENGTH	X-OFFSET	Y-OFFSET
1	1	2	1	1	5.580E+01	5.580E+01	0.
2	2	3	2	2	6.250E+01	6.250E+01	0.
3	1	4	3	3	3.058E+01	-7.300E+00	-2.970E+01
4	4	7	5	5	1.897E+02	-4.600E+01	-1.840E+02
5	7	10	7	7	1.278E+02	-3.100E+01	-1.240E+02
6	10	13	9	9	3.402E+02	-8.250E+01	-3.300E+02
7	2	5	4	4	3.010E+01	4.867E+00	-2.970E+01
8	3	6	4	4	3.010E+01	4.867E+00	-2.970E+01
9	5	8	6	6	1.865E+02	3.067E+01	-1.840E+02
10	6	9	6	6	1.865E+02	3.067E+01	-1.840E+02
11	8	11	8	8	1.257E+02	2.067E+01	-1.240E+02
12	9	12	8	8	1.257E+02	2.067E+01	-1.240E+02
13	11	14	10	10	3.457E+02	5.685E+01	-3.410E+02
14	12	15	10	10	3.457E+02	5.685E+01	-3.410E+02

PROB (CONTD)
901 Q = 0 KIPS

TABLE 4A - JOINT LOADS AND LINEAR RESTRAINTS

INPUT OF JOINT DATA

JOINT	FORCE(X)	FORCE(Y)	MOMENT(Z)	SPRING(X)	SPRING(Y)	SPRING(Z)
2	-0.	-1.520E+01	-4.360E+01	-0.	-0.	-0.

ACCUMULATED JOINT DATA

SAME AS INPUT FOR THIS PROBLEM

TABLE 4B - JOINT SUPPORT CURVE NUMBERS

NO DATA

TABLE 4C - JOINT SUPPORT CURVES

NO DATA

PROB (CONTD)
901 Q = 0 KIPS

TABLE 5A - MEMBER STIFFNESS DATA

STIFF TYPE	MOD OF ELAST	PRISMATIC I	PRISMATIC A	NON LIN	NUMB CRDS	AXIS OPT	OUTPUT OPT	PIN FROM	PIN TO
1	-0.	-0.	-0.	1	1	1	-0	-0	-0

STIFF TYPE 1 CONT

FROM JOINT NA	NSX	NSY	NSZ	TO JOINT NA	NSX	NSY	NSZ	Q - MULT	W - MULT
1	-0	-0	-0	1	-0	-0	-0	-0.	-0.

STIFF TYPE	MOD OF ELAST	PRISMATIC I	PRISMATIC A	NON LIN	NUMB CRDS	AXIS OPT	OUTPUT OPT	PIN FROM	PIN TO
2	-0.	-0.	-0.	1	1	1	-0	-0	-0

STIFF TYPE 2 CONT

FROM JOINT NA	NSX	NSY	NSZ	TO JOINT NA	NSX	NSY	NSZ	Q - MULT	W - MULT
1	-0	-0	-0	1	-0	-0	-0	-0.	-0.

STIFF TYPE	MOD OF ELAST	PRISMATIC I	PRISMATIC A	NON LIN	NUMB CRDS	AXIS OPT	OUTPUT OPT	PIN FROM	PIN TO
3	-0.	-0.	-0.	1	1	1	-0	-40	-0

STIFF TYPE 3 CONT

FROM JOINT NA	NSX	NSY	NSZ	TO JOINT NA	NSX	NSY	NSZ	Q - MULT	W - MULT
2	-0	-0	-0	2	-0	-0	-0	-0.	-0.

STIFF TYPE	MOD OF ELAST	PRISMATIC I	PRISMATIC A	NON LIN	NUMB CRDS	AXIS OPT	OUTPUT OPT	PIN FROM	PIN TO
4	-0.	-0.	-0.	1	1	1	-0	-40	-0

STIFF TYPE 4 CONT

FROM JOINT NA	NSX	NSY	NSZ	TO JOINT NA	NSX	NSY	NSZ	Q - MULT	W - MULT
2	-0	-0	-0	2	-0	-0	-0	-0.	-0.

```
STIFF  MOD OF    PRISMATIC PRISMATIC  NON NUMB AXIS  OUTPUT   PIN  PIN
 TYPE  ELAST         I          A     LIN CRDS  OPT   OPT    FROM   TO


   5-0.        -0.        -0.              1    1    1   -0          -0   -0

STIFF TYPE    5 CONT
    FROM JOINT                  TO JOINT
   NA  NSX  NSY  NSZ         NA  NSX  NSY  NSZ        Q - MULT    W - MULT
    2    1    4   -0          2    2    5   -0      -1.000E-04  1.000E-03


STIFF  MOD OF    PRISMATIC PRISMATIC  NON NUMB AXIS  OUTPUT   PIN  PIN
 TYPE  ELAST         I          A     LIN CRDS  OPT   OPT    FROM   TO


   6-0.        -0.        -0.              1    1    1   -0          -0   -0

STIFF TYPE    6 CONT
    FROM JOINT                  TO JOINT
   NA  NSX  NSY  NSZ         NA  NSX  NSY  NSZ        Q - MULT    W - MULT
    2    1    4   -0          2    2    5   -0      -1.000E-04  1.000E-03


STIFF  MOD OF    PRISMATIC PRISMATIC  NON NUMB AXIS  OUTPUT   PIN  PIN
 TYPE  ELAST         I          A     LIN CRDS  OPT   OPT    FROM   TO


   7-0.        -0.        -0.              1    1    1   -0          -0   -0

STIFF TYPE    7 CONT
    FROM JOINT                  TO JOINT
   NA  NSX  NSY  NSZ         NA  NSX  NSY  NSZ        Q - MULT    W - MULT
    2    2    5   -0          2    3    6   -0      -1.000E-04  1.000E-03


STIFF  MOD OF    PRISMATIC PRISMATIC  NON NUMB AXIS  OUTPUT   PIN  PIN
 TYPE  ELAST         I          A     LIN CRDS  OPT   OPT    FROM   TO


   8-0.        -0.        -0.              1    1    1   -0          -0   -0

STIFF TYPE    8 CONT
    FROM JOINT                  TO JOINT
   NA  NSX  NSY  NSZ         NA  NSX  NSY  NSZ        Q - MULT    W - MULT
    2    2    5   -0          2    3    6   -0      -1.000E-04  1.000E-03


STIFF  MOD OF    PRISMATIC PRISMATIC  NON NUMB AXIS  OUTPUT   PIN  PIN
 TYPE  ELAST         I          A     LIN CRDS  OPT   OPT    FROM   TO


   9-0.        -0.        -0.              1    1    1   -0          -0   -0

STIFF TYPE    9 CONT
    FROM JOINT                  TO JOINT
   NA  NSX  NSY  NSZ         NA  NSX  NSY  NSZ        Q - MULT    W - MULT
    2    3    6   -0          2    3    6   -0      -1.000E-04  1.000E-03


STIFF  MOD OF    PRISMATIC PRISMATIC  NON NUMB AXIS  OUTPUT   PIN  PIN
 TYPE  ELAST         I          A     LIN CRDS  OPT   OPT    FROM   TO


  10-0.        -0.        -0.              1    1    1   -0          -0   -0

STIFF TYPE   10 CONT
    FROM JOINT                  TO JOINT
   NA  NSX  NSY  NSZ         NA  NSX  NSY  NSZ        Q - MULT    W - MULT
    2    3    6   -0          2    3    6   -0      -1.000E-04  1.000E-03


TABLE 5B - CROSS SECTION DATA


INPUT OF CROSS SECTIONS
CROSS NUMB WIDTH OR  DEPTH OR   Y-CENT  RECT=0 SIG-EP   SIG-MULT   EP-MULT

SECT  CRDS  O-DIAM   THICKNESS          PIPE=1  NUMB

    1    3
           3.150E+01 3.540E+01 0.          -0     1       1.000E-02 1.000E-05
           1.220E+00 1.000E+00 1.370E+01   -0     2       1.000E+00 1.000E-05
           1.220E+00 1.000E+00-1.370E+01   -0     2       1.000E+00 1.000E-05
    2    4
           1.575E+01 1.575E+01 0.          -0     1       1.000E-02 1.000E-05
           2.286E+00 1.000E+00 6.695E+00   -0     2       1.000E+00 1.000E-05
           2.286E+00 1.000E+00-6.695E+00   -0     2       1.000E+00 1.000E-05
           1.524E+00 1.000E+00 0.          -0     2       1.000E+00 1.000E-05


TABLE 5C - STRESS STRAIN CURVES


CURVE NUMB SYMT (1 = YES,
NUMB  PTS  OPT   0 = NO)

    1   10    0
SIG                   -257 -302 -283 -227 -132    0   28   14    0    0

EPS                   -400 -192 -144  -96  -48    0   10   30  200 2000

    2    3    1
SIG                      0   54   54

EPS                      0  183 1830


TABLE 5D - SUPPORT CURVES FOR MEMBERS


CURVE NUMB SYMT (1 = YES,
NUMB  PTS  OPT   0 = NO)

    1    8    1
Q                        0  184  353  507  614  768  798  798
```

```
W                  0   25   50   75  100  150  200  250

  2    8    1
Q                  0  219  405  569  712  876  909  909

W                  0   25   50   75  100  150  200  250

  3    8    1
Q                 -0 2276 3986 4380 4073 3635 3635 3635

W                  0   25   50   75  100  150  200  250

  4    9    1
Q                  0  372  469  590  743  850 1008 1179 1179

W                  0   10   20   39   79  118  197  315 3150

  5    9    1
Q                  0 1074 1356 1705 2149 2458 2916 3410 3410

W                  0   10   20   39   79  118  197  315 3150

  6    9    1
Q                  0 3178 4011 5045 6357 7275 86271009010090

W                  0   10   20   39   79  118  197  315 3150
```

PROB (CONTD)
901 Q = 0 KIPS

TABLE 6 - MEMBER LOAD DATA

LOAD TYPE	UNIFORM QX	UNIFORM QY	NO CARDS	AXIS OPT
1	-0.	-9.700E-02	-0	2
2	-0.	-9.700E-02	-0	2
3	-0.	-2.100E-02	-0	2
4	-0.	-2.100E-02	-0	2
5	-0.	-2.100E-02	-0	2
6	-0.	-2.100E-02	-0	2
7	-0.	-2.100E-02	-0	2
8	-0.	-2.100E-02	-0	2
9	-0.	-2.100E-02	-0	2
10	-0.	-2.100E-02	-0	2

PROB (CONTD)
901 Q = 0 KIPS

TABLE 7 - ITERATION CONTROL

FRAME SOLUTION

NUMB ITER	FORCE ERROR	MOMENT ERROR	MONITOR JOINTS
10	1.000E-01	1.000E+01	1 4 7 10 13

MEMBER SOLUTIONS

NUMB ITER	FORCE ERROR	MOMENT ERROR	MONITOR MEMBERS
10	1.000E-02	1.000E+00	1 3 6 9 12

***** FRAME ITERATION NO 1 *****

MEMB NO	MEMB ITER		MEMBER DISPLACEMENTS AXIAL	LATERAL	ROTATIONAL	MEMBER EQULIBRIUM ERRORS AXIAL	LATERAL	ROTATIONAL
1	1							
		FROM JOINT	-1.188E-03	-1.109E-02	-2.966E-05	1.476E-02	-6.410E-02	2.992E-04
		CENTERLINE	-1.206E-03	-1.169E-02	-2.270E-05	2.353E-02	5.105E-03	-1.769E-02
		TO JOINT	-1.224E-03	-1.204E-02	-7.099E-06	1.483E-02	5.368E-03	-5.530E-03
1	2							
		FROM JOINT	-1.188E-03	-1.109E-02	-2.966E-05	5.483E-06	1.323E-05	7.375E-05
		CENTERLINE	-1.206E-03	-1.169E-02	-2.270E-05	4.268E-08	3.541E-09	8.353E-08
		TO JOINT	-1.224E-03	-1.204E-02	-7.101E-06	1.686E-07	4.049E-09	1.705E-07

MEMBER 1 CONVERGED AFTER ITERATION 2

MEMBER 2 CONVERGED AFTER ITERATION 2

MEMB NO	MEMB ITER							
3	1							
		FROM JOINT	1.089E-02	1.368E-03	-2.934E-05	-8.142E-05	3.967E-05	-3.202E-02
		CENTERLINE	1.085E-02	1.020E-03	-2.591E-05	-5.659E-05	8.213E-04	-2.908E-02
		TO JOINT	1.071E-02	7.580E-04	-1.727E-05	-2.864E-05	6.429E-04	-1.992E-02

MEMBER 3 CONVERGED AFTER ITERATION 1

MEMBER 4 CONVERGED AFTER ITERATION 1

MEMBER 5 CONVERGED AFTER ITERATION 1

MEMB NO	MEMB ITER							
6	1							
		FROM JOINT	6.268E-03	1.565E-04	-6.471E-08	-3.813E-03	-2.767E-03	-1.001E-06
		CENTERLINE	5.272E-03	1.605E-04	-4.926E-10	-2.870E-03	7.884E-05	-1.181E-07
		TO JOINT	4.877E-03	1.603E-04	9.303E-11	-2.497E-03	-2.114E-06	1.617E-09

