FINITE-ELEMENT METHOD OF ANALYSIS FOR PLANE CURVED GIRDERS

by

William P. Dawkins

Research Report Number 56-20

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

Research Project 3-5-63-56

conducted for

The Texas Highway Department

in cooperation with the
U. S. Department of Transportation
Federal Highway Administration

by the

CENTER FOR HIGHWAY RESEARCH
THE UNIVERSITY OF TEXAS AT AUSTIN

June 1971

The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the Federal Highway Administration.

PREFACE

A method for analyzing plane, curved girders is presented in this report. The method combines the versatility of finite-element modeling with the efficiency of direct matrix structural analysis techniques. The procedure for describing the geometry and loading of the girder follows closely the methods used in discrete-element beam-column modeling presented in previous reports. It is presumed that the reader has a knowledge of matrix algebra and manipulations and is acquainted with conventional procedures for analysis of curved members. A review of Chapter 1 of Ref 4 will be of assistance in understanding the analytical procedures described herein.

This is the twentieth in a series of reports that describe work done under Research Project 3-5-63-56, "Development of Methods for Computer Simulation of Beam-Columns and Grid-Beam and Slab Systems." The reader will find it advantageous to review Research Report No. 56-1 which provides background information on discrete-element modeling of beam-columns.

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.

William P. Dawkins

October 1970

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 finite-element solution for beam-columns that is a basic tool in subsequent reports.

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 bent caps.

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.

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

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.

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.

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.

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.

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.

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.

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 of solving for the deflected shape of freely discontinuous plates and pavement slabs subjected to a variety of loads.

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.

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.

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.

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 the small-dimension test results for plates and slabs, along with some cyclic data on the slab.

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 an experimental program developed in the laboratory for the evaluation of the coefficient of subgrade reaction for use in the solution of small dimension slabs on layered foundations based on the discrete-element method.

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.

Report No. 56-18, "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.

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 my be applied to a wide variety of problems by utilizing them within appropriate programs.

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.

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 of plane frame structures that has the capability to economically analyze skewed frames and trusses with variable cross-section members randomly loaded and supported for a large number of loading conditions.

ABSTRACT

A method for analyzing plane, curved girders is presented. The continuous girder is replaced by an assemblage of straight, prismatic elements which are chords of the original curve. Each straight element is considered as a grid type member. The entire assemblage is treated as a special case of a grid structure. Conventional matrix methods of structural analysis are used to derive the equilibrium equations and a direct recursion-inversion solution procedure is utilized. Flexural properties, loads and restraints are allowed to vary at will along the girder.

A computer program which applies the analytical procedure is described. Output information provided by the program includes all displacements of each station, the shear in each element and the bending and torsion moments about normal and tangential directions, respectively.

Results obtained with the program are compared with other analytical procedures and with experimental data.

KEY WORDS: computers, finite-element analysis, curved beams, girders, matrix analysis.

SUMMARY

A method is developed for the analysis of curved structural members. The curvature is in a single plane, thus it is particularly suited for application to curved highway girders. The girders are replaced mathemetically by an easily visualized assemblage of straight elements which are chords of the curved beam.

The equilibrium equations of the structural assemblage are solved by high-speed digital computer. Bending properties, loads, and elastic restraints may vary freely along the member.

A computer program which applies the analytical procedure is described. Output information provided by the program includes displacements, rotations, the shear in each element, and the bending and torsion moments about normal and tangential directions, respectively.

This report includes documentation for the development of the equilibrium equations, a listing of the computer program with flow charts, a guide for the use of the program, a brief comparison to test measurements, and sample problems with results.

IMPLEMENTATION STATEMENT

A concise method for the analysis of plane, curved girders has been developed. The method consists of replacing the curved member with an assemblage of straight structural elements which forms an easily visualized structural model.

Several areas requiring additional research have been encountered during the course of this study. One area that needs work to make utilization of the program more convenient for the highway bridge designer would be the development of a user-oriented data generation routine. The variable increment length capability of the computer program may require a significant amount of manual computation to obtain the data required as input, particularly in the case of distributed data. The distribution procedure should be modified to accept data which are distributed with respect to distance along the member as well as with respect to stations as is now the case. A further modification of the program should be to permit elastic restraints at the stations at orientations other than in the global coordinate directions.

Another area that needs study concerns the determination of the effective torsional rigidity of open cross-sections when warping effects are present. The use of the conventional torsional stiffness parameter yields excellent results at points which are located at some distance from the point of restraint. However, in the vicinity of the restraints, warping of the cross-sections creates additional torsional rigidity which is not accounted for by the conventional term. For conventional curved highway bridge members, this effect will be small but should be considered by the investigator when interpreting results.

This program can be put to immediate use by bridge designers for aid in the analysis of curved girders which are supported in diverse ways. Connecting diaphragms can be represented by appropriate restraints; support settlements can be considered; and various torsional stiffness variations can be included.

It is recommended that this program be put into test use by designers of the Texas Highway Department to further evaluate its uses, and to investigate needed extensions or modifications to make it acceptable to the everyday user.

TABLE OF CONTENTS

PREFACE iii

LIST OF REPORTS v

ABSTRACT AND KEY WORDS vii

SUMMARY ix

IMPLEMENTATION STATEMENT xi

NOMENCLATURE xv

CHAPTER 1. INTRODUCTION

Purpose 1
Preliminary Considerations 1

CHAPTER 2. METHOD OF ANALYSIS

Assumptions 3
Development of Equations 3
Solution of Simultaneous Equations 12
Support Reactions and Internal Forces 13

CHAPTER 3. THE COMPUTER PROGRAM

FORTRAN Program 17
Description of Girder 17
Girder Supports and Restraints 19
Element Stiffnesses and Coordinate System 19
Applied Loads and Moments 19
Input Data 20
Output Data 20

CHAPTER 4. EXAMPLE SOLUTIONS

Rectangular Bracket 23
Semicircular Bow Girder 23
Circular Arc I-Beam 26
Straight Beam Solution 26
Curved Highway Girder 31

CHAPTER 5. CONCLUSIONS AND RECOMMENDATIONS

Conclusions 33
Recommendations 33

REFERENCES 35

APPENDICES

Appendix 1. Torsional Rigidities 39
Appendix 2. Input Forms 45
Appendix 3. Flow Diagrams 63
Appendix 4. Listing 75
Appendix 5. Sample Data 87
Appendix 6. Output 91

THE AUTHOR 105

NOMENCLATURE

Symbol	Typical Units	Definition
$\bar{a}_i$	lb/in	(3 × 3) Continuity matrix
$\bar{A}_i$	in.	(3 × 1) Recursion matrix
$\bar{b}_i$	lb/in	(3 × 3) Continuity matrix
$\bar{B}_i$	----	(3 × 3) Recursion matrix
$\bar{c}_i$	lb/in	(3 × 3) Continuity matrix
$\bar{d}_i$	lb	(3 × 1) Continuity matrix
EI_z	in-lb/rad	Flexural rigidity
$f^i_{y,m}$	lb	Force in Y_m-direction at station m in element i
$\bar{f}^i_m$	in-lb,lb	(3 × 1) Matrix of end forces at station m of element i in element coordinate system
$\bar{f}^i_{\eta,m}$	in-lb,lb	(3 × 1) Matrix of end forces at station m of element i in normal and tangential coordinate system
F_y	lb	Applied load in Y-direction
$\bar{F}_i$	in-lb,lb	(3 × 1) Matrix of loads applied to station i
GJ	in-lb/rad	Torsional rigidity
i	----	Integer
L	in.	Element length
m	----	Integer

Symbol	Typical Units	Definition
$m^i_{x,n}$, $m^i_{z,n}$	in-lb	Bending and torsion moments, respectively, at station i of element n in element coordinate system
$M_{x,i}$, $M_{z,i}$	in-lb	Moments applied to station i in X- and Z-directions, respectively
n	----	Integer
$\overline{Q}_i$	in-lb, lb	(3 × 1) Matrix of reactions at station i in global coordinate system
$R_{x,i}$, $R_{z,i}$	in-lb/rad	Elastic restraints at station i against rotation in X- and Z-directions, respectively
$\overline{R}_i$	in-lb/rad, lb/in	(3 × 3) Matrix of elastic restraints at station i
$\overline{S}^i_{m,n}$	in-lb/rad, lb/in	(3 × 3) Matrix relating end forces at station m to unit displacements at station n for element i in element coordinate system
$S_{y,i}$	lb/in	Elastic restraint at station i against translation in Y-direction
$\overline{T}_{\alpha,n}$	----	(3 × 3) Coordinate transformation matrix for element n
$\overline{T}^*_{\alpha,n}$	----	Transpose of $\overline{T}_{\alpha,n}$
$\overline{u}^i_m$	rad, in.	(3 × 1) Matrix of displacements at station m of element i in element coordinate system
$\overline{U}_i$	rad, in.	(3 × 1) Matrix of displacements at station i in global coordinate system
v^i_m	in.	Displacement of station m in Y_m-direction for element i
V_i	in.	Displacement of station i in Y-direction
X, Y, Z	----	Global coordinate system
X_m, Y_m, Z_m	----	Element coordinate system

Symbol	Typical Units	Definition
α_i	rad	Angle measured clockwise about Y-axis from X-axis to X_m-axis for element i
β_i	rad	Angle between tangent and chord for element i
η_i, ζ_i	--	Normal and tangential directions for element i
θ_m^i	rad	Rotation of end m about Z_m-axis for element i
Θ_i	rad	Rotation of station i about Z-axis
ϕ_m^i	rad	Rotation of end m about X_m-axis for element i
Φ_i	rad	Rotation of station i about X-axis

CHAPTER 1. INTRODUCTION

Purpose

The construction of modern highway systems has led to ever increasing use of continuously curved or polygonally curved girders and beams. Safe and economical design of these structural elements requires a general procedure for determining the displacements and internal forces induced by live and dead loading. Although the analysis of curved beams has been the subject of many studies, no totally general analytical procedure has yet been devised. A variety of methods have been proposed; however, these methods are limited to special classes of problems (Refs 2, 10, and 11) or lead to highly complex arithmetic expressions which are of practical utility only when a digital computer is used to perform the operations (Ref 9).

Development of the digital computer and finite-or discrete-element methods have permitted the formulation of nearly completely general analytical procedures for many structural problems (Ref 7).

The purpose of this report is to present a finite-element method of analysis for plane curved girders with all loads applied normal to the plane of the member.

Preliminary Considerations

The basic concept of finite-element or discrete-element analysis is the formulation of a model which maintains a high degree of geometric and behavioral similarity with the real structure, but which can be readily analyzed. Models of structures curved in space have been proposed previously (Refs 1 and 8). These models replace the continuously curved member with a number of straight segments which are chords of the curve. Obviously, the greater the number of segments, the higher the degree of geometric similarity.

When the curved member lies in a single plane and is loaded normal to that plane, the polygonally curved model becomes a special case of a grid type structure (Ref 5). This type of structure can be analyzed by conventional matrix methods of analysis and, as demonstrated later in this report by example problems, the model responds to externally applied loads in the same fashion as the continuously curved member. In addition, the finite-element analysis procedure can be utilized to solve those problems which are not susceptible to solution in closed form.

CHAPTER 2. METHOD OF ANALYSIS

Assumptions

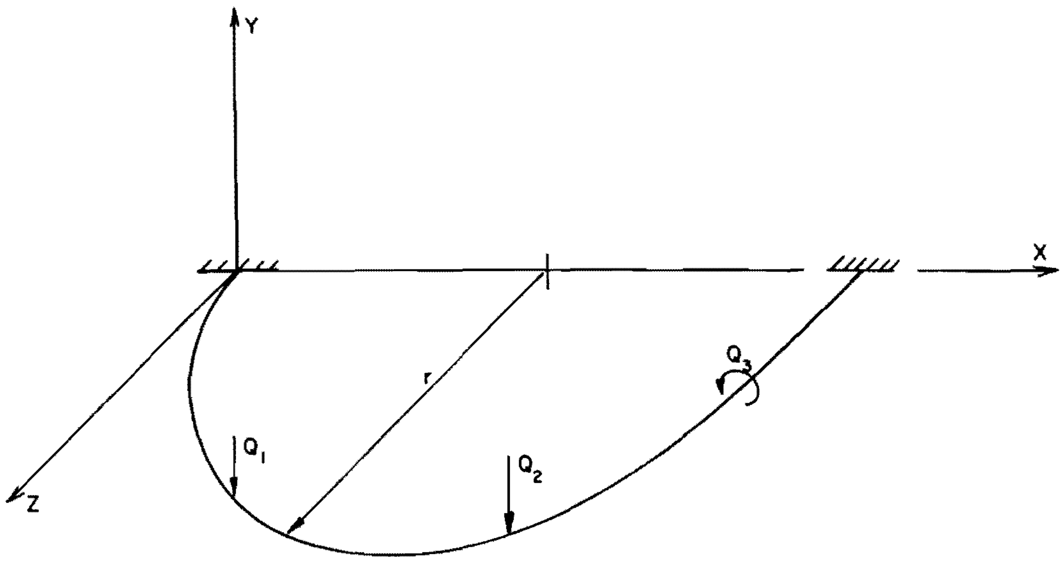
A plane curved girder and a finite-element model of the girder are shown in Fig 1. As stated in the preceding section, the finite-element model is a special case of a plane grid and conventional matrix analysis techniques will be used to determine the displacements and internal forces in the model. In the succeeding derivations, it is assumed that all loads and restraints are applied only at the intersections of the chord elements. These intersections are referred to as the joints or stations of the girder. Stations are assigned sequential identification numbers starting from one end of the structure. Each element is identified by the larger of its two end station numbers.

The usual assumptions of frame analysis are maintained (Ref 4). Primarily, these assumptions are that the structure is linearly elastic and that all displacements are small compared to other dimensions of the structure.

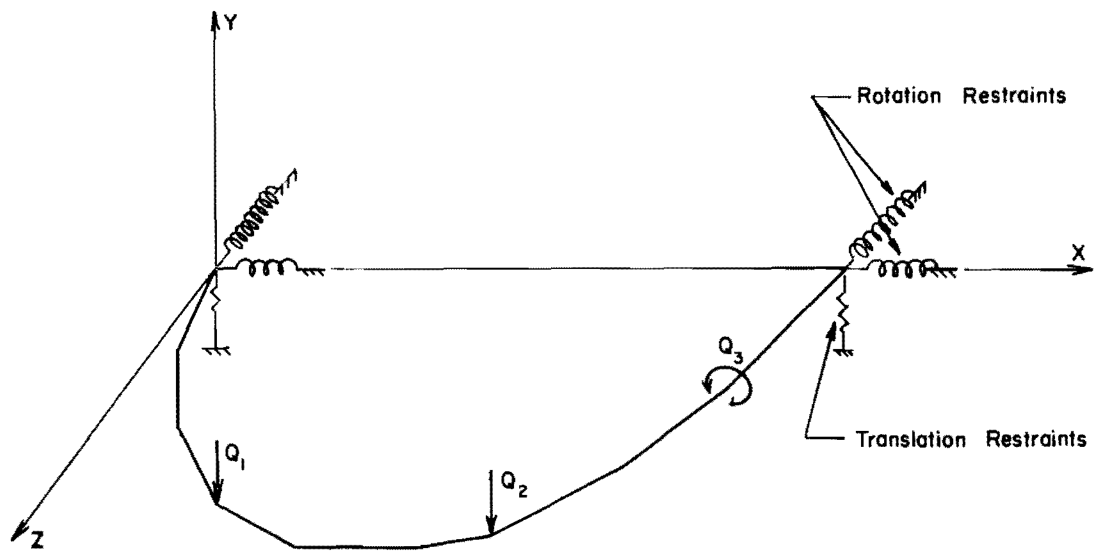
Development of Equations

Details of the finite-element model are shown in Fig 2. Since this is a grid structure, each joint in the model may be subjected to three external forces or elastic restraints and may undergo three displacement components.

A free body of the i^{th} element of the model appears in Fig 3. There are three internal forces as shown in Fig 3(a) and three displacement components as shown in Fig 3(b) at each end of the element. The member end forces and end displacements (Fig 3) are related to an auxiliary, or member, coordinate system. The X_m-axis is defined by the centroidal axis of the prismatic element. The Y_m- and Z_m-axes are the principal axes of the cross-section. Since the member lies in the X-Z plane, it is assumed that the Y_m-axis and the global Y-axis, Figs 2 and 3, are parallel, and that the X_m-Z_m and global X-Z planes coincide. Although these assumptions limit the orientation of the principal axes of the cross-section of the element, it is not felt that this is a serious limitation (Refs 4 and 8).



(a) Continuous curved girder.



(b) Finite-element model.

Fig 1. Curved girder and finite-element model.

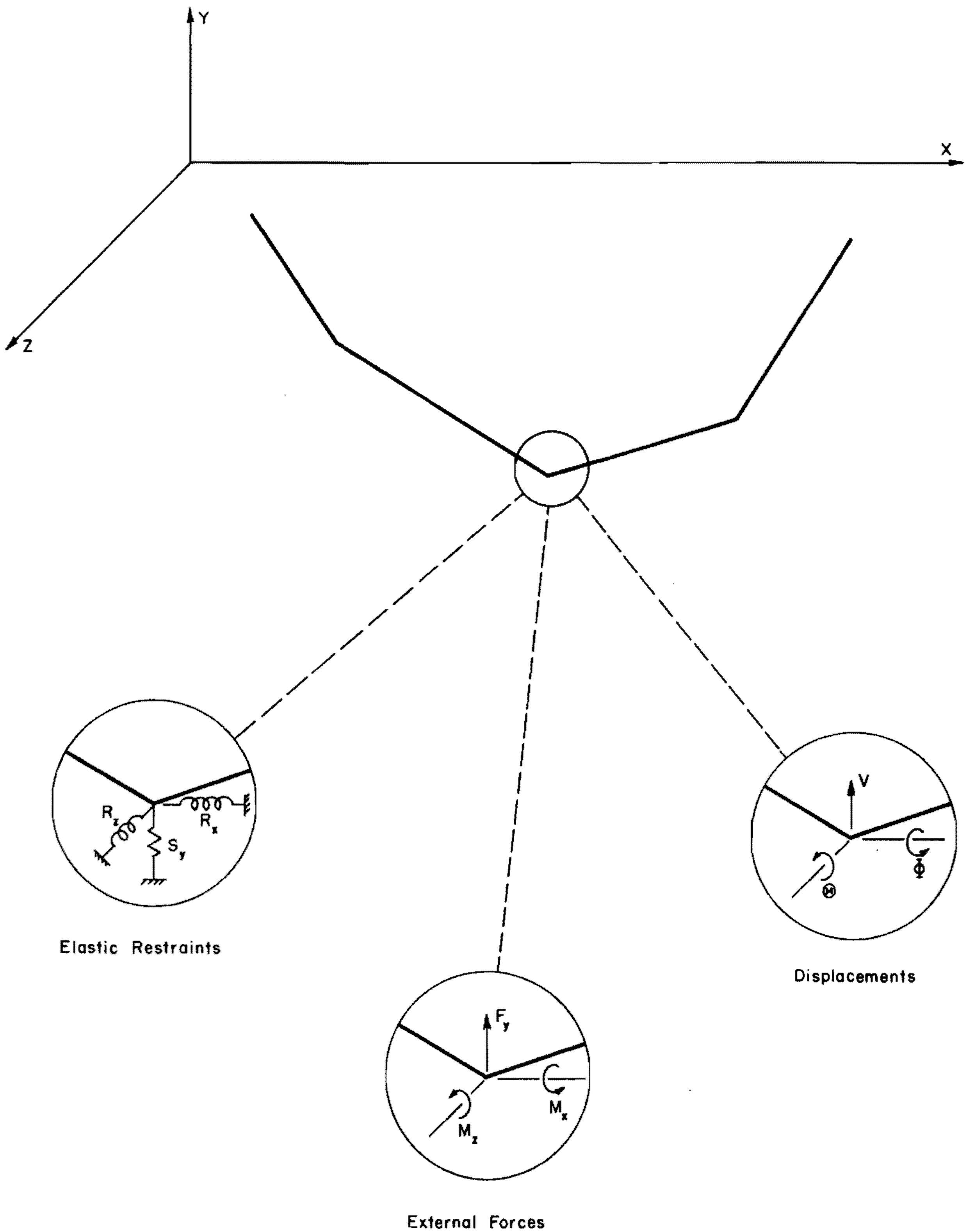
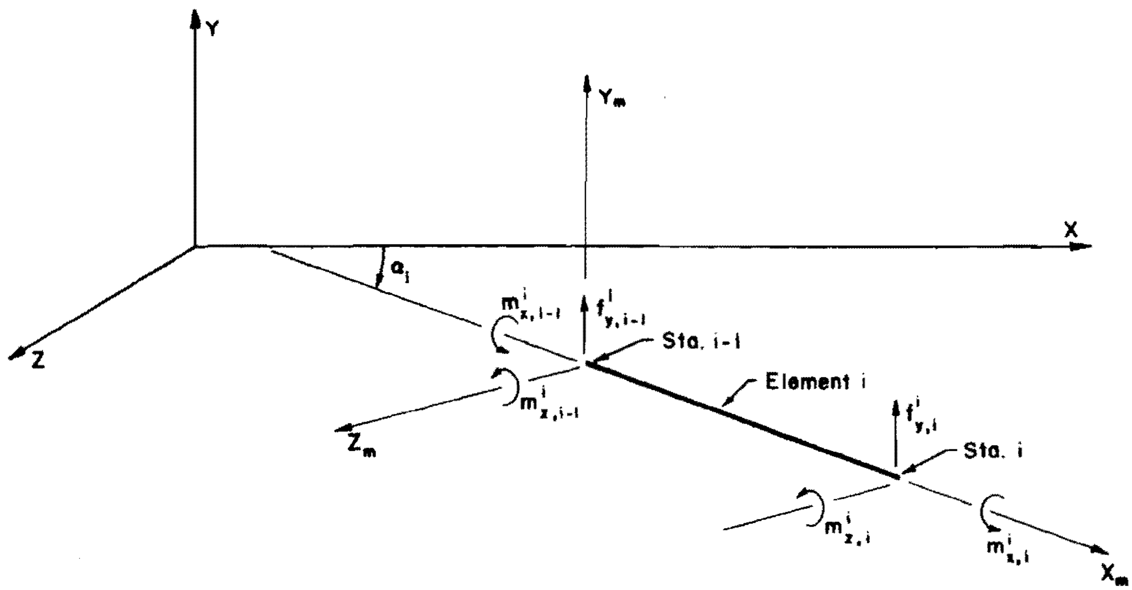
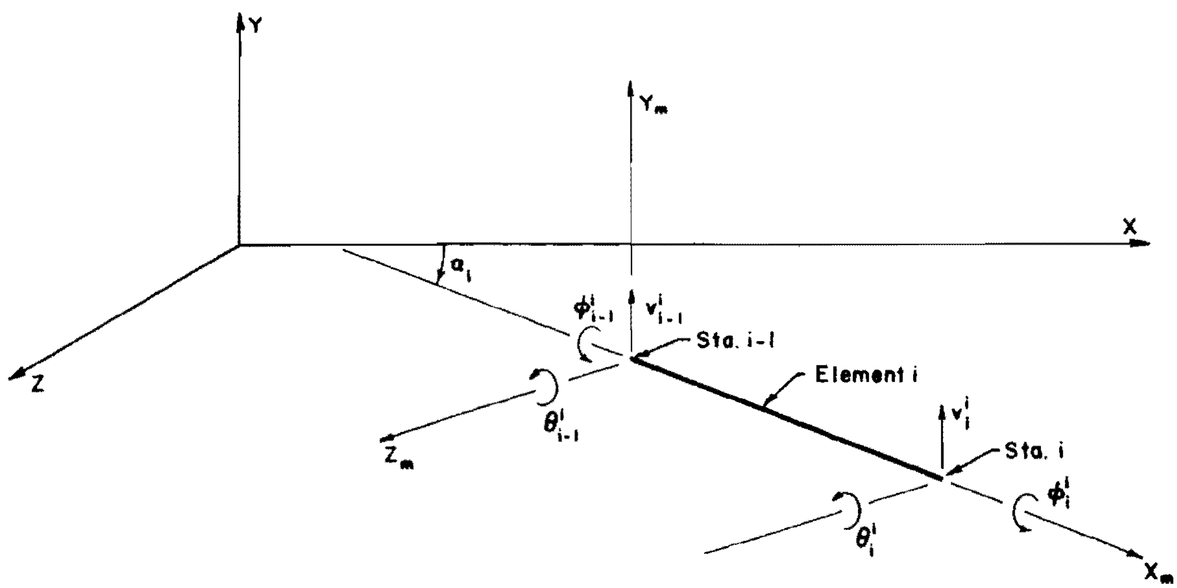


Fig 2. Joint details of finite-element model.



(a) Element end forces.



(b) Element end displacements.

Fig 3. Free-body of i^{th} finite element.

The element end forces are related to the element end displacements by Ref 4.

$$\begin{bmatrix} m^i_{x,i-1} \\ f^i_{y,i-1} \\ m^i_{z,i-1} \\ m^i_{x,i} \\ f^i_{y,i} \\ m^i_{z,i} \end{bmatrix} = \begin{bmatrix} \frac{GJ}{L} & 0 & 0 & \frac{-GJ}{L} & 0 & 0 \\ 0 & \frac{12EI_z}{L^3} & \frac{6EI_z}{L^2} & 0 & \frac{-12EI_z}{L^3} & \frac{6EI_z}{L^2} \\ 0 & \frac{6EI_z}{L^2} & \frac{4EI_z}{L} & 0 & \frac{-6EI_z}{L^2} & \frac{2EI_z}{L} \\ \frac{-GJ}{L} & 0 & 0 & \frac{GJ}{L} & 0 & 0 \\ 0 & \frac{-12EI_z}{L^3} & \frac{-6EI_z}{L^2} & 0 & \frac{12EI_z}{L^3} & \frac{-6EI_z}{L^2} \\ 0 & \frac{6EI_z}{L^2} & \frac{2EI_z}{L} & 0 & \frac{-6EI_z}{L^2} & \frac{4EI_z}{L} \end{bmatrix} \begin{bmatrix} \phi^i_{i-1} \\ v^i_{i-1} \\ \theta^i_{i-1} \\ \phi^i_i \\ v^i_i \\ \theta^i_i \end{bmatrix} \qquad (1)$$

Where the forces $m^i_{x,i-1}$, $f^i_{y,i-1}$, etc. and the displacements ϕ^i_{i-1}, v^i_{i-1}, etc. are readily identified in Fig 3, and

GJ = torsional rigidity* of element i,

L = length of element i,

EI_z = bending rigidity of element i about Z_m-axis.

The matrix equation (Eq 1) may be expressed conveniently in the form

$$\begin{bmatrix} \bar{f}^i_{i-1} \\ \bar{f}^i_i \end{bmatrix} \quad \begin{bmatrix} \bar{S}^i_{i-1,i-1} & \bar{S}^i_{i-1,i} \\ \bar{S}^i_{i,i-1} & \bar{S}^i_{i,i} \end{bmatrix} \quad \begin{bmatrix} \bar{u}^i_{i-1} \\ \bar{u}^i_i \end{bmatrix} \qquad (2)$$

* See Appendix 1 for discussion of torsional rigidity.

where

$\bar{f}^{i}_{m}$ = (3 × 1) matrix of end forces at station m in element i,

$\bar{S}^{i}_{m,n}$ = (3 × 3) matrix of stiffness coefficients relating element end forces at station m to unit displacements at station n for element i, and

$\bar{u}^{i}_{m}$ = (3 × 1) matrix of displacements of end m in element i.

Equation 2 is expanded to

$$\bar{f}^{i}_{i-1} = \bar{S}^{i}_{i-1,i-1}\bar{u}^{i}_{i-1} + \bar{S}^{i}_{i-1,i}\bar{u}^{i}_{i} \tag{3}$$

$$\bar{f}^{i}_{i} = \bar{S}^{i}_{i,i-1}\bar{u}^{i}_{i-1} + \bar{S}^{i}_{i,i}\bar{u}^{i}_{i} \tag{4}$$

A free-body of the i^{th} station of the finite element model is shown in Fig 4. The conditions of equilibrium of the station are expressed by

$$M_{x,i} - R_{x,i}\Phi_i - \cos\alpha_i m^{i}_{x,i} + \sin\alpha_i m^{i}_{z,i} - \cos\alpha_{i+1} m^{i+1}_{x,i}$$

$$+ \sin\alpha_{i+1} m^{i+1}_{z,i} = 0 \tag{5}$$

$$F_{y,i} - S_{y,i}V_i - f^{i}_{y,i} - f^{i+1}_{y,i} = 0 \tag{6}$$

$$M_{z,i} - R_{z,i}\Theta_i - \sin\alpha_i m^{i}_{x,i} - \cos\alpha_i m^{i}_{z,i} - \sin\alpha_{i+1} m^{i+1}_{x,i}$$

$$- \cos\alpha_{i+1} m^{i+1}_{z,i} = 0 \tag{7}$$

where

α_n = angle measured clockwise about Y-axis from X-axis to X_m-axis for element n, Fig 3.

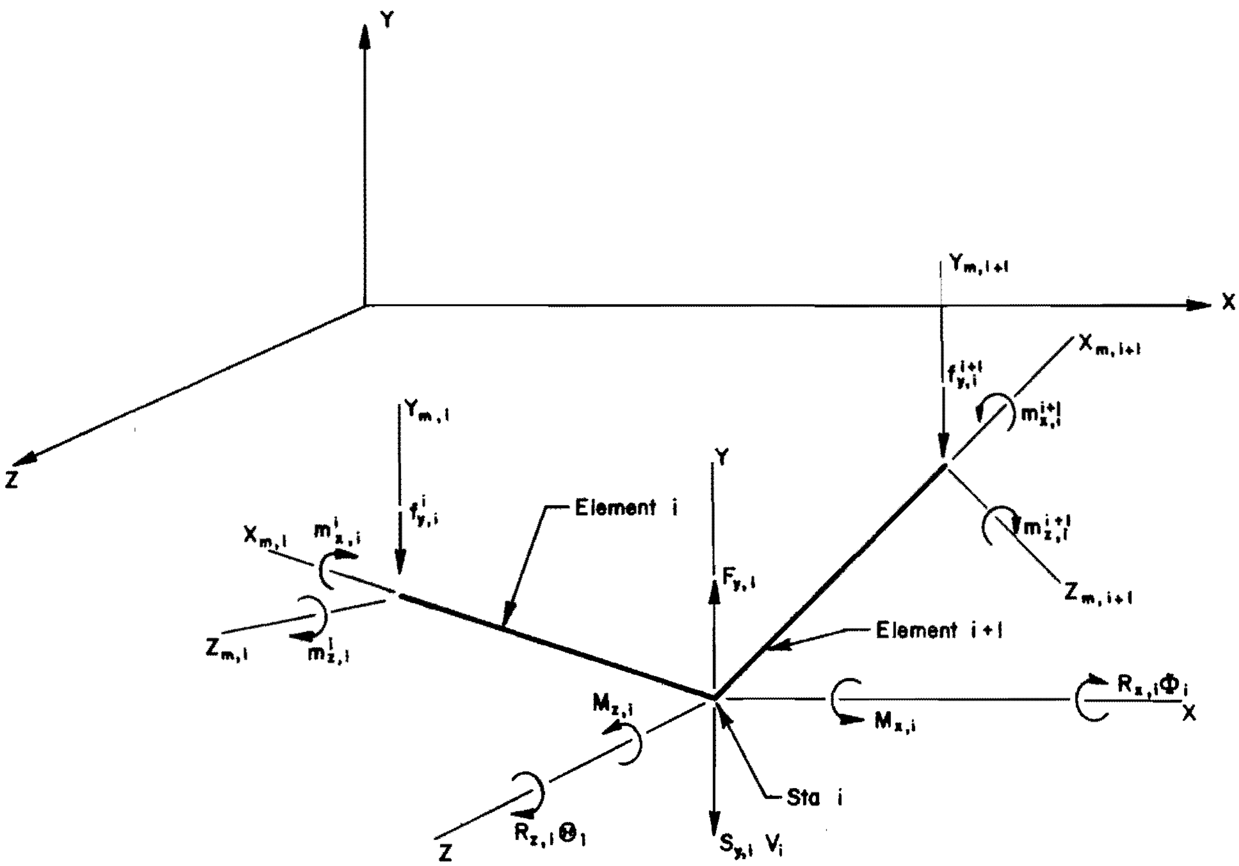


Fig 4. Free-body of ith station.