MEMBER 6 CONVERGED AFTER ITERATION 1

MEMBER 7 CONVERGED AFTER ITERATION 1

MEMBER 8 CONVERGED AFTER ITERATION 1

MEMB NO	MEMB ITER							
9	1							
		FROM JOINT	1.123E-02	-2.647E-03	2.603E-05	1.501E-04	-3.677E-03	5.727E-03
		CENTERLINE	1.024E-02	-8.301E-04	1.601E-05	-3.643E-05	2.307E-03	3.817E-03
		TO JOINT	9.169E-03	-2.525E-04	2.310E-06	3.565E-05	1.013E-03	5.951E-04

MEMBER 9 CONVERGED AFTER ITERATION 1

MEMBER 10 CONVERGED AFTER ITERATION 1

MEMBER 11 CONVERGED AFTER ITERATION 1

MEMB NO	MEMB ITER							
12	1							
		FROM JOINT	7.907E-03	-2.357E-04	1.235E-06	4.388E-04	-1.559E-04	4.205E-04
		CENTERLINE	7.240E-03	-1.690E-04	1.262E-06	3.786E-04	-1.647E-05	4.213E-04
		TO JOINT	6.616E-03	-1.209E-04	5.990E-07	2.130E-04	1.671E-04	1.782E-04

MEMBER 12 CONVERGED AFTER ITERATION 1

MEMBER 13 CONVERGED AFTER ITERATION 1

MEMBER 14 CONVERGED AFTER ITERATION 1

1 JOINTS NOT CONVERGED AT END OF FRAME ITERATION 1

***** FRAME ITERATION NO 2 *****

MEMB NO	MEMB ITER		MEMBER DISPLACEMENTS AXIAL	LATERAL	ROTATIONAL	MEMBER EQULIBRIUM ERRORS AXIAL	LATERAL	ROTATIONAL
1	1							
		FROM JOINT	-1.213E-03	-1.110E-02	-2.948E-05	1.176E-05	2.798E-05	1.626E-04
		CENTERLINE	-1.232E-03	-1.170E-02	-2.257E-05	-4.551E-07	-2.843E-07	4.215E-06
		TO JOINT	-1.251E-03	-1.204E-02	-7.084E-06	-1.008E-07	-2.118E-07	5.461E-07

MEMBER 1 CONVERGED AFTER ITERATION 1

MEMBER 2 CONVERGED AFTER ITERATION 1

3	1							
		FROM JOINT	1.091E-02	1.347E-03	-2.915E-05	6.096E-09	2.292E-09	4.329E-07
		CENTERLINE	1.086E-02	1.001E-03	-2.568E-05	4.549E-09	1.194E-08	4.166E-07
		TO JOINT	1.073E-02	7.426E-04	-1.700E-05	2.255E-09	-4.253E-10	4.883E-07

MEMBER 3 CONVERGED AFTER ITERATION 1

MEMBER 4 CONVERGED AFTER ITERATION 1

MEMBER 5 CONVERGED AFTER ITERATION 1

6	1							
		FROM JOINT	6.279E-03	1.565E-04	-9.111E-08	-2.194E-05	-1.014E-04	-1.347E-08
		CENTERLINE	5.279E-03	1.606E-04	-2.122E-09	-1.553E-05	2.038E-05	-3.126E-10
		TO JOINT	4.884E-03	1.603E-04	3.525E-10	-1.399E-05	2.436E-07	-2.310E-11

MEMBER 6 CONVERGED AFTER ITERATION 1

MEMBER 7 CONVERGED AFTER ITERATION 1

MEMBER 8 CONVERGEO AFTER ITERATION 1

9	1							
		FROM JOINT	1.123E-02	-2.670E-03	2.632E-05	2.256E-08	-6.874E-05	-6.201E-08
		CENTERLINE	1.024E-02	-8.278E-04	1.622E-05	-4.897E-08	6.522E-05	-4.628E-08
		TO JOINT	9.173E-03	-2.498E-04	2.222E-06	-2.578E-08	-2.962E-05	1.946E-08

MEMBER 9 CONVERGED AFTER ITERATION 1

MEMBER 10 CONVERGED AFTER ITERATION 1

MEMBER 11 CONVERGED AFTER ITERATION 1

12	1							
		FROM JOINT	7.917E-03	-2.343E-04	1.216E-06	1.413E-07	5.773E-06	-1.886E-09
		CENTERLINE	7.249E-03	-1.688E-04	1.243E-06	6.781E-08	-3.314E-07	-1.936E-09
		TO JOINT	6.626E-03	-1.215E-04	5.892E-07	-2.562E-07	-6.852E-06	-3.801E-10

MEMBER 12 CONVERGED AFTER ITERATION 1

MEMBER 13 CONVERGED AFTER ITERATION 1

MEMBER 14 CONVERGED AFTER ITERATION 1

ALL JOINTS CONVERGED AT END OF ITERATION 2

SUMMARY OF FRAME ITERATIONS

JOINT NO	FRAME ITER	JOINT DISPLACEMENTS DISP(X)	DISP(Y)	ROTATION(Z)	JOINT EQULIBRIUM ERRORS ERR(X)	ERR(Y)	ERR(Z)
1	1	-1.184E-03	-1.092E-02	-2.967E-05	9.192E-02	-4.947E-02	-1.115E-01
1	2	-1.209E-03	-1.094E-02	-2.948E-05	1.082E-02	7.770E-04	1.306E-02
4	1	-1.862E-03	-1.054E-02	-1.548E-05	9.544E-03	-3.064E-03	-1.065E-02
4	2	-1.880E-03	-1.055E-02	-1.521E-05	-9.543E-03	2.567E-03	-5.933E-02
7	1	-1.597E-03	-8.186E-03	-2.812E-06	-9.160E-04	5.762E-04	-8.240E-04
7	2	-1.601E-03	-8.199E-03	-2.820E-06	1.791E-03	-2.568E-03	-3.955E-02
10	1	-1.447E-03	-6.474E-03	-5.633E-07	-4.135E-03	-2.367E-02	-1.355E-04
10	2	-1.450E-03	-6.486E-03	-5.626E-07	4.791E-04	1.167E-02	-2.645E-02
13	1	-1.023E-03	-4.755E-03	1.575E-10	3.021E-04	1.203E-03	3.898E-10
13	2	-1.025E-03	-4.762E-03	1.741E-10	2.698E-03	1.081E-02	2.565E-04

PROB (CONTD)
901 Q = 0 KIPS

TABLE 8 - JOINT DISPLACEMENTS AND REACTIONS

	DISPLACEMENTS			REACTIONS		
JOINT	DISP(X)	DISP(Y)	ROTATION(Z)	REACT(X)	REACT(Y)	REACT(Z)
1	-1.209E-03	-1.094E-02	-2.948E-05	0.	0.	0.
2	-1.256E-03	-1.207E-02	-2.246E-06	0.	0.	0.
3	-1.285E-03	-1.082E-02	3.260E-05	0.	0.	0.
4	-1.880E-03	-1.055E-02	-1.521E-05	0.	0.	0.
5	-1.155E-03	-1.182E-02	1.680E-05	0.	0.	0.
6	-3.765E-04	-1.047E-02	2.951E-05	0.	0.	0.
7	-1.601E-03	-8.199E-03	-2.820E-06	0.	0.	0.
8	1.248E-03	-8.807E-03	1.376E-06	0.	0.	0.
9	1.084E-03	-8.014E-03	1.108E-06	0.	0.	0.
10	-1.450E-03	-6.486E-03	-5.626E-07	0.	0.	0.
11	1.047E-03	-6.988E-03	3.704E-07	0.	0.	0.
12	9.526E-04	-6.415E-03	4.141E-07	0.	0.	0.
13	-1.025E-03	-4.762E-03	1.741E-10	0.	0.	0.
14	7.304E-04	-5.042E-03	-4.151E-11	0.	0.	0.
15	6.742E-04	-4.705E-03	-9.421E-11	0.	0.	0.

PROB (CONTD)
901 Q = 0 KIPS

TABLE 9 - MEMBER RESULTS

MEMBER NUMBER 1 STIFF TYPE 1 LOAD TYPE 1
LENGTH = 5.580E+01 ALPHA = 1.000E+00 BETA = 0.
GOES FROM JOINT 1 TO JOINT 2

OUTPUT DISTANCES ARE FROM JOINT 1 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	-1.209E-03	-1.094E-02	-2.948E-05	-2.541E+00	8.509E+00	-2.267E+01
5.580E+00	-1.213E-03	-1.110E-02	-2.948E-05	-2.541E+00	7.967E+00	2.330E+01
1.116E+01	-1.218E-03	-1.126E-02	-2.873E-05	-2.541E+00	7.426E+00	6.625E+01
1.674E+01	-1.223E-03	-1.142E-02	-2.730E-05	-2.541E+00	6.885E+00	1.062E+02
2.232E+01	-1.227E-03	-1.157E-02	-2.523E-05	-2.541E+00	6.344E+00	1.431E+02
2.790E+01	-1.232E-03	-1.170E-02	-2.257E-05	-2.541E+00	5.802E+00	1.770E+02
3.348E+01	-1.237E-03	-1.182E-02	-1.938E-05	-2.541E+00	5.261E+00	2.078E+02
3.906E+01	-1.241E-03	-1.192E-02	-1.570E-05	-2.541E+00	4.720E+00	2.357E+02
4.464E+01	-1.246E-03	-1.199E-02	-1.159E-05	-2.541E+00	4.179E+00	2.605E+02
5.022E+01	-1.251E-03	-1.204E-02	-7.084E-06	-2.541E+00	3.637E+00	2.823E+02
5.580E+01	-1.256E-03	-1.207E-02	-2.246E-06	-2.541E+00	3.096E+00	3.011E+02

PROB (CONTD)
901 Q = 0 KIPS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 2 STIFF TYPE 2 LOAD TYPE 2
LENGTH = 6.250E+01 ALPHA = 1.000E+00 BETA = 0.
GOES FROM JOINT 2 TO JOINT 3

OUTPUT DISTANCES ARE FROM JOINT 2 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	-1.256E-03	-1.207E-02	-2.246E-06	-1.331E+00	-2.057E+00	3.153E+02
6.250E+00	-1.259E-03	-1.207E-02	3.473E-06	-1.331E+00	-2.663E+00	3.006E+02
1.250E+01	-1.262E-03	-1.203E-02	8.883E-06	-1.331E+00	-3.269E+00	2.820E+02
1.875E+01	-1.265E-03	-1.196E-02	1.391E-05	-1.331E+00	-3.876E+00	2.597E+02
2.500E+01	-1.268E-03	-1.186E-02	1.849E-05	-1.331E+00	-4.482E+00	2.336E+02
3.125E+01	-1.271E-03	-1.173E-02	2.256E-05	-1.331E+00	-5.088E+00	2.037E+02
3.750E+01	-1.274E-03	-1.157E-02	2.603E-05	-1.331E+00	-5.694E+00	1.700E+02
4.375E+01	-1.277E-03	-1.140E-02	2.884E-05	-1.331E+00	-6.301E+00	1.325E+02
5.000E+01	-1.279E-03	-1.122E-02	3.091E-05	-1.331E+00	-6.907E+00	9.122E+01
5.625E+01	-1.282E-03	-1.102E-02	3.219E-05	-1.331E+00	-7.513E+00	4.616E+01
6.250E+01	-1.285E-03	-1.082E-02	3.260E-05	-1.331E+00	-8.119E+00	-2.692E+00

PROB (CONTD)
901 Q = 0 KIPS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 3 STIFF TYPE 3 LOAD TYPE 3
LENGTH = 3.058E+01 ALPHA = -2.387E-01 BETA = -9.711E-01
GOES FROM JOINT 1 TO JOINT 4

OUTPUT DISTANCES ARE FROM JOINT 1 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	1.091E-02	1.436E-03	-2.948E-05	-8.873E+00	-4.469E-01	2.268E+01
3.058E+00	1.091E-02	1.347E-03	-2.915E-05	-8.935E+00	-4.316E-01	2.134E+01
6.117E+00	1.090E-02	1.258E-03	-2.883E-05	-8.997E+00	-4.163E-01	2.005E+01
9.175E+00	1.090E-02	1.170E-03	-2.854E-05	-9.060E+00	-4.009E-01	1.880E+01
1.223E+01	1.090E-02	1.084E-03	-2.826E-05	-9.122E+00	-3.856E-01	1.760E+01
1.529E+01	1.086E-02	1.001E-03	-2.568E-05	-9.185E+00	-3.703E-01	1.644E+01
1.835E+01	1.083E-02	9.263E-04	-2.327E-05	-9.247E+00	-3.549E-01	1.533E+01
2.141E+01	1.080E-02	8.586E-04	-2.103E-05	-9.309E+00	-3.396E-01	1.427E+01
2.447E+01	1.077E-02	7.975E-04	-1.894E-05	-9.372E+00	-3.243E-01	1.326E+01
2.753E+01	1.073E-02	7.426E-04	-1.700E-05	-9.434E+00	-3.089E-01	1.229E+01
3.058E+01	1.070E-02	6.934E-04	-1.521E-05	-9.496E+00	-2.936E-01	1.137E+01

PROB (CONTD)
901 Q = 0 KIPS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 4 STIFF TYPE 5 LOAD TYPE 5
LENGTH = 1.897E+02 ALPHA = -2.425E-01 BETA = -9.701E-01
GOES FROM JOINT 4 TO JOINT 7

OUTPUT DISTANCES ARE FROM JOINT 4 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	1.070E-02	7.358E-04	-1.521E-05	-9.498E+00	-2.461E-01	1.131E+01
1.897E+01	1.048E-02	5.341E-04	-6.553E-06	-9.735E+00	-1.975E-01	7.094E+00
3.793E+01	1.027E-02	4.622E-04	-1.421E-06	-9.972E+00	-1.477E-01	3.818E+00
5.690E+01	1.004E-02	4.615E-04	1.076E-06	-1.021E+01	-1.003E-01	1.491E+00
7.587E+01	9.818E-03	4.903E-04	1.783E-06	-1.045E+01	-6.010E-02	1.231E-02
9.483E+01	9.585E-03	5.215E-04	1.418E-06	-1.069E+01	-2.954E-02	-7.892E-01
1.138E+02	9.347E-03	5.403E-04	5.254E-07	-1.093E+01	-8.848E-03	-1.109E+00
1.328E+02	9.104E-03	5.403E-04	-5.251E-07	-1.117E+01	3.597E-03	-1.125E+00
1.517E+02	8.856E-03	5.208E-04	-1.511E-06	-1.141E+01	1.066E-02	-9.719E-01
1.707E+02	8.602E-03	4.843E-04	-2.307E-06	-1.166E+01	1.584E-02	-7.199E-01
1.897E+02	8.343E-03	4.353E-04	-2.820E-06	-1.190E+01	2.140E-02	-3.702E-01

PROB (CONTD)
901 Q = 0 KIPS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 5 STIFF TYPE 7 LOAD TYPE 7
LENGTH = 1.278E+02 ALPHA = -2.425E-01 BETA = -9.701E-01
GOES FROM JOINT 7 TO JOINT 10

OUTPUT DISTANCES ARE FROM JOINT 7 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	8.343E-03	4.353E-04	-2.820E-06	-1.190E+01	1.904E-02	-4.098E-01
1.278E+01	8.165E-03	3.980E-04	-2.998E-06	-1.201E+01	2.022E-02	-1.512E-01
2.556E+01	7.987E-03	3.595E-04	-3.011E-06	-1.205E+01	1.857E-02	1.081E-01
3.834E+01	7.808E-03	3.218E-04	-2.874E-06	-1.202E+01	1.443E-02	3.245E-01
5.113E+01	7.630E-03	2.866E-04	-2.620E-06	-1.191E+01	9.431E-03	4.779E-01
6.391E+01	7.455E-03	2.552E-04	-2.289E-06	-1.173E+01	4.720E-03	5.663E-01
7.669E+01	7.283E-03	2.283E-04	-1.919E-06	-1.148E+01	9.193E-04	5.992E-01
8.947E+01	7.115E-03	2.061E-04	-1.542E-06	-1.117E+01	-1.835E-03	5.904E-01
1.023E+02	6.952E-03	1.888E-04	-1.180E-06	-1.080E+01	-3.819E-03	5.527E-01
1.150E+02	6.795E-03	1.758E-04	-8.486E-07	-1.036E+01	-5.628E-03	4.931E-01
1.278E+02	6.644E-03	1.669E-04	-5.626E-07	-9.892E+00	-7.678E-03	4.091E-01

PROB (CONTD)
901 Q = 0 KIPS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 6 STIFF TYPE 9 LOAD TYPE 9
LENGTH = 3.402E+02 ALPHA = -2.425E-01 BETA = -9.701E-01
GOES FROM JOINT 10 TO JOINT 13

OUTPUT DISTANCES ARE FROM JOINT 10 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	6.644E-03	1.669E-04	-5.626E-07	-9.904E+00	-5.311E-03	3.826E-01
3.402E+01	6.279E-03	1.565E-04	-9.111E-08	-8.622E+00	-5.402E-03	1.763E-01
6.803E+01	5.964E-03	1.567E-04	7.050E-08	-7.416E+00	-3.017E-03	1.524E-02
1.020E+02	5.694E-03	1.591E-04	5.899E-08	-6.300E+00	-5.084E-04	-2.889E-02
1.361E+02	5.467E-03	1.603E-04	1.828E-08	-5.262E+00	3.539E-04	-1.937E-02
1.701E+02	5.279E-03	1.606E-04	-2.122E-09	-4.288E+00	3.043E-04	-4.824E-03
2.041E+02	5.128E-03	1.604E-04	-5.067E-09	-3.367E+00	9.698E-05	1.332E-03
2.381E+02	5.013E-03	1.603E-04	-2.447E-09	-2.487E+00	-8.563E-06	1.775E-03
2.721E+02	4.932E-03	1.602E-04	-3.177E-10	-1.638E+00	-2.543E-05	7.496E-04
3.061E+02	4.884E-03	1.603E-04	3.525E-10	-8.083E-01	-1.479E-05	4.501E-05
3.402E+02	4.868E-03	1.603E-04	1.741E-10	1.114E-02	-4.598E-06	-2.565E-04

PROB (CONTD)
901 Q = 0 KIPS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 7 STIFF TYPE 4 LOAD TYPE 4
LENGTH = 3.010E+01 ALPHA = 1.617E-01 BETA = -9.868E-01
GOES FROM JOINT 2 TO JOINT 5

OUTPUT DISTANCES ARE FROM JOINT 2 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	1.171E-02	-3.191E-03	-2.246E-06	-1.011E+01	-4.318E-01	2.939E+01
3.010E+00	1.171E-02	-3.197E-03	-1.817E-06	-1.017E+01	-4.421E-01	2.808E+01
6.019E+00	1.170E-02	-3.202E-03	-1.408E-06	-1.024E+01	-4.523E-01	2.673E+01
9.029E+00	1.170E-02	-3.206E-03	-1.019E-06	-1.030E+01	-4.625E-01	2.535E+01
1.204E+01	1.169E-02	-3.208E-03	-6.510E-07	-1.036E+01	-4.727E-01	2.395E+01
1.505E+01	1.166E-02	-3.205E-03	2.816E-06	-1.042E+01	-4.830E-01	2.251E+01
1.806E+01	1.162E-02	-3.192E-03	6.066E-06	-1.048E+01	-4.932E-01	2.104E+01
2.107E+01	1.159E-02	-3.169E-03	9.094E-06	-1.055E+01	-5.034E-01	1.954E+01
2.408E+01	1.155E-02	-3.137E-03	1.190E-05	-1.061E+01	-5.136E-01	1.801E+01
2.709E+01	1.151E-02	-3.098E-03	1.447E-05	-1.067E+01	-5.238E-01	1.645E+01
3.010E+01	1.147E-02	-3.050E-03	1.680E-05	-1.073E+01	-5.341E-01	1.486E+01

PROB (CONTD)
901 Q = 0 KIPS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 8 STIFF TYPE 4 LOAD TYPE 4
LENGTH = 3.010E+01 ALPHA = 1.617E-01 BETA = -9.868E-01
GOES FROM JOINT 3 TO JOINT 6

OUTPUT DISTANCES ARE FROM JOINT 3 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	1.047E-02	-3.017E-03	3.260E-05	-8.232E+00	1.184E-02	-2.705E+00
3.010E+00	1.046E-02	-2.919E-03	3.256E-05	-8.294E+00	1.622E-03	-2.686E+00
6.019E+00	1.046E-02	-2.821E-03	3.252E-05	-8.356E+00	-8.599E-03	-2.697E+00
9.029E+00	1.046E-02	-2.723E-03	3.248E-05	-8.419E+00	-1.882E-02	-2.739E+00
1.204E+01	1.045E-02	-2.626E-03	3.243E-05	-8.481E+00	-2.904E-02	-2.812E+00
1.505E+01	1.042E-02	-2.529E-03	3.201E-05	-8.543E+00	-3.926E-02	-2.916E+00
1.806E+01	1.039E-02	-2.433E-03	3.156E-05	-8.606E+00	-4.948E-02	-3.050E+00
2.107E+01	1.036E-02	-2.339E-03	3.109E-05	-8.668E+00	-5.970E-02	-3.215E+00
2.408E+01	1.033E-02	-2.246E-03	3.060E-05	-8.730E+00	-6.992E-02	-3.411E+00
2.709E+01	1.030E-02	-2.155E-03	3.007E-05	-8.793E+00	-8.014E-02	-3.638E+00
3.010E+01	1.027E-02	-2.065E-03	2.951E-05	-8.855E+00	-9.036E-02	-3.895E+00

PROB (CONTD)
901 Q = 0 KIPS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 9 STIFF TYPE 6 LOAD TYPE 6
LENGTH = 1.865E+02 ALPHA = 1.644E-01 BETA = -9.864E-01
GOES FROM JOINT 5 TO JOINT 8

OUTPUT DISTANCES ARE FROM JOINT 5 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	1.147E-02	-3.082E-03	1.680E-05	-1.073E+01	-5.669E-01	1.485E+01
1.865E+01	1.123E-02	-2.670E-03	2.632E-05	-1.096E+01	-4.138E-01	5.711E+00
3.731E+01	1.099E-02	-2.150E-03	2.868E-05	-1.119E+01	-2.680E-01	-5.951E-01
5.596E+01	1.075E-02	-1.632E-03	2.642E-05	-1.142E+01	-1.417E-01	-4.299E+00
7.462E+01	1.050E-02	-1.182E-03	2.171E-05	-1.165E+01	-4.451E-02	-5.891E+00
9.327E+01	1.024E-02	-8.278E-04	1.622E-05	-1.188E+01	2.080E-02	-5.969E+00
1.119E+02	9.982E-03	-5.740E-04	1.109E-05	-1.212E+01	5.705E-02	-5.122E+00
1.306E+02	9.718E-03	-4.072E-04	6.941E-06	-1.235E+01	7.021E-02	-3.846E+00
1.492E+02	9.448E-03	-3.066E-04	4.002E-06	-1.259E+01	6.717E-02	-2.506E+00
1.679E+02	9.173E-03	-2.498E-04	2.222E-06	-1.283E+01	5.416E-02	-1.342E+00
1.865E+02	8.893E-03	-2.171E-04	1.376E-06	-1.307E+01	3.627E-02	-4.869E-01

PROB (CONTD)
901 Q = 0 KIPS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 10 STIFF TYPE 6 LOAD TYPE 6
LENGTH = 1.865E+02 ALPHA = 1.644E-01 BETA = -9.864E-01
GOES FROM JOINT 6 TO JOINT 9

OUTPUT DISTANCES ARE FROM JOINT 6 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	1.027E-02	-2.093E-03	2.951E-05	-8.855E+00	-1.285E-01	-3.791E+00
1.865E+01	1.007E-02	-1.581E-03	2.522E-05	-9.101E+00	-5.778E-02	-5.493E+00
3.731E+01	9.873E-03	-1.159E-03	1.992E-05	-9.346E+00	-7.556E-04	-5.955E+00
5.596E+01	9.668E-03	-8.376E-04	1.461E-05	-9.592E+00	3.718E-02	-5.528E+00
7.462E+01	9.458E-03	-6.097E-04	9.937E-06	-9.839E+00	5.709E-02	-4.573E+00
9.327E+01	9.242E-03	-4.600E-04	6.247E-06	-1.009E+01	6.244E-02	-3.402E+00
1.119E+02	9.021E-03	-3.691E-04	3.634E-06	-1.033E+01	5.769E-02	-2.246E+00
1.306E+02	8.795E-03	-3.174E-04	2.017E-06	-1.058E+01	4.709E-02	-1.251E+00
1.492E+02	8.563E-03	-2.882E-04	1.211E-06	-1.083E+01	3.384E-02	-4.904E-01
1.679E+02	8.326E-03	-2.682E-04	9.892E-07	-1.108E+01	1.977E-02	1.079E-02
1.865E+02	8.083E-03	-2.489E-04	1.108E-06	-1.134E+01	5.510E-03	2.468E-01

PROB (CONTD)
901 Q = 0 KIPS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 11 STIFF TYPE 8 LOAD TYPE 8
LENGTH = 1.257E+02 ALPHA = 1.644E-01 BETA = -9.864E-01
GOES FROM JOINT 8 TO JOINT 11