These equations may be arranged in matrix form as

$$\begin{bmatrix} M_{x,i} \\ F_{y,i} \\ M_{z,i} \end{bmatrix} - \begin{bmatrix} R_{x,i} & 0 & 0 \\ 0 & S_{y,i} & 0 \\ 0 & 0 & R_{z,i} \end{bmatrix} \begin{bmatrix} \Phi_i \\ V_i \\ \Theta_i \end{bmatrix}$$

$$- \begin{bmatrix} \cos\alpha_i & 0 & -\sin\alpha_i \\ 0 & 1 & 0 \\ \sin\alpha_i & 0 & \cos\alpha_i \end{bmatrix} \begin{bmatrix} m^i_{x,i} \\ f^i_{y,i} \\ m^i_{z,i} \end{bmatrix}$$

$$- \begin{bmatrix} \cos\alpha_{i+1} & 0 & -\sin\alpha_{i+1} \\ 0 & 1 & 0 \\ \sin\alpha_{i+1} & 0 & \cos\alpha_{i+1} \end{bmatrix} \begin{bmatrix} m^{i+1}_{x,i} \\ f^{i+1}_{y,i} \\ m^{i+1}_{z,i} \end{bmatrix} = 0 \tag{8}$$

Introducing

$$\overline{T}_{\alpha,n} = \begin{bmatrix} \cos\alpha_n & 0 & -\sin\alpha_n \\ 0 & 1 & 0 \\ \sin\alpha_n & 0 & \cos\alpha_n \end{bmatrix} \tag{9}$$

$$\overline{F}_i = \begin{bmatrix} M_{x,i} \\ F_{y,i} \\ M_{z,i} \end{bmatrix} \tag{10}$$

$$\bar{R}_i = \begin{bmatrix} R_{x,i} & 0 & 0 \\ 0 & S_{y,i} & 0 \\ 0 & 0 & R_{z,i} \end{bmatrix} \tag{11}$$

and

$$\bar{U}_i = \begin{bmatrix} \Phi_i \\ V_i \\ \Theta_i \end{bmatrix} \tag{12}$$

Equation 8 may be expressed in matrix notation as

$$\bar{F}_i - \bar{R}_i\bar{U}_i - \bar{T}_{\alpha,i}\bar{f}_i^i - \bar{T}_{\alpha,i+1}\bar{f}_i^{i+1} = 0 \tag{13}$$

Substitution of Eqs 3 and 4 in Eq 13 yields

$$\bar{F}_i - \bar{R}_i\bar{U}_i - \bar{T}_{\alpha,i}\bar{S}^i_{i,i-1}\bar{u}^i_{i-1} - \bar{T}_{\alpha,i}\bar{S}^i_{i,i}\bar{u}^i_i - \bar{T}_{\alpha,i+1}\bar{S}^{i+1}_{i,i}\bar{u}^{i+1}_i$$

$$- \bar{T}_{\alpha,i+1}\bar{S}^{i+1}_{i,i+1}\bar{u}^{i+1}_{i+1} = 0 \tag{14}$$

Element end displacements $\bar{u}^i_{i-1}$, $\bar{u}^i_i$, $\bar{u}^{i+1}_i$, $\bar{u}^{i+1}_{i+1}$ (Fig 3b) are related to the station displacements $\bar{U}_{i-1}$, $\bar{U}_i$, $\bar{U}_{i+1}$ (Fig 2) by the transformations (Ref 4)

$$\bar{u}^i_{i-1} = \bar{T}^*_{\alpha,i}\bar{U}_{i-1}$$

$$\bar{u}^i_i = \bar{T}^*_{\alpha,i}\bar{U}_i$$

$$\bar{u}_i^{i+1} = \bar{T}^*_{\alpha,i+1}\bar{U}_i$$

$$\bar{u}_{i+1}^{i+1} = \bar{T}^*_{\alpha,i+1}\bar{U}_{i+1} \qquad (15)$$

where

$$\bar{T}^*_{\alpha,n} = \text{transpose (Ref 5) of } \bar{T}_{\alpha,n} \cdot$$

Combination of Eqs 14 and 15 leads to the governing equation

$$(\bar{T}_{\alpha,i}\bar{S}^i_{i,i-1}\bar{T}^*_{\alpha,i})\bar{U}_{i-1} + (\bar{T}_{\alpha,i}S^i_{i,i}\bar{T}^*_{\alpha,i} + \bar{T}_{\alpha,i+1}\bar{S}^{i+1}_{i,i}\bar{T}^*_{\alpha,i+1}$$

$$+ \bar{R}_i)\bar{U}_i + (\bar{T}_{\alpha,i+1}\bar{S}^{i+1}_{i,i+1}\bar{T}^*_{\alpha,i+1})\bar{U}_{i+1} = \bar{F}_i \qquad (16)$$

Equation 16 expresses the load-deflection relationship which must be satisfied at every station in the finite-element model.

Solution of Simultaneous Equations

Equation 16 may be more compactly expressed as

$$\bar{a}_i\bar{U}_{i-1} + \bar{b}_i\bar{U}_i + \bar{c}_i\bar{U}_{i+1} + \bar{d}_i = 0 \qquad (17)$$

where $\bar{a}_i$, $\bar{b}_i$, and $\bar{c}_i$ are (3×3) matrices of stiffness coefficients and $\bar{d}_i$ is a (3×1) vector of external loads.

Evaluation of this equation at every station in the finite-element model leads to a set of simultaneous, linear, matrix equations in the unknown displacements of the stations. An efficient procedure for solution of these equations has been discussed by Endres and Matlock (Ref 3). Only an outline of the procedure is given here.

At each interior station i, the unknown displacement vectors $\bar{U}_i$ and $\bar{U}_{i+1}$ satisfy the equation

$$\bar{U}_i = \bar{A}_i + \bar{B}_i \bar{U}_{i+1} \tag{18}$$

if

$$\bar{A}_i = -(\bar{a}_i \bar{B}_{i-1} + \bar{b}_i)^{-1} (\bar{a}_i \bar{A}_{i-1} + \bar{d}_i) \tag{19}$$

and

$$\bar{B}_i = -(\bar{a}_i \bar{B}_{i-1} + \bar{b}_i)^{-1} \bar{c}_i \tag{20}$$

where the superscript -1 indicates the inverse of the matrix (Ref 5). Since evaluation of Eq 17 at end station 0 results in $\bar{a}_0 = 0$, values of $\bar{A}_i$ and $\bar{B}_i$ may be determined sequentially for each station beginning at station 0 and proceeding to the final station n. At station n evaluation of Eq 17 leads to zero values for both $\bar{c}_n$ and $\bar{B}_n$. Hence, Eq 18 yields $\bar{U}_n = \bar{A}_n$. Since $\bar{A}_n$ can be evaluated from known data, a solution for $\bar{U}_n$ is obtained. Other values for displacement vectors may be obtained by back substitution in Eq 18.

Support Reactions and Internal Forces

Support reactions are obtained from the equation

$$\bar{Q}_i = \bar{R}_i \bar{U}_i \tag{21}$$

where

$\bar{Q}_i$ = (3 × 1) matrix of forces in the three support springs at station i related to the global coordinate system.

Element end forces, $\bar{f}^i_{i-1}$ and $\bar{f}^i_i$, may be determined from known station displacements by application of Eqs 15, 3, and 4, respectively. As previously stated, the forces obtained from these equations are related to the member coordinate system for the straight chord element. For design purposes, it is desirable that the internal forces be known in relation to a tangent and normal to the curved member. The element and tangential coordinate systems for

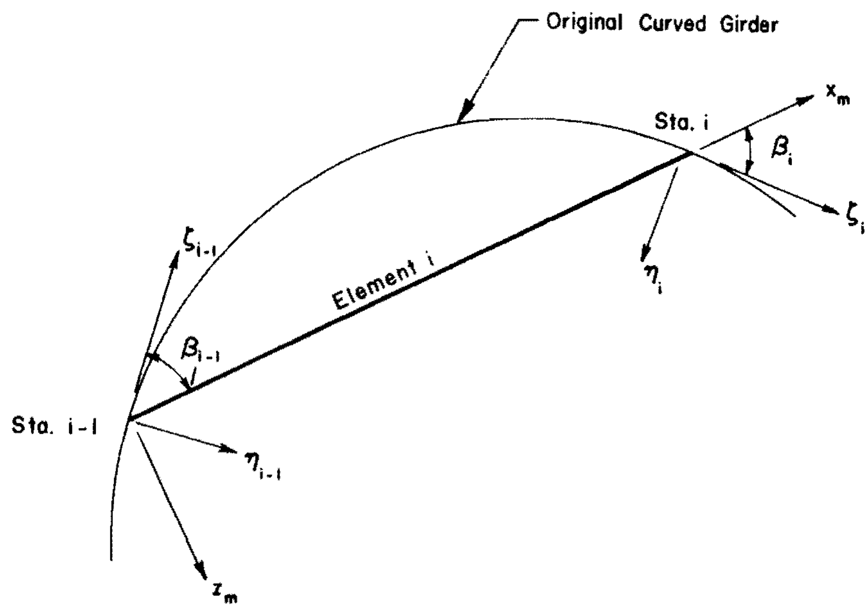


Fig 5. Normal and tangential coordinate systems for element i.

the i^{th} element are shown in Fig 5. The element end forces may be expressed in relation to the normal and tangential coordinates by the transformation

$$\bar{f}^{i}_{\eta,i-1} = \bar{T}^{*}_{\beta,i}\,\bar{f}^{i}_{i-1}$$

$$\bar{f}^{i}_{\eta,i} = \bar{T}^{*}_{\beta,i}\,\bar{f}^{i}_{i} \tag{22}$$

where

$\bar{f}^{i}_{\eta,m}$ = (3 × 1) matrix of end forces in element i in normal and tangential directions at station m,

$\bar{T}_{\beta,m}$ = (3 × 3) transformation matrix of the form of $\bar{T}_{\eta}$ of Eq 9 except evaluated for angle β_m , Fig 5,

$\bar{T}^{*}_{\beta,m}$ = transpose of $\bar{T}_{\beta,m}$.

CHAPTER 3. THE COMPUTER PROGRAM

FORTRAN Program

The procedures described in the preceding chapter have been programmed for solution on a digital computer. The program is written in FORTRAN IV for the Control Data Corporation 6600 Computer. With minor changes, the program will be operable on other computer systems. However, no solution should be attempted on machines operating with less than twelve significant decimal figures in arithmetic operations. A summary flow diagram for the FORTRAN program is given in Fig 6. Detailed flow charts and a listing of the program are included in Appendices 3 and 4.

The input data, insofar as is possible, has the same form as conventional beam-column data (Ref 7). The form of the input data is shown in the Guide for Data Input in Appendix 2. The following paragraphs give the assumptions on which the input data are based.

Description of Girder

The global coordinate system is selected arbitrarily and the geometry of the girder is referenced to the global system. The plane of the curved girder must lie in the global X-Z plane and one principal axis of the girder cross-section must be parallel to the global Y-axis.

In order that as much data as possible may be generated automatically, the girder is assumed to be composed of combinations of straight and circularly curved segments. Required data for each station on the girder consist of the station number, beginning with station zero, and the global X and Z coordinates of the station. Station numbers and coordinates for a segment of the girder are generated automatically at equal intervals along a straight line between indicated end points if the segment is not designated as a curve. For a curved section, the global X-Z coordinates of the center of the circular arc must be supplied in addition to the station numbers and coordinates for the terminal stations of the section. Intermediate stations are generated

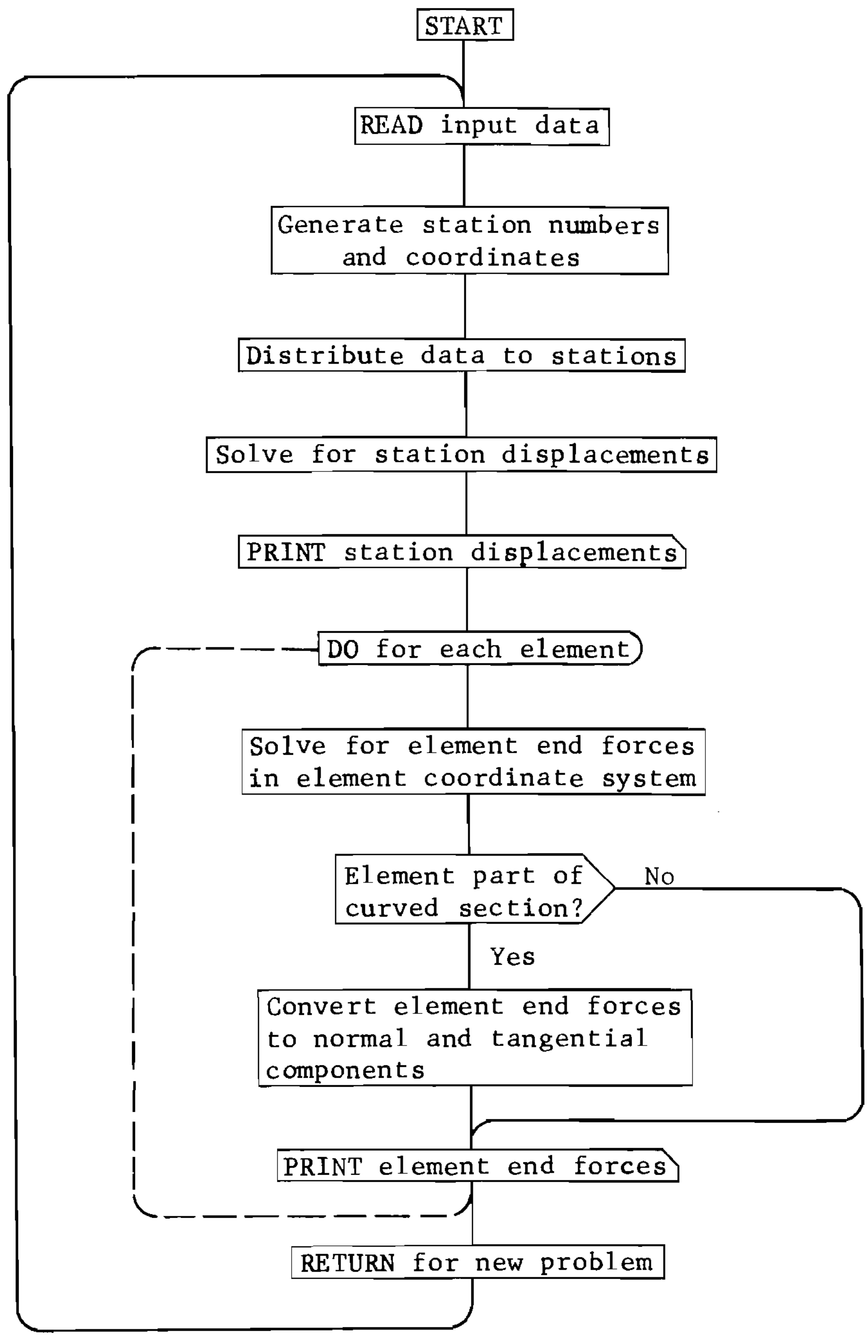


Fig 6. Summary flow chart.

at equal arc lengths between the terminals. The included angle for any arc length must not exceed 180^{o}.

The above interpolation procedure permits the use of unequal increment lengths.

Girder Supports and Restraints

The girder must be restrained to prevent all possible rigid body displacements. Three elastic restraints may be applied to each station. These include restraint of rotation of the joint about the global X-axis, restraint of translation of the joint in the global Y-direction and restraint of rotation of the joint about the global Z-axis. Unyielding supports may be simulated by specifying a large value of elastic restraint. Elastic restraints may be applied to individual stations or may be distributed over a range of stations in the same manner as the spring supports of ordinary beam-column data (Ref 7) provided that the increment length is constant within the distribution range.

Element Stiffnesses and Coordinate System

Each element of the girder between adjacent stations is assumed to be a straight, prismatic elastic grid member. Torsional and flexural stiffnesses are supplied related to a coordinate system defined separately for each element. In this special coordinate system, the X_m-axis is defined by the centroidal axis of the prismatic element and the Z_m-axis is oriented such that the X_m-Z_m plane and the global X-Z plane coincide. In addition, the positive Y_m-direction is parallel to the global Y-axis. As stated previously, the X_m, Y_m, and Z_m-directions are assumed to be the principal axes of the element cross-section (Fig 3).

Stiffness values may be supplied for individual elements or may be automatically distributed over a section of the girder by linear interpolation between specified end stations. This automatic generation option must be applied only over those sections of the girder having a constant element length, otherwise erroneous stiffness values may result.

Applied Loads and Moments

Loads and moments are applied to stations related to the global coordinate system. Forces are assumed to be positive when the vector is in the same direction as the positive Y-axis. Forces in the global X- and Z-directions are not permitted. A moment about the X- or Z-axis is positive when the vector, given by the right-hand screw rule, points in the positive X- or Z-direction. Moments about the Y-axis are not permitted.

Input Data

Formats and additional explanatory information for the input data are given in Appendix 2. The data for each problem are arranged in tabular form as outlined below. Two alphanumeric cards are required at the beginning of each data deck. These are followed by

(1) Problem Identification card with alphanumeric description of the problem. The program terminates if the problem identification is blank.

(2) Table 1. Program Control Data - 1 card. Each of Tables 2, 3, 4, and 5 may be retained from the preceding problem by inserting the code "KEEP" at the appropriate location in Table 1. The number of cards added to each table is supplied on this card.

(3) Table 2. Station Coordinates. The station number and global coordinates of each station are supplied. The number of cards added to this table is given in Table 1. When stations are to be generated on a circular arc, the card containing the station number and coordinates of the beginning station must also include the identifier "CURVE" and the global coordinates of the center of the arc. Addition of information to Table 2 held from the preceding problem is not permitted.

(4) Table 3. Elastic Restraints. The number of cards in this table is specified in Table 1.

(5) Table 4. Element Stiffnesses. The number of cards is specified in Table 1. Care must be taken to insure that every element has been assigned a nonzero value of flexural and torsional stiffness. Otherwise the program will terminate.

(6) Table 5. Applied Loads and Moments. The number of cards is specified in Table 1.

As many problems may be run in succession as desired. The data coding sheets for the example problems of Chapter 4 are reproduced in Appendix 5.

Output Data

All input data are echo printed as read. Output of the computed data is arranged in Table 6 as follows

(1) Station Displacements in Global Coordinate Directions. The identification number, global coordinates, rotations about the global X- and Z-axes and deflection in the global Y-direction are printed for each station. The sign convention for the displacements is given in Fig 2.

(2) Element End Forces in Normal and Tangential Directions. The member end forces are initially computed related to the member coordinate system of the element (Fig 3). If the element is part of a curved section, the end forces are transformed to normal and tangential directions as shown in Fig 5.

Output data for the example problems of Chapter 4 are given in Appendix 6.

CHAPTER 4. EXAMPLE SOLUTIONS

A variety of problems have been solved to verify the analytical procedure and the computer program described in the preceding chapters. The results obtained by the program are compared with closed form solutions, other numerical procedures and with experimental data. The input data and the computer output are presented in Appendices 5 and 6, respectively.

Rectangular Bracket

The rectangular bracket shown in Fig 7 is composed of hypothetical straight, circular cross-section members having equal bending and torsion stiffnesses. The behavior of members of this type is not affected by warping of the cross-section (see Appendix 1). Hence, the method of analysis described in Chapter 2 does not introduce any further approximation and the results are identical with those obtained by application of any method of indeterminate structural analysis (see, for instance, Ref 6).

Output data from the computer analysis for this structure are presented as Problem CG11 in Appendix 6. Although 36 stations were used to give a more detailed determination of the deflections and internal forces, an exact solution for forces and deflections at the stations could have been obtained using as few as three elements and four stations. In the latter case, the four stations necessary are those labeled 0, 16, 20, and 36 in Fig 7.

Semicircular Bow Girder

The pipe girder shown in Fig 8a is subjected to a uniformly distributed lateral load. As in the previous example no warping effects are present and the problem is readily solved by conventional methods of indeterminate structural analysis (Ref 6). The solutions obtained by the finite-element method and by a closed form method are tabulated in Fig 8b. It is seen that excellent agreement is obtained for as few as ten increments in the model. Agreement is further improved when twenty increments are used.

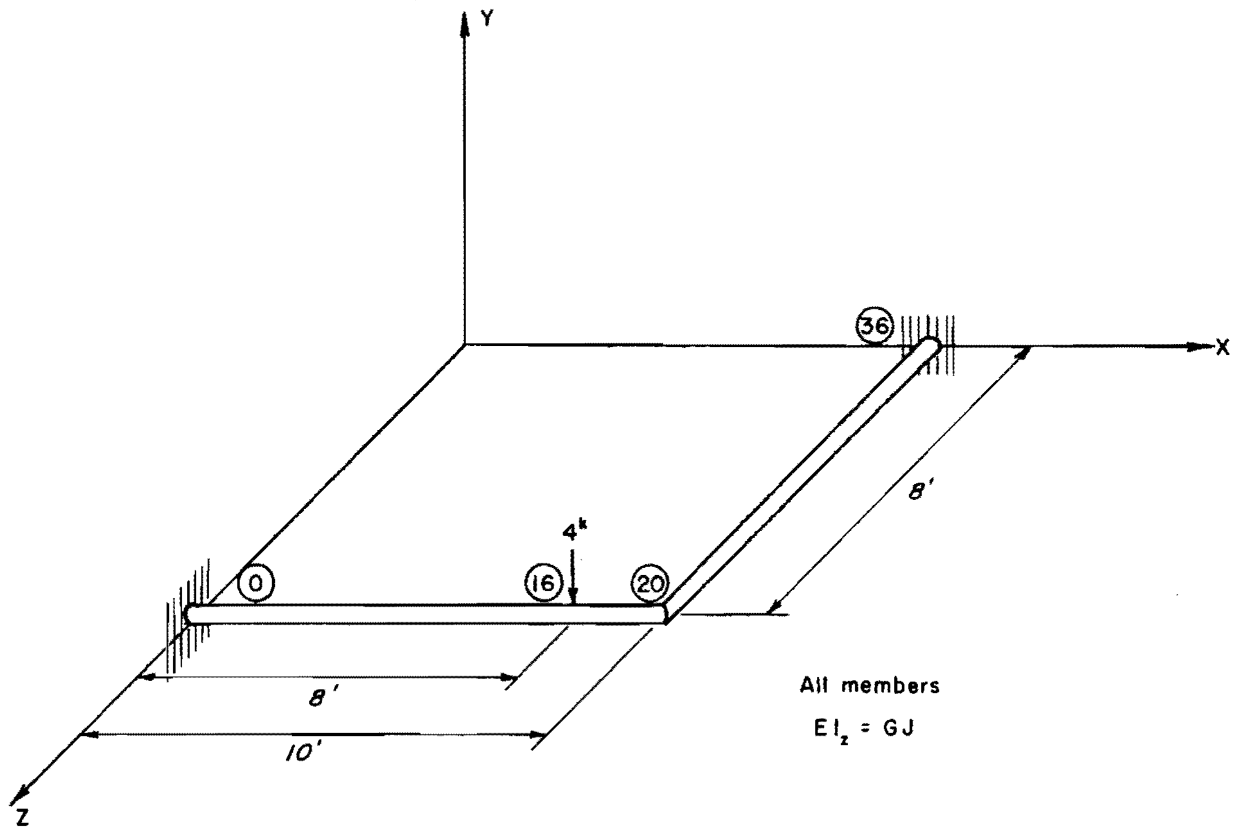
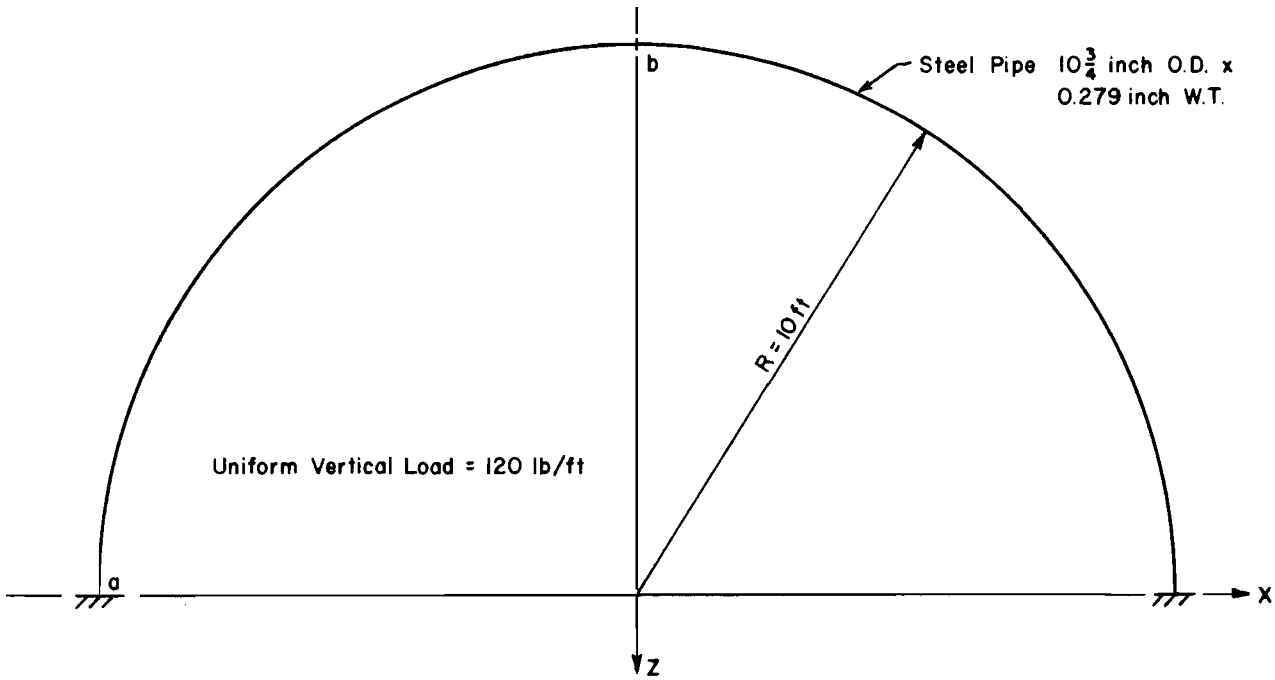


Fig 7. Rectangular bracket.



(a) Plan view, semicircular bow girder.

	Point a			Point b		
	Least Work	PCGR		Least Work	PCGR	
		10 Incr	20 Incr		10 Incr	20 Incr
Bending Moment (lb-in)	1.440×10^5	1.428×10^5	1.437×10^5	-3.934×10^4	-3.954×10^4	-3.939×10^4
Twisting Moment (lb.-in)	-4.285×10^4	-4.385×10^4	-4.310×10^4	0	0	0
Vertical Reaction (lb)	1.885×10^3	1.885×10^3	1.885×10^3	—	—	—
Vertical Deflection (in)	0	0	0	-0.2176	-0.2165	-0.2173

(b) Comparison of results.

Fig 8. Comparison of results with closed-form solution.

Output data for this problem are included in Appendix 6 as Problems CG12 and CG13.

Circular Arc I-Beam

The experimental and analytical results of a study of the circularly curved I-section, shown schematically in Fig 9, are reported in Ref 10. These data, together with the solution obtained with the method reported herein are compared in Figs 10 and 11 for two loading conditions. It is pointed out in Ref 9 that although the beam was encased in concrete at each end, the ends of the beam were not completely restrained as was assumed in the analysis (Fig 9). This is evidenced by the nonzero vertical deflection indicated at station zero in Fig 10b. The deflections obtained by the finite-element analysis agree well with those obtained experimentally as reported in Ref 10.

Since the ends of the beam are built in, the end cross-sections are not free to warp. This increased stiffness results in a reduction of the angle of twist in the vicinity of the restraint. This effect is evident in the comparisons presented in Fig 11. The effect of warping restraint is not considered in the finite-element analysis; hence, the twist angles indicated are higher than those obtained experimentally. However, excellent agreement is obtained in the center portion of the beam where the effect of the warping restraint is reduced.

Straight Beam Solution

Since an ordinary straight beam is a special case of the grid analysis method described in this report, the program may be used to solve a wide variety of beam problems. One particular advantage is the ability to use varying increment lengths in describing the beam. To illustrate the use of the program in this respect the beam shown in Fig 12 is solved and the results are compared with those reported in Ref 7. It is seen that excellent agreement is obtained with the previously reported procedure.

It should be noted, however, that the beam is solved as a special case of a grid structure. As such it is expected by the program that the structure will be subjected to the effects of moments about the X-axis even though none are imposed by the loading system. As a consequence nominal values of torsional rigidity (GJ) and restraint against rigid body rotation about the X-axis (RX)

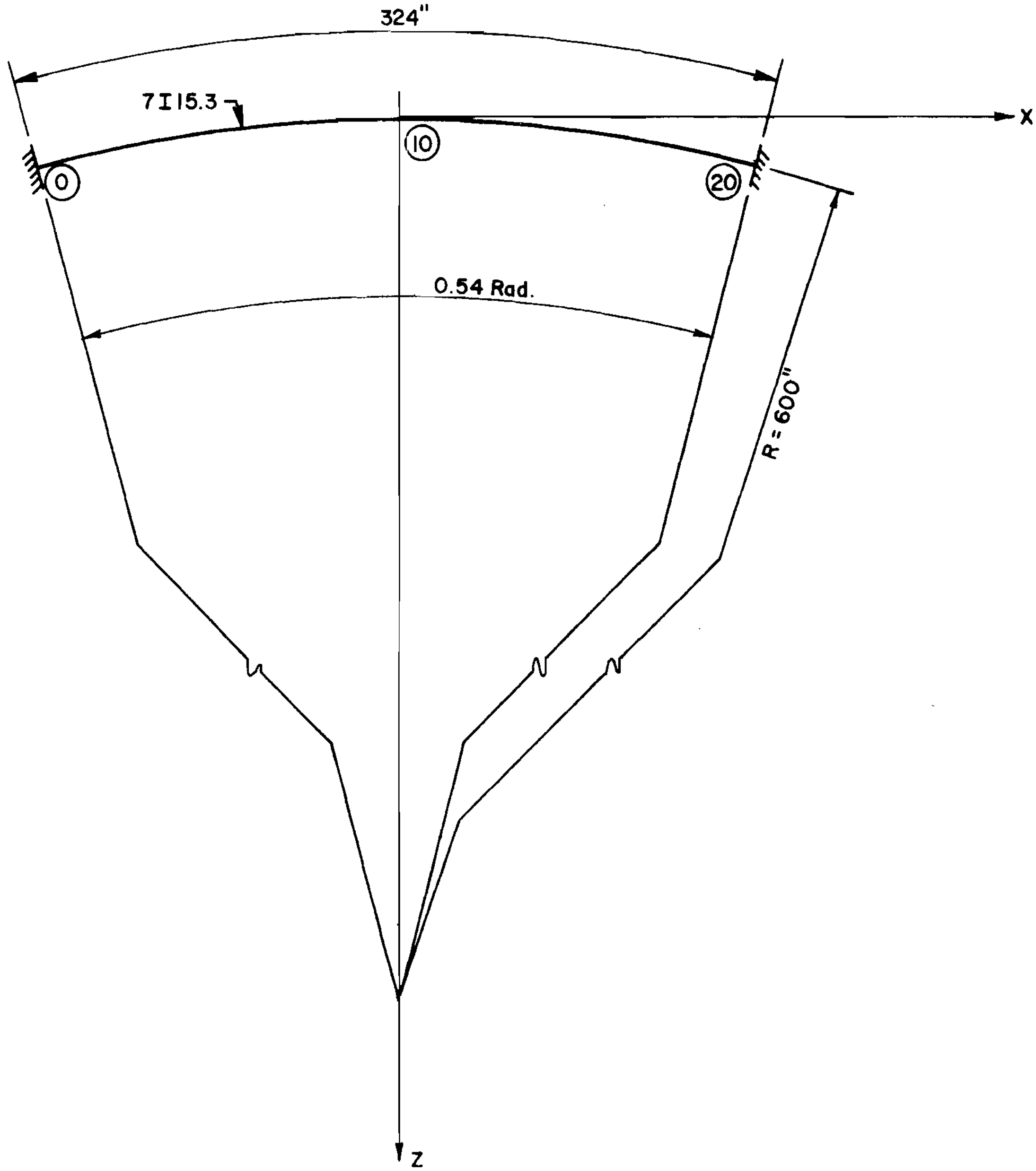
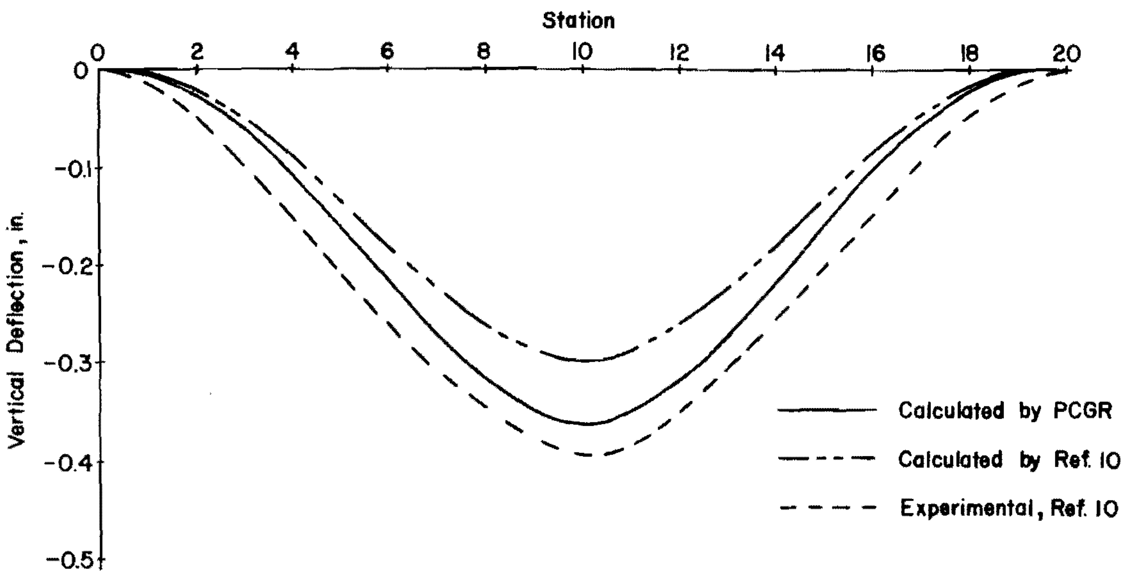
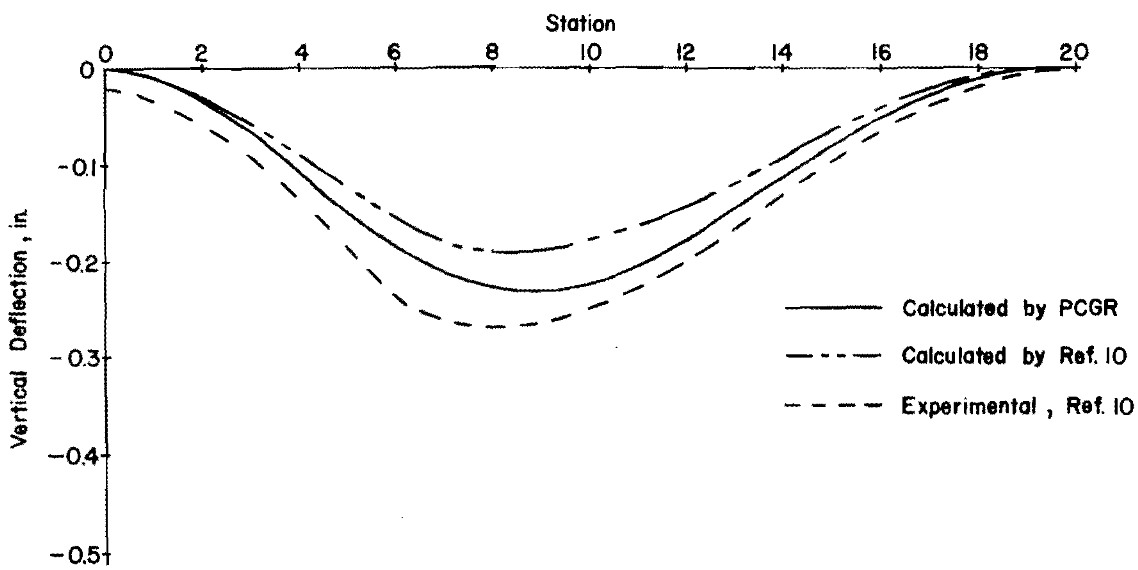


Fig 9. Circular arc I-beam (after Ref 10).

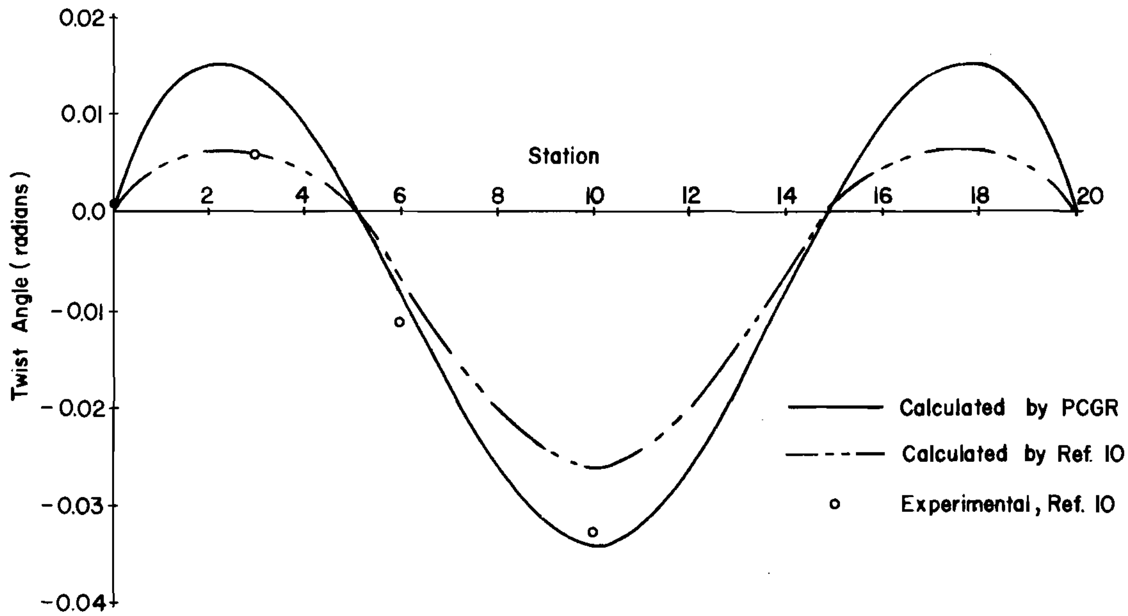


(a) Vertical deflection due to 1-kip vertical load at station 10.

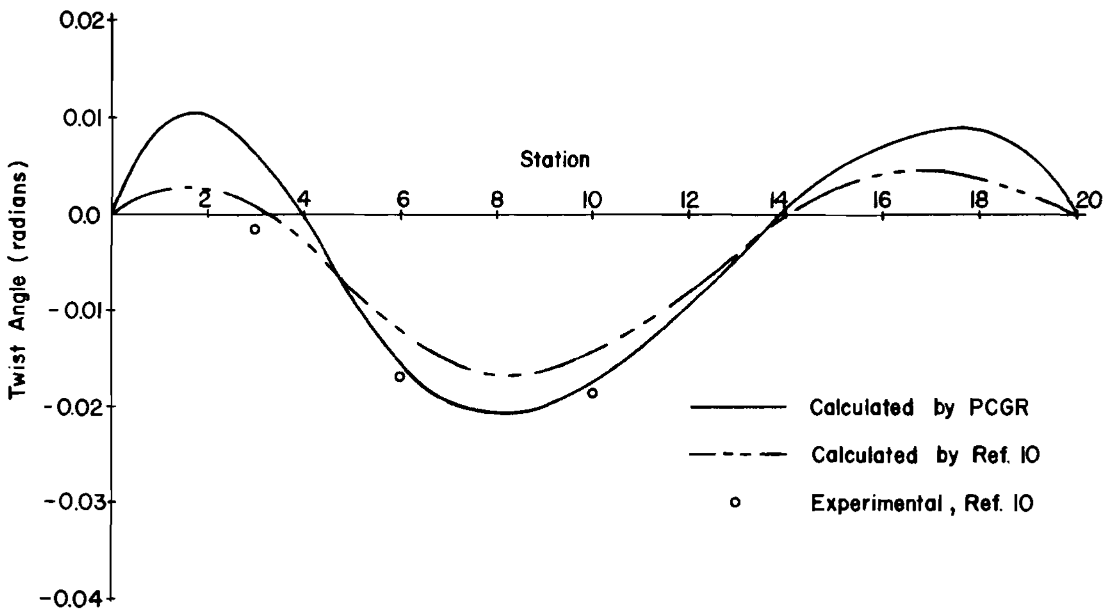


(b) Vertical deflection due to 1-kip vertical load at station 6.

Fig 10. Comparison of calculated and experimental deflections for circular I-beam (after Ref 10).

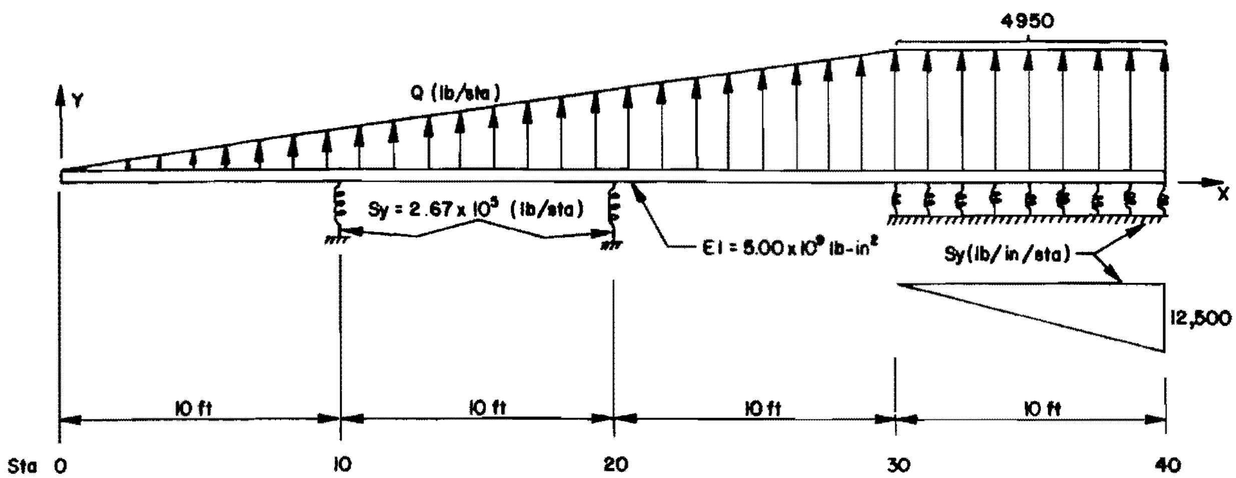


(a) Twist angle due to 1-kip vertical load at station 10.



(b) Twist angle due to 1-kip vertical load at station 6.

Fig 11. Comparison of calculated and experimental twist angles for circular arc I-beam (after Ref 2).



(a) Continuous straight beam (after Ref 7).

Station	Deflection (in)		Bending Moment (lb-in)	
	Ref 7	PCGR	Ref 7	PCGR
0	5.740×10^{-1}	5.775×10^{-1}	-5.035×10^{-4}	0
10	4.713×10^{-2}	4.701×10^{-2}	3.267×10^{5}	3.267×10^{5}
20	2.141×10^{-1}	2.143×10^{-1}	1.124×10^{6}	1.127×10^{6}
30	1.298	1.291	-9.790×10^{5}	-9.795×10^{5}
35	1.047	1.045	-3.335×10^{5}	-3.347×10^{5}
40	5.315×10^{-1}	5.328×10^{-1}	-1.263×10^{-4}	0

(b) Comparison of results.

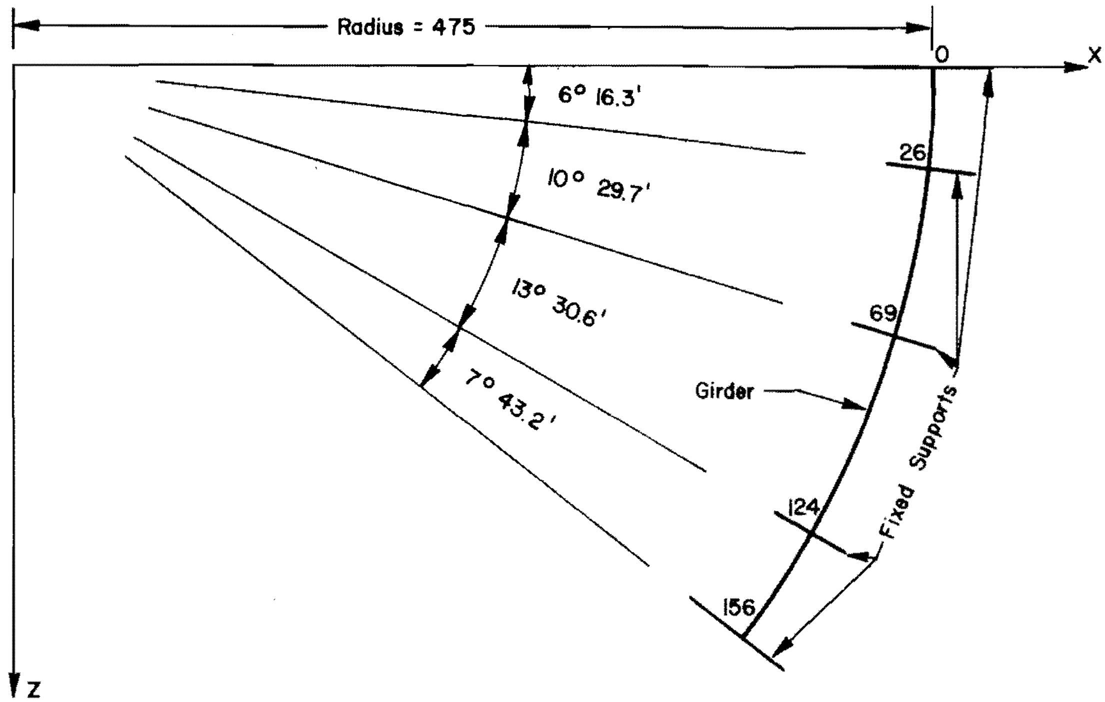
Fig 12. Comparison of results with discrete-element analysis of continuous beam.

must both be supplied. In the case at hand, unit values of these data were utilized (see Appendices 5 and 6).

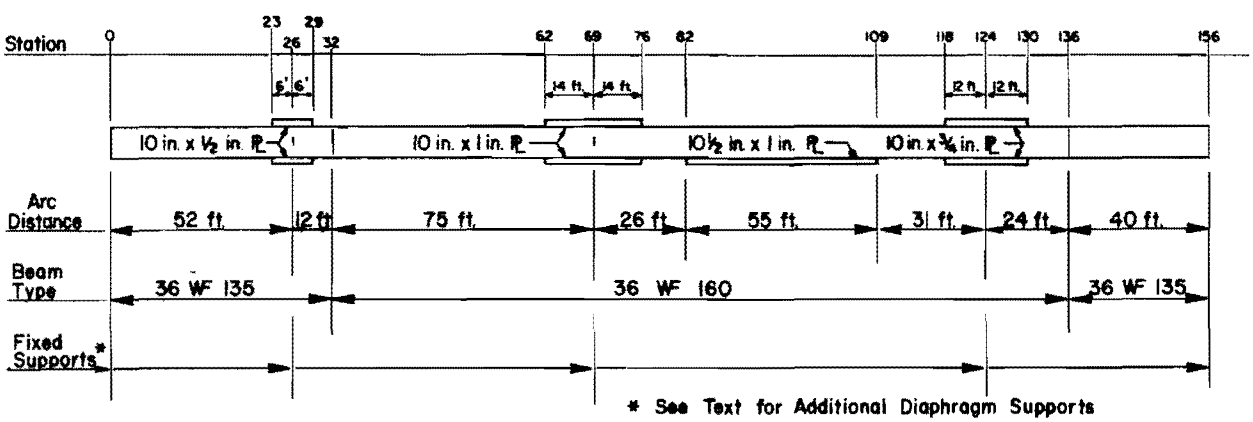
Curved Highway Girder

A curved girder which is similar to those used in curved highway bridge structures is shown in Fig 13. In addition to the fixed supports shown in the figure, it is assumed that diaphragms, parallel to the global X-axis, frame into the girder at every tenth station beginning at station 3 and ending at station 153. The numerical values of restraint (see Appendices 5 and 6) are for a pair of 15LJ33.9 sections at each diaphragm station.

Although the wide flange cross-section is susceptible to the effects of warping of the cross-section it is unlikely that any significant amount of warping will be provided by the supports. Hence, the analytical procedure described in this report may be utilized with sufficient accuracy. Restraint against twisting of the girder, provided by the deck slab will tend to make the results of the analysis err on the side of safety.



(a) Plan.



(b) Elevation.

Fig 13. Typical curved highway girder.

CHAPTER 5. CONCLUSIONS AND RECOMMENDATIONS

Conclusions

A method for analysis of plane curved girders has been presented. The method consists of replacing the curved member with an assemblage of straight structural elements which are chords of the original curve. Each of the chord elements is then analyzed as a grid member using conventional matrix methods of structural analysis. The resulting equations are solved using a direct solution on the digital computer. The program, PCGR2, has been used to solve a number of problems to verify the method of analysis and the accuracy of the computer program. As demonstrated by the example problems, the method is applicable to a wide variety of practical problems.

Recommendations

Several significant areas requiring additional research have been encountered during the course of this study.

Of primary importance is the determination of the effective torsional rigidity of open cross-sections when warping effects are present. The use of the conventional torsional stiffness parameter yields excellent results at points which are located at some distance from the point of restraint. However, in the vicinity of the restraint, warping of the cross-sections creates additional torsional rigidity which is not accounted for by the conventional term.

Utilization of the variable increment length capability of the computer program described herein may require a large amount of manual computation to obtain the data required as input, particularly in the case of distributed data. The distribution procedure should be modified to accept data which are distributed with respect to distance along the member as well as with respect to stations as is now the case. A further modification of the program should be to permit elastic restraints at the stations at orientations other than in the global coordinate directions.

REFERENCES

1. Baron, Frank, "Matrix Analysis of Structures Curved in Space," Proceedings, Vol 87, No. ST3, American Society of Civil Engineers, March 1961.

2. Brookhart, G. C., "Circular-Arc I-Type Girders," Proceedings, Vol 93, No. ST6, American Society of Civil Engineers, December 1967.

3. 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.

4. Gere, J. M., and W. Weaver, Jr., Analysis of Framed Structures, D. Van Nostrand Co., Inc., Princeton, New Jersey, 1965.

5. Gere, J. M., and W. Weaver, Jr., Matrix Algebra for Engineers, D. Van Nostrand Co., Inc., Princeton, New Jersey, 1965.

6. Kinney, J. S., Indeterminate Structural Analysis, Addison-Wesley Publishing Co., Inc., Reading, Massachusetts, 1957.

7. Matlock, Hudson, and T. A. 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 at Austin, September 1966.

8. Michalos, James, "Matrix Formulation of the Force Method for a Structure Curved in Space," Publications, Vol 26, International Association for Bridge and Structural Engineering, Zurich, 1966.

9. Soto, M. H., "Analysis of Suspended Curved Girder," Proceedings, Vol 92, No. ST1, American Society of Civil Engineers, February 1966.

10. Spates, K. R., and C. P. Heins, Jr., "The Analysis of Single Curved Girders with Various Loadings and Boundary Conditions," Progress Report for Maryland State Roads Commission and U.S. Bureau of Public Roads, Civil Engineering Department, University of Maryland at College Park, June 1968.

11. Thibodeaux, M. H., "Numerical Analysis of Normally Loaded Plane Frames," thesis presented to the University of Illinois, Urbana, in partial fulfillment of the requirements for the degree of Doctor of Philosophy, 1958.

12. Timoshenko, S., Strength of Materials, Vol I and II, D. Van Nostrand Co., Inc., Princeton, New Jersey, Third Edition, 1956.

APPENDIX 1

TORSIONAL RIGIDITIES

APPENDIX 1. TORSIONAL RIGIDITIES

In the derivations of Chapter 2, the relationship between the twisting moments and angular displacements at the ends of the prismatic element is

$$m^{i}_{x,i-1} = \frac{GJ}{L}(\phi^{i}_{i-1} - \phi^{i}_{i}) \tag{A1.1}$$

and

$$m^{i}_{x,i} = \frac{GJ}{L}(-\phi^{i}_{i-1} + \phi^{i}_{i}) \tag{A1.2}$$

This relationship is referred to as the St. Venant theory of torsion and is well documented in any standard reference on strength of materials (see, for instance, Ref 12). The factor GJ in the equations is the torsional rigidity of the element, where G is the shear modulus of the material and the value of J depends on the geometry of the cross-section. For example, for a solid circular cross-section, J is the polar moment of inertia of the circle and

$$J = \frac{\pi r^4}{4} \tag{A1.3}$$

where r is the radius of circle. Values of J for other solid or closed cross-sections are tabulated in Ref 12.

When the cross-section is composed of thin rectangular elements, such as I or H sections, and the cross-section is free to warp out of its original plane, the factor J may be obtained from

$$J = \frac{1}{3}\sum_{i=1}^{n} b_i t_i^3 \tag{A1.4}$$

where

n = number of plates in cross-section,

b_i = width of i^{th} plate, and

t_i = thickness of i^{th} plate.

This equation was utilized for determining the torsional rigidities for problem CG41 and is applicable since no warping restraint is imposed at any cross-section.

In the structure analyzed in problems CG31 and CG32, the ends of the I sections were encased in concrete and warping of the cross-section was inhibited. In this case the torque-twist relations expressed in Eqs A1.1 and A1.2 are not directly applicable and a more complex relationship between twisting moment and twist angle should be used (see Ref 12, Vol II, pp 255-265). However, to apply this more complex relationship, an additional unknown must be introduced at every station; that is, the rotation of the member about the global Y-axis. This would increase the amount of computational effort by twenty-five percent. In view of the excellent comparison with experimental results indicated in Figs 10 and 11 at points remote from the applied warping restraints, the additional refinement appears to be unwarranted. A more expedient approach appears to be to increase the conventional torsional rigidity in the vicinity of a warping restraint. The amount of increase and the region of the member to which the increase should be applied must be the subjects of further study.

APPENDIX 2

INPUT FORMS

GUIDE FOR DATA INPUT FOR PCGR 2

with supplementary notes

extracted from

FINITE-ELEMENT METHOD OF ANALYSIS FOR PLANE CURVED GIRDERS

by

William P. Dawkins

June 1971

IDENTIFICATION OF RUN (2 alphanumeric cards per run)

1 ... 80

1 ... 80

IDENTIFICATION OF PROBLEM (one card each problem; program stops if PROB NAME blank)

PROB NAME		
		Description of problem (alphanumeric)
1–4		11–80

TABLE 1. PROGRAM CONTROL DATA (one card each problem)

ENTER "KEEP" TO HOLD PRIOR TABLE 2	3	4	5	NUM CARDS ADDED FOR TABLE 2	3	4	5
				I5	I5	I5	I5
6–9	11–14	16–19	21–24	31–35	40	45	50

TABLE 2. STATION COORDINATES (number of cards according to TABLE 1, none if preceding TABLE 2 is held.) Coordinates are generated at equal intervals for omitted stations.

	GLOBAL COORDINATES		ENTER "CURVE" FOR CURVED MEMBER	COORDINATES OF CENTER OF CIRCLE IN GLOBAL X-Z PLANE	
STA.	X	Z		XC	ZC
I5	E10.3	E10.3		E10.3	E10.3
6–10	16–25	35	56–60	70	80

TABLE 3. ELASTIC RESTRAINTS (number of cards according to TABLE 1). Data added to storage as lumped quantities per station (or per increment length), linearly interpolated between values input at indicated end stations, with 1/2 values at each end station. Concentrated effects are established as full values at single stations by setting final station = initial station.*

FROM STA	TO STA	ENTER "CONTD" IF CONTD TO NEXT CARD	RESTRAINTS IN GLOBAL COORDINATE DIRECTIONS		
			RX	SY	RZ
I5	I5		E10.3	E10.3	E10.3

6 10 15 20 30 40 50 60 70 80

TABLE 4. ELEMENT STIFFNESSES (number of cards according to Table 1). Element stiffnesses*** are added to storage as lumped quantities for each increment, linearly interpolated between values input at indicated end stations, with full values for all increments. Two nonzero values of stiffness must be supplied for each increment.** Stiffness data are interpreted as applying over a segment of the structure as indicated by the "FROM" - "TO" station specifications, therefore, the "TO" station must be greater than the "FROM" station.

FROM STA	TO STA	ENTER "CONTD" IF CONTD TO NEXT CARD	TORSION STIFFNESS GJ	BENDING STIFFNESS*** ABOUT Z_m EIZ
I5	I5		E10.3	E10.3

6 10 15 20 30 40 50 60

* See page 57 for separate explanation of sequencing procedure.

** See page 59 for separate explanation of sequencing procedure.

*** Element stiffnesses are supplied related to element coordinate systems. (See page 55 for explanation.)

TABLE 5. APPLIED LOADS AND MOMENTS (number of cards according to TABLE 1). Data added to storage as lumped quantities per station (or per increment length), linearly interpolated between values input at indicated end stations, with 1/2 values at each end station. Concentrated effects are established as full values at single stations by setting final station = initial station.*

			FORCES IN GLOBAL COORDINATE DIRECTIONS		
FROM STA	TO STA	ENTER "CONTD" IF CONTD TO NEXT CARD	XM	FY	ZM
I5	I5		E10.3	E10.3	E10.3
6–10	10–15	15–20	20–30	30–40	40–50

Card columns: 6, 10, 15, 20, 30, 40, 50, 60, 70, 80

STOP CARD (one blank card at end of run)
1–80

*See page 57 for separate explanation of sequencing procedure.

GENERAL PROGRAM NOTES

The data cards must be stacked in proper order for the program to run.

Input in integer fields must be right justified in field.

A consistent set of units must be used for all input data - e.g., pounds and inches.

TABLE 1. PROGRAM CONTROL DATA

All "KEEP" blocks must be blank for the first problem of a run.

If Table 2 is held, no new information may be added to Table 2. If Table 2 is to be revised, it must be supplied with all data.

For each of Tables 3, 4, and 5 the data are accumulated in storage by adding to previously stored data. The number of cards input is, therefore, independent of the hold option.

TABLE 2. STATION COORDINATES

Stations are assumed to lie on straight lines or segments of circular curves. If columns 56-60 are blank, the segment is assumed to be a straight line. If "CURVE" is inserted in columns 56-60, the segment is assumed to be a circular arc. The values of XC and ZC are Global coordinates of the center of the circle in the Global X-Z plane. The first card of a sequence governs whether the segment is a straight line or a circle; therefore, columns 56-80 on the last card in Table 2 are ignored.

A maximum of 50 cards is permitted in Table 2.

The maximum number of curves is 20.

The first card in Table 2 must contain the information for station zero.

The maximum number of stations in the member is 200.

TABLE 3. ELASTIC RESTRAINTS

Typical units:	SY	RX, RZ
	lb/in	in-lb/radian

Data are distributed to stations between indicated end stations according to the station-by-station interpolation procedure shown on page 57.

There is no restriction on the order of cards in Table 3 except that within a distribution sequence the stations must be in ascending order. The maximum number of cards in Table 3 is 50.

The station-to-station distance must be constant within the interpolation interval indicated by the FROM-TO stations.

TABLE 4. ELEMENT STIFFNESSES

Typical units:	GJ	EIZ
	lb-in^2	lb-in^2

Data in this Table should not be entered (nor held from the preceding problem) which would yield nonzero values beyond the ends of the real structure.

Data in this Table are distributed according to the element-by-element interpolation procedure shown on page 59.

The station-to-station distance must be constant within the interpolation interval indicated by the FROM-TO stations.

A maximum of 50 cards is permitted in Table 4.

TABLE 5. APPLIED LOADS AND MOMENTS

Typical units:	FY	MX, MZ
	lb	lb-in

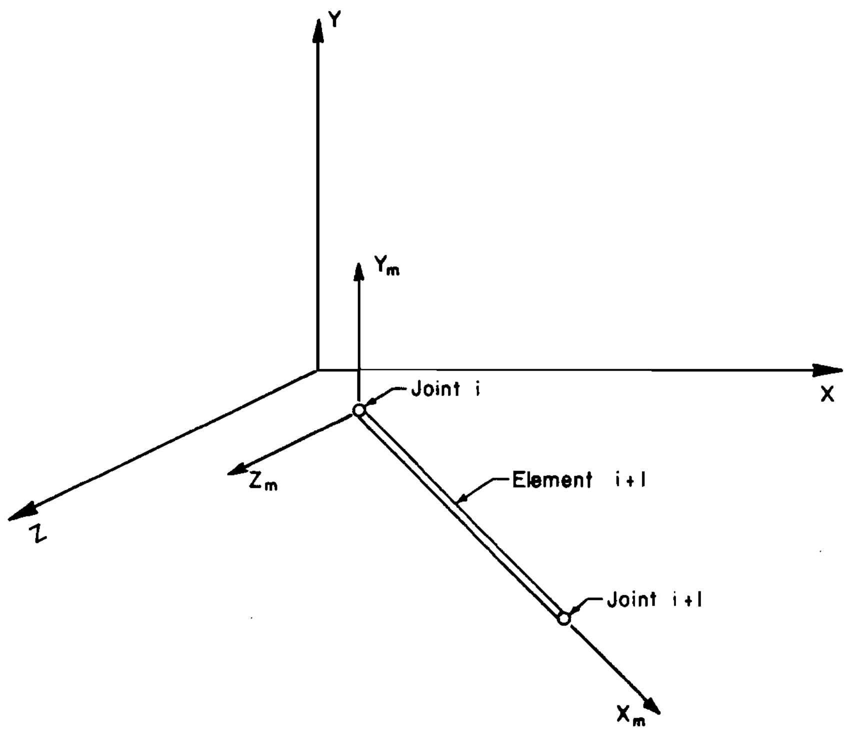
Data in this Table are distributed according to the station-by-station interpolation procedure shown on page 57.

The station-to-station distance must be constant within the interpolation interval indicated by the FROM-TO stations.

An applied load is positive if its vector has the same sense as the corresponding Global Axis.

An applied moment is positive if its vector, given by the right-hand screw rule, has the same sense as the Global X- or Z-Axis.

Element stiffnesses are related to a coordinate system defined separately for each element as follows:



X, Y, Z -- Global coordinate system

X_m, Y_m, Z_m = Element coordinate system

X_m = Centroidal axis of prismatic element

Y_m, Z_m = Principal axes of element cross section

Element must be oriented such that Y and Y_m axes are parallel and X_m-Z_m and X-Z planes coincide.