OUTPUT DISTANCES ARE FROM JOINT 8 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	8.893E-03	-2.172E-04	1.376E-06	-1.306E+01	3.168E-02	-6.398E-01
1.257E+01	8.701E-03	-2.019E-04	1.077E-06	-1.316E+01	2.011E-02	-3.193E-01
2.514E+01	8.509E-03	-1.894E-04	9.359E-07	-1.319E+01	1.079E-02	-1.345E-01
3.771E+01	8.316E-03	-1.780E-04	8.789E-07	-1.314E+01	4.219E-03	-4.833E-02
5.028E+01	8.125E-03	-1.671E-04	8.549E-07	-1.302E+01	-3.781E-05	-2.874E-02
6.286E+01	7.937E-03	-1.565E-04	8.304E-07	-1.282E+01	-2.453E-03	-4.956E-02
7.543E+01	7.752E-03	-1.463E-04	7.867E-07	-1.254E+01	-3.479E-03	-9.068E-02
8.800E+01	7.571E-03	-1.369E-04	7.157E-07	-1.221E+01	-3.477E-03	-1.373E-01
1.006E+02	7.396E-03	-1.285E-04	6.173E-07	-1.180E+01	-2.660E-03	-1.783E-01
1.131E+02	7.227E-03	-1.214E-04	4.980E-07	-1.134E+01	-1.057E-03	-2.043E-01
1.257E+02	7.065E-03	-1.160E-04	3.704E-07	-1.084E+01	1.175E-03	-2.050E-01

PROB (CONTD)
901 Q = 0 KIPS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 12 STIFF TYPE 8 LOAD TYPE 8
LENGTH = 1.257E+02 ALPHA = 1.644E-01 BETA = -9.864E-01
GOES FROM JOINT 9 TO JOINT 12

OUTPUT DISTANCES ARE FROM JOINT 9 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	8.083E-03	-2.489E-04	1.108E-06	-1.134E+01	4.379E-03	1.687E-01
1.257E+01	7.917E-03	-2.343E-04	1.216E-06	-1.145E+01	-2.279E-03	1.759E-01
2.514E+01	7.749E-03	-2.185E-04	1.305E-06	-1.150E+01	-6.397E-03	1.111E-01
3.771E+01	7.582E-03	-2.018E-04	1.344E-06	-1.148E+01	-7.788E-03	1.474E-02
5.028E+01	7.415E-03	-1.849E-04	1.323E-06	-1.139E+01	-7.397E-03	-8.509E-02
6.286E+01	7.249E-03	-1.688E-04	1.243E-06	-1.123E+01	-6.025E-03	-1.716E-01
7.543E+01	7.087E-03	-1.539E-04	1.115E-06	-1.100E+01	-4.260E-03	-2.369E-01
8.800E+01	6.929E-03	-1.409E-04	9.544E-07	-1.071E+01	-2.440E-03	-2.790E-01
1.006E+02	6.775E-03	-1.300E-04	7.743E-07	-1.037E+01	-6.442E-04	-2.985E-01
1.131E+02	6.626E-03	-1.215E-04	5.892E-07	-9.965E+00	1.290E-03	-2.954E-01
1.257E+02	6.484E-03	-1.152E-04	4.141E-07	-9.523E+00	3.472E-03	-2.662E-01

PROB (CONTD)
901 Q = 0 KIPS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 13 STIFF TYPE 10 LOAD TYPE 10
LENGTH = 3.457E+02 ALPHA = 1.644E-01 BETA = -9.864E-01
GOES FROM JOINT 11 TO JOINT 14

OUTPUT DISTANCES ARE FROM JOINT 11 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	7.065E-03	-1.161E-04	3.704E-07	-1.085E+01	-2.450E-04	-1.790E-01
3.457E+01	6.659E-03	-1.080E-04	1.117E-07	-9.436E+00	2.186E-03	-1.227E-01
6.914E+01	6.308E-03	-1.067E-04	-1.742E-08	-8.108E+00	1.922E-03	-2.797E-02
1.037E+02	6.008E-03	-1.077E-04	-3.263E-08	-6.882E+00	5.673E-04	1.023E-02
1.383E+02	5.756E-03	-1.086E-04	-1.421E-08	-5.743E+00	-8.960E-05	1.126E-02
1.729E+02	5.548E-03	-1.088E-04	-1.092E-09	-4.677E+00	-1.640E-04	4.042E-03
2.074E+02	5.381E-03	-1.088E-04	2.305E-09	-3.670E+00	-7.103E-05	-8.004E-05
2.420E+02	5.253E-03	-1.087E-04	1.491E-09	-2.709E+00	-5.614E-06	-8.695E-04
2.766E+02	5.164E-03	-1.087E-04	3.437E-10	-1.783E+00	1.165E-05	-4.685E-04
3.111E+02	5.110E-03	-1.087E-04	-1.129E-10	-8.798E-01	8.908E-06	-6.415E-05
3.457E+02	5.093E-03	-1.087E-04	-4.151E-11	1.255E-02	3.588E-06	1.474E-04

PROB (CONTD)
901 Q = 0 KIPS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 14 STIFF TYPE 10 LOAD TYPE 10
LENGTH = 3.457E+02 ALPHA = 1.644E-01 BETA = -9.864E-01
GOES FROM JOINT 12 TO JOINT 15

OUTPUT DISTANCES ARE FROM JOINT 12 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	6.484E-03	-1.153E-04	4.141E-07	-9.534E+00	1.779E-03	-2.401E-01
3.457E+01	6.127E-03	-1.069E-04	9.478E-08	-8.292E+00	3.180E-03	-1.324E-01
6.914E+01	5.819E-03	-1.063E-04	-3.609E-08	-7.125E+00	2.153E-03	-2.024E-02
1.037E+02	5.556E-03	-1.077E-04	-3.930E-08	-6.047E+00	4.815E-04	1.649E-02
1.383E+02	5.334E-03	-1.086E-04	-1.396E-08	-5.046E+00	-1.845E-04	1.307E-02
1.729E+02	5.151E-03	-1.088E-04	4.457E-10	-4.110E+00	-1.981E-04	3.738E-03
2.074E+02	5.004E-03	-1.088E-04	3.116E-09	-3.225E+00	-7.012E-05	-6.230E-04
2.420E+02	4.892E-03	-1.087E-04	1.630E-09	-2.381E+00	1.844E-06	-1.110E-03
2.766E+02	4.813E-03	-1.087E-04	2.536E-10	-1.567E+00	1.551E-05	-4.958E-04
3.111E+02	4.767E-03	-1.087E-04	-2.042E-10	-7.731E-01	9.579E-06	-3.818E-05
3.457E+02	4.751E-03	-1.087E-04	-9.421E-11	1.101E-02	3.178E-06	1.665E-04

PROB (CONTD)
901 Q = 0 KIPS

TABLE 10 - JOINT EQUILIBRIUM ERRORS

JOINT	ERR(X) FORCE	ERR(Y) FORCE	ERR(Z) MOMENT
1	1.082E-02	7.770E-04	1.306E-02
2	8.031E-04	1.069E-04	1.185E-03
3	-1.153E-02	2.072E-03	-1.347E-02
4	-9.543E-03	2.567E-03	-5.933E-02
5	3.436E-03	4.005E-04	-9.784E-04
6	1.367E-02	2.648E-03	1.037E-01
7	1.791E-03	-2.568E-03	-3.955E-02
8	4.755E-03	-1.275E-03	-1.528E-01
9	1.324E-03	-1.654E-03	-7.804E-02
10	4.791E-04	1.167E-02	-2.645E-02
11	-9.823E-04	1.312E-02	2.606E-02
12	-4.162E-04	1.155E-02	2.620E-02
13	2.698E-03	1.081E-02	2.565E-04
14	-2.060E-03	1.238E-02	-1.474E-04
15	-1.808E-03	1.086E-02	-1.665E-04

SOIL SUPPORTED BENT - GALATI RUMANIA
THREE BATTERED PILES

PROB

902 Q = 80 KIPS

TABLE 1 - PROGRAM CONTROL DATA
PROBLEM TYPE 2

INPUT TABLES

TABLE NUMBER	HOLD DATA FROM LAST PROBLEM (1 = YES,0 = NO)	NUMBER OF CARDS ADDED FOR THIS PRO-LEM
2	1	-0
3	1	-0
4A	1	1
4B	-0	-0
4C	-0	-0
5A	1	-0
5B	1	-0
5C	1	-0
5D	1	-0
6	1	-0
7	1	-0

OUTPUT TABLES

TABLE NUMBER	SUPPRESS OUTPUT (1 = YES,0 = NO)
8	-0
9	-0
10	-0

PROB (CONTD)
902 Q = 80 KIPS

TABLE 2 - FRAME GEOMETRY DATA

HOLDING DATA FROM THE PREVIOUS PROBLEM PLUS THE FOLLOWING

NONE

COMPUTED JOINT COORDINATES

JOINT	X	Y
1	-0.	-0.
2	5.580E+01	0.
3	1.183E+02	0.
4	-7.300E+00	-2.970E+01
5	6.067E+01	-2.970E+01
6	1.232E+02	-2.970E+01
7	-5.330E+01	-2.137E+02
8	9.134E+01	-2.137E+02
9	1.538E+02	-2.137E+02
10	-8.430E+01	-3.377E+02
11	1.120E+02	-3.377E+02
12	1.745E+02	-3.377E+02
13	-1.668E+02	-6.677E+02
14	1.689E+02	-6.787E+02
15	2.314E+02	-6.787E+02

PROB (CONTD)
902 Q = 80 KIPS

TABLE 3 - MEMBER LOCATION DATA

HOLDING DATA FROM THE PREVIOUS PROBLEM PLUS THE FOLLOWING

NONE

COMPUTED MEMBER NUMBERS,LENGTHS, AND OFFSETS

MEMBER NUMB	FROM JOINT	TO JOINT	STIFF TYPE	LOAD TYPE	LENGTH	X-OFFSET	Y-OFFSET
1	1	2	1	1	5.580E+01	5.580E+01	0.
2	2	3	2	2	6.250E+01	6.250E+01	0.
3	1	4	3	3	3.058E+01	-7.300E+00	-2.970E+01
4	4	7	5	5	1.897E+02	-4.600E+01	-1.840E+02
5	7	10	7	7	1.278E+02	-3.100E+01	-1.240E+02
6	10	13	9	9	3.402E+02	-8.250E+01	-3.300E+02
7	2	5	4	4	3.010E+01	4.867E+00	-2.970E+01
8	3	6	4	4	3.010E+01	4.867E+00	-2.970E+01
9	5	8	6	6	1.865E+02	3.067E+01	-1.840E+02
10	6	9	6	6	1.865E+02	3.067E+01	-1.840E+02
11	8	11	8	8	1.257E+02	2.067E+01	-1.240E+02
12	9	12	8	8	1.257E+02	2.067E+01	-1.240E+02
13	11	14	10	10	3.457E+02	5.685E+01	-3.410E+02
14	12	15	10	10	3.457E+02	5.685E+01	-3.410E+02

*** COMPUTED MEMBER NUMBERS AGREE WITH LAST PROBLEM ***

PROB (CONTD)
902 Q = 80 KIPS

TABLE 4A - JOINT LOADS AND LINEAR RESTRAINTS

HOLDING DATA FROM THE PREVIOUS PROBLEM PLUS THE FOLLOWING

INPUT OF JOINT DATA

JOINT	FORCE(X)	FORCE(Y)	MOMENT(Z)	SPRING(X)	SPRING(Y)	SPRING(Z)
3	-8.000E+01	-0.	-9.040E+02	-0.	-0.	-0.

ACCUMULATED JOINT DATA

JOINT	FORCE(X)	FORCE(Y)	MOMENT(Z)	SPRING(X)	SPRING(Y)	SPRING(Z)
2	0.	-1.520E+01	-4.360E+01	0.	0.	0.
3	-8.000E+01	0.	-9.040E+02	0.	0.	0.