Procedure for Station-by-Station Distribution

Individual-Card Input

Case 1a. Data concentrated at one station

Case 1b. Data uniformly distributed

FROM STA → TO STA	CONTD ?	R_x	S_y, . . . etc.	
7 → 7			3.0	●
5 → 15		2.0		◒
15 → 20		4.0	1.0	◒
10 → 20			2.0	○

Multiple-Card Sequence

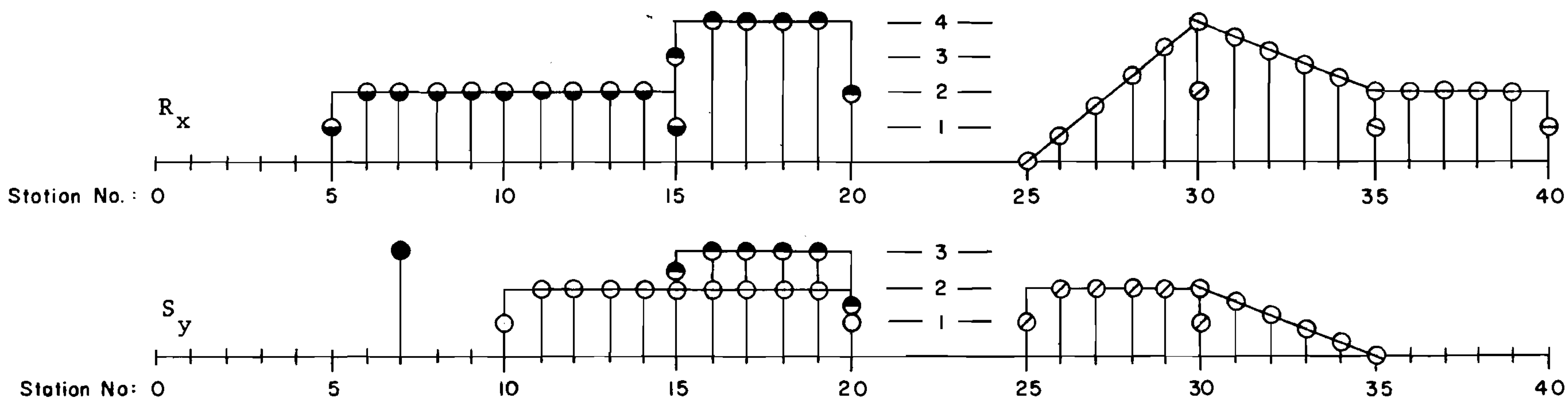
Case 2. First-of-sequence

Case 3. Interior-of-sequence

Case 4. End-of-sequence

FROM STA	TO STA	CONTD ?	R_x	S_y
25		CØNTD	0.0	2.0
	30	CØNTD	4.0	2.0
	35	CØNTD	2.0	
	40		2.0	

Resulting Distribution of Data



Procedure for element by element distribution

Individual-Card Input

Case 1a. Data for one element

Case 1b. Data uniformly distributed

FROM STA	TO STA	CONTD ?	GJ or EIZ
0 →	1		4.0
1 →	15		2.0
15 →	20		4.0
5 →	10		1.0

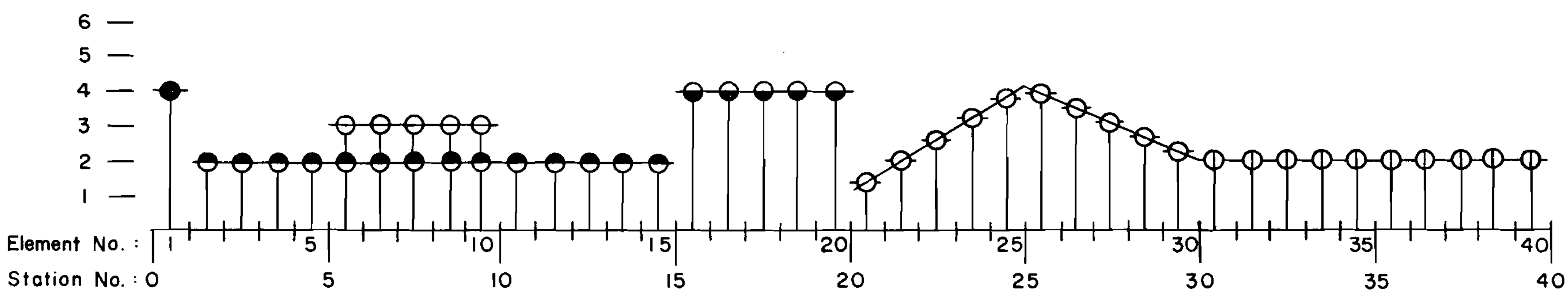
Multiple-Card Sequence

Case 2. First-of-sequence

Case 3. Interior-of-sequence

Case 4. End-of-sequence

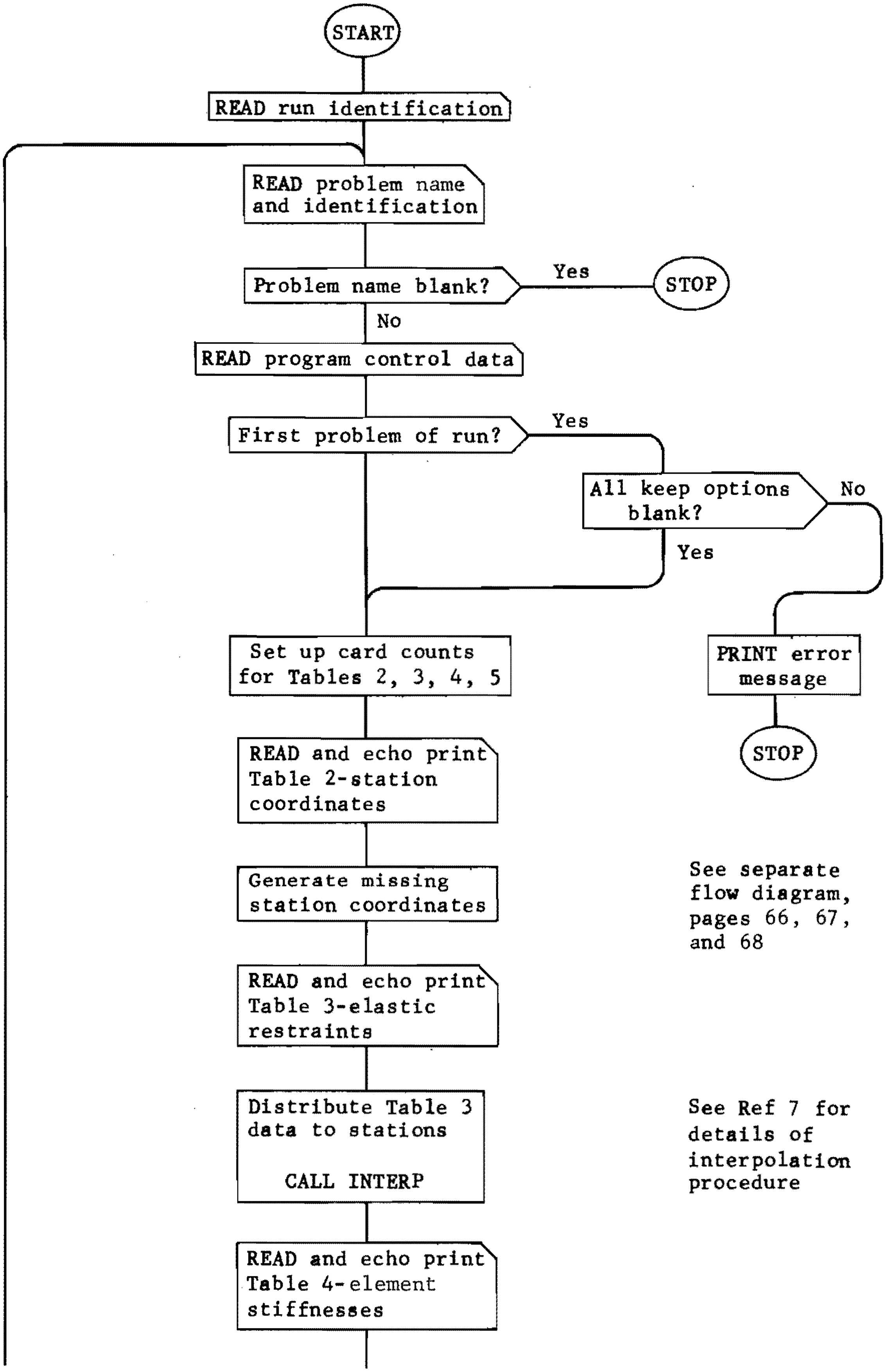
FROM STA	TO STA	CONTD ?	GJ or EIZ
20		CØNTD	1.0
	25	CØNTD	4.0
	30	CØNTD	2.0
	40		2.0

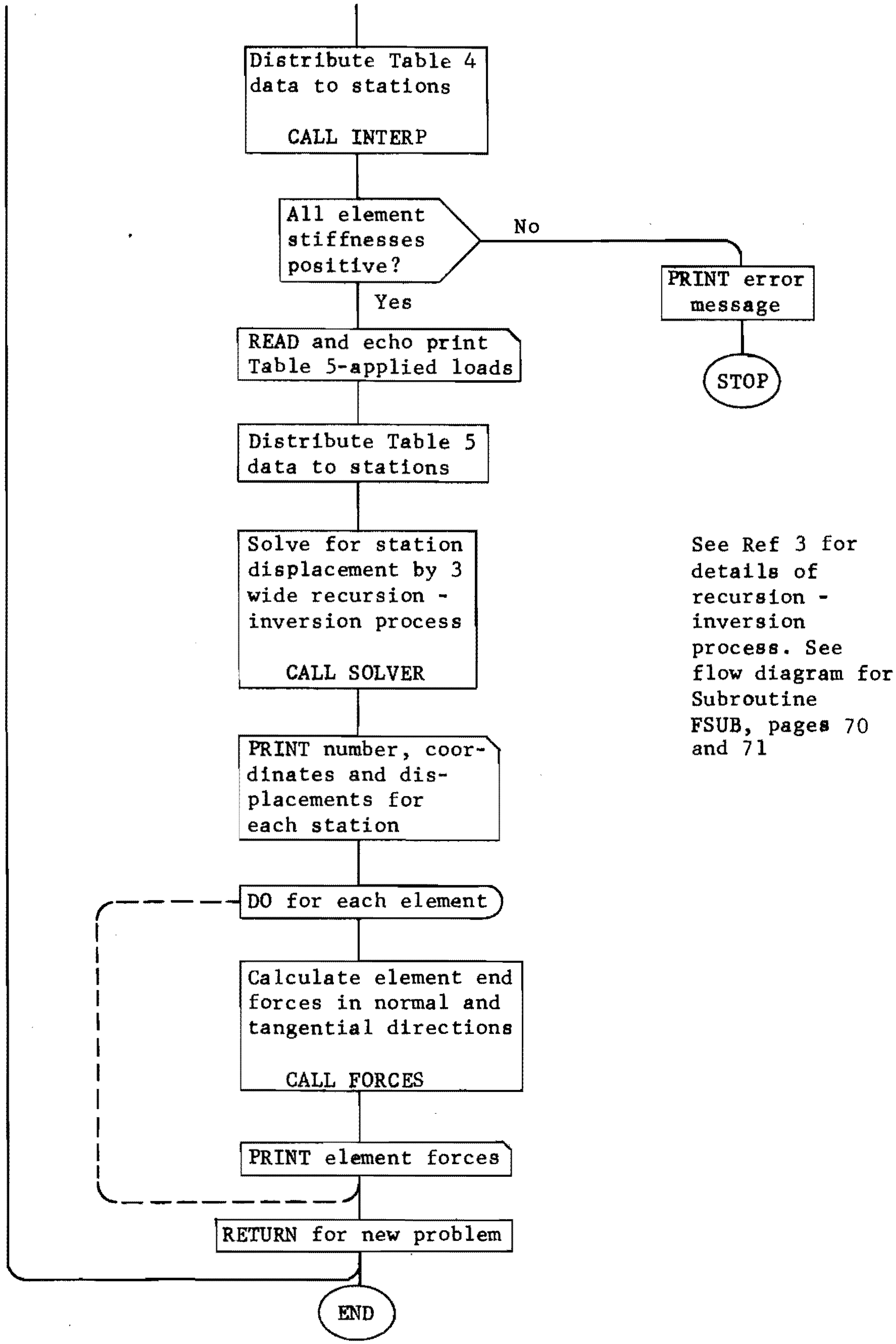


APPENDIX 3

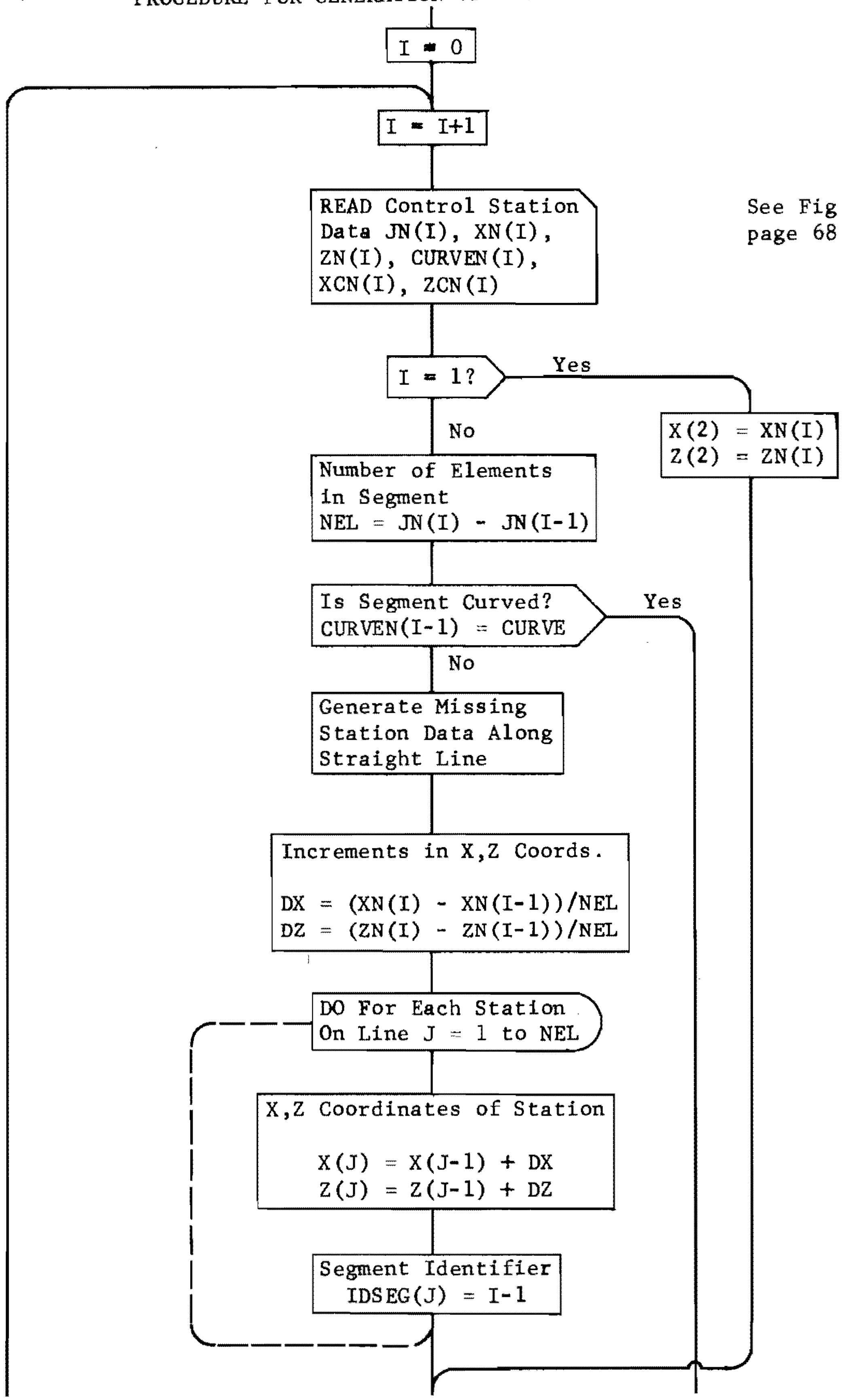
FLOW DIAGRAMS

PROGRAM PCGR2

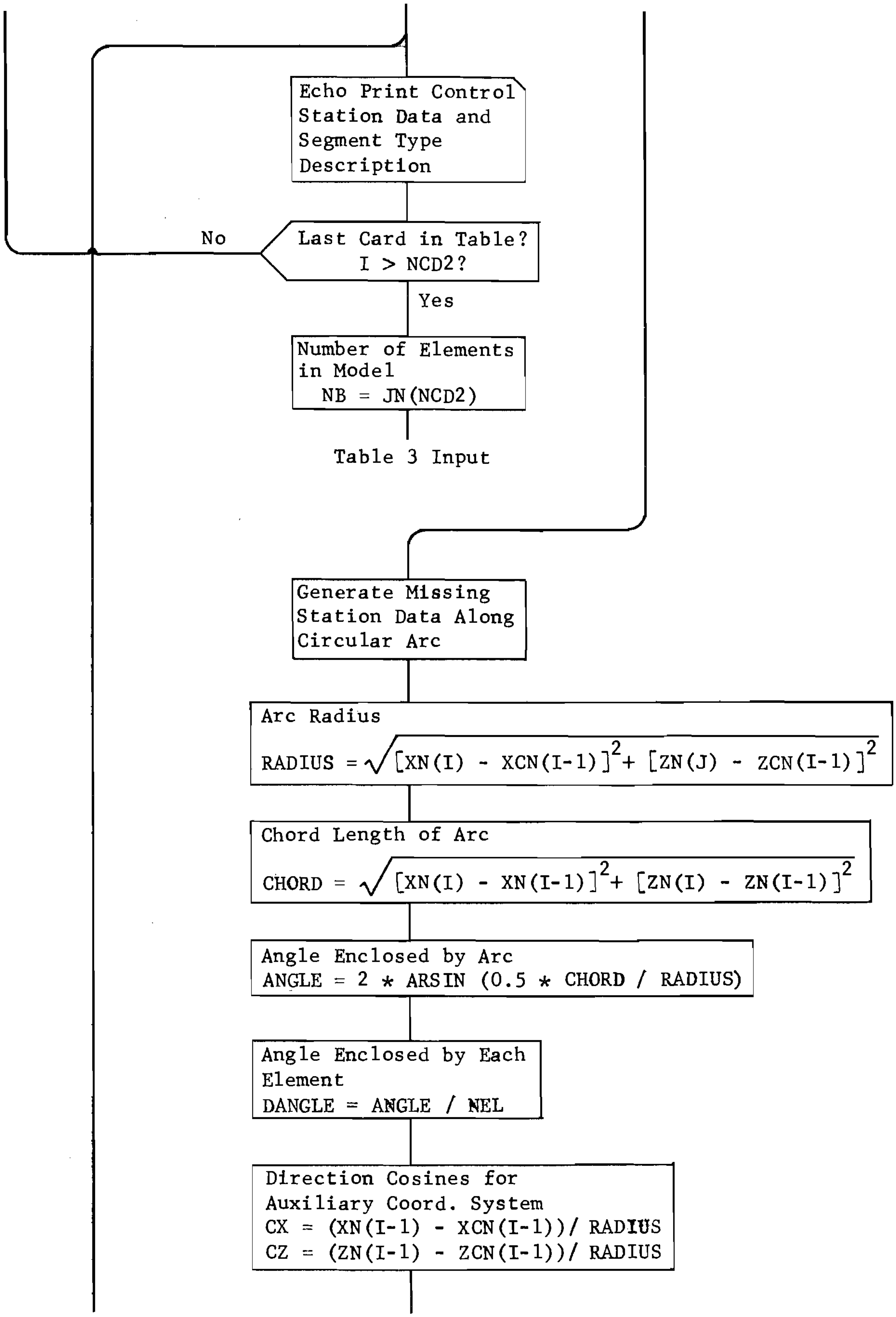


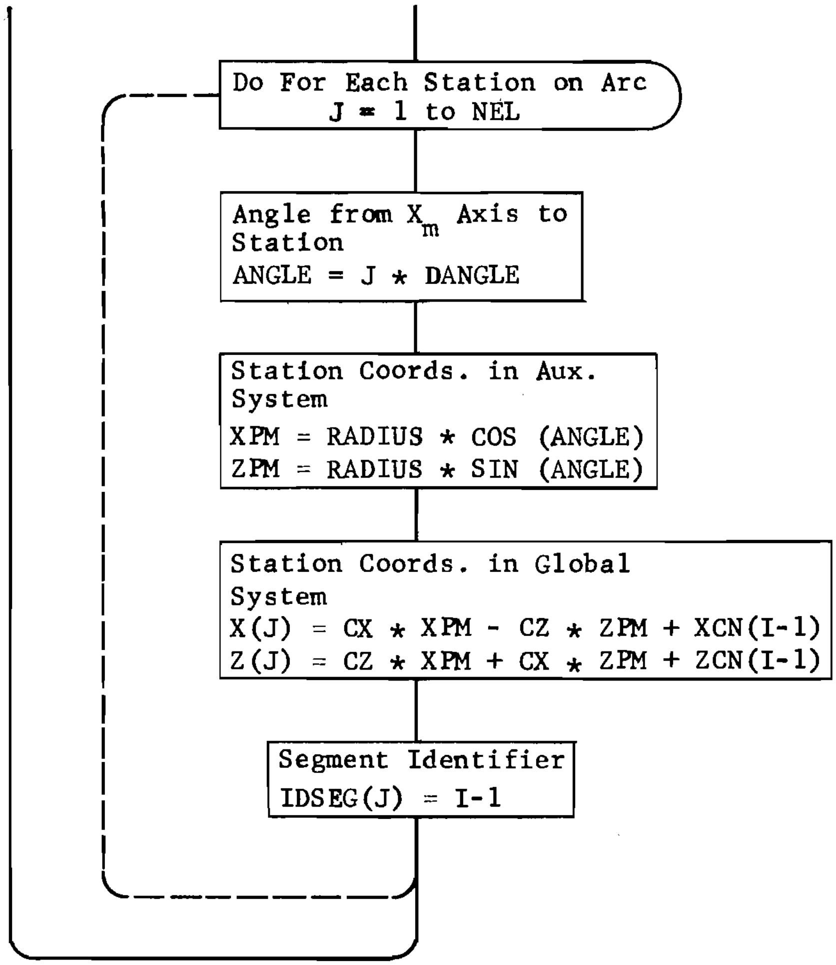

Distribute Table 4 data to stations
CALL INTERP
All element stiffnesses positive?
No
PRINT error message
STOP
Yes
READ and echo print Table 5-applied loads
Distribute Table 5 data to stations
Solve for station displacement by 3 wide recursion - inversion process
CALL SOLVER
See Ref 3 for details of recursion - inversion process. See flow diagram for Subroutine FSUB, pages 70 and 71
PRINT number, coordinates and displacements for each station
DO for each element
Calculate element end forces in normal and tangential directions
CALL FORCES
PRINT element forces
RETURN for new problem
END

PROCEDURE FOR GENERATION OF MISSING STATION DATA



See Fig A1, page 68


Echo Print Control Station Data and Segment Type Description
No
Last Card in Table? I > NCD2?
Yes
Number of Elements in Model NB = JN(NCD2)
Table 3 Input
Generate Missing Station Data Along Circular Arc
Arc Radius
RADIUS = √([XN(I) - XCN(I-1)]² + [ZN(J) - ZCN(I-1)]²)
Chord Length of Arc
CHORD = √([XN(I) - XN(I-1)]² + [ZN(I) - ZN(I-1)]²)
Angle Enclosed by Arc
ANGLE = 2 * ARSIN (0.5 * CHORD / RADIUS)
Angle Enclosed by Each Element
DANGLE = ANGLE / NEL
Direction Cosines for Auxiliary Coord. System
CX = (XN(I-1) - XCN(I-1))/ RADIUS
CZ = (ZN(I-1) - ZCN(I-1))/ RADIUS


Do For Each Station on Arc
J = 1 to NEL
Angle from X_m Axis to Station
ANGLE = J * DANGLE
Station Coords. in Aux. System
XPM = RADIUS * COS (ANGLE)
ZPM = RADIUS * SIN (ANGLE)
Station Coords. in Global System
X(J) = CX * XPM - CZ * ZPM + XCN(I-1)
Z(J) = CZ * XPM + CX * ZPM + ZCN(I-1)
Segment Identifier
IDSEG(J) = I-1

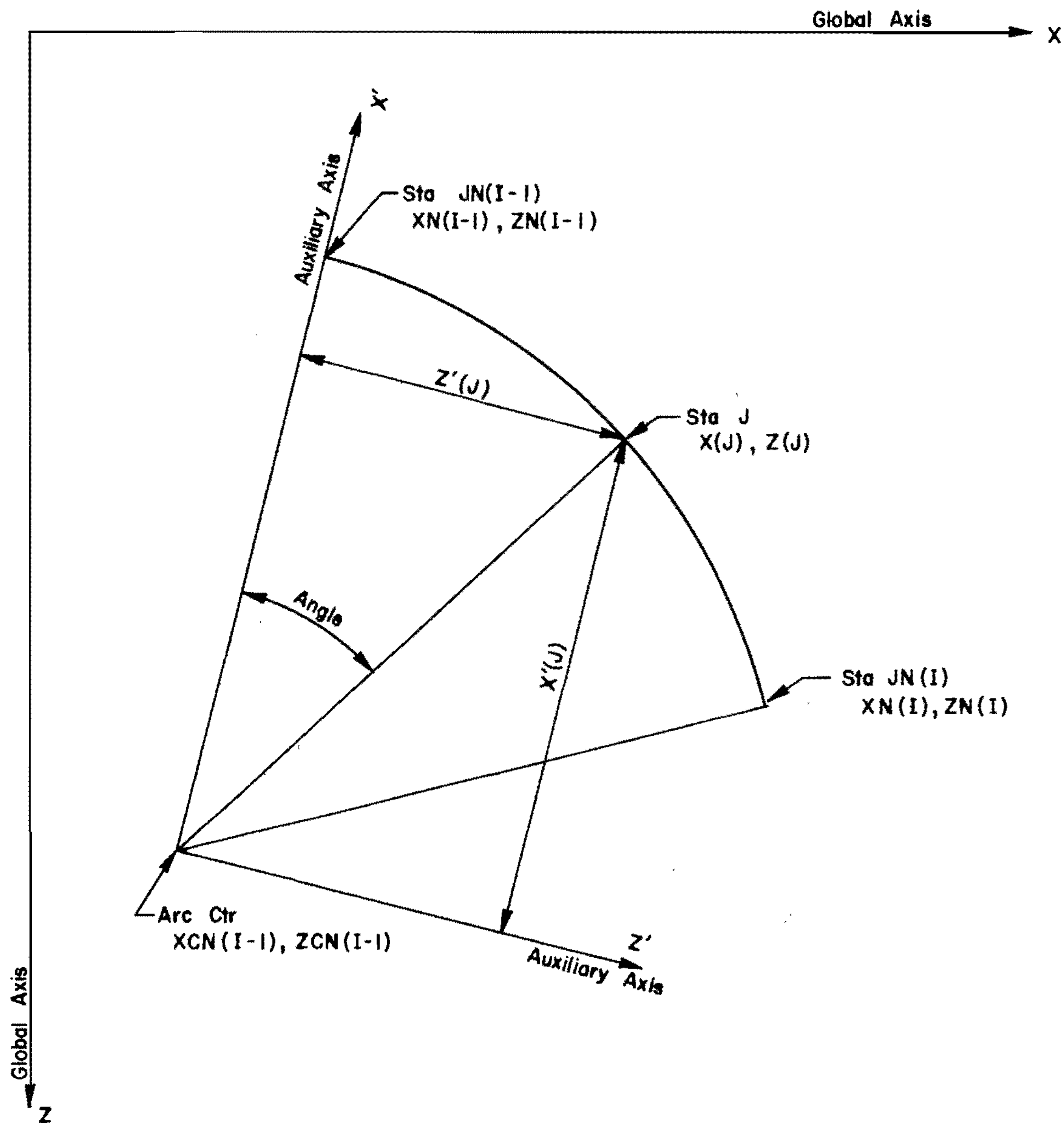
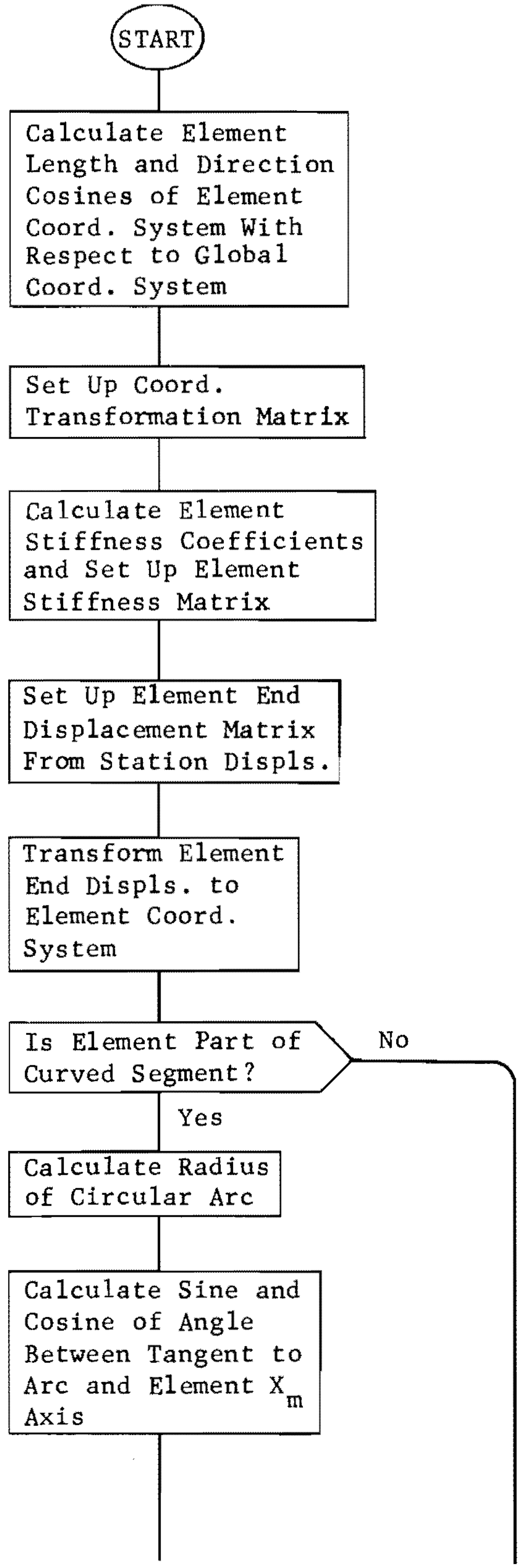
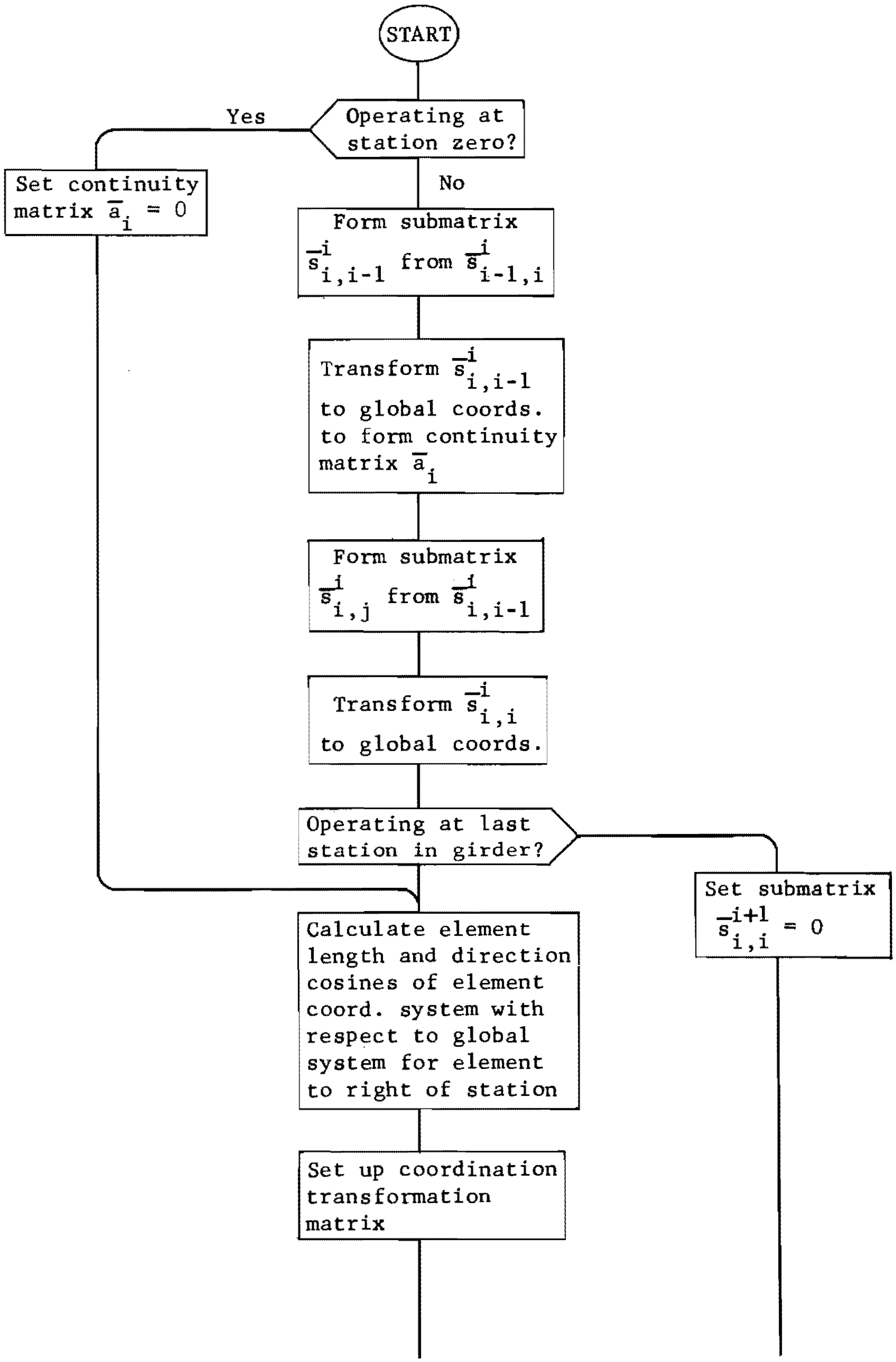


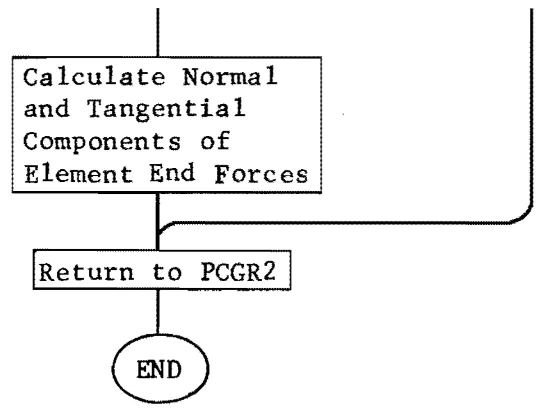
Fig A1. Auxiliary coordinate system for stations on circular arc.

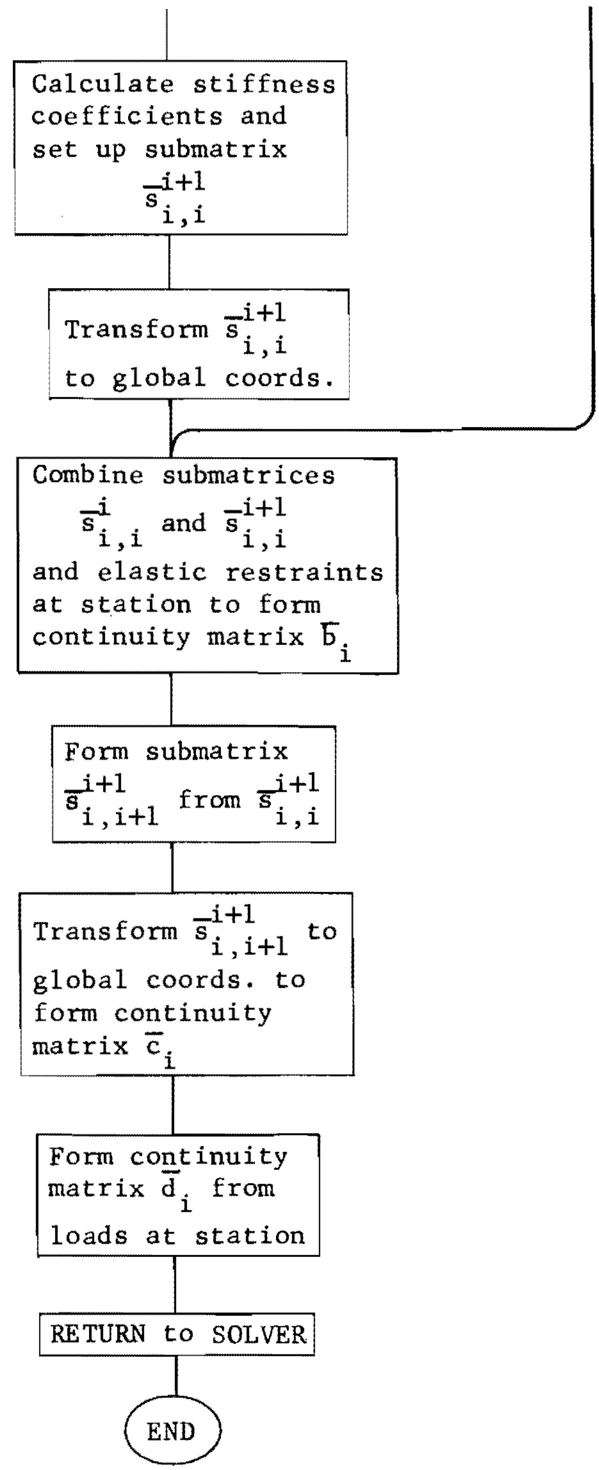
SUBROUTINE FORCES



SUBROUTINE FSUB




Calculate Normal and Tangential Components of Element End Forces
Return to PCGR2
END


Calculate stiffness coefficients and set up submatrix $\bar{s}^{i+1}_{i,i}$
Transform $\bar{s}^{i+1}_{i,i}$ to global coords.
Combine submatrices $\bar{s}^{i}_{i,i}$ and $\bar{s}^{i+1}_{i,i}$ and elastic restraints at station to form continuity matrix $\bar{b}_i$
Form submatrix $\bar{s}^{i+1}_{i,i+1}$ from $\bar{s}^{i+1}_{i,i}$
Transform $\bar{s}^{i+1}_{i,i+1}$ to global coords. to form continuity matrix $\bar{c}_i$
Form continuity matrix $\bar{d}_i$ from loads at station
RETURN to SOLVER
END