TABLE 4B - JOINT SUPPORT CURVE NUMBERS

NO DATA

TABLE 4C - JOINT SUPPORT CURVES

NO DATA

PROB (CONTD)
902 Q = 80 KIPS

TABLE 5A - MEMBER STIFFNESS DATA

HOLDING DATA FROM THE PREVIOUS PROBLEM PLUS THE FOLLOWING

NONE

TABLE 5B - CROSS SECTION DATA

HOLDING DATA FROM THE PREVIOUS PROBLEM PLUS THE FOLLOWING

NONE

TABLE 5C - STRESS STRAIN CURVES

HOLDING DATA FROM THE PREVIOUS PROBLEM PLUS THE FOLLOWING

NONE

TABLE 5D - SUPPORT CURVES FOR MEMBERS

HOLDING DATA FROM THE PREVIOUS PROBLEM PLUS THE FOLLOWING

NONE

PROB (CONTD)
902 Q = 80 KIPS

TABLE 6 - MEMBER LOAD DATA

HOLDING DATA FROM THE PREVIOUS PROBLEM PLUS THE FOLLOWING

NONE

```
PROB (CONTD)
  902      Q = 80 KIPS


TABLE 7 -  ITERATION CONTROL


HOLDING DATA FROM THE PREVIOUS PROBLEM


          FRAME SOLUTION

        NUMB       FORCE     MOMENT
       ITER        ERROR      ERROR                    MONITOR JOINTS

        10      1.000E-01 1.000E+01              1    4    7   10   13


         MEMBER SOLUTIONS

        NUMB       FORCE     MOMENT
        ITER       ERROR      ERROR                    MONITOR MEMBERS

        10      1.000E-02 1.000E+00              1    3    6    9   12


***** FRAME ITERATION NO     1 *****

 MEMB MEMB          MEMBER DISPLACEMENTS                 MEMBER EQULIBRIUM ERRORS
  NO  ITER       AXIAL  LATERAL  ROTATIONAL          AXIAL      LATERAL     ROTATIONAL

    1    1
FROM JOINT    -1.016E-01 -1.179E-02 -3.046E-05  5.234E-01  1.429E-02  8.766E+00
CENTERLINE    -1.019E-01 -1.293E-02 -6.246E-05 -1.457E-01  2.746E-03 -3.579E-01
 TO JOINT     -1.021E-01 -1.417E-02 -3.937E-05 -8.982E-03  7.574E-03 -2.886E-01

    1    2
FROM JOINT    -1.016E-01 -1.179E-02 -3.033E-05  6.318E-06  4.187E-06 -1.044E-05
CENTERLINE    -1.019E-01 -1.293E-02 -6.252E-05 -1.031E-05  1.159E-04 -1.594E-04
 TO JOINT     -1.021E-01 -1.416E-02 -3.939E-05 -1.718E-06 -3.228E-06  6.095E-06

MEMBER    1 CONVERGED AFTER ITERATION    2


MEMBER    2 CONVERGED AFTER ITERATION    2


    3    1
FROM JOINT     3.556E-02 -9.588E-02  3.460E-06  4.101E-03  2.331E-02  1.494E-01
CENTERLINE     3.534E-02 -9.529E-02  1.755E-04  4.178E+00  3.843E-01  6.447E-01
 TO JOINT      3.468E-02 -9.047E-02  5.874E-04  2.610E+00  1.435E+00  2.159E+00
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```
    3    2
FROM JOINT     3.556E-02 -9.588E-02  6.981E-07  4.499E-05 -1.105E-03 -3.624E-03
CENTERLINE     3.539E-02 -9.537E-02  1.771E-04  4.405E-01 -4.558E-01  1.826E+00
 TO JOINT      3.472E-02 -9.047E-02  5.902E-04 -1.215E-01 -1.363E-01 -9.301E-01

    3    3
FROM JOINT     3.556E-02 -9.588E-02  6.773E-07  3.329E-08 -2.517E-07 -5.980E-07
CENTERLINE     3.540E-02 -9.537E-02  1.776E-04  8.956E-04  5.515E-04 -1.174E-03
 TO JOINT      3.472E-02 -9.047E-02  5.899E-04 -5.604E-04 -5.312E-05 -3.714E-03

MEMBER    3 CONVERGED AFTER ITERATION    3


MEMBER    4 CONVERGED AFTER ITERATION    3


MEMBER    5 CONVERGED AFTER ITERATION    1


    6    1
FROM JOINT     1.693E-02  1.059E-04  1.415E-06 -1.007E-02  4.543E-04  4.346E-04
CENTERLINE     1.329E-02  1.622E-04 -6.165E-08 -7.582E-03 -2.077E-04 -7.977E-06
 TO JOINT      1.186E-02  1.602E-04  3.101E-09 -6.596E-03  6.587E-06  6.353E-08

    6    2
FROM JOINT     1.693E-02  1.072E-04  1.482E-06 -2.948E-05 -1.916E-04  2.657E-08
CENTERLINE     1.329E-02  1.624E-04 -8.863E-08 -1.995E-05 -2.259E-04  7.146E-10
 TO JOINT      1.185E-02  1.602E-04  4.350E-09 -1.905E-05  1.804E-05 -3.328E-10

MEMBER    6 CONVERGED AFTER ITERATION    2


MEMBER    7 CONVERGED AFTER ITERATION    4


MEMBER    8 CONVERGED AFTER ITERATION    4


    9    1
FROM JOINT    -2.143E-03 -7.949E-02  1.019E-03  4.545E+00  1.042E+00 -2.461E+01
CENTERLINE    -1.303E-03 -1.288E-02  5.326E-04 -9.909E-02 -3.507E-01 -2.252E-01
 TO JOINT     -6.029E-04  2.795E-03  2.253E-06 -4.023E-02  4.382E-02  4.915E-03

    9    2
FROM JOINT    -2.224E-03 -8.115E-02  8.664E-04  4.084E+00  1.680E+00  8.724E+00
CENTERLINE    -1.364E-03 -1.896E-02  6.060E-04  3.430E-01 -5.104E-01 -6.408E-01
 TO JOINT     -6.176E-04  2.455E-03  3.812E-05  6.671E-03  2.179E-02 -1.844E-02

    9    3
FROM JOINT    -2.147E-03 -8.106E-02  8.735E-04  1.005E-02  1.728E-02 -7.490E-02
CENTERLINE    -1.316E-03 -1.924E-02  6.003E-04  1.184E-05 -3.568E-04 -2.514E-05
 TO JOINT     -6.078E-04  2.414E-03  4.230E-05  7.279E-05  2.481E-03  3.683E-06

    9    4
FROM JOINT    -2.146E-03 -8.106E-02  8.735E-04  3.136E-06  4.956E-06 -1.804E-05
```

```
CENTERLINE    -1.316E-03 -1.924E-02  6.003E-04  3.368E-09 -1.935E-06 -8.131E-10
 TO JOINT     -6.078E-04  2.414E-03  4.235E-05  4.064E-09  3.138E-05  1.647E-09

MEMBER    9 CONVERGED AFTER ITERATION     4


MEMBER   10 CONVERGED AFTER ITERATION     3


MEMBER   11 CONVERGED AFTER ITERATION     2


   12     1
FROM JOINT     5.671E-04  2.055E-03 -4.032E-05 -4.356E-03  9.647E-03  2.256E-02
CENTERLINE     8.091E-04  2.976E-04 -2.230E-05 -3.646E-03 -3.186E-03  9.665E-03
 TO JOINT      1.002E-03 -2.079E-04 -1.424E-06 -2.520E-03 -3.362E-03  8.117E-04

MEMBER   12 CONVERGED AFTER ITERATION     1


MEMBER   13 CONVERGED AFTER ITERATION     1


MEMBER   14 CONVERGED AFTER ITERATION     1



    9 JOINTS NOT CONVERGED AT END OF FRAME ITERATION      1


***** FRAME ITERATION NO      2 *****

 MEMB MEMB          MEMBER DISPLACEMENTS                  MEMBER EQULIBRIUM ERRORS
  NO  ITER      AXIAL  LATERAL  ROTATIONAL           AXIAL       LATERAL     ROTATIONAL

   .1     1
FROM JOINT    -2.488E-01  9.460E-03 -5.042E-04  7.049E-03  7.070E-04 -7.169E-01
CENTERLINE    -2.491E-01 -2.367E-03 -5.414E-04  3.079E-03 -7.203E-02 -1.027E+00
 TO JOINT     -2.493E-01 -1.407E-02 -4.934E-04 -1.750E-02 -3.919E-03 -7.161E-01

    1     2
FROM JOINT    -2.488E-01  9.460E-03 -5.042E-04 -1.614E-08  2.157E-09  2.488E-08
CENTERLINE    -2.491E-01 -2.367E-03 -5.414E-04  1.543E-07 -1.204E-06 -1.667E-06
 TO JOINT     -2.493E-01 -1.407E-02 -4.934E-04  3.367E-08 -4.208E-09  1.528E-07

MEMBER    1 CONVERGED AFTER ITERATION     2


MEMBER    2 CONVERGED AFTER ITERATION     2


    3     1
FROM JOINT     4.749E-02 -2.459E-01 -4.582E-04 -3.529E-02  2.744E-03 -5.075E-01
CENTERLINE     4.769E-02 -2.505E-01 -7.946E-05 -4.524E+00  9.536E+00 -1.106E+01
 TO JOINT      4.766E-02 -2.454E-01  8.386E-04  5.800E-01 -1.015E+00  8.953E+00

    3     2
FROM JOINT     4.749E-02 -2.459E-01 -4.565E-04  7.564E-06  7.235E-04  2.533E-03
CENTERLINE     4.761E-02 -2.505E-01 -8.110E-05  5.464E-02  4.395E-02 -6.952E-02
 TO JOINT      4.764E-02 -2.454E-01  8.405E-04  5.435E-02 -1.014E-02  7.434E-02

    3     3
FROM JOINT     4.749E-02 -2.459E-01 -4.565E-04 -2.355E-08 -9.563E-08  6.295E-08
CENTERLINE     4.761E-02 -2.505E-01 -8.107E-05  1.488E-06 -1.033E-06  2.060E-06
 TO JOINT      4.764E-02 -2.454E-01  8.405E-04  7.350E-07  5.215E-08 -1.041E-06

MEMBER    3 CONVERGED AFTER ITERATION     3


MEMBER    4 CONVERGED AFTER ITERATION     3


MEMBER    5 CONVERGED AFTER ITERATION     2


    6     1
FROM JOINT     2.285E-02 -1.907E-05  2.468E-06 -5.612E-03 -4.289E-02  2.991E-04
CENTERLINE     1.774E-02  1.673E-04 -1.776E-07 -4.214E-03  9.169E-04 -8.791E-06
 TO JOINT      1.572E-02  1.600E-04  1.053E-08 -3.660E-03 -2.906E-05  9.998E-08

    6     2
FROM JOINT     2.285E-02 -2.463E-05  2.333E-06 -1.643E-05 -2.145E-03 -3.491E-08
CENTERLINE     1.774E-02  1.696E-04 -2.470E-07 -1.108E-05 -3.445E-06  7.743E-10
 TO JOINT      1.572E-02  1.599E-04  1.619E-08 -1.056E-05  3.079E-05 -1.039E-09

MEMBER    6 CONVERGED AFTER ITERATION     2


MEMBER    7 CONVERGED AFTER ITERATION     3


MEMBER    8 CONVERGED AFTER ITERATION     3


    9     1
FROM JOINT    -1.896E-02 -2.148E-01  1.825E-03  2.169E+01  5.081E-01  1.155E+01
CENTERLINE    -1.592E-02 -6.741E-02  1.652E-03 -5.996E+00  5.463E-01 -1.345E+00
 TO JOINT     -1.304E-02  8.892E-04  2.677E-04  4.470E+00 -8.080E-01 -2.120E+00

    9     2
FROM JOINT    -1.802E-02 -2.135E-01  1.950E-03 -2.174E+00  1.102E+00  5.542E+00
CENTERLINE    -1.587E-02 -6.554E-02  1.650E-03  4.043E-02 -3.625E-02  1.811E-01
 TO JOINT     -1.281E-02  9.530E-04  2.567E-04 -1.779E-01  3.816E-01  4.086E+00

    9     3
FROM JOINT    -1.798E-02 -2.136E-01  1.942E-03 -9.404E-02 -1.347E-01 -1.903E+00
CENTERLINE    -1.578E-02 -6.539E-02  1.647E-03 -6.263E-04 -3.178E-04  4.355E-03
 TO JOINT     -1.281E-02  9.498E-04  2.578E-04 -7.770E-04  2.821E-03  2.520E-02
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   9    4
FROM JOINT    -1.798E-02 -2.136E-01  1.942E-03 -4.929E-04 -6.143E-04 -8.670E-03
CENTERLINE    -1.578E-02 -6.539E-02  1.647E-03  3.675E-07  3.599E-06  5.952E-07