APPENDIX 4

LISTING

```
      PROGRAM PCGR 2 (INPUT,OUTPUT)                                     07AG9
C                                                                        7AG9
C-----ANALYSIS OF PLANE ELASTIC CURVED LINES TREATED AS AN ASSEMBLAGE   07AG9
C         OF GRID MEMBERS - WPD                                         07AG9
C
C-----THIS PROGRAM WILL OPERATE ON EITHER CDC6600 OR IBM360/50 SYSTEMS.
C     THOSE CARDS NEEDED TO OPERATE ON THE IBM360/50 ARE INCLUDED AS
C     FOLLOWING COMPANION CARDS TO THE CDC CARDS AND HAVE A C IN COLUMN
C     ONE AND THE SYMBOLS IBM IN COLUMNS 78 THRU 80. OTHER ADDITIONAL
C     CARDS SUCH AS THE SELECTIVE DOUBLE PRECISION STATEMENTS ARE ALSO
C     TAGGED WITH IBM AND NULLED WITH A C. WHEN CONVERTING TO THE
C     IBM360/50 SYSTEM, THE COMPANION CDC6600 CARDS SHOULD BE RETAINED
C     AND NULLED WITH AN ADDED C.
C
C*****NOTATION                                                           7AG9
C         A(,,), B(,,)         RECURSION COEFFICIENTS                   07AG9
C         AA(,), BB(,), CC(,) CONTINUITY COEFFICIENTS                   07AG9
C         ANGLE                ANGLE IN ARC, ANGLE TO STATION           07AG9
C         CHORD                CHORD LENGTH FOR ARC                     07AG9
C         CONTD                COMPARISON PARAM                         07AG9
C         CONT3, CONT4, CONT5 CONTINUATION CODE FOR DATA DISTRIBUTION   07AG9
C         CURVEN(), CID        CODE TO INDICATE CURVED SEGMENT FO GIRDER 07AG9
C         CX, CZ               DIRECTION COSINES                        07AG9
C         DANGLE               ANGLE INCREMENT                          07AG9
C         DD(,)                CONTINUITY COEFFICIENTS                  07AG9
C         DX, DZ               COORDINATE INCREMENTS                    07AG9
C         EIZ(), EIZN()        FLEXURAL STIFFNESS                       07AG9
C         FJ                   DUMMY VARIABLE                           07AG9
C         FORCE(,)             ELEMENT END FORCE                        07AG9
C         FY(), FYN()          APPLIED FORCE IN Y DIRECTION             07AG9
C         GJ(), GJN()          TORSION STIFFNESS                        07AG9
C         I, J, JJ             INTEGER INDICES                          07AG9
C         ID1(), ID2()         ALPHANUMERIC RUN AND PROB DESCRIPTION    07AG9
C         IDSEG(), ISEG        SEGMENT IDENT NO                         07AG9
C         IMEM                 ELEMENT NO                               07AG9
C         INI3, INI4, INI5     INITIAL STATION IN DATA DISTRIBUTION     07AG9
C         INL3, INL4, INL5     FINAL STATION IN DATA DISTRIBUTION       07AG9
C         ISTA                 STA NUMBER                               07AG9
C         ISTART, ISTOP        INITIAL, FINAL STATIONS IN SEQUENCE      07AG9
C         ITEST                COMPARISON PARAM                         07AG9
C         JN()                 INPUT STATION NUMBER                     07AG9
C         JNUM                 STA NO                                   07AG9
C         KEEP                 COMPARISON PARAM                         07AG9
C         KEEP2,KEEP3,KEEP4    CODE TO HOLD PRECEDING TABLE             07AG9
C         LSM                  DISTRIBUTION TYPE PARAM                  07AG9
C         MAX                  COUNTER                                  07AG9
C         NB                   NO ELEMENTS IN MODEL                     07AG9
C         NCD2,NCD3,NCD4,NCD5 NO CARDS ADDED TO TABLE                   07AG9
C         NCI2,NCI3,NCI4,NCI5 INITIAL CARD COUNTER FOR TABLE            07AG9
C         NCT2,NCT3,NCT4,NCT5 TOTAL NO CARDS IN TABLE                   07AG9
C         NEL                  NUMBER OF ELEMENTS IN SEGMENT            07AG9
C         NEW                  COMPARISON PARAM                         07AG9
C         NI                   DIMENSION PARAM                          07AG9
C         NIL                  COMPARISON PARAM                         07AG9
C         NJ                   MAX NO STATIONS IN MODEL, DIMENSION PARAM 07AG9
C         NPROB                PROB NAME                                07AG9
C         NT                   TABLE NO                                 07AG9
C         RADIUS               ARC RADIUS                               07AG9
C         RT(,)                COORD TRANSFORMATION COEFFICIENT         07AG9
C         RX(), RXN()          ELASTIC ROTATION RESTRAINT ABOUT X AXIS  07AG9
C         RZ(), RZN()          ELASTIC ROTATION RESTRAINT ABOUT Z AXIS  07AG9
C         S(,)                 ELEMENT STIFFNESS COEFFICIENT            07AG9
C         SINE, COSINE         TRIG FUNCTIONS TO TRANSFORM ELEMENT FORCES07AG9
C         SY(), SYN()          ELASTIC TRANSLATION RESTRAINT IN Y DIR   07AG9
C         TF                   DUMMY VARIABLE                           07AG9
C         X(), Z()             GLOBAL COORDINATES                       07AG9
C         XCN(), ZCN(), XC, ZCCOORDINATES OF ARC CENTER                 07AG9
C         XL, XL2, XL3         ELEMENT LENGTH, SQUARED, CUBED           07AG9
C         XM(), ZM()           APPLIED MOMENTS                          07AG9
C         XN(), ZN()           INPUT STATION COORDINATES                07AG9
C         XPM, ZPM             AUXILIARY STA COORDS                     07AG9
C         W(), WTS(), WTM()    STATION DISPLACEMENTS                    07AG9
C         ZERO                 COMPARISON PARAM                         07AG9
C*****NOTATION                                                           7AG9
C                                                                        7AG9
C-----DOUBLE PRECISION DECK                                             07AG9IBM
C     IMPLICIT REAL*8 ( A-H,O-Z )                                       07AG9IBM
C                                                                        7AG9
      DIMENSION A(203,3,1), B(203,3,3), CONT3(50), CONT4(50), CONT5(50),07AG9
     1          CURVEN(20), EIZ(203), EIZN(50), FORCE(6,1), FY(203),    07AG9
     2          FYN(50), GJ(203), GJN(50), ID1(40), ID2(20), IDSEG(203),07AG9
     3          INI3(50), INI4(50), INI5(50),                           07AG9
     3          INL3(50), INL4(50), INL5(50), JN(50), RX(203), RXN(50), 07AG9
     4          RZ(203), RZN(50), SY(203), SYN(50), X(203), XCN(20),    07AG9
     5          XM(203), XMN(50), XN(50), Z(203), ZCN(20), ZM(203),     07AG9
     6          ZMN(50), ZN(50), W(203,3)                               07AG9
C                                                                        7AG9
            NJ = 203                                                    07AG9
            NI = 50                                                     07AG9
      DATA ITEST, NEW, CURVE, KEEP / 4H     , 4HNEW , 4HCURV, 4HKEEP /  07AG9
      DATA CONTD / 4HCONT /                                             07AG9
 1000 FORMAT ( 20A4 )                                                   07AG9
 1001 FORMAT (    5H1      , 80X, 10HI-----TRIM )                       22JL0
 1002 FORMAT (   52H      PROGRAM PCGR2 - DECK 1 - DAWKINS              22JL0
     1                              28H  REVISION DATE 22 JULY 1970   )REVISED
 1003 FORMAT ( 5X, 20A4 )                                               07AG9
 1004 FORMAT (/// 9H      PROB, /, 5X, 20A4 )                           07AG9
 1005 FORMAT ( 5X, 4( A4, 1X ), 5X, 4I5 )                               07AG9
 1006 FORMAT (///35H      TABLE 1 - PROGRAM CONTROL DATA                07AG9
     1   / 44X, 20H          TABLE NUMBER                               07AG9
     2   / 44X, 25H       2     3     4     5                           07AG9
     3  //      28H           PRIOR-DATA OPTIONS, 19X, 4( A4, 2X ),     07AG9
     4   /      38H           NUM CARDS INPUT THIS PROBLEM, 6X, 4I6 )   07AG9
 1007 FORMAT (///34H      TABLE 2 - STATION COORDINATES                 07AG9
     1  //, 5X,  45H        STA          GLOBAL COORDINATES             07AG9
     2          26H      SEGMENT TYPE AND DATA                          07AG9
     3   /, 5X,  46H                      X            Z             /  107AG9
 1008 FORMAT (  46H           USING DATA FROM THE PREVIOUS PROBLEM )    07AG9
```

```
1009 FORMAT ( 5X, I5, 5X, 2E10.3, 20X, A4, 1X, 2E10.3 )                 07AG9
 10100FORMAT ( 45X,                                                     -7AG9
    1            13H     STRAIGHT )                                     07AG9
C1011 FORMAT (10X, I5, 5X, 1P2D12.3 )                                   07AG9IBM
 1011 FORMAT (10X, I5, 5X,   2E12.3 )                                   060C9CDC
 10120FORMAT ( 46X,                                                     07AG9
    1            30H     CURVE      XC             ZC                   07AG9
C   2    /,      55X, 1P2D12.3 )                                        07AG9IBM
    2    /,      55X,   2E12.3 )                                        060C9CDC
 10130FORMAT (///39H     TABLE 3 - ELASTIC RESTRAINTS                   07AG9
    1  //, 5X,  49H      FROM  TO CONTD      RX          SY          RZ  /)07AG9
 1014 FORMAT (5X,46H     USING DATA FROM THE PREVIOUS PROBLEM PLUS )     07AG9
 1015 FORMAT ( / 25H                      NONE )                        07AG9
 1016 FORMAT ( 5X, 2I5, A4, 1X, 6E10.3 )                                07AG9
C1017 FORMAT (10X, 2I4, 1X, A4, 1X, 1P6D11.3 )                          07AG9IBM
 1017 FORMAT (10X, 2I4, 1X, A4, 1X,   6E11.3 )                          07AG9CDC
 10180FORMAT (///50H     TABLE 4 - ELEMENT STIFFNESSES                  07AG9
    1  //, 5X,  40H      FROM  TO CONTD      GJ          EIZ         /)07AG9
 10190FORMAT (///40H     TABLE 5 - APPLIED LOADS AND MOMENTS            07AG9
    1  //, 5X,  48H      FROM  TO CONTD      XM          FY          ZM  /)07AG9
 1020 FORMAT (///17H     PROB (CONTD), /, 5X, 20A4 )                    07AG9
 10210FORMAT (///25H     TABLE 6 - RESULTS                              07AG9
    1  //, 2X,  47H      STATION DISPLACEMENTS IN GLOBAL COORDINATE     22JL0
    2            15H DIRECTIONS                                         07AG9
    3  //, 2X,  40H         STA        GLOBAL COORDINATES               22JL0
    4     8X,   20H      DISPLACEMENTS                                  07AG9
    5   /, 2X,  51H                X               Z            X ROTATION 22JL0
    6           30H  Y DEFLECTION     Z ROTATION         / )            07AG9
C1022 FORMAT ( 7X, I5, 1P2D12.3, 3X, 3D14.3 )                           22JL0IBM
 1022 FORMAT ( 7X, I5,   2E12.3, 3X, 3E14.3 )                           22JL0CDC
 10230FORMAT (///25H     TABLE - 6 (CONTD)                              07AG9
    1  //, 2X,  48H      ELEMENT END FORCES IN NORMAL AND TANGENTIAL    22JL0
    2            15H DIRECTIONS                                         07AG9
    3  //, 2X,  45H        ELEM                 END(I-1)                22JL0
    4            25H                   END(I)                           07AG9
    5   /, 2X,  48H        NO.    TWISTING     SHEAR       BENDING      22JL0
    6           35H  TWISTING      SHEAR       BENDING                  07AG9
    7   /, 2X,  48H        (I)      MOMENT       FORCE        MOMENT    22JL0
    8           35H   MOMENT        FORCE       MOMENT      / )         07AG9
C1024 FORMAT ( 7X, I5, 1P6D12.3 )                                       22JL0IBM
 1024 FORMAT ( 7X, I5,   6E12.3 )                                       22JL0CDC
C                                                                        7AG9
C-----DEFINE TEST PARAMETERS                                            07AG9
C                                                                        7AG9
                NIL    = 0                                              07AG9
                ZERO   = 0.0                                            07AG9
C                                                                        7AG9
C-----PROGRAM AND PROBLEM IDENTIFICATION                                07AG9
C                                                                        7AG9
      READ 1000, ( ID1(I), I = 1, 40 )                                  07AG9
      CALL TIC TOC (1)                                                  09JA0CDC
   10 READ 1000, NPROB, ( ID2(I), I = 1, 19 )                           07AG9
         IF ( NPROB .EQ. ITEST ) GO TO 999                              07AG9
      PRINT 1001                                                        22JL0
      PRINT 1002                                                        07AG9
      PRINT 1003, ( ID1(I), I = 1, 40 )                                 07AG9
```

```
      PRINT 1004, NPROB, ( ID2(I), I = 1, 19 )                          07AG9
C                                                                        7AG9
C-----INPUT TABLE 1. PROGRAM CONTROL DATA                               07AG9
C                                                                        7AG9
     0READ 1005, KEEP2, KEEP3, KEEP4, KEEP5,                            07AG9
     1             NCD2 , NCD3 , NCD4 , NCD5                            07AG9
     0PRINT 1006, KEEP2, KEEP3, KEEP4, KEEP5,                           07AG9
     1              NCD2 , NCD3 , NCD4 , NCD5                           07AG9
C                                                                        7AG9
C-----TEST ALL HOLD OPTIONS BLANK FOR NEW PROBLEM                       07AG9
C                                                                        7AG9
         IF ( NEW .EQ. ITEST ) GO TO 20                                 07AG9
         IF ( KEEP2 .EQ. KEEP ) GO TO 900                               07AG9
         IF ( KEEP3 .EQ. KEEP ) GO TO 900                               07AG9
         IF ( KEEP4 .EQ. KEEP ) GO TO 900                               07AG9
         IF ( KEEP5 .EQ. KEEP ) GO TO 900                               07AG9
C                                                                        7AG9
              NEW = ITEST                                               07AG9
   20    IF ( KEEP2 .EQ. KEEP ) GO TO 30                                07AG9
         IF ( NCD2 .LT. 2 )    GO TO 901                                07AG9
         GO TO 40                                                       07AG9
   30    IF ( NCD2 .NE. NIL ) GO TO 902                                 07AG9
   40    IF ( KEEP3 .EQ. KEEP ) GO TO 50                                07AG9
              NCI3 = 1                                                  07AG9
              NCT3 = NCD3                                               07AG9
         GO TO 60                                                       07AG9
   50         NCI3 = NCT3 + 1                                           07AG9
              NCT3 = NCT3 + NCD3                                        07AG9
   60    IF ( NCT3 .EQ. NIL ) GO TO 903                                 07AG9
         IF ( KEEP4 .EQ. KEEP ) GO TO 70                                07AG9
              NCI4 = 1                                                  07AG9
              NCT4 = NCD4                                               07AG9
         GO TO 100                                                      07AG9
   70         NCI4 = NCT4 + 1                                           07AG9
              NCT4 = NCT4 + NCD4                                        07AG9
C                                                                        7AG9
  100    IF ( KEEP5 .EQ. KEEP ) GO TO 110                               07AG9
              NCI5 = 1                                                  07AG9
              NCT5 = NCD5                                               07AG9
         GO TO 120                                                      07AG9
  110         NCI5 = NCT5 + 1                                           07AG9
              NCT5 = NCT5 + NCD5                                        07AG9
C                                                                        7AG9
C-----READ, ECHO PRINT AND DISTRIBUTE TABLE 2 - STATION COORDINATES     07AG9
C                                                                        7AG9
  120 PRINT 1007                                                         7AG9
         IF ( KEEP2 .NE. KEEP ) GO TO 130                               07AG9
      PRINT 1008                                                        07AG9
         GO TO 235                                                      07AG9
  130         I = 0                                                     07AG9
  140         I = I + 1                                                 07AG9
      READ 1009, JN(I), XN(I),        ZN(I), CURVEN(I), XCN(I), ZCN(I)  07AG9
         IF ( I .GT. 1 ) GO TO 150                                      07AG9
              X(2) = XN(1)                                              07AG9
              Z(2) = ZN(1)                                              07AG9
         GO TO 190                                                      07AG9
```

```
 150          NEL = JN(I) - JN(I-1)                                       07AG9
        IF ( NEL .LT. 1 ) GO TO 904                                       07AG9
              DENOM = NEL                                                 07AG9
        IF ( CURVEN(I-1) .EQ. CURVE ) GO TO 200                           07AG9
C                                                                          7AG9
C-----STRAIGHT SEGMENT - GENERATE STATION COORDINATES                     07AG9
C                                                                          7AG9
 160          DX = ( XN(I) - XN(I-1) ) / DENOM                            07AG9
              DZ = ( ZN(I) - ZN(I-1) ) / DENOM                            07AG9
              ISTART = JN(I-1) + 3                                        07AG9
              ISTOP  = JN(I) + 2                                          07AG9
        DO 170 J = ISTART, ISTOP                                          07AG9
              X(J) = X(J-1) + DX                                          07AG9
              Z(J) = Z(J-1) + DZ                                          07AG9
              IDSEG(J) = I - 1                                            07AG9
 170    CONTINUE                                                          07AG9
 180 PRINT 1010                                                           07AG9
 190 PRINT 1011, JN(I), XN(I),         ZN(I)                              07AG9
        IF ( I .LT. NCD2 ) GO TO 140                                      07AG9
        GO TO 230                                                         07AG9
C                                                                          7AG9
C-----CURVED SEGMENT - GENERATE STATION COORDINATES                       07AG9
C                                                                          7AG9
C     SOLVE FOR ANGLE BETWEEN RADII THROUGH STATIONS JN(I-1) AND JN(I)    07AG9
C                                                                          7AG9
 200          DX = XN(I) - XCN(I-1)                                       07AG9
              DZ = ZN(I) - ZCN(I-1)                                       07AG9
C             RADIUS = DSQRT (( DX * DX ) + ( DZ * DZ ))                  07AG9IBM
              FLE = DX * DX + DZ * DZ                                     030C9CDC
              RADIUS = SQRT ( FLE )                                       030C9CDC
              DX = XN(I) - XN(I-1)                                        07AG9
              DZ = ZN(I) - ZN(I-1)                                        07AG9
C             CHORD = DSQRT (( DX * DX ) + ( DZ * DZ ))                   07AG9IBM
              FLE = DX * DX + DZ * DZ                                     030C9CDC
              CHORD  = SQRT ( FLE )                                       030C9CDC
C             ANGLE = 2. * DARSIN ( 0.5 * CHORD / RADIUS )                07AG9IBM
              FLE = 0.5 * CHORD / RADIUS                                  030C9CDC
              ANGLE = 2. * ASIN ( FLE )                                   030C9CDC
              DANGLE = ANGLE / DENOM                                      07AG9
C                                                                          7AG9
C-----ESTABLISH DIRECTION COSINES FOR X' AXIS WRT X-Z AXES                 07AG9
C                                                                          7AG9
              CX = ( XN(I-1) - XCN(I-1) ) / RADIUS                        07AG9
              CZ = ( ZN(I-1) - ZCN(I-1) ) / RADIUS                        07AG9
C                                                                          7AG9
C-----CHECK FOR CW OR CCW GENERATION REQUIRED                             07AG9
C                                                                          7AG9
     0        ZPM = -CZ * ( XN(I) - XCN(I-1) )                            07AG9
     1              + CX * ( ZN(I) - ZCN(I-1) )                           07AG9
        IF ( ZPM .LT. 0.0 ) GO TO 202                                     07AG9
              SIGN = 1.0                                                  07AG9
        GO TO 204                                                         07AG9
 202          SIGN = - 1.0                                                07AG9
C                                                                          7AG9
C-----GENERATE COORDINATES OF STATIONS ON CURVE WRT XYZ SYSTEM             07AG9
C                                                                          7AG9
```

```
              NEL = NEL - 1                                               07AG9
 204    DO 220 J = 1, NEL                                                 07AG9
              FJ = J                                                      07AG9
              ANGLE = FJ * DANGLE                                         07AG9
C             XPM = RADIUS * DCOS ( ANGLE )                               07AG9IBM
              XPM = RADIUS *  COS ( ANGLE )                               06JA0CDC
C             ZPM = SIGN * RADIUS * DSIN ( ANGLE )                        07AG9IBM
              ZPM = SIGN * RADIUS *  SIN ( ANGLE )                        06JA0CDC
              JNUM = JN(I-1) + 2 + J                                      07AG9
              X(JNUM) = CX * XPM - CZ * ZPM + XCN(I-1)                    07AG9
              Z(JNUM) = CZ * XPM + CX * ZPM + ZCN(I-1)                    07AG9
              IDSEG(JNUM) = SIGN * ( I - 1 )                              06JA0
 220    CONTINUE                                                          07AG9
              JNUM = JN(I) + 2                                            07AG9
              X(JNUM) = XN(I)                                             07AG9
              Z(JNUM) = ZN(I)                                             07AG9
              IDSEG(JNUM) = SIGN * ( I - 1 )                              06JA0
C                                                                          7AG9
 225 PRINT 1012, XCN(I-1), ZCN(I-1)                                       07AG9
        GO TO 190                                                         07AG9
 230          NB = JN(NCD2)                                               07AG9
C                                                                          7AG9
C-----READ, ECHO PRINT AND DISTRIBUTE TABLE 3 - ELASTIC RESTRAINTS        07AG9
C                                                                          7AG9
 235 PRINT 1013                                                           07AG9
        IF ( KEEP3 .NE. KEEP ) GO TO 240                                  07AG9
     PRINT 1014                                                           07AG9
        IF ( NCD3 .NE. NIL ) GO TO 240                                    07AG9
     PRINT 1015                                                           07AG9
        GO TO 260                                                         07AG9
 240    DO 250 I = NC13, NCT3                                             07AG9
     READ 1016, IN13(I), INL3(I), CONT3(I), RXN(I), SYN(I), RZN(I)        07AG9
C                                                                          7AG9
C------TEST STATIONS IN PROPER ORDER                                      07AG9
C                                                                          7AG9
     IF ( IN13(I) .GT. INL3(I) .AND. CONT3(I) .NE. CONTD ) GO TO 905      07AG9
     PRINT 1017, IN13(I), INL3(I), CONT3(I), RXN(I), SYN(I), RZN(I)       07AG9
 250    CONTINUE                                                          -7AG9
C                                                                          7AG9
C-----DISTRIBUTE TABLE 3                                                  07AG9
C                                                                          7AG9
              LSM = 0                                                     07AG9
     CALL INTERP ( NB, NCT3, IN13, INL3, CONT3, RZN, RZ, LSM, NI, NJ )    07AG9
     CALL INTERP ( NB, NCT3, IN13, INL3, CONT3, RXN, RX, LSM, NI, NJ )    07AG9
     CALL INTERP ( NB, NCT3, IN13, INL3, CONT3, SYN, SY, LSM, NI, NJ )    07AG9
C                                                                          7AG9
C-----READ, ECHO PRINT AND DISTRIBUTE TABLE 4 - ELEMENT STIFFNESSES       07AG9
C                                                                          7AG9
 260 PRINT 1018                                                           14JL0
        IF ( KEEP4 .NE. KEEP ) GO TO 270                                  14JL0
     PRINT 1014                                                           07AG9
        IF ( NCD4 .NE. NIL ) GO TO 270                                    07AG9
     PRINT 1015                                                           07AG9
        GO TO 300                                                         07AG9
 270    DO 280 I = NC14, NCT4                                             07AG9
     READ 1016, IN14(I), INL4(I), CONT4(I), GJN(I), EIZN(I)               07AG9
```

```
C                                                                      7AG9
C-----TEST STATIONS IN PROPER ORDER                                   07AG9
C                                                                      7AG9
      IF ( INI4(I) .GE. INL4(I) .AND. CONT4(I) .NE. CONTD ) GO TO 906 07AG9
      PRINT 1017, INI4(I), INL4(I), CONT4(I), GJN(I), EIZN(I)         07AG9
  280     CONTINUE                                                     7AG9
C                                                                      7AG9
C-----DISTRIBUTE TABLE 4                                              07AG9
C                                                                      7AG9
              LSM = 1                                                 07AG9
      CALL INTERP ( NB, NCT4, INI4, INL4, CONT4, GJN, GJ, LSM, NI, NJ ) 07AG9
      CALL INTERP ( NB, NCT4, INI4, INL4, CONT4, EIZN, EIZ, LSM, NI, NJ)07AG9
C                                                                      7AG9
C-----TEST STIFFNESSES FOR ALL NONZERO AND POSITIVE                   07AG9
C                                                                      7AG9
              MAX = NB + 2                                            07AG9
          DO 290 I = 3, MAX                                           07AG9
          IF ( GJ(I)  .LE. ZERO ) GO TO 908                           07AG9
          IF ( EIZ(I) .LE. ZERO ) GO TO 908                           07AG9
  290     CONTINUE                                                    07AG9
C                                                                      7AG9
C-----READ, ECHO PRINT AND DISTRIBUTE TABLE 5 - APPLIED LOADS         07AG9
C                                                                      7AG9
  300 PRINT 1019                                                       7AG9
          IF ( KEEP5 .NE. KEEP ) GO TO 310                            07AG9
      PRINT 1014                                                      07AG9
          IF ( NCD5 .NE. NIL ) GO TO 310                              07AG9
      PRINT 1015                                                      07AG9
          GO TO 330                                                   07AG9
  310     DO 320 I = NCI5, NCT5                                       07AG9
      READ 1016, INI5(I), INL5(I), CONT5(I), XMN(I), FYN(I), ZMN(I)   07AG9
C                                                                      7AG9
C-----TEST STATIONS IN PROPER ORDER                                   07AG9
C                                                                      7AG9
      IF ( INI5(I) .GT. INL5(I) .AND. CONT5(I) .NE. CONTD ) GO TO 907 07AG9
      PRINT 1017, INI5(I), INL5(I), CONT5(I), XMN(I), FYN(I), ZMN(I)  07AG9
  320     CONTINUE                                                    07AG9
  330     CONTINUE                                                    07AG9
C                                                                      7AG9
C-----DISTRIBUTE TABLE 5                                              07AG9
C                                                                      7AG9
              LSM = 0                                                 07AG9
      CALL INTERP ( NB, NCT5, INI5, INL5, CONT5, ZMN, ZM, LSM, NI, NJ ) 07AG9
      CALL INTERP ( NB, NCT5, INI5, INL5, CONT5, XMN, XM, LSM, NI, NJ ) 07AG9
      CALL INTERP ( NB, NCT5, INI5, INL5, CONT5, FYN, FY, LSM, NI, NJ ) 07AG9
C                                                                      7AG9
C-----END OF DATA INPUT - BEGIN SOLUTION                              07AG9
C                                                                      7AG9
C                                                                      7AG9
C                                                                      7AG9
C-----CALL RECURSION-INVERSION SOLVER FOR 3 WIDE BANDED MATRIX EQUATIONS07AG9
C                                                                      7AG9
     0CALL SOLVER ( NJ, NB, W, X, Z, SY, RX, RZ, GJ, EIZ, FY, XM, ZM, 07AG9
     1              A, B )                                            07AG9
C                                                                      7AG9
C                                                                      7AG9
C                                                                      7AG9
C-----PRINT RESULTS                                                   07AG9
C                                                                      7AG9
      PRINT 1001                                                      22JL0
      PRINT 1002                                                      07AG9
      PRINT 1003, ( ID1(I), I = 1, 40 )                               07AG9
      PRINT 1020, NPROB, ( ID2(I), I = 1, 19 )                        07AG9
      PRINT 1021                                                      07AG9
          DO 340 I = 2, MAX                                           07AG9
              ISTA = I - 2                                            07AG9
      PRINT 1022, ISTA, X(I), Z(I), W(I,2), W(I,1), W(I,3)            07AG9
  340     CONTINUE                                                    07AG9
C                                                                      7AG9
C-----CALCULATE ELEMENT END FORCES                                    07AG9
C                                                                      7AG9
      PRINT 1001                                                      22JL0
      PRINT 1002                                                      07AG9
      PRINT 1003, ( ID1(I), I = 1, 40 )                               07AG9
      PRINT 1020, NPROB, ( ID2(I), I = 1, 19 )                        07AG9
      PRINT 1023                                                      07AG9
          DO 350 I = 3, MAX                                           07AG9
              IMEM = I - 2                                            07AG9
              ISEG = IABS ( IDSEG(I) )                                06JA0
              SIGN = IDSEG(I) / ISEG                                  06JA0
              CID = CURVEN(ISEG)                                      07AG9
              XC = XCN(ISEG)                                          07AG9
              ZC = ZCN(ISEG)                                          07AG9
      CALL FORCES ( NJ, I, W, X, Z, GJ, EIZ, FORCE, SIGN, CID, XC, ZC ) 06JA0
     0PRINT 1024, IMEM, FORCE(2,I), FORCE(1,I), FORCE(3,I),           07AG9
     1             FORCE(5,I), FORCE(4,I), FORCE(6,I)                 07AG9
  350     CONTINUE                                                    07AG9
C                                                                      7AG9
C-----END OF SOLUTION                                                 07AG9
C                                                                      7AG9
      CALL TIC TOC (4)                                                09JA0CDC
C-----CHECK FOR NEW PROBLEM                                           07AG9
C                                                                      7AG9
          GO TO 10                                                    07AG9
C                                                                      7AG9
C-----ERROR MESSAGES                                                  07AG9
C                                                                      7AG9
  900 PRINT 9000                                                       7AG9
 9000 FORMAT (///23H     ILLEGAL KEEP DATA. )                         07AG9
              NT = 1                                                  07AG9
          GO TO 998                                                   07AG9
  998 PRINT 9998, NT, NPROB                                           07AG9
 99980FORMAT ( / 32H     CHECK INPUT DATA FOR TABLE , I1,             07AG9
     1          10H , PROBLEM , A4 )                                  06JA0
  999 CALL EXIT                                                       07AG9
  901 PRINT 9001                                                      07AG9
 9001 FORMAT (///50H     INSUFFICIENT STATION COORDINATE INFORMATION.  )07AG9
              NT = 2                                                  07AG9
          GO TO 998                                                   07AG9
  902 PRINT 9002                                                      07AG9
 9002 FORMAT (///46H     CANNOT BOTH KEEP AND ADD DATA TO TABLE 2. )  07AG9
              NT = 2                                                  07AG9
```

```
      GO TO 998                                                   07AG9
  903 PRINT 9003                                                  07AG9
 9003 FORMAT (///33H     INSUFFICIENT SUPPORTS.                  )07AG9
               NT = 3                                             07AG9
      GO TO 998                                                   07AG9
  904 PRINT 9004                                                  07AG9
 9004 FORMAT (///50H     ILLEGAL STATION COORDINATE DATA.        )07AG9
               NT = 2                                             07AG9
      GO TO 998                                                   07AG9
  905 PRINT 9005                                                  07AG9
 9005 FORMAT (///30H     ILLEGAL STATION SEQUENCE. )              07AG9
               NT = 3                                             07AG9
      GO TO 998                                                   07AG9
  906 PRINT 9005                                                  07AG9
               NT = 4                                             07AG9
      GO TO 998                                                   07AG9
  907 PRINT 9005                                                  07AG9
               NT = 5                                             07AG9
      GO TO 998                                                   07AG9
  908 PRINT 9008                                                  07AG9
 9008 FORMAT (///42H     ZERO OR NEGATIVE STIFFNESS SPECIFIED. )  07AG9
               NT = 5                                             07AG9
      GO TO 998                                                   07AG9
C                                                                  7AG9
C     END PCGR 2                                                  07AG9
C                                                                  7AG9
      END                                                          7AG9
```

```
      0SUBROUTINE INTERP ( NB, NCT, INI, INL, CONT, VARYN, VARY,        07AG9
     1                     LSM, NI, NJ )                                07AG9
C                                                                        7AG9
C-----LINEAR INTERPOLATION SUBROUTINE                                   07AG9
C                                                                        7AG9
C          LSM = 1 - VARIABLES DEFINED MIDWAY BETWEEN STATIONS          07AG9
C          LSM = 0 - VARIABLES DEFINED AT STATIONS                      07AG9
C                                                                        7AG9
C      IMPLICIT REAL*8 ( A-H,O-Z )                                      07AG9IBM
       DATA  CONTD / 4HCONT /                                           07AG9
       DIMENSION          INI(NI), INL(NI), CONT(NI), VARYN(NI), VARY(NJ)07AG9
          DO 10 I = 1, NJ                                               07AG9
             VARY(I) = 0.0                                              07AG9
   10     CONTINUE                                                      07AG9
C                                                                        7AG9
             ASM = LSM                                                  07AG9
             ASM = 0.5 * ASM                                            07AG9
             KR2 = 0                                                    07AG9
          DO 140 NC = 1, NCT                                            07AG9
             KR1 = KR2                                                  07AG9
          IF ( CONT(NC) .EQ. CONTD ) GO TO 20                           07AG9
   15        KR2 = 0                                                    07AG9
          GO TO 30                                                      07AG9
   20        KR2 = 1                                                    07AG9
   30        KSW = 1 + KR2 + 2 * KR1                                    07AG9
          IF ( KR1 .EQ. 1 ) GO TO 40                                    07AG9
             NC1 = NC                                                   07AG9
             JV = INI(NC1) + LSM                                        07AG9
          IF ( KR2 .EQ. 1 ) GO TO 130                                   07AG9
   40     IF ( INL(NC) .LE. NB ) GO TO 80                               07AG9
             JS2 = NB                                                   07AG9
             DIFF = JS2 - JV + LSM                                      07AG9
             DENOM = INL(NC) - JV + LSM                                 07AG9
    0        VEND = VARYN(NC1) + ( VARYN(NC) - VARYN(NC1) )             07AG9
    1              * ( DIFF/DENOM )                                     07AG9
          GO TO ( 50, 60, 70, 70 ), KSW                                 07AG9
   50     IF ( INI(NC) .GT. NB ) GO TO 130                              07AG9
          GO TO 90                                                      07AG9
   60     IF ( INI(NC1) .GT. NB ) GO TO 130                             07AG9
          GO TO 90                                                      07AG9
   70     IF ( KSWP .EQ. 2 ) GO TO 60                                   07AG9
          IF ( INL(NC1) .GT. NB ) GO TO 130                             07AG9
          GO TO 90                                                      07AG9
   80        JS2 = INL(NC)                                              07AG9
             VEND = VARYN(NC)                                           07AG9
   90        J1 = JV + 2                                                07AG9
             J2 = JS2 + 2                                               07AG9
             DENOM = J2 - J1 + LSM                                      07AG9
             JINCR = 1                                                  07AG9
             ESM = 1.0                                                  07AG9
             ISW = 1                                                    07AG9
          IF ( DENOM .NE. 0.0  ) GO TO 100                              07AG9
             DENOM = 1.0                                                07AG9
             ISW = 0                                                    07AG9
  100     DO 110 J = J1, J2, JINCR                                      07AG9
             DIFF = J - J1                                              07AG9
```

```
            PART = ( DIFF + ASM ) / DENOM                                      07AG9
    0       VARY(J) = VARY(J) + ( VARYN(NC1) + PART                            07AG9
    1             * ( VEND - VARYN(NC1) ) ) * ESM                              07AG9
  110     CONTINUE                                                             07AG9
          IF ( LSM .EQ. 1 ) GO TO 120                                          07AG9
          IF ( ISW .EQ. 0 ) GO TO 120                                          07AG9
            JINCR = J2 - J1                                                    07AG9
            ESM = - 0.5                                                        07AG9
            ISW = 0                                                            07AG9
          GO TO 100                                                            07AG9
  120     IF ( KR2 .EQ. 0 ) GO TO 130                                          07AG9
            JV = INL(NC) + LSM                                                 07AG9
  130       NC1 = NC                                                           07AG9
            KSWP = KSW                                                         07AG9
  140     CONTINUE                                                             07AG9
C                                                                               7AG9
C                                                                               7AG9
      RETURN                                                                   07AG9
C                                                                               7AG9
C     END INTERP                                                               07AG9
      END                                                                       7AG9
```

```
      SUBROUTINE SOLVER ( NJ, NB, W, X, Z, SY, RX, RZ, GJ, EIZ,                07AG9
     1                    FY, XM, ZM, A, B )                                   07AG9
C                                                                               7AG9
C-----SOLVE SIMULTANEOUS EQUATIONS BY RECURSION-INVERSION PROCEDURE             07AG9
C                                                                               7AG9
C      IMPLICIT REAL*8 ( A-H,O-Z )                                             07AG9IBM
      DIMENSION A(NJ,3,1), AA(3,3), AM1(3,1), ATM(3,1), B(NJ,3,3),             07AG9
     1          BB(3,3), BM1(3,3), BTM(3,3), C(3,3), CC(3,3), DD(3,1),         07AG9
     2          EIZ(NJ), FY(NJ), GJ(NJ), RX(NJ), RZ(NJ), SY(NJ), X(NJ),        07AG9
     3          XM(NJ), Z(NJ), ZM(NJ), W(NJ,3), WP1(3,1)                       07AG9
C                                                                               7AG9
C-----INITIALIZE                                                               07AG9
C                                                                               7AG9
          DO 30 I = 1, NJ                                                      07AG9
          DO 10 J = 1, 3                                                       07AG9
            A(I,J,1) = 0.0                                                     07AG9
          DO 10 K = 1, 3                                                       07AG9
            B(I,J,K) = 0.0                                                     07AG9
   10     CONTINUE                                                             07AG9
   30     CONTINUE                                                             07AG9
C                                                                               7AG9
C-----FORWARD PASS - SOLVE FOR RECURSION COEFFICIENTS                          07AG9
C                                                                               7AG9
            MAX = NB + 2                                                       07AG9
          DO 80 J = 2, MAX                                                     07AG9
            JJ = J                                                             07AG9
C                                                                               7AG9
C-----FORM CONTINUITY MATRICES                                                 07AG9
C                                                                               7AG9
      CALL FSUB ( NJ, NB, AA, BB, CC, DD, JJ, X, Z, SY, RX, RZ, GJ,            07AG9
     1            EIZ, FY, XM, ZM )                                            07AG9
C                                                                               7AG9
C-----CALCULATE C MATRIX                                                       07AG9
C                                                                               7AG9
          DO 40 I = 1, 3                                                       07AG9
          DO 40 K = 1, 3                                                       07AG9
            BM1(I,K) = B(J-1,I,K)                                              07AG9
   40     CONTINUE                                                             07AG9
        CALL MFFV ( AA, BM1, C, 3, 3 )                                         07AG9
        CALL ASFF ( BB, C, C, 3, 3, 1 )                                        07AG9
        CALL INVR ( C, JJ )                                                    07AG9
        CALL NEG ( C )                                                         07AG9
C                                                                               7AG9
C-----CALCULATE B COEFFICIENT                                                  07AG9
C                                                                               7AG9
        CALL MFFV ( C, CC, BTM, 3, 3 )                                         07AG9
          DO 50 I = 1, 3                                                       07AG9
          DO 50 K = 1, 3                                                       07AG9
            B(J, I,K) = BTM(I,K)                                               07AG9
   50     CONTINUE                                                             07AG9
C                                                                               7AG9
C-----CALCULATE A COEFFICIENT                                                  07AG9
C                                                                               7AG9
          DO 60 I = 1, 3                                                       07AG9
            AM1(I,1) = A(J-1,I,1)                                              07AG9
   60     CONTINUE                                                             07AG9
```

```
      CALL MFFV ( AA, AM1, ATM, 3, 1 )                                 07AG9
              ISIGN = -1                                               07AG9
      CALL ASFF ( ATM, DD, ATM, 3, 1, ISIGN )                          07AG9
      CALL MFFV ( C, ATM, AM1, 3, 1 )                                  07AG9
          DO 70 I = 1, 3                                               07AG9
              A(J,I,1) = AM1(I,1)                                      07AG9
   70     CONTINUE                                                     07AG9
   80     CONTINUE                                                     07AG9
C                                                                       7AG9
C-----BACKSUBSTITUTION - SOLVE FOR DISPLACEMENTS                        07AG9
C                                                                       7AG9
          DO 90 I = 1, 3                                               07AG9
              WP1(I,1) = 0.0                                           07AG9
   90     CONTINUE                                                     07AG9
          DO 130 L = 2, MAX                                            07AG9
              J = MAX -L + 2                                           07AG9
          DO 100 I = 1, 3                                              07AG9
          DO 100 K = 1, 3                                              07AG9
              BTM(I,K) = B(J,I,K)                                      07AG9
  100     CONTINUE                                                     07AG9
      CALL MFFV ( BTM, WP1, ATM, 3, 1 )                                07AG9
C                                                                       7AG9
C-----CALCULATE DISPLACEMENTS                                          07AG9
C                                                                       7AG9
          DO 110 I = 1, 3                                              07AG9
              W(J,I) = A(J,I,1) + ATM(I,1)                             07AG9
  110     CONTINUE                                                     07AG9
          DO 120 I = 1, 3                                              07AG9
              WP1(I,1) = W(J,I)                                        07AG9
  120     CONTINUE                                                     07AG9
  130     CONTINUE                                                     07AG9
C                                                                       7AG9
      RETURN                                                           07AG9
C                                                                       7AG9
C     END SOLVER                                                       07AG9
      END                                                               7AG9
```

```
      0SUBROUTINE FSUB ( NJ, NB, AA, BB, CC, DD, JJ, X, Z, SY, RX,     07AG9
      1                  RZ, GJ, EIZ, FY, XM, ZM )                     07AG9
C-----FORM MATRICES FROM STIFFNESS TERMS                                07AG9
C                                                                       7AG9
C      IMPLICIT REAL*8 ( A-H,O-Z )                                     07AG9IBM
      0DIMENSION AA(3,3), BB(3,3), CC(3,3), DD(3,1),X(NJ), Z(NJ), SY(NJ),07AG9
      1          RX(NJ), RZ(NJ), GJ(NJ), EIZ(NJ), FY(NJ), XM(NJ),      07AG9
      2          ZM(NJ), S(3,3), RT(3,3)                               07AG9
C                                                                       7AG9
C-----TEST FOR BEGINNING OF STRUCTURE                                  07AG9
C                                                                       7AG9
          IF ( JJ .NE. 2 ) GO TO 20                                    07AG9
          DO 10 I = 1, 3                                               07AG9
          DO 10 J = 1, 3                                               07AG9
              AA(I,J) = 0.0                                            07AG9
              S(I,J) = 0.0                                             07AG9
              RT(I,J) = 0.0                                            07AG9
              BB(I,J) = 0.0                                            07AG9
   10     CONTINUE                                                     07AG9
          GO TO 60                                                     07AG9
C                                                                       7AG9
C-----FORM PARTIAL STIFFNESS MATRIX S(JJ,JJ-1,JJ-1) FROM S(JJ-1,JJ,JJ-1)07AG9
C                                                                       7AG9
   20         S(1,3) = -S(1,3)                                         07AG9
              S(3,1) = - S(3,1)                                        07AG9
C                                                                       7AG9
C-----FORM PRODUCT RT-TRANS * S * RT                                   07AG9
C                                                                       7AG9
      CALL RTSR ( RT, S, AA )                                          07AG9
C                                                                       7AG9
C-----FORM PARTIAL STIFFNESS MATRIX S(JJ,JJ,JJ) FROM S(JJ,JJ-1,JJ)     07AG9
C                                                                       7AG9
              S(1,1) = - S(1,1)                                        07AG9
              S(2,2) = - S(2,2)                                        07AG9
              S(3,1) = - S(3,1)                                        07AG9
              S(3,3) = 2.0 * S(3,3)                                    07AG9
C                                                                       7AG9
C-----FORM PRODUCT RT-TRANS * S * RT                                   07AG9
C                                                                       7AG9
      CALL RTSR ( RT, S, BB )                                          07AG9
C                                                                       7AG9
C-----TEST FOR END OF STRUCTURE                                        07AG9
C                                                                       7AG9
          IF ( JJ .LT. NB + 2 ) GO TO 60                               07AG9
          DO 40 I = 1, 3                                               07AG9
          DO 40 J = 1, 3                                               07AG9
              CC(I,J) = 0.0                                            07AG9
   40     CONTINUE                                                     07AG9
          GO TO 120                                                    07AG9
C                                                                       7AG9
C-----FORM ROTATION MATRIX FOR MEMBER JJ + 1                           07AG9
C                                                                       7AG9
   60         DX =  X(JJ+1) - X(JJ)                                    07AG9
              DZ =  Z(JJ+1) - Z(JJ)                                    07AG9
              XL2 = DX * DX + DZ * DZ                                  07AG9
C             XL = DSQRT ( XL2 )                                       07AG9IBM
```

```
          XL =  SQRT ( XL2 )                                                   06JA0CDC
          XL3 = XL * XL2                                                       07AG9
          CX = DX / XL                                                         07AG9
          CZ = DZ / XL                                                         07AG9
      DO 70 I = 1, 3                                                           07AG9
      DO 70 J = 1, 3                                                           07AG9
          RT(I,J) = 0.0                                                        07AG9
   70 CONTINUE                                                                 07AG9
          RT(1,1) =  1.0                                                       07AG9
          RT(3,2) = - CZ                                                       07AG9
          RT(2,2) =  CX                                                        07AG9
          RT(2,3) =   CZ                                                       07AG9
          RT(3,3) =   CX                                                       07AG9
C                                                                               7AG9
C-----FORM PARTIAL STIFFNESS MATRIX S(JJ,JJ,JJ+1)                              07AG9
C                                                                               7AG9
          S(1,1) = 12.0 * EIZ(JJ+1) / XL3                                      07AG9
          S(2,2) = GJ(JJ+1) / XL                                               07AG9
          S(3,3) = 4.0 * EIZ(JJ+1) / XL                                        07AG9
          S(1,3) = + 6.0 * EIZ(JJ+1) / XL2                                     07AG9
          S(3,1) = S(1,3)                                                      07AG9
C                                                                               7AG9
C-----FORM PRODUCT RT-TRANS * S * RT                                           07AG9
C                                                                               7AG9
      CALL RTSR ( RT, S, CC )                                                  07AG9
C                                                                               7AG9
C-----COMBINE BB AND CC                                                        07AG9
C                                                                               7AG9
      CALL ASFF ( BB, CC, BB, 3, 3, 1 )                                        07AG9
C                                                                               7AG9
C-----FORM PARTIAL STIFFNESS MATRIX S(JJ,JJ+1,JJ+1) FROM S(JJ,JJ,JJ+1)         07AG9
C                                                                               7AG9
          S(1,1) = - S(1,1)                                                    07AG9
          S(2,2) = - S(2,2)                                                    07AG9
          S(3,1) = - S(3,1)                                                    07AG9
          S(3,3) = 0.5 * S(3,3)                                                07AG9
C                                                                               7AG9
C-----FORM PRODUCT RT-TRANS * S * RT                                           07AG9
C                                                                               7AG9
      CALL RTSR ( RT, S, CC )                                                  07AG9
C                                                                               7AG9
C-----ADD SUPPORT SPRINGS TO BB MATRIX                                         07AG9
C                                                                               7AG9
  120     BB(1,1) = BB(1,1) + SY(JJ)                                           07AG9
          BB(2,2) = BB(2,2) + RX(JJ)                                           07AG9
          BB(3,3) = BB(3,3) + RZ(JJ)                                           07AG9
C                                                                               7AG9
C-----FORM DD MATRIX                                                           07AG9
C                                                                               7AG9
          DD(1,1) = FY(JJ)                                                     07AG9
          DD(2,1) = XM(JJ)                                                     07AG9
          DD(3,1) = ZM(JJ)                                                     07AG9
      RETURN                                                                   07AG9
C                                                                               7AG9
C     END FSUB                                                                 07AG9
      END                                                                      07AG9
```

```
      SUBROUTINE RTSR ( R , S, X )                                             07AG9
C                                                                               7AG9
C-----FORM PRODUCT ( RT*S*R = X )                                              07AG9
C                                                                               7AG9
C     IMPLICIT REAL*8 ( A-H,O-Z )                                              07AG9IBM
      DIMENSION R(3,3), S(3,3), X(3,3), T(3,3)                                 07AG9
C                                                                               7AG9
          DO 20 I = 1, 3                                                       07AG9
          DO 20 J = 1, 3                                                       07AG9
              TEMP = 0.0                                                       07AG9
          DO 10 K = 1, 3                                                       07AG9
              TEMP = TEMP + R(K,I) * S(K,J)                                    07AG9
   10     CONTINUE                                                             07AG9
              T(I,J) = TEMP                                                    07AG9
   20     CONTINUE                                                             07AG9
C                                                                               7AG9
      CALL MFFV ( T, R, X, 3, 3 )                                              07AG9
C                                                                               7AG9
          RETURN                                                               07AG9
C                                                                               7AG9
C         END RTSR                                                             07AG9
      END                                                                      07AG9
```

```
      SUBROUTINE MFFV ( X, Y, Z, M, N )                                        07AG9
C                                                                               7AG9
C---- MULTIPLY FULL MATRIX BY FULL MATRIX OR VECTOR                            07AG9
C     ( X * Y = Z )                                                            07AG9
C                                                                               7AG9
C     IMPLICIT REAL*8 ( A-H,O-Z )                                              07AG9IBM
      DIMENSION X(M,M), Y(M,N) , Z(M,N)                                        07AG9
C                                                                               7AG9
          DO 20 J = 1, N                                                       07AG9
          DO 20 I = 1, M                                                       07AG9
              TEMP = 0.0                                                       07AG9
          DO 10 K = 1, M                                                       07AG9
              TEMP = TEMP + X(I,K) * Y(K,J)                                    07AG9
   10     CONTINUE                                                             07AG9
              Z(I,J) = TEMP                                                    07AG9
   20 CONTINUE                                                                 07AG9
C                                                                               7AG9
      RETURN                                                                   07AG9
C                                                                               7AG9
C     END MFFV                                                                 07AG9
      END                                                                      07AG9
```

```
      SUBROUTINE ASFF ( X, Y, Z, M, N, ISIGN )                          07AG9
C                                                                        7AG9
C-----ADD OR SUBTRACT FULL MATRICES                                     07AG9
C     ( X + Y = Z ) OR ( X - Y = Z )                                    07AG9
C                                                                        7AG9
C     IMPLICIT REAL*8 ( A-H,O-Z )                                       07AG9IBM
      DIMENSION X(M,N), Y(M,N), Z(M,N)                                  07AG9
C                                                                        7AG9
            IF ( ISIGN ) 30, 10, 10                                     07AG9
   10       DO 20 I = 1, M                                              07AG9
            DO 20 J = 1, N                                              07AG9
                 Z(I,J) = X(I,J) + Y(I,J)                               07AG9
   20       CONTINUE                                                    07AG9
            GO TO 50                                                    07AG9
C                                                                        7AG9
   30       DO 40 I = 1, M                                              07AG9
            DO 40 J = 1, N                                              07AG9
                 Z(I,J) = X(I,J) - Y(I,J)                               07AG9
   40       CONTINUE                                                    07AG9
C                                                                        7AG9
   50 RETURN                                                             7AG9
C                                                                        7AG9
C     END ASFF                                                          07AG9
      END                                                               07AG9
```

```
      SUBROUTINE INVR ( X, ISTA )                                       07AG9
C                                                                        7AG9
C-----INVERT MATRIX                                                     07AG9
C                                                                        7AG9
C     IMPLICIT REAL*8 ( A-H,O-Z )                                       07AG9IBM
      DIMENSION X(3,3)                                                  07AG9
C                                                                        7AG9
 1000 FORMAT (    31H1    NO INVERSE EXISTS, ISTA = , I3 )              07AG9
C1001 FORMAT ( 3( 4X, 1PD10.3 ) )                                       07AG9IBM
 1001 FORMAT ( 3( 4X,   E10.3 ) )                                       07AG9CDC
                 EP = 1.0E-10                                           07AG9
C                                                                        7AG9
            DO 40 I = 1, 3                                              07AG9
C           IF ( DABS ( X(I,I) ) .LT. EP ) GO TO 50                     07AG9IBM
            IF (  ABS ( X(I,I) ) .LT. EP ) GO TO 50                     06JA0CDC
                 S = 1.0 / X(I,I)                                       07AG9
            DO 10 J = 1, 3                                              07AG9
                 X(I,J) = X(I,J) * S                                    07AG9
   10       CONTINUE                                                    07AG9
                 X(I,I) = S                                             07AG9
            DO 30 J = 1, 3                                              07AG9
            IF ( J .EQ. I ) GO TO 30                                    07AG9
                 S = X(J,I)                                             07AG9
                 X(J,I) = 0.0                                           07AG9
            DO 20 K = 1, 3                                              07AG9
                 X(J,K) = X(J,K) - S * X(I,K)                           07AG9
   20       CONTINUE                                                    07AG9
   30       CONTINUE                                                    07AG9
   40       CONTINUE                                                    07AG9
      RETURN                                                            07AG9
C                                                                        7AG9
   50            ISTA = ISTA - 2                                        07AG9
      PRINT 1000, ISTA                                                  07AG9
      PRINT 1001, (( X(I,J), J = 1, 3 ), I = 1, 3 )                     07AG9
C                                                                        7AG9
C     END INVR                                                          07AG9
      END                                                                7AG9
```

```
      SUBROUTINE NEG ( X )                                          07AG9
C                                                                    7AG9
C-----NEGATE A FULL MATRIX OR A VECTOR                              07AG9
C      ( X = - X )                                                  07AG9
C                                                                    7AG9
C     IMPLICIT REAL*8 ( A-H,O-Z )                                   07AG9IBM
      DIMENSION X(3,3)                                              07AG9
C                                                                    7AG9
         DO 10 J = 1, 3                                             07AG9
         DO 10 I = 1, 3                                             07AG9
            X(I,J) = - X(I,J)                                       07AG9
   10    CONTINUE                                                   07AG9
C                                                                    7AG9
      RETURN                                                        07AG9
C                                                                    7AG9
C     END NEG                                                       07AG9
      END                                                           07AG9


      SUBROUTINE FORCES ( NJ, I, W, X, Z, GJ, EIZ, FORCE,           06JA0
     1                    SIGN, CID, XC, ZC )                       06JA0
C                                                                    7AG9
C-----CALCULATE ELEMENT END FORCES RELATED TO MEMBER AXES           07AG9
C                                                                    7AG9
C     IMPLICIT REAL*8 ( A-H,O-Z )                                   07AG9IBM
      DIMENSION EIZ(NJ), FORCE(6,1), GJ(NJ), S(6,6), RT(6,6), W(NJ,3), 07AG9
     1          WTS(6,1), WTM(6,1), X(NJ), Z(NJ)                    07AG9
      DATA CURVE / 4HCURV /                                         07AG9
C                                                                    7AG9
C-----SET UP MEMBER STIFFNESS MATRIX AND ROTATION MATRIX            07AG9
C                                                                    7AG9
            DX = X(I) - X(I-1)                                      07AG9
            DZ = Z(I) - Z(I-1)                                      07AG9
C           XL = DSQRT ( DX * DX + DZ * DZ )                        07AG9IBM
            XL2 = DX * DX + DZ * DZ                                 07AG9CDC
            XL =  SQRT ( XL2 )                                      07AG9CDC
            XL3 = XL * XL2                                          07AG9
            CX = DX / XL                                            07AG9
            CZ = DZ / XL                                            07AG9
         DO 10 J = 1, 6                                             07AG9
         DO 10 K = 1, 6                                             07AG9
            RT(J,K) = 0.0                                           07AG9
   10    CONTINUE                                                   07AG9
            RT(1,1) =  1.0                                          07AG9
            RT(3,2) = - CZ                                          07AG9
            RT(2,2) =  CX                                           07AG9
            RT(2,3) =   CZ                                          07AG9
            RT(3,3) =   CX                                          07AG9
         DO 40 J = 4, 6                                             07AG9
         DO 40 K = 4, 6                                             07AG9
            RT(J,K) = RT(J-3, K-3)                                  07AG9
   40    CONTINUE                                                   07AG9
C                                                                    7AG9
C-----FORM STIFFNESS MATRIX                                         07AG9
C                                                                    7AG9
         DO 50 J = 1, 6                                             07AG9
         DO 50 K = 1, 6                                             07AG9
            S(J,K) = 0.0                                            07AG9
   50    CONTINUE                                                   07AG9
            S(1,1) =    12.0 * EIZ(I) / XL3                         07AG9
            S(2,2) =    GJ(I) / XL                                  07AG9
            S(3,3) =    4.0 * EIZ(I) / XL                           07AG9
         DO 60 J = 1, 2                                             07AG9
            S(J,J+3) = - S(J,J)                                     07AG9
            S(J+3,J) = - S(J,J)                                     07AG9
            S(J+3,J+3) = S(J,J)                                     07AG9
   60    CONTINUE                                                   07AG9
            S(6,6) = S(3,3)                                         07AG9
            S(1,3) = 6.0 * EIZ(I) / XL2                             07AG9
            S(1,6) = S(1,3)                                         07AG9
            S(3,1) = S(1,3)                                         07AG9
            S(3,4) = - S(1,3)                                       07AG9
            S(4,3) = - S(1,3)                                       07AG9
            S(4,6) = - S(1,3)                                       07AG9
            S(6,1) = S(1,3)                                         07AG9
            S(6,4) = - S(1,3)                                       07AG9
            S(3,6) = 0.5 * S(3,3)                                   07AG9
            S(6,3) = S(3,6)                                         07AG9
C                                                                    7AG9
C-----DEFINE DEFLECTION MATRIX                                      07AG9
C                                                                    7AG9
         DO 70 J = 1, 3                                             07AG9
            WTS(J,1) = W(I-1,J)                                     07AG9
            WTS(J+3,1) = W(I,J)                                     07AG9
   70    CONTINUE                                                   07AG9
C                                                                    7AG9
C-----CONVERT DISPLACEMENTS TO MEMBER COORDINATE SYSTEM             07AG9
C                                                                    7AG9
      CALL MFFV ( RT, WTS, WTM, 6 , 1 )                             07AG9
C                                                                    7AG9
C-----CALCULATE FORCES                                              07AG9
C                                                                    7AG9
      CALL MFFV ( S, WTM, FORCE, 6 , 1 )                            07AG9
C                                                                    7AG9
         IF ( CID .NE. CURVE ) GO TO 80                             07AG9
C                                                                    7AG9
C-----TRANSFORM ELEMENT END FORCES TO NORMAL AND TANGENTIAL DIRECTIONS 07AG9
C                                                                    7AG9
C           RADIUS = DSQRT (( XC - X(I) )**2 + ( ZC - Z(I) )**2 )   07AG9IBM
            FLE = ( XC - X(I) )**2 + ( ZC - Z(I) )**2               03OC9CDC
            RADIUS = SQRT ( FLE )                                   03OC9CDC
            SINE = 0.5 * XL / RADIUS                                07AG9
C           COSINE = DSQRT ( 1.0 - SINE * SINE )                    07AG9IBM
            FLE = 1.0 - SINE * SINE                                 03OC9CDC
            COSINE = SQRT ( FLE )                                   03OC9CDC
            TF = FORCE(2,1)                                         07AG9
            FORCE(2,1) = TF * COSINE - SIGN * FORCE(3,1) * SINE     06JA0
            FORCE(3,1) = FORCE(3,1) * COSINE + SIGN * TF * SINE     06JA0
            TF = FORCE(5,1)                                         07AG9
            FORCE(5,1) = TF * COSINE + SIGN * FORCE(6,1) * SINE     06JA0
            FORCE(6,1) = FORCE(6,1) * COSINE - SIGN * TF * SINE     06JA0
   80    CONTINUE                                                   07AG9
C                                                                    7AG9
      RETURN                                                        07AG9
C                                                                    7AG9
C     END FORCES                                                    07AG9
      END                                                            7AG9
```

APPENDIX 5

SAMPLE DATA

```
PCGR 2 - EXAMPLE PROBLEMS FOR REPORT
    CODED 7/69 - WPD
CG11      RECTANGULAR BRACKET
                                        3    2    1    1
      0        0.000E00  9.600E01
     20        1.200E02  9.600E01
     36        1.200E02  0.000E00
      0    0       1.000E20  1.000E20  1.000E20
     36   36       1.000E20  1.000E20  1.000E20
      0   36       1.000E09  1.000E09
     16   16                -4.000E03
CG12      SEMICIRCULAR BOW GIRDER - 10 INCREMENTS
                                        3    2    1    1
      0       -1.200E02  0.000E00                      CURVE  0.000E00   0.000E00
      5        0.000E00 -1.200E02                      CURVE  0.000E00   0.000E00
     10        1.200E02  0.000E00
      0    0       1.000E20  1.000E20  1.000E20
     10   10       1.000E20  1.000E20  1.000E20
      0   10       3.022E09  3.777E09
      0   10                -3.770E02
CG13      SEMICIRCULAR BOW GIRDER - 20 INCREMENTS
                                        3    2    1    1
      0       -1.200E02  0.000E00                      CURVE  0.000E00   0.000E00
     10        0.000E00 -1.200E02                      CURVE  0.000E00   0.000E00
     20        1.200E02  0.000E00
      0    0       1.000E20  1.000E20  1.000E20
     20   20       1.000E20  1.000E20  1.000E20
      0   20       3.022E09  3.777E09
      0   20                -1.885E02
CG21      SOLUTION OF BEAM - EXAMPLE PROB 4 - CFHR REPORT 56-1
                                        2    4    1    3
      0        0.000E00  0.000E00
     40        4.800E02  0.000E00
     10   10       1.000E00  2.670E05
     20   20                 2.670E05
     30      CONTD           0.000E00
          40                 1.250E04
      0   40       1.000E00  5.000E09
      0      CONTD           0.000E00
          30CONTD            4.950E03
          40                 4.950E03
CG31      MARYLAND REPORT - LOADING CASE 1
                                        2    2    1    1
      0       -1.600E02  2.174E01                      CURVE  0.000E00   6.000E02
     20        1.600E02  2.174E01
      0    0       1.000E20  1.000E20  1.000E20
     20   20       1.000E20  1.000E20  1.000E20
      0   20       2.829E06  1.086E09
     10   10                -1.000E03
CG32      MARYLAND REPORT - LOADING CASE 2
    KEEP KEEP KEEP                      0    0    0    1
      6    6                -1.000E03
CG41      TYPICAL CURVED HIGHWAY GIRDER
                                        7   21   10   10
      0        5.700E03  0.000E00                      CURVE  0.000E00   0.000E00
     32        5.648E03  7.657E02                      CURVE  0.000E00   0.000E00
     62        5.504E03  1.483E03                      CURVE  0.000E00   0.000E00
     82        5.360E03  1.940E03                      CURVE  0.000E00   0.000E00
    109        5.099E03  2.547E03                      CURVE  0.000E00   0.000E00
    118        4.994E03  2.748E03                      CURVE  0.000E00   0.000E00
    156        4.492E03  3.509E03
      0    0                 1.000E20
      3    3       7.000E05  3.000E05  8.000E08
     13   13       7.000E05  3.000E05  8.000E08
     23   23       7.000E05  3.000E05  8.000E08
     26   26                 1.000E20
     33   33       7.000E05  3.000E05  8.000E08
     43   43       7.000E05  3.000E05  8.000E08
     53   53       7.000E05  3.000E05  8.000E08
     63   63       7.000E05  3.000E05  8.000E08
     69   69                 1.000E20
     73   73       7.000E05  3.000E05  8.000E08
     83   83       7.000E05  3.000E05  8.000E08
     93   93       7.000E05  3.000E05  8.000E08
    103  103       7.000E05  3.000E05  8.000E08
    113  113       7.000E05  3.000E05  8.000E08
    123  123       7.000E05  3.000E05  8.000E08
    124  124                 1.000E20
    133  133       7.000E05  3.000E05  8.000E08
    143  143       7.000E05  3.000E05  8.000E08
    153  153       7.000E05  3.000E05  8.000E08
    156  156                 1.000E20
      0   32       7.824E07  2.339E11
     23   29       1.428E08  9.747E10
     32   62       1.420E08  2.922E11
     62   82       1.420E08  2.922E11
     62   76       6.235E08  2.054E11
     82  109       4.537E08  4.000E11
    109  118       1.420E08  2.922E11
    118  136       1.420E08  2.922E11
    118  130       3.862E08  1.519E11
    136  156       7.824E07  2.339E11
      0   32                -1.670E03
     23   29                -6.800E01
     32   62                -1.749E03
     62   82                -1.720E03
     62   76                -1.360E02
     82  109                -1.825E03
    109  118                -1.816E03
    118  136                -1.720E03
    118  130                -1.020E02
    136  156                -1.670E03
      TERMINATE
```

APPENDIX 6

OUTPUT

PROGRAM PCGR2 - DECK 1 - DAWKINS　　REVISION DATE 22 JULY 1970
PCGR 2 - EXAMPLE PROBLEMS FOR REPORT
CODED 7/69 - WPD

PROB
CG11　RECTANGULAR BRACKET

TABLE 1 - PROGRAM CONTROL DATA

	TABLE NUMBER 2	3	4	5
PRIOR-DATA OPTIONS				
NUM CARDS INPUT THIS PROBLEM	3	2	1	1

TABLE 2 - STATION COORDINATES

STA	GLOBAL COORDINATES X	Z	SEGMENT TYPE AND DATA
0	0.	9.600E+01	
			STRAIGHT
20	1.200E+02	9.600E+01	
			STRAIGHT
36	1.200E+02	0.	

TABLE 3 - ELASTIC RESTRAINTS

FROM	TO CONTD	RX	SY	RZ
0	0	1.000E+20	1.000E+20	1.000F+20
36	36	1.000E+20	1.000E+20	1.000F+20

TABLE 4 - ELEMENT STIFFNESSES

FROM	TO CONTD	GJ	EIZ
0	36	1.000E+09	1.000E+09

TABLE 5 - APPLIED LOADS AND MOMENTS

FROM	TO CONTD	XM	FY	ZM
16	16	-0.	-4.000E+03	-0.

PROGRAM PCGR2 - DECK 1 - DAWKINS　　REVISION DATE 22 JULY 1970
PCGR 2 - EXAMPLE PROBLEMS FOR REPORT
CODED 7/69 - WPD

PROB (CONTD)
CG11　RECTANGULAR BRACKET

TABLE 6 - RESULTS

STATION DISPLACEMENTS IN GLOBAL COORDINATE DIRECTIONS

STA	GLOBAL COORDINATES X	Z	DISPLACEMENTS X ROTATION	Y DEFLECTION	Z ROTATION
0	0.	9.600E+01	4.036E-16	-2.108E-17	-1.347E-15
1	6.000E+00	9.600E+01	2.422E-04	-2.349E-03	-7.703E-04
2	1.200E+01	9.600E+01	4.843E-04	-9.092E-03	-1.465E-03
3	1.800E+01	9.600E+01	7.265E-04	-1.977E-02	-2.083E-03
4	2.400E+01	9.600E+01	9.686E-04	-3.394E-02	-2.626E-03
5	3.000E+01	9.600E+01	1.211E-03	-5.113E-02	-3.093E-03
6	3.600E+01	9.600E+01	1.453E-03	-7.090E-02	-3.483E-03
7	4.200E+01	9.600E+01	1.695E-03	-9.278E-02	-3.798E-03
8	4.800E+01	9.600E+01	1.937E-03	-1.163E-01	-4.037E-03
9	5.400E+01	9.600E+01	2.179E-03	-1.411E-01	-4.200E-03
10	6.000E+01	9.600E+01	2.422E-03	-1.666E-01	-4.288E-03
11	6.600E+01	9.600E+01	2.664E-03	-1.924E-01	-4.299E-03
12	7.200E+01	9.600E+01	2.906E-03	-2.180E-01	-4.235E-03
13	7.800E+01	9.600E+01	3.148E-03	-2.430E-01	-4.094E-03
14	8.400E+01	9.600E+01	3.390E-03	-2.670E-01	-3.878E-03
15	9.000E+01	9.600E+01	3.632E-03	-2.894E-01	-3.586E-03
16	9.600E+01	9.600E+01	3.875E-03	-3.099E-01	-3.217E-03
17	1.020E+02	9.600E+01	4.117E-03	-3.280E-01	-2.845E-03
18	1.080E+02	9.600E+01	4.359E-03	-3.441E-01	-2.542E-03
19	1.140E+02	9.600E+01	4.601E-03	-3.587E-01	-2.306E-03
20	1.200E+02	9.600E+01	4.843E-03	-3.720E-01	-2.138E-03
21	1.200E+02	9.000E+01	5.051E-03	-3.422E-01	-2.004E-03
22	1.200E+02	8.400E+01	5.191E-03	-3.115E-01	-1.871E-03
23	1.200E+02	7.800E+01	5.263E-03	-2.801E-01	-1.737E-03
24	1.200E+02	7.200E+01	5.267E-03	-2.485E-01	-1.604E-03
25	1.200E+02	6.600E+01	5.203E-03	-2.170E-01	-1.470E-03
26	1.200E+02	6.000E+01	5.070E-03	-1.862E-01	-1.336E-03
27	1.200E+02	5.400E+01	4.870E-03	-1.563E-01	-1.203E-03
28	1.200E+02	4.800E+01	4.601E-03	-1.270E-01	-1.069E-03
29	1.200E+02	4.200E+01	4.264E-03	-1.012E-01	-9.354E-04
30	1.200E+02	3.600E+01	3.859E-03	-7.682E-02	-8.018E-04
31	1.200E+02	3.000E+01	3.386E-03	-5.505E-02	-6.681E-04
32	1.200E+02	2.400E+01	2.845E-03	-3.632E-02	-5.345E-04
33	1.200E+02	1.800E+01	2.236E-03	-2.104E-02	-4.009E-04
34	1.200E+02	1.200E+01	1.559E-03	-9.626E-03	-2.673E-04
35	1.200E+02	6.000E+00	8.135E-04	-2.475E-03	-1.336E-04
36	1.200E+02	0.	1.413E-15	-1.892E-17	-2.227E-16

PROB (CONTD)
CG11 RECTANGULAR BRACKET

TABLE - 6 (CONTD)

ELEMENT END FORCES IN NORMAL AND TANGENTIAL DIRECTIONS

ELEM NO. (I)	END(I-1) TWISTING MOMENT	SHEAR FORCE	BENDING MOMENT	END(I) TWISTING MOMENT	SHEAR FORCE	BENDING MOMENT
1	-4.036E+04	2.108E+03	1.347E+05	4.036E+04	-2.108E+03	-1.221E+05
2	-4.036E+04	2.108E+03	1.221E+05	4.036E+04	-2.108E+03	-1.094E+05
3	-4.036E+04	2.108E+03	1.094E+05	4.036E+04	-2.108E+03	-9.676E+04
4	-4.036E+04	2.108E+03	9.676E+04	4.036E+04	-2.108E+03	-8.411E+04
5	-4.036E+04	2.108E+03	8.411E+04	4.036E+04	-2.108E+03	-7.146E+04
6	-4.036E+04	2.108E+03	7.146E+04	4.036E+04	-2.108E+03	-5.881E+04
7	-4.036E+04	2.108E+03	5.881E+04	4.036E+04	-2.108E+03	-4.616E+04
8	-4.036E+04	2.108E+03	4.616E+04	4.036E+04	-2.108E+03	-3.352E+04
9	-4.036E+04	2.108E+03	3.352E+04	4.036E+04	-2.108E+03	-2.087E+04
10	-4.036E+04	2.108E+03	2.087E+04	4.036E+04	-2.108E+03	-8.217E+03
11	-4.036E+04	2.108E+03	8.217E+03	4.036E+04	-2.108E+03	4.432E+03
12	-4.036E+04	2.108E+03	-4.432E+03	4.036E+04	-2.108E+03	1.708E+04
13	-4.036E+04	2.108E+03	-1.708E+04	4.036E+04	-2.108E+03	2.973E+04
14	-4.036E+04	2.108E+03	-2.973E+04	4.036E+04	-2.108E+03	4.238E+04
15	-4.036E+04	2.108E+03	-4.238E+04	4.036E+04	-2.108E+03	5.503E+04
16	-4.036E+04	2.108E+03	-5.503E+04	4.036E+04	-2.108E+03	6.768E+04
17	-4.036E+04	-1.892E+03	-6.768E+04	4.036E+04	1.892E+03	5.632E+04
18	-4.036E+04	-1.892E+03	-5.632E+04	4.036E+04	1.892E+03	4.497E+04
19	-4.036E+04	-1.892E+03	-4.497E+04	4.036E+04	1.892E+03	3.362E+04
20	-4.036E+04	-1.892E+03	-3.362E+04	4.036E+04	1.892E+03	2.227E+04
21	2.227E+04	-1.892E+03	-4.036E+04	-2.227E+04	1.892E+03	2.901E+04
22	2.227E+04	-1.892E+03	-2.901E+04	-2.227E+04	1.892E+03	1.766E+04
23	2.227E+04	-1.892E+03	-1.766E+04	-2.227E+04	1.892E+03	6.306E+03
24	2.227E+04	-1.892E+03	-6.306E+03	-2.227E+04	1.892E+03	-5.045E+03
25	2.227E+04	-1.892E+03	5.045E+03	-2.227E+04	1.892E+03	-1.640E+04
26	2.227E+04	-1.892E+03	1.640E+04	-2.227E+04	1.892E+03	-2.775E+04
27	2.227E+04	-1.892E+03	2.775E+04	-2.227E+04	1.892E+03	-3.910E+04
28	2.227E+04	-1.892E+03	3.910E+04	-2.227E+04	1.892E+03	-5.045E+04
29	2.227E+04	-1.892E+03	5.045E+04	-2.227E+04	1.892E+03	-6.180E+04
30	2.227E+04	-1.892E+03	6.180E+04	-2.227E+04	1.892E+03	-7.315E+04
31	2.227E+04	-1.892E+03	7.315E+04	-2.227E+04	1.892E+03	-8.450E+04
32	2.227E+04	-1.892E+03	8.450E+04	-2.227E+04	1.892E+03	-9.585E+04
33	2.227E+04	-1.892E+03	9.585E+04	-2.227E+04	1.892E+03	-1.072E+05
34	2.227E+04	-1.892E+03	1.072E+05	-2.227E+04	1.892E+03	-1.186E+05
35	2.227E+04	-1.892E+03	1.186E+05	-2.227E+04	1.892E+03	-1.299E+05
36	2.227E+04	-1.892E+03	1.299E+05	-2.227E+04	1.892E+03	-1.413E+05

TIME FOR THIS PROBLEM = 0 MINUTES .621 SECONDS

ELAPSED CPU TIME = 0 MINUTES 9.137 SECONDS

PROB
CG12 SEMICIRCULAR BOW GIRDER - 10 INCREMENTS

TABLE 1 - PROGRAM CONTROL DATA

	TABLE NUMBER 2	3	4	5
PRIOR-DATA OPTIONS				
NUM CARDS INPUT THIS PROBLEM	3	2	1	1

TABLE 2 - STATION COORDINATES

STA	GLOBAL COORDINATES X	Z	SEGMENT TYPE AND DATA	XC	ZC
0	-1.200E+02	0.			
			CURVE	0.	0.
5	0.	-1.200E+02			
			CURVE	0.	0.
10	1.200E+02	0.			

TABLE 3 - ELASTIC RESTRAINTS

FROM	TO CONTD	RX	SY	RZ
0	0	1.000E+20	1.000E+20	1.000E+20
10	10	1.000E+20	1.000E+20	1.000E+20

TABLE 4 - ELEMENT STIFFNESSES

FROM	TO CONTD	GJ	EIZ
0	10	3.022E+09	3.777E+09

TABLE 5 - APPLIED LOADS AND MOMENTS

FROM	TO CONTD	XM	FY	ZM
0	10	-0.	-3.770E+02	-0.

PROGRAM PCGR2 - DECK 1 - DAWKINS REVISION DATE 22 JULY 1970
PCGR 2 - EXAMPLE PROBLEMS FOR REPORT
CODED 7/69 - WPD

PROB (CONTD)
CG12 SEMICIRCULAR BOW GIRDER - 10 INCREMENTS

TABLE 6 - RESULTS

STATION DISPLACEMENTS IN GLOBAL COORDINATE DIRECTIONS

STA	GLOBAL COORDINATES X	Z	DISPLACEMENTS X ROTATION	Y DEFLECTION	Z ROTATION
0	-1.200E+02	0.	-1.428E-15	-1.885E-17	-4.385E-16
1	-1.141E+02	-3.708E+01	-1.099E-03	-2.364E-02	-4.378E-04
2	-9.708E+01	-7.053E+01	-1.681E-03	-8.093E-02	-6.493E-04
3	-7.053E+01	-9.708E+01	-1.942E-03	-1.468E-01	-6.079E-04
4	-3.708E+01	-1.141E+02	-2.036E-03	-1.976E-01	-3.607E-04
5	0.	-1.200E+02	-2.057E-03	-2.165E-01	-1.249E-16
6	3.708E+01	-1.141E+02	-2.036E-03	-1.976E-01	3.607E-04
7	7.053E+01	-9.708E+01	-1.942E-03	-1.468E-01	6.079E-04
8	9.708E+01	-7.053E+01	-1.681E-03	-8.093E-02	6.493E-04
9	1.141E+02	-3.708E+01	-1.099E-03	-2.364E-02	4.378E-04
10	1.200E+02	0.	-1.428E-15	-1.885E-17	4.385E-16

PROGRAM PCGR2 - DECK 1 - DAWKINS REVISION DATE 22 JULY 1970
PCGR 2 - EXAMPLE PROBLEMS FOR REPORT
CODED 7/69 - WPD

PROB (CONTD)
CG12 SEMICIRCULAR BOW GIRDER - 10 INCREMENTS

TABLE - 6 (CONTD)

ELEMENT END FORCES IN NORMAL AND TANGENTIAL DIRECTIONS

ELEM NO. (I)	END(I-1) TWISTING MOMENT	SHEAR FORCE	BENDING MOMENT	END(I) TWISTING MOMENT	SHEAR FORCE	BENDING MOMENT
1	-4.385E+04	1.096E+03	1.428E+05	7.532E+03	-1.696E+03	-8.647E+04
2	-7.532E+03	1.319E+03	8.647E+04	-1.181E+04	-1.319E+03	-3.563E+04
3	1.181E+04	9.425E+02	3.563E+04	-1.670E+04	-9.425E+02	4.710E+03
4	1.670E+04	5.655E+02	-4.710E+03	-1.111E+04	-5.655E+02	3.061E+04
5	1.111E+04	1.885E+02	-3.061E+04	-3.968E-09	-1.885E+02	3.954E+04
6	-6.577E-09	-1.885E+02	-3.954E+04	1.111E+04	1.885E+02	3.061E+04
7	-1.111E+04	-5.655E+02	-3.061E+04	1.670E+04	5.655E+02	4.710E+03
8	-1.670E+04	-9.425E+02	-4.710E+03	1.181E+04	9.425E+02	-3.563E+04
9	-1.181E+04	-1.319E+03	3.563E+04	-7.532E+03	1.319E+03	-8.647E+04
10	7.532E+03	-1.696E+03	8.647E+04	-4.385E+04	1.696E+03	-1.428E+05

TIME FOR THIS PROBLEM = 0 MINUTES .244 SECONDS

ELAPSED CPU TIME = 0 MINUTES 9.381 SECONDS

PROGRAM PCGR2 - DECK 1 - DAWKINS REVISION DATE 22 JULY 1970
PCGR 2 - EXAMPLE PROBLEMS FOR REPORT
CODED 7/69 - WPD

PROB
CG13 SEMICIRCULAR BOW GIRDER - 20 INCREMENTS

TABLE 1 - PROGRAM CONTROL DATA

	TABLE NUMBER 2	3	4	5
PRIOR-DATA OPTIONS				
NUM CARDS INPUT THIS PROBLEM	3	2	1	1

TABLE 2 - STATION COORDINATES

STA	GLOBAL COORDINATES X	Z	SEGMENT TYPE AND DATA	XC	ZC
0	-1.200E+02	0.			
			CURVE	0.	0.
10	0.	-1.200E+02			
			CURVE	0.	0.
20	1.200E+02	0.			

TABLE 3 - ELASTIC RESTRAINTS

FROM	TO	CONTD	RX	SY	RZ
0	0		1.000E+20	1.000E+20	1.000E+20
20	20		1.000E+20	1.000E+20	1.000E+20

TABLE 4 - ELEMENT STIFFNESSES

FROM	TO	CONTD	GJ	EIZ
0	20		3.022E+09	3.777E+09

TABLE 5 - APPLIED LOADS AND MOMENTS

FROM	TO	CONTD	XM	FY	ZM
0	20		-0.	-1.885E+02	-0.

PROGRAM PCGR2 - DECK 1 - DAWKINS REVISION DATE 22 JULY 1970
PCGR 2 - EXAMPLE PROBLEMS FOR REPORT
CODED 7/69 - WPD

PROB (CONTD)
CG13 SEMICIRCULAR BOW GIRDER - 20 INCREMENTS

TABLE A - RESULTS

STATION DISPLACEMENTS IN GLOBAL COORDINATE DIRECTIONS

STA	GLOBAL COORDINATES X	Z	DISPLACEMENTS X ROTATION	Y DEFLECTION	Z ROTATION
0	-1.200E+02	0.	-1.437E-15	-1.885E-17	-4.310E-16
1	-1.185E+02	-1.877E+01	-6.296E-04	-6.356E-03	-2.476E-04
2	-1.141E+02	-3.708E+01	-1.101E-03	-2.397E-02	-4.483E-04
3	-1.069E+02	-5.448E+01	-1.443E-03	-5.004E-02	-5.894E-04
4	-9.708E+01	-7.053E+01	-1.680E-03	-8.146E-02	-6.650E-04
5	-8.485E+01	-8.485E+01	-1.837E-03	-1.150E-01	-6.747E-04
6	-7.053E+01	-9.708E+01	-1.936E-03	-1.475E-01	-6.228E-04
7	-5.448E+01	-1.069E+02	-1.993E-03	-1.760E-01	-5.174E-04
8	-3.708E+01	-1.141E+02	-2.024E-03	-1.983E-01	-3.695E-04
9	-1.877E+01	-1.185E+02	-2.039E-03	-2.124E-01	-1.923E-04
10	0.	-1.200E+02	-2.043E-03	-2.173E-01	6.128E-15
11	1.877E+01	-1.185E+02	-2.039E-03	-2.124E-01	1.923E-04
12	3.708E+01	-1.141E+02	-2.024E-03	-1.983E-01	3.695E-04
13	5.448E+01	-1.069E+02	-1.993E-03	-1.760E-01	5.174E-04
14	7.053E+01	-9.708E+01	-1.936E-03	-1.476E-01	6.228E-04
15	8.485E+01	-8.485E+01	-1.837E-03	-1.150E-01	6.747E-04
16	9.708E+01	-7.053E+01	-1.680E-03	-8.146E-02	6.650E-04
17	1.069E+02	-5.448E+01	-1.443E-03	-5.004E-02	5.894E-04
18	1.141E+02	-3.708E+01	-1.101E-03	-2.397E-02	4.483E-04
19	1.185E+02	-1.877E+01	-6.296E-04	-6.356E-03	2.476E-04
20	1.200E+02	0.	-1.437E-15	-1.885E-17	4.310E-16

PROB (CONTD)
CG13   SEMICIRCULAR BOW GIRDER - 20 INCREMENTS

TABLE - 6 (CONTD)

ELEMENT END FORCES IN NORMAL AND TANGENTIAL DIRECTIONS

ELEM		END(I-1)			END(I)	
NO. (I)	TWISTING MOMENT	SHEAR FORCE	BENDING MOMENT	TWISTING MOMENT	SHEAR FORCE	BENDING MOMENT
1	-4.310E+04	1.791E+03	1.437E+05	2.273E+04	-1.791E+03	-1.151E+05
2	-2.273E+04	1.602E+03	1.151E+05	6.822E+03	-1.602E+03	-8.713E+04
3	-6.822E+03	1.414E+03	8.713E+04	-4.803E+03	-1.414E+03	-6.058E+04
4	4.803E+03	1.225E+03	6.058E+04	-1.241E+04	-1.225E+03	-3.608E+04
5	1.241E+04	1.037E+03	3.608E+04	-1.637E+04	-1.037E+03	-1.424E+04
6	1.637E+04	8.482E+02	1.424E+04	-1.714E+04	-8.482E+02	4.424E+03
7	1.714E+04	6.597E+02	-4.424E+03	-1.527E+04	-6.597E+02	1.944E+04
8	1.527E+04	4.712E+02	-1.944E+04	-1.134E+04	-4.712E+02	3.043E+04
9	1.134E+04	2.827E+02	-3.043E+04	-6.023E+03	-2.827E+02	3.714E+04
10	6.023E+03	9.425E+01	-3.714E+04	8.554E-08	-9.425E+01	3.939E+04
11	-1.164E-07	-9.425E+01	-3.939E+04	6.023E+03	9.425E+01	3.714E+04
12	-6.023E+03	-2.827E+02	-3.714E+04	1.134E+04	2.827E+02	3.043E+04
13	-1.134E+04	-4.712E+02	-3.043E+04	1.527E+04	4.712E+02	1.944E+04
14	-1.527E+04	-6.597E+02	-1.944E+04	1.714E+04	6.597E+02	4.424E+03
15	-1.714E+04	-8.482E+02	-4.424E+03	1.637E+04	8.482E+02	-1.424E+04
16	-1.637E+04	-1.037E+03	1.424E+04	1.241E+04	1.037E+03	-3.608E+04
17	-1.241E+04	-1.225E+03	3.608E+04	4.803E+03	1.225E+03	-6.058E+04
18	-4.803E+03	-1.414E+03	6.058E+04	-6.822E+03	1.414E+03	-8.713E+04
19	6.822E+03	-1.602E+03	8.713E+04	-2.273E+04	1.602E+03	-1.151E+05
20	2.273E+04	-1.791E+03	1.151E+05	-4.310E+04	1.791E+03	-1.437E+05

TIME FOR THIS PROBLEM =   0 MINUTES   .429 SECONDS

ELAPSED CPU TIME =   0 MINUTES   9.810 SECONDS

PROB
CG21   SOLUTION OF BEAM - EXAMPLE PROB 4 - CFHR REPORT 56-1

TABLE 1 - PROGRAM CONTROL DATA

	TABLE NUMBER 2	3	4	5
PRIOR-DATA OPTIONS				
NUM CARDS INPUT THIS PROBLEM	2	4	1	3

TABLE 2 - STATION COORDINATES

STA	GLOBAL COORDINATES X	Z	SEGMENT TYPE AND DATA
0	0.	0.	
			STRAIGHT
40	4.800E+02	0.	

TABLE 3 - ELASTIC RESTRAINTS

FROM	TO	CONTD	RX	SY	RZ
10	10		1.000E+00	2.670E+05	-0.
20	20		-0.	2.670E+05	-0.
30	-0	CONT	-0.	0.	-0.
-0	40		-0.	1.250E+04	-0.

TABLE 4 - ELEMENT STIFFNESSES

FROM	TO	CONTD	GJ	EIZ
0	40		1.000E+00	5.000E+09

TABLE 5 - APPLIED LOADS AND MOMENTS

FROM	TO	CONTD	XM	FY	ZM
0	-0	CONT	-0.	0.	-0.
-0	30	CONT	-0.	4.950E+03	-0.
-0	40		-0.	4.950E+03	-0.

PROGRAM PCGR2 - DECK 1 - DAWKINS REVISION DATE 22 JULY 1970
PCGR 2 - EXAMPLE PROBLEMS FOR REPORT
CODED 7/69 - WPD

PROB (CONTD)
CG21 SOLUTION OF BEAM - EXAMPLE PROB 4 - CFHR REPORT 56-1

TABLE 6 - RESULTS

STATION DISPLACEMENTS IN GLOBAL COORDINATE DIRECTIONS

STA	GLOBAL COORDINATES X	Z	X ROTATION	DISPLACEMENTS Y DEFLECTION	Z ROTATION
0	0.	0.	0.	5.775E-01	-4.810E-03
1	1.200E+01	0.	0.	5.198E-01	-4.810E-03
2	2.400E+01	0.	0.	4.621E-01	-4.808E-03
3	3.600E+01	0.	0.	4.045E-01	-4.796E-03
4	4.800E+01	0.	0.	3.471E-01	-4.763E-03
5	6.000E+01	0.	0.	2.903E-01	-4.692E-03
6	7.200E+01	0.	0.	2.347E-01	-4.561E-03
7	8.400E+01	0.	0.	1.812E-01	-4.345E-03
8	9.600E+01	0.	0.	1.309E-01	-4.012E-03
9	1.080E+02	0.	0.	8.549E-02	-3.527E-03
10	1.200E+02	0.	0.	4.701E-02	-2.850E-03
11	1.320E+02	0.	0.	1.731E-02	-2.116E-03
12	1.440E+02	0.	0.	-4.073E-03	-1.456E-03
13	1.560E+02	0.	0.	-1.771E-02	-8.156E-04
14	1.680E+02	0.	0.	-2.349E-02	-1.349E-04
15	1.800E+02	0.	0.	-2.057E-02	6.499E-04
16	1.920E+02	0.	0.	-7.197E-03	1.608E-03
17	2.040E+02	0.	0.	1.904E-02	2.813E-03
18	2.160E+02	0.	0.	6.161E-02	4.342E-03
19	2.280E+02	0.	0.	1.249E-01	6.281E-03
20	2.400E+02	0.	0.	2.143E-01	8.715E-03
21	2.520E+02	0.	0.	3.331E-01	1.091E-02
22	2.640E+02	0.	0.	4.724E-01	1.215E-02
23	2.760E+02	0.	0.	6.213E-01	1.253E-02
24	2.880E+02	0.	0.	7.701E-01	1.215E-02
25	3.000E+02	0.	0.	9.105E-01	1.114E-02
26	3.120E+02	0.	0.	1.035E+00	9.599E-03
27	3.240E+02	0.	0.	1.139E+00	7.655E-03
28	3.360E+02	0.	0.	1.218E+00	5.434E-03
29	3.480E+02	0.	0.	1.269E+00	3.065E-03
30	3.600E+02	0.	0.	1.291E+00	6.859E-04
31	3.720E+02	0.	0.	1.286E+00	-1.565E-03
32	3.840E+02	0.	0.	1.255E+00	-3.567E-03
33	3.960E+02	0.	0.	1.202E+00	-5.247E-03
34	4.080E+02	0.	0.	1.130E+00	-6.572E-03
35	4.200E+02	0.	0.	1.045E+00	-7.546E-03
36	4.320E+02	0.	0.	9.506E-01	-8.202E-03
37	4.440E+02	0.	0.	8.496E-01	-8.593E-03
38	4.560E+02	0.	0.	7.451E-01	-8.787E-03
39	4.680E+02	0.	0.	6.392E-01	-8.856E-03
40	4.800E+02	0.	0.	5.328E-01	-8.869E-03

PROGRAM PCGR2 - DECK 1 - DAWKINS REVISION DATE 22 JULY 1970
PCGR 2 - EXAMPLE PROBLEMS FOR REPORT
CODED 7/69 - WPD

PROB (CONTD)
CG21 SOLUTION OF BEAM - EXAMPLE PROB 4 - CFHR REPORT 56-1

TABLE - 6 (CONTD)

ELEMENT END FORCES IN NORMAL AND TANGENTIAL DIRECTIONS

ELEM NO. (I)	END(I-1) TWISTING MOMENT	SHEAR FORCE	BENDING MOMENT	END(I) TWISTING MOMENT	SHEAR FORCE	BENDING MOMENT
1	0.	-4.396E-07	-3.159E-06	0.	4.396E-07	-2.980E-06
2	0.	1.650E+02	-1.356E-06	0.	-1.650E+02	1.980E+03
3	0.	4.950E+02	-1.980E+03	0.	-4.950E+02	7.920E+03
4	0.	9.900E+02	-7.920E+03	0.	-9.900E+02	1.980E+04
5	0.	1.650E+03	-1.980E+04	0.	-1.650E+03	3.960E+04
6	0.	2.475E+03	-3.960E+04	0.	-2.475E+03	6.930E+04
7	0.	3.465E+03	-6.930E+04	0.	-3.465E+03	1.109E+05
8	0.	4.620E+03	-1.109E+05	0.	-4.620E+03	1.663E+05
9	0.	5.940E+03	-1.663E+05	0.	-5.940E+03	2.376E+05
10	0.	7.425E+03	-2.376E+05	0.	-7.425E+03	3.267E+05
11	0.	-3.477E+03	-3.267E+05	0.	3.477E+03	2.850E+05
12	0.	-1.662E+03	-2.850E+05	0.	1.662E+03	2.650E+05
13	0.	3.177E+02	-2.650E+05	0.	-3.177E+02	2.688E+05
14	0.	2.463E+03	-2.688E+05	0.	-2.463E+03	2.984E+05
15	0.	4.773E+03	-2.984E+05	0.	-4.773E+03	3.557E+05
16	0.	7.248E+03	-3.557E+05	0.	-7.248E+03	4.426E+05
17	0.	9.888E+03	-4.426E+05	0.	-9.888E+03	5.613E+05
18	0.	1.269E+04	-5.613E+05	0.	-1.269E+04	7.136E+05
19	0.	1.566E+04	-7.136E+05	0.	-1.566E+04	9.015E+05
20	0.	1.880E+04	-9.015E+05	0.	-1.880E+04	1.127E+06
21	0.	-3.513E+04	-1.127E+06	0.	3.513E+04	7.056E+05
22	0.	-3.166E+04	-7.056E+05	0.	3.166E+04	3.256E+05
23	0.	-2.803E+04	-3.256E+05	0.	2.803E+04	-1.074E+04
24	0.	-2.424E+04	1.074E+04	0.	2.424E+04	-3.016E+05
25	0.	-2.028E+04	3.016E+05	0.	2.028E+04	-5.449E+05
26	0.	-1.615E+04	5.449E+05	0.	1.615E+04	-7.387E+05
27	0.	-1.186E+04	7.387E+05	0.	1.186E+04	-8.811E+05
28	0.	-7.407E+03	8.811E+05	0.	7.407E+03	-9.700E+05
29	0.	-2.787E+03	9.700E+05	0.	2.787E+03	-1.003E+06
30	0.	1.998E+03	1.003E+06	0.	-1.998E+03	-9.795E+05
31	0.	6.948E+03	9.795E+05	0.	-6.948E+03	-8.961E+05
32	0.	1.029E+04	8.961E+05	0.	-1.029E+04	-7.726E+05
33	0.	1.210E+04	7.726E+05	0.	-1.210E+04	-6.274E+05
34	0.	1.255E+04	6.274E+05	0.	-1.255E+04	-4.768E+05
35	0.	1.184E+04	4.768E+05	0.	-1.184E+04	-3.347E+05
36	0.	1.026E+04	3.347E+05	0.	-1.026E+04	-2.116E+05
37	0.	8.081E+03	2.116E+05	0.	-8.081E+03	-1.146E+05
38	0.	5.597E+03	1.146E+05	0.	-5.597E+03	-4.741E+04
39	0.	3.096E+03	4.741E+04	0.	-3.096E+03	-1.026E+04
40	0.	8.551E+02	1.026E+04	0.	-8.551E+02	-1.669E-06