 TO JOINT     -1.281E-02  9.500E-04  2.578E-04  1.296E-06 -2.922E-05 -6.996E-06

MEMBER     9 CONVERGED AFTER ITERATION     4


MEMBER    10 CONVERGED AFTER ITERATION     4


MEMBER    11 CONVERGED AFTER ITERATION     2


   12    1
FROM JOINT     4.164E-03  4.695E-03  9.254E-06 -3.104E-02  9.014E-02 -2.036E-01
CENTERLINE     3.962E-03  2.072E-03 -6.638E-05  2.521E-03 -1.637E-03  2.375E-02
 TO JOINT      3.757E-03 -3.760E-05 -1.768E-05 -4.468E-03 -7.827E-03 -1.313E-03

   12    2
FROM JOINT     4.163E-03  4.697E-03  9.527E-06 -3.511E-07 -3.980E-05  7.763E-07
CENTERLINE     3.961E-03  2.075E-03 -6.659E-05  3.552E-07  1.628E-05 -3.067E-07
 TO JOINT      3.757E-03 -3.822E-05 -1.759E-05 -2.685E-06  1.291E-05 -2.766E-06

MEMBER    12 CONVERGED AFTER ITERATION     2


MEMBER    13 CONVERGED AFTER ITERATION     2


MEMBER    14 CONVERGED AFTER ITERATION     2



    10 JOINTS NOT CONVERGED AT END OF FRAME ITERATION     2


***** FRAME ITERATION NO      3 *****

 MEMB MEMB        MEMBER DISPLACEMENTS                MEMBER EQULIBRIUM ERRORS
  NO  ITER      AXIAL  LATERAL  ROTATIONAL          AXIAL      LATERAL    ROTATIONAL

    1    1
FROM JOINT    -3.094E-01  2.188E-02 -7.140E-04  3.353E-04  1.282E-04 -7.106E-02
CENTERLINE    -3.096E-01  5.365E-03 -7.507E-04  8.336E-04 -1.147E-02 -8.550E-02
 TO JOINT     -3.099E-01 -1.095E-02 -6.966E-04 -1.445E-03 -7.593E-05 -7.356E-02

    1    2
FROM JOINT    -3.094E-01  2.188E-02 -7.140E-04  1.482E-10  1.439E-09 -9.262E-09
CENTERLINE    -3.096E-01  5.365E-03 -7.507E-04  8.294E-09 -4.975E-09  5.599E-09
 TO JOINT     -3.099E-01 -1.095E-02 -6.966E-04  7.731E-09 -1.603E-09  1.135E-09

MEMBER     1 CONVERGED AFTER ITERATION     2
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MEMBER     2 CONVERGED AFTER ITERATION     2


    3    1
FROM JOINT     4.874E-02 -3.086E-01 -6.665E-04  1.128E-03  2.091E-04  2.112E-01
CENTERLINE     4.898E-02 -3.157E-01 -2.672E-04 -1.463E-01  3.049E-02  4.945E-01
 TO JOINT      4.963E-02 -3.119E-01  8.327E-04 -1.113E+00 -2.731E+00 -1.315E+00

    3    2
FROM JOINT     4.874E-02 -3.086E-01 -6.664E-04  2.034E-08  3.492E-06  1.252E-05
CENTERLINE     4.898E-02 -3.157E-01 -2.669E-04 -2.409E-05  1.618E-05  1.507E-04
 TO JOINT      4.962E-02 -3.119E-01  8.322E-04 -2.747E-03  4.782E-03  1.456E-03

MEMBER     3 CONVERGED AFTER ITERATION     2


MEMBER     4 CONVERGED AFTER ITERATION     3


MEMBER     5 CONVERGED AFTER ITERATION     2


    6    1
FROM JOINT     2.414E-02 -5.508E-05  4.018E-07  3.572E-03 -4.426E-02 -3.689E-05
CENTERLINE     1.871E-02  1.719E-04 -2.322E-07 -9.142E-04  1.379E-03 -2.484E-07
 TO JOINT      1.656E-02  1.598E-04  2.043E-08 -7.929E-04 -5.855E-05  1.714E-08

    6    2
FROM JOINT     2.414E-02 -6.324E-05  1.333E-07  1.091E-05 -1.802E-03 -7.539E-09
CENTERLINE     1.871E-02  1.738E-04 -2.519E-07 -2.490E-06  4.413E-04 -1.442E-10
 TO JOINT      1.656E-02  1.597E-04  2.426E-08 -2.311E-06 -1.742E-06 -1.499E-10

MEMBER     6 CONVERGED AFTER ITERATION     2


MEMBER     7 CONVERGED AFTER ITERATION     2


MEMBER     8 CONVERGED AFTER ITERATION     2


    9    1
FROM JOINT    -2.593E-02 -2.777E-01  2.318E-03 -4.786E+00  1.587E+00 -1.076E+02
CENTERLINE    -2.208E-02 -8.989E-02  2.202E-03 -2.031E+00 -5.584E-02  2.257E+00
 TO JOINT     -1.598E-02 -2.106E-03  3.277E-04  2.064E+00  1.262E+00 -3.035E+00

    9    2
FROM JOINT    -2.633E-02 -2.784E-01  2.225E-03 -1.437E+00  5.835E-01  1.081E+00
CENTERLINE    -2.238E-02 -9.104E-02  2.229E-03  3.819E-02 -7.594E-03 -7.107E-02
 TO JOINT     -1.593E-02 -2.027E-03  3.211E-04 -3.213E-02 -4.618E-02 -3.053E-01

    9    3
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FROM JOINT    -2.637E-02 -2.785E-01  2.216E-03 -5.921E-02  1.337E-02  2.697E-02
CENTERLINE    -2.234E-02 -9.098E-02  2.229E-03  1.022E-04  1.470E-05  1.640E-04
 TO JOINT     -1.593E-02 -2.029E-03  3.211E-04  3.923E-04 -2.351E-04 -2.984E-04

    9    4
FROM JOINT    -2.637E-02 -2.785E-01  2.216E-03 -9.183E-05  1.151E-05  1.366E-05
CENTERLINE    -2.234E-02 -9.098E-02  2.228E-03  4.909E-07  3.526E-06 -1.821E-08
 TO JOINT     -1.593E-02 -2.029E-03  3.211E-04 -2.719E-07 -1.404E-05 -9.006E-07

MEMBER     9 CONVERGED AFTER ITERATION     4


MEMBER    10 CONVERGED AFTER ITERATION     3


MEMBER    11 CONVERGED AFTER ITERATION     2


   12     1
FROM JOINT     5.551E-03  3.262E-03  1.181E-04 -4.168E-03  1.280E-02  1.039E-02
CENTERLINE     5.172E-03  2.825E-03 -6.634E-05  1.259E-02  1.792E-02  6.382E-02
 TO JOINT      4.812E-03  2.311E-04 -2.825E-05 -9.640E-04 -1.635E-03 -1.874E-03

   12     2
FROM JOINT     5.550E-03  3.265E-03  1.184E-04 -2.732E-07 -1.294E-04 -4.241E-09
CENTERLINE     5.172E-03  2.840E-03 -6.642E-05  7.352E-07  1.884E-04 -1.511E-05
 TO JOINT      4.812E-03  2.325E-04 -2.845E-05  6.158E-07 -1.715E-04  2.658E-05

MEMBER    12 CONVERGED AFTER ITERATION     2


MEMBER    13 CONVERGED AFTER ITERATION     2


MEMBER    14 CONVERGED AFTER ITERATION     2



    9 JOINTS NOT CONVERGED AT END OF FRAME ITERATION     4


***** FRAME ITERATION NO      4 *****

 MEMB MEMB        MEMBER DISPLACEMENTS               MEMBER EQULIBRIUM ERRCRS
  NO  ITER      AXIAL  LATERAL  ROTATIONAL        AXIAL     LATERAL    ROTATTONAL

    1     1
FROM JOINT    -3.162E-01  2.357E-02 -7.360E-04  1.513E-06  3.237E-07 -8.160E-04
CENTERLINE    -3.165E-01  6.567E-03 -7.726E-04  1.617E-06  4.496E-06 -7.429E-04
 TO JOINT     -3.167E-01 -1.023E-02 -7.183E-04 -5.059E-06 -7.630E-08 -8.240E-04

MEMBER     1 CONVERGED AFTER ITERATION     1

MEMBER     2 CONVERGED AFTER ITERATION     1


    3     1
FROM JOINT     4.861E-02 -3.157E-01 -6.884E-04  1.006E-05  1.595E-06  1.972E-03
CENTERLINE     4.885E-02 -3.231E-01 -2.882E-04 -3.725E-04  7.665E-05  2.991E-03
 TO JOINT      4.953E-02 -3.195E-01  8.175E-04 -1.133E-03  2.221E-04  2.615E-03

MEMBER     3 CONVERGED AFTER ITERATION     1


MEMBER     4 CONVERGED AFTER ITERATION     2


MEMBER     5 CONVERGED AFTER ITERATION     1


    6     1
FROM JOINT     2.419E-02 -6.183E-05 -5.641E-07  4.553E-05 -9.812E-03 -7.111E-07
CENTERLINE     1.875E-02  1.744E-04 -2.436E-07 -3.578E-05  4.167E-04  3.270E-10
 TO JOINT      1.659E-02  1.596E-04  2.707E-08 -3.064E-05 -3.900E-05  4.852E-10

MEMBER     6 CONVERGED AFTER ITERATION     1


MEMBER     7 CONVERGED AFTER ITERATION     1


MEMBER     8 CONVERGED AFTER ITERATION     1


    9     1
FROM JOINT    -2.771E-02 -2.855E-01  2.245E-03 -3.487E-01  1.036E-01  5.955E-01
CENTERLINE    -2.316E-02 -9.240E-02  2.303E-03  5.705E-02 -3.409E-02 -9.099E-01
 TO JOINT     -1.599E-02 -1.509E-03  3.075E-04  4.737E-02 -2.222E-03 -1.849E-01

    9     2
FROM JOINT    -2.772E-02 -2.855E-01  2.243E-03 -1.492E-03  4.626E-04  5.394E-03
CENTERLINE    -2.315E-02 -9.243E-02  2.301E-03  4.072E-04 -9.007E-05 -1.654E-03
 TO JOINT     -1.599E-02 -1.512E-03  3.077E-04  1.974E-04  5.928E-04 -5.385E-04

MEMBER     9 CONVERGED AFTER ITERATION     2


MEMBER    10 CONVERGED AFTER ITERATION     2


MEMBER    11 CONVERGED AFTER ITERATION     2


   12     1
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FROM JOINT	5.538E-03	2.742E-03	1.401E-04	-9.823E-05	1.119E-03	-4.514E-06
CENTERLINE	5.161E-03	2.894E-03	-6.295E-05	-4.854E-04	2.915E-03	-2.938E-03
TO JOINT	4.801E-03	2.971E-04	-2.991E-05	-1.153E-05	4.904E-04	7.633E-06

MEMBER 12 CONVERGED AFTER ITERATION 1

MEMBER 13 CONVERGED AFTER ITERATION 1

MEMBER 14 CONVERGED AFTER ITERATION 1

ALL JOINTS CONVERGED AT END OF ITERATION 4

SUMMARY OF FRAME ITERATIONS

JOINT NO	FRAME ITER	JOINT DISPLACEMENTS DISP(X)	DISP(Y)	ROTATION(Z)	JOINT EQUILIBRIUM ERRORS ERR(X)	ERR(Y)	ERR(Z)
1	1	-1.016E-01	-1.167E-02	-1.329E-05	-2.695E+00	1.212E+01	-1.908E+02
1	2	-2.487E-01	1.221E-02	-4.812E-04	1.098E+01	9.651E+00	1.204E+02
1	3	-3.093E-01	2.580E-02	-6.903E-04	6.276E-01	7.696E-01	6.899E+00
1	4	-3.161E-01	2.761E-02	-7.123E-04	1.465E-03	-1.844E-03	9.132E-03
4	1	-9.423E-02	-1.238E-02	6.656E-04	-8.631E+00	-9.391E+00	-2.037E+02
4	2	-2.469E-01	1.180E-02	9.946E-04	-1.341E+01	-8.535E+00	5.220E-01
4	3	-3.119E-01	2.555E-02	1.049E-03	-7.090E-01	-2.952E-01	-1.360E+01
4	4	-3.193E-01	2.746E-02	1.037E-03	2.922E-04	6.532E-03	-2.783E-01
7	1	-3.084E-03	-2.457E-02	-3.744E-05	-5.627E-02	1.380E-01	2.957E+01
7	2	-3.312E-03	-3.384E-02	7.284E-05	-1.848E+00	-1.944E-01	9.304E+01
7	3	-6.843E-03	-3.493E-02	2.526E-04	-5.343E-01	-3.036E-01	1.709E+01
7	4	-7.793E-03	-3.477E-02	2.876E-04	-1.192E-02	-6.162E-03	4.748E-01
10	1	-4.353E-03	-1.773E-02	-9.633E-08	-1.662E-02	-1.381E-02	3.483E-02
10	2	-5.948E-03	-2.398E-02	-8.325E-06	-8.732E-02	-1.857E-01	-1.482E-01
10	3	-6.145E-03	-2.538E-02	-1.753E-05	9.300E-03	-1.409E-02	-1.075E+00
10	4	-6.113E-03	-2.545E-02	-1.963E-05	7.984E-03	-2.234E-03	-4.227E-02
13	1	-2.706E-03	-1.148E-02	2.320E-09	1.068E-02	4.251E-02	4.142E-04
13	2	-3.638E-03	-1.521E-02	9.804E-09	4.521E-03	1.781E-02	3.711E-03
13	3	-3.840E-03	-1.602E-02	1.906E-08	8.644E-04	3.540E-03	4.960E-03
13	4	-3.848E-03	-1.605E-02	2.649E-08	2.848E-05	2.899E-05	1.474E-03

PROB (CONTD)
902 Q = 80 KIPS

TABLE 8 - JOINT DISPLACEMENTS AND REACTIONS

JOINT	DISPLACEMENTS DISP(X)	DISP(Y)	ROTATION(Z)	REACTIONS REACT(X)	REACT(Y)	REACT(Z)
1	-3.161E-01	2.761E-02	-7.123E-04	0.	0.	0.
2	-3.168E-01	-1.417E-02	-6.909E-04	0.	0.	0.
3	-3.180E-01	-5.379E-02	-5.818E-04	0.	0.	0.
4	-3.193E-01	2.746E-02	1.037E-03	0.	0.	0.
5	-3.183E-01	-2.072E-02	1.113E-03	0.	0.	0.
6	-3.170E-01	-5.745E-02	1.165E-03	0.	0.	0.
7	-7.793E-03	-3.477E-02	2.876E-04	0.	0.	0.
8	-1.518E-04	1.531E-02	1.207E-04	0.	0.	0.
9	1.102E-03	-5.526E-03	2.728E-04	0.	0.	0.
10	-6.113E-03	-2.545E-02	-1.963E-05	0.	0.	0.
11	-1.821E-03	1.004E-02	-1.031E-05	0.	0.	0.
12	7.673E-04	-4.656E-03	-1.899E-05	0.	0.	0.
13	-3.848E-03	-1.605E-02	2.649E-08	0.	0.	0.
14	-9.461E-04	5.017E-03	1.923E-08	0.	0.	0.
15	5.034E-04	-3.678E-03	2.386E-08	0.	0.	0.

PROB (CONTD)
902 Q = 80 KIPS

TABLE 9 - MEMBER RESULTS

MEMBER NUMBER 1 STIFF TYPE 1 LOAD TYPE 1
LENGTH = 5.580E+01 ALPHA = 1.000E+00 BETA = 0.
GOES FROM JOINT 1 TO JOINT 2

OUTPUT DISTANCES ARE FROM JOINT 1 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	-3.161E-01	2.761E-02	-7.123E-04	-3.738E+01	6.394E+01	-1.606E+03
5.580E+00	-3.162E-01	2.357E-02	-7.360E-04	-3.738E+01	6.340E+01	-1.250E+03
1.116E+01	-3.163E-01	1.941E-02	-7.538E-04	-3.738E+01	6.286E+01	-8.979E+02
1.674E+01	-3.163E-01	1.517E-02	-7.659E-04	-3.738E+01	6.232E+01	-5.485E+02
2.232E+01	-3.164E-01	1.088E-02	-7.721E-04	-3.738E+01	6.178E+01	-2.021E+02
2.790E+01	-3.165E-01	6.567E-03	-7.726E-04	-3.738E+01	6.124E+01	1.413E+02
3.348E+01	-3.165E-01	2.268E-03	-7.674E-04	-3.738E+01	6.069E+01	4.816E+02
3.906E+01	-3.166E-01	-1.986E-03	-7.566E-04	-3.738E+01	6.015E+01	8.189E+02
4.464E+01	-3.167E-01	-6.164E-03	-7.402E-04	-3.738E+01	5.961E+01	1.153E+03
5.022E+01	-3.167E-01	-1.023E-02	-7.183E-04	-3.738E+01	5.907E+01	1.484E+03
5.580E+01	-3.168E-01	-1.417E-02	-6.909E-04	-3.738E+01	5.853E+01	1.813E+03

PROB (CONTD)
902 Q = 80 KIPS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 2 STIFF TYPE 2 LOAD TYPE 2
LENGTH = 6.250E+01 ALPHA = 1.000E+00 BETA = 0.
GOES FROM JOINT 2 TO JOINT 3

OUTPUT DISTANCES ARE FROM JOINT 2 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	-3.168E-01	-1.417E-02	-6.909E-04	-6.190E+01	5.303E-01	6.292E+02
6.250E+00	-3.169E-01	-1.845E-02	-6.792E-04	-6.190E+01	-7.596E-02	6.309E+02
1.250E+01	-3.170E-01	-2.266E-02	-6.674E-04	-6.190E+01	-6.822E-01	6.288E+02
1.875E+01	-3.172E-01	-2.679E-02	-6.557E-04	-6.190E+01	-1.288E+00	6.229E+02
2.500E+01	-3.173E-01	-3.085E-02	-6.441E-04	-6.190E+01	-1.895E+00	6.132E+02
3.125E+01	-3.174E-01	-3.484E-02	-6.328E-04	-6.190E+01	-2.501E+00	5.997E+02
3.750E+01	-3.175E-01	-3.876E-02	-6.217E-04	-6.190E+01	-3.107E+00	5.824E+02
4.375E+01	-3.177E-01	-4.262E-02	-6.110E-04	-6.190E+01	-3.713E+00	5.614E+02
5.000E+01	-3.178E-01	-4.640E-02	-6.008E-04	-6.190E+01	-4.320E+00	5.365E+02
5.625E+01	-3.179E-01	-5.013E-02	-5.910E-04	-6.190E+01	-4.926E+00	5.078E+02
6.250E+01	-3.180E-01	-5.379E-02	-5.818E-04	-6.190E+01	-5.532E+00	4.754E+02

PROB (CONTD)
902 Q = 80 KIPS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 3 STIFF TYPE 3 LOAD TYPE 3
LENGTH = 3.058E+01 ALPHA = -2.387E-01 BETA = -9.711E-01
GOES FROM JOINT 1 TO JOINT 4

OUTPUT DISTANCES ARE FROM JOINT 1 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	4.864E-02	-3.136E-01	-7.123E-04	-7.101E+01	-2.104E+01	1.606E+03
3.058E+00	4.861E-02	-3.157E-01	-6.884E-04	-7.108E+01	-2.103E+01	1.542E+03
6.117E+00	4.858E-02	-3.178E-01	-6.655E-04	-7.114E+01	-2.101E+01	1.477E+03
9.175E+00	4.856E-02	-3.198E-01	-6.436E-04	-7.120E+01	-2.100E+01	1.413E+03
1.223E+01	4.853E-02	-3.217E-01	-6.226E-04	-7.127E+01	-2.098E+01	1.349E+03
1.529E+01	4.885E-02	-3.231E-01	-2.882E-04	-7.133E+01	-2.097E+01	1.285E+03
1.835E+01	4.911E-02	-3.235E-01	2.288E-05	-7.139E+01	-2.095E+01	1.221E+03
2.141E+01	4.931E-02	-3.230E-01	3.108E-04	-7.146E+01	-2.094E+01	1.157E+03
2.447E+01	4.945E-02	-3.216E-01	5.756E-04	-7.152E+01	-2.092E+01	1.093E+03
2.753E+01	4.953E-02	-3.195E-01	8.175E-04	-7.158E+01	-2.090E+01	1.029E+03
3.058E+01	4.956E-02	-3.167E-01	1.037E-03	-7.164E+01	-2.089E+01	9.647E+02

PROB (CONTD)
902 Q = 80 KIPS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 4 STIFF TYPE 5 LOAD TYPE 5
LENGTH = 1.897E+02 ALPHA = -2.425E-01 BETA = -9.701E-01
GOES FROM JOINT 4 TO JOINT 7

OUTPUT DISTANCES ARE FROM JOINT 4 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	5.081E-02	-3.165E-01	1.037E-03	-7.173E+01	-2.060E+01	9.645E+02
1.897E+01	4.983E-02	-2.876E-01	1.937E-03	-7.144E+01	-1.803E+01	5.954E+02
3.793E+01	4.822E-02	-2.466E-01	2.347E-03	-7.116E+01	-1.524E+01	2.758E+02
5.690E+01	4.660E-02	-2.005E-01	2.482E-03	-7.089E+01	-1.225E+01	1.096E+01
7.587E+01	4.499E-02	-1.541E-01	2.395E-03	-7.062E+01	-9.121E+00	-1.953E+02
9.483E+01	4.339E-02	-1.109E-01	2.143E-03	-7.037E+01	-5.964E+00	-3.413E+02
1.138E+02	4.181E-02	-7.355E-02	1.782E-03	-7.014E+01	-2.885E+00	-4.272E+02
1.328E+02	4.024E-02	-4.366E-02	1.368E-03	-6.991E+01	1.665E-03	-4.555E+02
1.517E+02	3.869E-02	-2.170E-02	9.516E-04	-6.970E+01	2.575E+00	-4.308E+02
1.707E+02	3.715E-02	-7.248E-03	5.802E-04	-6.950E+01	4.485E+00	-3.604E+02
1.897E+02	3.562E-02	8.711E-04	2.876E-04	-6.931E+01	5.566E+00	-2.622E+02

PROB (CONTD)
902 Q = 80 KIPS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 5 STIFF TYPE 7 LOAD TYPE 7
LENGTH = 1.278E+02 ALPHA = -2.425E-01 BETA = -9.701E-01
GOES FROM JOINT 7 TO JOINT 10

OUTPUT DISTANCES ARE FROM JOINT 7 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	3.562E-02	8.711E-04	2.876E-04	-6.930E+01	5.576E+00	-2.618E+02
1.278E+01	3.459E-02	3.592E-03	1.437E-04	-6.894E+01	5.203E+00	-1.924E+02
2.556E+01	3.357E-02	4.745E-03	4.177E-05	-6.834E+01	4.566E+00	-1.290E+02
3.834E+01	3.257E-02	4.837E-03	-2.314E-05	-6.743E+01	3.689E+00	-7.578E+01
5.113E+01	3.157E-02	4.296E-03	-5.816E-05	-6.623E+01	2.728E+00	-3.470E+01
6.391E+01	3.060E-02	3.456E-03	-7.105E-05	-6.476E+01	1.811E+00	-5.968E+00
7.669E+01	2.965E-02	2.551E-03	-6.924E-05	-6.303E+01	1.029E+00	1.170E+01
8.947E+01	2.873E-02	1.726E-03	-5.905E-05	-6.105E+01	4.263E-01	2.043E+01
1.023E+02	2.784E-02	1.058E-03	-4.538E-05	-5.884E+01	1.331E-02	2.269E+01
1.150E+02	2.699E-02	5.670E-04	-3.159E-05	-5.641E+01	-2.284E-01	2.084E+01
1.278E+02	2.617E-02	2.417E-04	-1.963E-05	-5.381E+01	-3.569E-01	1.690E+01

PROB (CONTD)
902 Q = 80 KIPS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 6 STIFF TYPE 9 LOAD TYPE 9
LENGTH = 3.402E+02 ALPHA = -2.425E-01 BETA = -9.701E-01
GOES FROM JOINT 10 TO JOINT 13

OUTPUT DISTANCES ARE FROM JOINT 10 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	2.617E-02	2.417E-04	-1.963E-05	-5.381E+01	-3.652E-01	1.685E+01
3.402E+01	2.419E-02	-6.183E-05	-5.641E-07	-4.686E+01	-2.540E-01	5.739E+00
6.803E+01	2.247E-02	1.749E-05	3.931E-06	-4.031E+01	-1.060E-01	-4.123E-01
1.020E+02	2.100E-02	1.279E-04	2.338E-06	-3.426E+01	-4.771E-03	-1.476E+00
1.361E+02	1.977E-02	1.730E-04	4.663E-07	-2.862E+01	2.026E-02	-7.424E-01
1.701E+02	1.875E-02	1.744E-04	-2.436E-07	-2.333E+01	1.245E-02	-9.911E-02
2.041E+02	1.793E-02	1.655E-04	-2.391E-07	-1.833E+01	2.636E-03	1.045E-01
2.381E+02	1.730E-02	1.601E-04	-8.300E-08	-1.356E+01	-1.176E-03	8.050E-02
2.721E+02	1.686E-02	1.590E-04	5.661E-09	-8.946E+00	-1.172E-03	2.461E-02
3.061E+02	1.659E-02	1.596E-04	2.707E-08	-4.446E+00	-3.833E-04	7.771E-04
3.402E+02	1.651E-02	1.606E-04	2.649E-08	3.503E-05	2.060E-05	-1.474E-03

PROB (CONTD)
902 Q = 80 KIPS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 7 STIFF TYPE 4 LOAD TYPE 4
LENGTH = 3.010E+01 ALPHA = 1.617E-01 BETA = -9.868E-01
GOES FROM JOINT 2 TO JOINT 5

OUTPUT DISTANCES ARE FROM JOINT 2 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	-3.725E-02	-3.149E-01	-6.909E-04	4.620E+01	-1.727E+01	1.227E+03
3.010E+00	-3.723E-02	-3.170E-01	-6.730E-04	4.614E+01	-1.728E+01	1.175E+03
6.019E+00	-3.722E-02	-3.190E-01	-6.559E-04	4.608E+01	-1.729E+01	1.123E+03
9.029E+00	-3.720E-02	-3.209E-01	-6.395E-04	4.601E+01	-1.730E+01	1.071E+03
1.204E+01	-3.719E-02	-3.228E-01	-6.239E-04	4.595E+01	-1.731E+01	1.019E+03
1.505E+01	-3.601E-02	-3.242E-01	-2.893E-04	4.589E+01	-1.732E+01	9.664E+02
1.806E+01	-3.490E-02	-3.246E-01	2.718E-05	4.582E+01	-1.733E+01	9.142E+02
2.107E+01	-3.384E-02	-3.241E-01	3.257E-04	4.576E+01	-1.734E+01	8.621E+02
2.408E+01	-3.284E-02	-3.226E-01	6.061E-04	4.570E+01	-1.735E+01	8.099E+02
2.709E+01	-3.190E-02	-3.204E-01	8.685E-04	4.563E+01	-1.736E+01	7.578E+02
3.010E+01	-3.102E-02	-3.174E-01	1.113E-03	4.557E+01	-1.737E+01	7.056E+02

PROB (CONTD)
902 Q = 80 KIPS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 8 STIFF TYPE 4 LOAD TYPE 4
LENGTH = 3.010E+01 ALPHA = 1.617E-01 BETA = -9.868E-01
GOES FROM JOINT 3 TO JOINT 6

OUTPUT DISTANCES ARE FROM JOINT 3 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	1.651E-03	-3.226E-01	-5.818E-04	-2.530E+00	-1.876E+01	1.379E+03
3.010E+00	1.650E-03	-3.243E-01	-5.616E-04	-2.592E+00	-1.877E+01	1.323E+03
6.019E+00	1.649E-03	-3.259E-01	-5.423E-04	-2.655E+00	-1.878E+01	1.266E+03
9.029E+00	1.647E-03	-3.275E-01	-5.238E-04	-2.717E+00	-1.879E+01	1.210E+03
1.204E+01	1.646E-03	-3.291E-01	-5.062E-04	-2.780E+00	-1.880E+01	1.153E+03
1.505E+01	2.430E-03	-3.301E-01	-1.778E-04	-2.844E+00	-1.881E+01	1.097E+03
1.806E+01	3.154E-03	-3.302E-01	1.306E-04	-2.906E+00	-1.882E+01	1.040E+03
2.107E+01	3.818E-03	-3.294E-01	4.189E-04	-2.968E+00	-1.883E+01	9.834E+02
2.408E+01	4.420E-03	-3.277E-01	6.873E-04	-3.031E+00	-1.884E+01	9.266E+02
2.709E+01	4.961E-03	-3.252E-01	9.360E-04	-3.094E+00	-1.885E+01	8.699E+02
3.010E+01	5.439E-03	-3.221E-01	1.165E-03	-3.156E+00	-1.886E+01	8.131E+02

PROB (CONTD)
902 Q = 80 KIPS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 9 STIFF TYPE 6 LOAD TYPE 6
LENGTH = 1.865E+02 ALPHA = 1.644E-01 BETA = -9.864E-01
GOES FROM JOINT 5 TO JOINT 8

OUTPUT DISTANCES ARE FROM JOINT 5 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	-3.189E-02	-3.174E-01	1.113E-03	4.552E+01	-1.724E+01	7.052E+02
1.865E+01	-2.772E-02	-2.855E-01	2.243E-03	4.473E+01	-1.487E+01	4.064E+02
3.731E+01	-2.604E-02	-2.391E-01	2.681E-03	4.396E+01	-1.231E+01	1.538E+02
5.596E+01	-2.518E-02	-1.885E-01	2.729E-03	4.321E+01	-9.570E+00	-4.881E+01
7.462E+01	-2.433E-02	-1.385E-01	2.614E-03	4.246E+01	-6.739E+00	-1.990E+02
9.327E+01	-2.315E-02	-9.243E-02	2.301E-03	4.172E+01	-3.932E+00	-2.962E+02
1.119E+02	-2.121E-02	-5.442E-02	1.764E-03	4.100E+01	-1.274E+00	-3.421E+02
1.306E+02	-1.906E-02	-2.708E-02	1.168E-03	4.031E+01	1.103E+00	-3.410E+02
1.492E+02	-1.719E-02	-1.025E-02	6.438E-04	3.963E+01	2.953E+00	-2.992E+02
1.679E+02	-1.599E-02	-1.512E-03	3.077E-04	3.898E+01	3.914E+00	-2.298E+02
1.865E+02	-1.512E-02	2.367E-03	1.207E-04	3.834E+01	4.053E+00	-1.527E+02

PROB (CONTD)
902 Q = 80 KIPS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 10 STIFF TYPE 6 LOAD TYPE 6
LENGTH = 1.865E+02 ALPHA = 1.644E-01 BETA = -9.864E-01
GOES FROM JOINT 6 TO JOINT 9

OUTPUT DISTANCES ARE FROM JOINT 6 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	4.558E-03	-3.221E-01	1.165E-03	-3.109E+00	-1.887E+01	8.130E+02
1.865E+01	6.200E-03	-2.906E-01	2.156E-03	-3.418E+00	-1.648E+01	4.825E+02
3.731E+01	6.145E-03	-2.468E-01	2.492E-03	-3.720E+00	-1.390E+01	1.979E+02
5.596E+01	6.000E-03	-1.993E-01	2.567E-03	-4.019E+00	-1.111E+01	-3.638E+01
7.462E+01	5.848E-03	-1.524E-01	2.450E-03	-4.319E+00	-8.206E+00	-2.171E+02
9.327E+01	5.700E-03	-1.089E-01	2.191E-03	-4.619E+00	-5.274E+00	-3.429E+02
1.119E+02	5.654E-03	-7.149E-02	1.812E-03	-4.919E+00	-2.426E+00	-4.142E+02
1.306E+02	5.742E-03	-4.189E-02	1.357E-03	-5.217E+00	2.233E-01	-4.338E+02
1.492E+02	5.816E-03	-2.079E-02	9.108E-04	-5.513E+00	2.563E+00	-4.062E+02
1.679E+02	5.763E-03	-7.328E-03	5.435E-04	-5.808E+00	4.282E+00	-3.383E+02
1.865E+02	5.632E-03	1.788E-04	2.728E-04	-6.102E+00	5.237E+00	-2.466E+02

PROB (CONTD)
902 Q = 80 KIPS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 11 STIFF TYPE 8 LOAD TYPE 8
LENGTH = 1.257E+02 ALPHA = 1.644E-01 BETA = -9.864E-01
GOES FROM JOINT 8 TO JOINT 11

OUTPUT DISTANCES ARE FROM JOINT 8 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	-1.512E-02	2.367E-03	1.207E-04	3.844E+01	4.041E+00	-1.531E+02
1.257E+01	-1.457E-02	3.361E-03	4.117E-05	3.790E+01	3.529E+00	-1.052E+02
2.514E+01	-1.403E-02	3.531E-03	-1.104E-05	3.726E+01	2.910E+00	-6.437E+01
3.771E+01	-1.350E-02	3.190E-03	-4.073E-05	3.650E+01	2.213E+00	-3.210E+01
5.028E+01	-1.298E-02	2.588E-03	-5.330E-05	3.562E+01	1.530E+00	-8.756E+00
6.286E+01	-1.248E-02	1.906E-03	-5.405E-05	3.463E+01	9.253E-01	6.316E+00
7.543E+01	-1.199E-02	1.262E-03	-4.766E-05	3.354E+01	4.409E-01	1.446E+01
8.800E+01	-1.151E-02	7.234E-04	-3.786E-05	3.236E+01	9.083E-02	1.736E+01
1.006E+02	-1.106E-02	3.137E-04	-2.737E-05	3.110E+01	-1.307E-01	1.672E+01
1.131E+02	-1.062E-02	3.046E-05	-1.790E-05	2.977E+01	-2.428E-01	1.405E+01
1.257E+02	-1.020E-02	-1.452E-04	-1.031E-05	2.839E+01	-2.851E-01	1.060E+01

PROB (CONTD)
902 Q = 80 KIPS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 12 STIFF TYPE 8 LOAD TYPE 8
LENGTH = 1.257E+02 ALPHA = 1.644E-01 BETA = -9.864E-01
GOES FROM JOINT 9 TO JOINT 12

OUTPUT DISTANCES ARE FROM JOINT 9 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	5.632E-03	1.787E-04	2.728E-04	-6.096E+00	5.244E+00	-2.462E+02
1.257E+01	5.538E-03	2.742E-03	1.401E-04	-6.253E+00	4.893E+00	-1.819E+02
2.514E+01	5.444E-03	3.880E-03	4.543E-05	-6.368E+00	4.306E+00	-1.232E+02
3.771E+01	5.349E-03	4.043E-03	-1.566E-05	-6.430E+00	3.500E+00	-7.367E+01
5.028E+01	5.255E-03	3.614E-03	-4.950E-05	-6.440E+00	2.613E+00	-3.521E+01
6.286E+01	5.161E-03	2.894E-03	-6.295E-05	-6.401E+00	1.761E+00	-7.981E+00
7.543E+01	5.068E-03	2.097E-03	-6.261E-05	-6.315E+00	1.026E+00	9.074E+00
8.800E+01	4.977E-03	1.358E-03	-5.423E-05	-6.183E+00	4.537E-01	1.783E+01
1.006E+02	4.888E-03	7.502E-04	-4.228E-05	-6.007E+00	5.399E-02	2.049E+01
1.131E+02	4.801E-03	2.971E-04	-2.991E-05	-5.788E+00	-1.860E-01	1.920E+01
1.257E+02	4.719E-03	-8.645E-06	-1.899E-05	-5.539E+00	-3.185E-01	1.582E+01

PROB (CONTD)
902 Q = 80 KIPS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 13 STIFF TYPE 10 LOAD TYPE 10
LENGTH = 3.457E+02 ALPHA = 1.644E-01 BETA = -9.864E-01
GOES FROM JOINT 11 TO JOINT 14

OUTPUT DISTANCES ARE FROM JOINT 11 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	-1.020E-02	-1.450E-04	-1.031E-05	2.839E+01	-2.811E-01	1.063E+01
3.457E+01	-9.155E-03	-2.758E-04	1.095E-06	2.470E+01	-1.645E-01	2.843E+00
6.914E+01	-8.249E-03	-1.941E-04	2.871E-06	2.124E+01	-5.617E-02	-7.440E-01
1.037E+02	-7.475E-03	-1.198E-04	1.363E-06	1.804E+01	4.719E-03	-1.037E+00
1.383E+02	-6.823E-03	-9.623E-05	1.333E-07	1.506E+01	1.492E-02	-4.159E-01
1.729E+02	-6.284E-03	-9.929E-05	-2.233E-07	1.228E+01	7.279E-03	-5.476E-03
2.074E+02	-5.852E-03	-1.062E-04	-1.540E-07	9.642E+00	8.021E-04	8.730E-02
2.420E+02	-5.522E-03	-1.093E-04	-3.793E-08	7.128E+00	-1.112E-03	4.988E-02
2.766E+02	-5.289E-03	-1.096E-04	1.307E-08	4.703E+00	-7.399E-04	1.038E-02
3.111E+02	-5.150E-03	-1.090E-04	2.078E-08	2.337E+00	-1.581E-04	-1.275E-03
3.457E+02	-5.104E-03	-1.083E-04	1.923E-08	-2.885E-05	1.116E-05	-5.493E-04

PROB (CONTD)
902 Q = 80 KIPS

TABLE 9 - MEMBER RESULTS (CONTD)

MEMBER NUMBER 14 STIFF TYPE 10 LOAD TYPE 10
LENGTH = 3.457E+02 ALPHA = 1.644E-01 BETA = -9.864E-01
GOES FROM JOINT 12 TO JOINT 15

OUTPUT DISTANCES ARE FROM JOINT 12 ALONG THE MEMBER AXIS
ALL OUTPUT FORCES AND DISPLACEMENTS ARE WITH RESPECT TO THE MEMBER AXES

	DISPLACEMENTS			FORCES		
DISTANCE	AXIAL	LATERAL	ROTATIONAL	AXIAL	SHEAR	MOMENT
0.	4.719E-03	-8.746E-06	-1.899E-05	-5.539E+00	-3.263E-01	1.578E+01
3.457E+01	4.511E-03	-3.121E-04	-7.651E-07	-4.818E+00	-2.335E-01	5.483E+00
6.914E+01	4.332E-03	-2.410E-04	3.624E-06	-4.140E+00	-9.904E-02	-3.624E-01
1.037E+02	4.179E-03	-1.376E-04	2.143E-06	-3.515E+00	-4.424E-03	-1.366E+00
1.383E+02	4.050E-03	-9.628E-05	3.988E-07	-2.934E+00	1.867E-02	-6.688E-01
1.729E+02	3.944E-03	-9.571E-05	-2.386E-07	-2.390E+00	1.114E-02	-7.478E-02
2.074E+02	3.859E-03	-1.042E-04	-2.160E-07	-1.877E+00	2.112E-03	1.012E-01
2.420E+02	3.793E-03	-1.090E-04	-6.819E-08	-1.387E+00	-1.186E-03	7.129E-02
2.766E+02	3.747E-03	-1.098E-04	9.363E-09	-9.152E-01	-1.038E-03	1.918E-02
3.111E+02	3.720E-03	-1.092E-04	2.537E-08	-4.547E-01	-2.956E-04	-5.040E-04
3.457E+02	3.711E-03	-1.083E-04	2.386E-08	1.394E-05	2.437E-05	-1.264E-03

PROB (CONTD)
902 Q = 80 KIPS

TABLE 10 - JOINT EQUILIBRIUM ERRORS

JOINT	ERR(X) FORCE	ERR(Y) FORCE	ERR(Z) MOMENT
1	1.465E-03	-1.844E-03	9.132E-03
2	1.217E-03	-1.339E-03	1.536E-03
3	-2.188E-04	-1.714E-03	-2.143E-04
4	2.922E-04	6.532E-03	-2.783E-01
5	-2.036E-02	9.725E-02	-4.730E-01
6	-3.895E-03	4.127E-03	-1.116E-01
7	-1.192E-02	-6.162E-03	4.748E-01
8	2.726E-02	-9.403E-02	-4.451E-01
9	-6.608E-03	-6.633E-03	3.554E-01
10	7.984E-03	-2.234E-03	-4.227E-02
11	-2.860E-03	-3.159E-03	3.347E-02
12	7.564E-03	1.329E-03	-4.000E-02
13	2.848E-05	2.899E-05	1.474E-03
14	1.575E-05	-2.662E-05	5.493E-04
15	2.175E-05	1.776E-05	1.264E-03

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