TIME FOR THIS PROBLEM = 0 MINUTES .766 SECONDS

ELAPSED CPU TIME = 0 MINUTES 10.576 SECONDS

```
PROGRAM PCGR2 - DECK 1 - DAWKINS                    REVISION DATE 22 JULY 1970
PCGR 2 - EXAMPLE PROBLEMS FOR REPORT
     CODED 7/69 - WPD
```

PROB
CG31 MARYLAND REPORT - LOADING CASE 1

TABLE 1 - PROGRAM CONTROL DATA

	TABLE NUMBER 2	3	4	5
PRIOR-DATA OPTIONS				
NUM CARDS INPUT THIS PROBLEM	2	2	1	1

TABLE 2 - STATION COORDINATES

STA	GLOBAL COORDINATES X	Z	SEGMENT TYPE AND DATA	XC	ZC
0	-1.600E+02	2.174E+01			
			CURVE	0.	6.000E+02
20	1.600E+02	2.174E+01			

TABLE 3 - ELASTIC RESTRAINTS

FROM	TO CONTD	RX	SY	RZ
0	0	1.000E+20	1.000E+20	1.000E+20
20	20	1.000E+20	1.000E+20	1.000E+20

TABLE 4 - ELEMENT STIFFNESSES

FROM	TO CONTD	GJ	EIZ
0	20	2.829E+06	1.086E+09

TABLE 5 - APPLIED LOADS AND MOMENTS

FROM	TO CONTD	XM	FY	ZM
10	10	-0.	-1.000E+03	-0.


```
PROGRAM PCGR2 - DECK 1 - DAWKINS                    REVISION DATE 22 JULY 1970
PCGR 2 - EXAMPLE PROBLEMS FOR REPORT
     CODED 7/69 - WPD
```


PROB (CONTD)
CG31 MARYLAND REPORT - LOADING CASE 1

TABLE 6 - RESULTS

STATION DISPLACEMENTS IN GLOBAL COORDINATE DIRECTIONS

STA	GLOBAL COORDINATES X	Z	DISPLACEMENTS X ROTATION	Y DEFLECTION	Z ROTATION
0	-1.600E+02	2.174E+01	-1.086E-16	-5.000E-18	-4.880E-16
1	-1.443E+02	1.763E+01	1.018E-02	-5.707E-03	-3.376E-03
2	-1.286E+02	1.395E+01	1.417E-02	-2.620E-02	-4.888E-03
3	-1.127E+02	1.069E+01	1.310E-02	-6.137E-02	-5.122E-03
4	-9.675E+01	7.865E+00	8.154E-03	-1.088E-01	-4.573E-03
5	-8.073E+01	5.469E+00	5.243E-04	-1.643E-01	-3.636E-03
6	-6.466E+01	3.507E+00	-8.563E-03	-2.225E-01	-2.607E-03
7	-4.853E+01	1.979E+00	-1.787E-02	-2.775E-01	-1.684E-03
8	-3.238E+01	8.870E-01	-2.613E-02	-3.230E-01	-9.630E-04
9	-1.619E+01	2.314E-01	-3.209E-02	-3.536E-01	-4.374E-04
10	2.547E-11	1.281E-02	-3.450E-02	-3.646E-01	-3.178E-14
11	1.619E+01	2.314E-01	-3.209E-02	-3.536E-01	4.374E-04
12	3.238E+01	8.870E-01	-2.613E-02	-3.230E-01	9.630E-04
13	4.853E+01	1.979E+00	-1.787E-02	-2.775E-01	1.684E-03
14	6.466E+01	3.507E+00	-8.563E-03	-2.225E-01	2.607E-03
15	8.073E+01	5.469E+00	5.243E-04	-1.643E-01	3.636E-03
16	9.675E+01	7.865E+00	8.154E-03	-1.088E-01	4.573E-03
17	1.127E+02	1.069E+01	1.310E-02	-6.137E-02	5.122E-03
18	1.286E+02	1.395E+01	1.417E-02	-2.620E-02	4.888E-03
19	1.443E+02	1.763E+01	1.018E-02	-5.707E-03	3.376E-03
20	1.600E+02	2.174E+01	-1.086E-16	-5.000E-18	4.880E-16

PROGRAM PCGR2 - DECK 1 - DAWKINS REVISION DATE 22 JULY 1970
PCGR 2 - EXAMPLE PROBLEMS FOR REPORT
CODED 7/69 - WPD

PROB (CONTD)
CG31 MARYLAND REPORT - LOADING CASE 1

TABLE - 6 (CONTD)

ELEMENT END FORCES IN NORMAL AND TANGENTIAL DIRECTIONS

ELEM	END(I-1)			END(I)		
NO. (I)	TWISTING MOMENT	SHEAR FORCE	BENDING MOMENT	TWISTING MOMENT	SHEAR FORCE	BENDING MOMENT
1	-2.543E+03	5.000E+02	4.993E+04	1.304E+03	-5.000E+02	-4.188E+04
2	-1.304E+03	5.000E+02	4.188E+04	2.824E+02	-5.000E+02	-3.381E+04
3	-2.824E+02	5.000E+02	3.381E+04	-5.209E+02	-5.000E+02	-2.570E+04
4	5.209E+02	5.000E+02	2.570E+04	-1.105E+03	-5.000E+02	-1.758E+04
5	1.105E+03	5.000E+02	1.758E+04	-1.470E+03	-5.000E+02	-9.450E+03
6	1.470E+03	5.000E+02	9.450E+03	-1.615E+03	-5.000E+02	-1.310E+03
7	1.615E+03	5.000E+02	1.310E+03	-1.541E+03	-5.000E+02	6.831E+03
8	1.541E+03	5.000E+02	-6.831E+03	-1.247E+03	-5.000E+02	1.497E+04
9	1.247E+03	5.000E+02	-1.497E+04	-7.328E+02	-5.000E+02	2.309E+04
10	7.328E+02	5.000E+02	-2.309E+04	-2.975E-08	-5.000E+02	3.120E+04
11	3.084E-08	-5.000E+02	-3.120E+04	7.328E+02	5.000E+02	2.309E+04
12	-7.328E+02	-5.000E+02	-2.309E+04	1.247E+03	5.000E+02	1.497E+04
13	-1.247E+03	-5.000E+02	-1.497E+04	1.541E+03	5.000E+02	6.831E+03
14	-1.541E+03	-5.000E+02	-6.831E+03	1.615E+03	5.000E+02	-1.310E+03
15	-1.615E+03	-5.000E+02	1.310E+03	1.470E+03	5.000E+02	-9.450E+03
16	-1.470E+03	-5.000E+02	9.450E+03	1.105E+03	5.000E+02	-1.758E+04
17	-1.105E+03	-5.000E+02	1.758E+04	5.209E+02	5.000E+02	-2.570E+04
18	-5.209E+02	-5.080E+02	2.570E+04	-2.824E+02	5.000E+02	-3.381E+04
19	2.824E+02	-5.000E+02	3.381E+04	-1.304E+03	5.000E+02	-4.188E+04
20	1.304E+03	-5.000E+02	4.188E+04	-2.543E+03	5.000E+02	-4.993E+04

TIME FOR THIS PROBLEM = 0 MINUTES .364 SECONDS

ELAPSED CPU TIME = 0 MINUTES 10.940 SECONDS

PROGRAM PCGR2 - DECK 1 - DAWKINS REVISION DATE 22 JULY 1970
PCGR 2 - EXAMPLE PROBLEMS FOR REPORT
CODED 7/69 - WPD

PROB
CG32 MARYLAND REPORT - LOADING CASE 2

TABLE 1 - PROGRAM CONTROL DATA

	TABLE NUMBER 2	3	4	5
PRIOR-DATA OPTIONS	KEEP	KEEP	KEEP	
NUM CARDS INPUT THIS PROBLEM	0	0	0	1

TABLE 2 - STATION COORDINATES

STA GLOBAL COORDINATES X Z SEGMENT TYPE AND DATA

USING DATA FROM THE PREVIOUS PROBLEM

TABLE 3 - ELASTIC RESTRAINTS

FROM TO CONTD RX SY RZ

USING DATA FROM THE PREVIOUS PROBLEM PLUS

NONE

TABLE 4 - ELEMENT STIFFNESSES

FROM TO CONTD GJ EIZ

USING DATA FROM THE PREVIOUS PROBLEM PLUS

NONE

TABLE 5 - APPLIED LOADS AND MOMENTS

FROM	TO	CONTD	XM	FY	ZM
6	6		-0.	-1.000E+03	-0.

PROGRAM PCGR2 - DECK 1 - DAWKINS REVISION DATE 22 JULY 1970
PCGR 2 - EXAMPLE PROBLEMS FOR REPORT
CODED 7/69 - WPD

PROB (CONTD)
CG32 MARYLAND REPORT - LOADING CASE 2

TABLE 6 - RESULTS

STATION DISPLACEMENTS IN GLOBAL COORDINATE DIRECTIONS

STA	GLOBAL COORDINATES X	Z	DISPLACEMENTS X ROTATION	Y DEFLECTION	Z ROTATION
0	-1.600E+02	2.174E+01	-1.380E-16	-8.204E-18	-5.864E-16
1	-1.443E+02	1.763E+01	8.245E-03	-6.738E-03	-2.988E-03
2	-1.286E+02	1.395E+01	9.548E-03	-2.863E-02	-3.910E-03
3	-1.127E+02	1.069E+01	5.818E-03	-6.309E-02	-3.555E-03
4	-9.675E+01	7.865E+00	-9.843E-04	-1.053E-01	-2.557E-03
5	-8.073E+01	5.469E+00	-8.859E-03	-1.489E-01	-1.385E-03
6	-6.466E+01	3.507E+00	-1.578E-02	-1.873E-01	-3.465E-04
7	-4.853E+01	1.979E+00	-1.970E-02	-2.147E-01	2.970E-04
8	-3.238E+01	8.870E-01	-2.106E-02	-2.295E-01	6.172E-04
9	-1.619E+01	2.314E-01	-2.030E-02	-2.318E-01	7.708E-04
10	2.547E-11	1.281E-02	-1.787E-02	-2.225E-01	8.786E-04
11	1.619E+01	2.314E-01	-1.420E-02	-2.035E-01	1.025E-03
12	3.238E+01	8.870E-01	-9.760E-03	-1.772E-01	1.259E-03
13	4.853E+01	1.979E+00	-4.997E-03	-1.460E-01	1.590E-03
14	6.466E+01	3.507E+00	-3.652E-04	-1.130E-01	1.995E-03
15	8.073E+01	5.469E+00	3.685E-03	-8.075E-02	2.411E-03
16	9.675E+01	7.865E+00	6.711E-03	-5.187E-02	2.741E-03
17	1.127E+02	1.069E+01	8.275E-03	-2.841E-02	2.851E-03
18	1.286E+02	1.395E+01	7.951E-03	-1.175E-02	2.572E-03
19	1.443E+02	1.763E+01	5.326E-03	-2.443E-03	1.701E-03
20	1.600E+02	2.174E+01	-4.434E-17	-1.796E-18	2.076E-16

PROGRAM PCGR2 - DECK 1 - DAWKINS REVISION DATE 22 JULY 1970
PCGR 2 - EXAMPLE PROBLEMS FOR REPORT
CODED 7/69 - WPD

PROB (CONTD)
CG32 MARYLAND REPORT - LOADING CASE 2

TABLE - 6 (CONTD)

ELEMENT END FORCES IN NORMAL AND TANGENTIAL DIRECTIONS

ELEM NO. (I)	END(I-1) TWISTING MOMENT	SHEAR FORCE	BENDING MOMENT	END(I) TWISTING MOMENT	SHEAR FORCE	BENDING MOMENT
1	-2.338E+03	8.204E+02	6.019E+04	8.920E+02	-8.204E+02	-4.695E+04
2	-8.920E+02	8.204E+02	4.695E+04	-1.962E+02	-8.204E+02	-3.367E+04
3	1.962E+02	8.204E+02	3.367E+04	-9.256E+02	-8.204E+02	-2.037E+04
4	9.256E+02	8.204E+02	2.037E+04	-1.296E+03	-8.204E+02	-7.048E+03
5	1.296E+03	8.204E+02	7.048E+03	-1.306E+03	-8.204E+02	6.276E+03
6	1.306E+03	8.204E+02	-6.276E+03	-9.569E+02	-8.204E+02	1.959E+04
7	9.569E+02	-1.796E+02	-1.959E+04	-4.669E+02	1.796E+02	1.671E+04
8	4.669E+02	-1.796E+02	-1.671E+04	-5.511E+01	1.796E+02	1.380E+04
9	5.511E+01	-1.796E+02	-1.380E+04	2.782E+02	1.796E+02	1.089E+04
10	-2.782E+02	-1.796E+02	-1.089E+04	5.329E+02	1.796E+02	7.974E+03
11	-5.329E+02	-1.796E+02	-7.974E+03	7.087E+02	1.796E+02	5.049E+03
12	-7.087E+02	-1.796E+02	-5.049E+03	8.054E+02	1.796E+02	2.120E+03
13	-8.054E+02	-1.796E+02	-2.120E+03	8.231E+02	1.796E+02	-8.103E+02
14	-8.231E+02	-1.796E+02	8.103E+02	7.617E+02	1.796E+02	-3.740E+03
15	-7.617E+02	-1.796E+02	3.740E+03	6.212E+02	1.796E+02	-6.667E+03
16	-6.212E+02	-1.796E+02	6.667E+03	4.018E+02	1.796E+02	-9.589E+03
17	-4.018E+02	-1.796E+02	9.589E+03	1.036E+02	1.796E+02	-1.250E+04
18	-1.036E+02	-1.796E+02	1.250E+04	-2.732E+02	1.796E+02	-1.541E+04
19	2.732E+02	-1.796E+02	1.541E+04	-7.283E+02	1.796E+02	-1.831E+04
20	7.283E+02	-1.796E+02	1.831E+04	-1.261E+03	1.796E+02	-2.119E+04

TIME FOR THIS PROBLEM = 0 MINUTES .407 SECONDS

ELAPSED CPU TIME = 0 MINUTES 11.347 SECONDS

PROGRAM PCGR2 - DECK 1 - DAWKINS REVISION DATE 22 JULY 1970
PCGR 2 - EXAMPLE PROBLEMS FOR REPORT
CODED 7/69 - WPD

PROB
CG41 TYPICAL CURVED HIGHWAY GIRDER

TABLE 1 - PROGRAM CONTROL DATA

	TABLE NUMBER 2	3	4	5
PRIOR-DATA OPTIONS				
NUM CARDS INPUT THIS PROBLEM	7	21	10	10

TABLE 2 - STATION COORDINATES

STA	GLOBAL COORDINATES X	Z	SEGMENT TYPE AND DATA	XC	ZC
0	5.700E+03	0.			
			CURVE	0.	0.
32	5.648E+03	7.657E+02			
			CURVE	0.	0.
62	5.504E+03	1.483E+03			
			CURVE	0.	0.
82	5.360E+03	1.940E+03			
			CURVE	0.	0.
109	5.099E+03	2.547E+03			
			CURVE	0.	0.
118	4.994E+03	2.748E+03			
			CURVE	0.	0.
156	4.492E+03	3.509E+03			

TABLE 3 - ELASTIC RESTRAINTS

FROM	TO	CONTD	RX	SY	RZ
0	0		-0.	1.000E+20	-0.
3	3		7.000E+05	3.000E+05	8.000E+08
13	13		7.000E+05	3.000E+05	8.000E+08
23	23		7.000E+05	3.000E+05	8.000E+08
26	26		-0.	1.000E+20	-0.
33	33		7.000E+05	3.000E+05	8.000E+08
43	43		7.000E+05	3.000E+05	8.000E+08
53	53		7.000E+05	3.000E+05	8.000E+08
63	63		7.000E+05	3.000E+05	8.000E+08
69	69		-0.	1.000E+20	-0.
73	73		7.000E+05	3.000E+05	8.000E+08
83	83		7.000E+05	3.000E+05	8.000E+08
93	93		7.000E+05	3.000E+05	8.000E+08
103	103		7.000E+05	3.000E+05	8.000E+08
113	113		7.000E+05	3.000E+05	8.000E+08
123	123		7.000E+05	3.000E+05	8.000E+08
124	124		-0.	1.000E+20	-0.
133	133		7.000E+05	3.000E+05	8.000E+08
143	143		7.000E+05	3.000E+05	8.000E+08
153	153		7.000E+05	3.000E+05	8.000E+08
156	156		-0.	1.000E+20	-0.

TABLE 4 - ELEMENT STIFFNESSES

FROM	TO	CONTD	GJ	EIZ
0	32		7.824E+07	2.339E+11
23	29		1.428E+08	9.747E+10
32	62		1.420E+08	2.922E+11
62	82		1.420E+08	2.922E+11
62	76		6.235E+08	2.054E+11
82	109		4.537E+08	4.000E+11
109	118		1.420E+08	2.922E+11
118	136		1.420E+08	2.922E+11
118	130		3.862E+08	1.519E+11
136	156		7.824E+07	2.339E+11

TABLE 5 - APPLIED LOADS AND MOMENTS

FROM	TO	CONTD	XM	FY	ZM
0	32		-0.	-1.670E+03	-0.
23	29		-0.	-6.800E+01	-0.
32	62		-0.	-1.749E+03	-0.
62	82		-0.	-1.720E+03	-0.
62	76		-0.	-1.360E+02	-0.
82	109		-0.	-1.825E+03	-0.
109	118		-0.	-1.816E+03	-0.
118	136		-0.	-1.720E+03	-0.
118	130		-0.	-1.020E+02	-0.
136	156		-0.	-1.670E+03	-0.

PROGRAM PCGR2 - DECK 1 - DAWKINS REVISION DATE 22 JULY 1970
PCGR 2 - EXAMPLE PROBLEMS FOR REPORT
CODED 7/69 - WPD

PROB (CONTD)
C041 TYPICAL CURVED HIGHWAY GIRDER

TABLE 6 - RESULTS

STATION DISPLACEMENTS IN GLOBAL COORDINATE DIRECTIONS

STA	GLOBAL COORDINATES X	Z	DISPLACEMENTS X ROTATION	Y DEFLECTION	Z ROTATION
0	5.700E+03	0.	4.041E-04	-3.842E-17	-3.312E-04
1	5.700E+03	2.400E+01	4.004E-04	-9.652E-03	-3.312E-04
2	5.700E+03	4.801E+01	3.907E-04	-1.911E-02	-2.380E-04
3	5.700E+03	7.201E+01	3.780E-04	-2.830E-02	-1.026E-05
4	5.699E+03	9.601E+01	3.921E-04	-3.719E-02	-2.178E-03
5	5.699E+03	1.200E+02	3.953E-04	-4.525E-02	-4.021E-03
6	5.698E+03	1.440E+02	3.854E-04	-5.202E-02	-5.389E-03
7	5.698E+03	1.680E+02	3.599E-04	-5.717E-02	-6.185E-03
8	5.697E+03	1.920E+02	3.166E-04	-6.052E-02	-6.364E-03
9	5.696E+03	2.160E+02	2.547E-04	-6.209E-02	-5.930E-03
10	5.695E+03	2.400E+02	1.755E-04	-6.201E-02	-4.943E-03
11	5.694E+03	2.639E+02	8.318E-05	-6.060E-02	-3.511E-03
12	5.693E+03	2.879E+02	-1.403E-05	-5.831E-02	-1.796E-03
13	5.691E+03	3.119E+02	-1.032E-04	-5.573E-02	-9.545E-06
14	5.690E+03	3.358E+02	-5.359E-05	-5.336E-02	-7.514E-04
15	5.689E+03	3.598E+02	-1.526E-05	-5.092E-02	-1.486E-03
16	5.687E+03	3.838E+02	6.026E-06	-4.805E-02	-2.064E-03
17	5.685E+03	4.077E+02	6.252E-06	-4.449E-02	-2.386E-03
18	5.684E+03	4.316E+02	-1.604E-05	-4.014E-02	-2.408E-03
19	5.682E+03	4.556E+02	-5.888E-05	-3.499E-02	-2.133E-03
20	5.680E+03	4.795E+02	-1.159E-04	-2.919E-02	-1.619E-03
21	5.678E+03	5.034E+02	-1.758E-04	-2.299E-02	-9.737E-04
22	5.676E+03	5.273E+02	-2.208E-04	-1.678E-02	-3.576E-04
23	5.673E+03	5.512E+02	-2.267E-04	-1.100E-02	1.856E-05
24	5.671E+03	5.751E+02	-3.464E-04	-6.023E-03	1.574E-03
25	5.668E+03	5.990E+02	-4.327E-04	-2.191E-03	2.875E-03
26	5.666E+03	6.228E+02	-4.705E-04	-2.303E-16	3.829E-03
27	5.663E+03	6.467E+02	-4.608E-04	1.793E-04	4.319E-03
28	5.660E+03	6.705E+02	-4.305E-04	-1.408E-03	4.465E-03
29	5.658E+03	6.944E+02	-3.857E-04	-4.395E-03	4.364E-03
30	5.655E+03	7.182E+02	-2.619E-04	-8.573E-03	3.613E-03
31	5.652E+03	7.420E+02	-1.100E-04	-1.368E-02	2.577E-03
32	5.648E+03	7.657E+02	1.542E-04	-2.023E-02	8.546E-04
33	5.645E+03	7.899E+02	2.770E-04	-2.686E-02	4.136E-07
34	5.641E+03	8.140E+02	3.939E-04	-3.355E-02	-8.415E-04
35	5.638E+03	8.382E+02	4.896E-04	-3.992E-02	-1.599E-03
36	5.634E+03	8.623E+02	5.530E-04	-4.564E-02	-2.180E-03
37	5.630E+03	8.864E+02	5.765E-04	-5.046E-02	-2.522E-03
38	5.626E+03	9.105E+02	5.567E-04	-5.427E-02	-2.595E-03
39	5.623E+03	9.346E+02	4.949E-04	-5.707E-02	-2.398E-03
40	5.618E+03	9.587E+02	3.977E-04	-5.896E-02	-1.963E-03
41	5.614E+03	9.827E+02	2.772E-04	-6.016E-02	-1.353E-03
42	5.610E+03	1.007E+03	1.521E-04	-6.100E-02	-6.595E-04
43	5.606E+03	1.031E+03	4.760E-05	-6.191E-02	-6.677E-06
44	5.601E+03	1.055E+03	1.430E-04	-6.323E-02	-4.400E-04
45	5.597E+03	1.079E+03	2.364E-04	-6.468E-02	-9.306E-04
46	5.592E+03	1.103E+03	3.101E-04	-6.588E-02	-1.367E-03
47	5.587E+03	1.127E+03	3.512E-04	-6.656E-02	-1.668E-03
48	5.582E+03	1.150E+03	3.519E-04	-6.656E-02	-1.784E-03
49	5.577E+03	1.174E+03	3.102E-04	-6.580E-02	-1.697E-03
50	5.572E+03	1.198E+03	2.306E-04	-6.434E-02	-1.417E-03
51	5.567E+03	1.222E+03	1.243E-04	-6.232E-02	-9.888E-04
52	5.562E+03	1.246E+03	9.566E-06	-6.000E-02	-4.837E-04
53	5.556E+03	1.270E+03	-8.707E-05	-5.773E-02	-5.541E-06
54	5.551E+03	1.293E+03	1.819E-05	-5.570E-02	-4.128E-04
55	5.545E+03	1.317E+03	1.173E-04	-5.390E-02	-8.482E-04
56	5.540E+03	1.341E+03	1.883E-04	-5.171E-02	-1.204E-03
57	5.534E+03	1.365E+03	2.152E-04	-4.895E-02	-1.404E-03
58	5.528E+03	1.388E+03	1.890E-04	-4.548E-02	-1.400E-03
59	5.522E+03	1.412E+03	1.073E-04	-4.125E-02	-1.179E-03
60	5.516E+03	1.436E+03	-2.442E-05	-3.633E-02	-7.529E-04
61	5.510E+03	1.459E+03	-1.924E-04	-3.090E-02	-1.683E-04
62	5.504E+03	1.483E+03	-2.399E-04	-2.529E-02	1.481E-05
63	5.498E+03	1.506E+03	-2.345E-04	-1.990E-02	1.869E-05
64	5.491E+03	1.529E+03	-3.350E-04	-1.475E-02	4.322E-04
65	5.485E+03	1.552E+03	-4.207E-04	-1.003E-02	8.063E-04
66	5.478E+03	1.575E+03	-4.842E-04	-5.932E-03	1.125E-03
67	5.472E+03	1.598E+03	-5.164E-04	-2.700E-03	1.365E-03
68	5.465E+03	1.621E+03	-5.063E-04	-6.144E-04	1.500E-03
69	5.458E+03	1.644E+03	-4.407E-04	-2.822E-16	1.497E-03
70	5.451E+03	1.667E+03	-3.201E-04	-1.084E-03	1.312E-03
71	5.444E+03	1.690E+03	-1.687E-04	-3.614E-03	9.827E-04
72	5.437E+03	1.713E+03	5.827E-06	-7.231E-03	5.433E-04
73	5.430E+03	1.736E+03	1.975E-04	-1.163E-02	2.367E-05
74	5.422E+03	1.759E+03	2.272E-04	-1.652E-02	-1.680E-05
75	5.415E+03	1.781E+03	2.568E-04	-2.166E-02	-8.743E-05
76	5.407E+03	1.804E+03	2.810E-04	-2.683E-02	-1.652E-04
77	5.400E+03	1.827E+03	3.880E-04	-3.183E-02	-5.201E-04
78	5.392E+03	1.850E+03	4.477E-04	-3.641E-02	-7.499E-04
79	5.384E+03	1.872E+03	4.507E-04	-4.045E-02	-8.198E-04
80	5.376E+03	1.895E+03	3.964E-04	-4.392E-02	-7.226E-04
81	5.368E+03	1.917E+03	2.941E-04	-4.689E-02	-4.788E-04
82	5.360E+03	1.940E+03	1.600E-04	-4.953E-02	-1.274E-04
83	5.352E+03	1.963E+03	1.195E-04	-5.216E-02	-7.397E-06
84	5.343E+03	1.986E+03	1.925E-04	-5.480E-02	-1.984E-04
85	5.335E+03	2.009E+03	2.532E-04	-5.753E-02	-3.813E-04
86	5.326E+03	2.032E+03	2.930E-04	-5.986E-02	-5.262E-04
87	5.317E+03	2.055E+03	3.069E-04	-6.172E-02	-6.130E-04
88	5.308E+03	2.077E+03	2.930E-04	-6.305E-02	-6.312E-04
89	5.299E+03	2.100E+03	2.534E-04	-6.383E-02	-5.802E-04
90	5.290E+03	2.123E+03	1.939E-04	-6.415E-02	-4.688E-04
91	5.281E+03	2.146E+03	1.242E-04	-6.415E-02	-3.154E-04
92	5.272E+03	2.168E+03	5.827E-05	-6.405E-02	-1.478E-04
93	5.262E+03	2.191E+03	1.443E-05	-6.414E-02	-3.403E-06
94	5.253E+03	2.214E+03	5.448E-05	-6.464E-02	-5.946E-05
95	5.243E+03	2.236E+03	9.801E-05	-6.537E-02	-1.513E-04
96	5.234E+03	2.259E+03	1.334E-04	-6.608E-02	-2.441E-04
97	5.224E+03	2.281E+03	1.526E-04	-6.659E-02	-3.128E-04
98	5.214E+03	2.304E+03	1.517E-04	-6.678E-02	-3.416E-04
99	5.204E+03	2.326E+03	1.303E-04	-6.662E-02	-3.247E-04
100	5.194E+03	2.348E+03	9.273E-05	-6.614E-02	-2.654E-04
101	5.184E+03	2.371E+03	4.722E-05	-6.545E-02	-1.765E-04
102	5.174E+03	2.393E+03	6.687E-06	-6.472E-02	-8.002E-05
103	5.163E+03	2.415E+03	-1.132E-05	-6.419E-02	-7.366E-06

104	5.153E+03	2.437E+03	1.248E-04	-6.405E-02	-2.655E-04
105	5.142E+03	2.459E+03	2.609E-04	-6.405E-02	-5.500E-04
106	5.132E+03	2.481E+03	3.814E-04	-6.388E-02	-8.216E-04
107	5.121E+03	2.503E+03	4.746E-04	-6.329E-02	-1.050E-03
108	5.110E+03	2.525E+03	5.331E-04	-6.213E-02	-1.216E-03
109	5.099E+03	2.547E+03	3.555E-04	-5.959E-02	-9.252E-04
110	5.088E+03	2.570E+03	3.442E-04	-5.675E-02	-9.686E-04
111	5.076E+03	2.592E+03	2.236E-04	-5.311E-02	-7.841E-04
112	5.065E+03	2.614E+03	2.638E-05	-4.889E-02	-4.318E-04
113	5.053E+03	2.637E+03	-1.972E-04	-4.443E-02	-3.396E-06
114	5.041E+03	2.659E+03	-1.989E-04	-4.003E-02	3.746E-06
115	5.030E+03	2.681E+03	-2.204E-04	-3.558E-02	3.178E-05
116	5.018E+03	2.704E+03	-2.826E-04	-3.095E-02	1.276E-04
117	5.006E+03	2.726E+03	-3.899E-04	-2.610E-02	3.062E-04
118	4.994E+03	2.748E+03	-4.030E-04	-2.093E-02	3.204E-04
119	4.982E+03	2.769E+03	-4.135E-04	-1.619E-02	3.432E-04
120	4.971E+03	2.790E+03	-4.094E-04	-1.163E-02	3.545E-04
121	4.959E+03	2.811E+03	-3.738E-04	-7.454E-03	3.294E-04
122	4.947E+03	2.832E+03	-2.854E-04	-3.911E-03	2.362E-04
123	4.935E+03	2.853E+03	-1.183E-04	-1.308E-03	3.608E-05
124	4.923E+03	2.873E+03	-4.125E-04	-2.799E-16	6.666E-04
125	4.911E+03	2.894E+03	-5.819E-04	-3.395E-04	1.079E-03
126	4.899E+03	2.915E+03	-6.680E-04	-2.118E-03	1.318E-03
127	4.886E+03	2.935E+03	-6.934E-04	-5.020E-03	1.427E-03
128	4.874E+03	2.956E+03	-6.767E-04	-8.771E-03	1.444E-03
129	4.861E+03	2.976E+03	-6.324E-04	-1.314E-02	1.401E-03
130	4.849E+03	2.997E+03	-5.715E-04	-1.796E-02	1.320E-03
131	4.836E+03	3.017E+03	-3.177E-04	-2.313E-02	9.273E-04
132	4.823E+03	3.038E+03	-3.321E-05	-2.857E-02	4.857E-04
133	4.810E+03	3.058E+03	2.837E-04	-3.422E-02	-4.588E-07
134	4.798E+03	3.078E+03	6.797E-04	-4.002E-02	-6.160E-04
135	4.785E+03	3.098E+03	1.047E-03	-4.563E-02	-1.204E-03
136	4.771E+03	3.118E+03	1.339E-03	-5.073E-02	-1.687E-03
137	4.758E+03	3.139E+03	1.687E-03	-5.504E-02	-2.271E-03
138	4.745E+03	3.159E+03	1.812E-03	-5.831E-02	-2.518E-03
139	4.732E+03	3.179E+03	1.712E-03	-6.050E-02	-2.423E-03
140	4.718E+03	3.198E+03	1.413E-03	-6.171E-02	-2.024E-03
141	4.705E+03	3.218E+03	9.695E-04	-6.218E-02	-1.401E-03
142	4.691E+03	3.238E+03	4.688E-04	-6.227E-02	-6.743E-04
143	4.677E+03	3.258E+03	2.775E-05	-6.245E-02	-8.921E-06
144	4.664E+03	3.278E+03	8.071E-04	-6.311E-02	-1.096E-03
145	4.650E+03	3.297E+03	1.606E-03	-6.374E-02	-2.236E-03
146	4.636E+03	3.317E+03	2.299E-03	-6.379E-02	-3.243E-03
147	4.622E+03	3.336E+03	2.785E-03	-6.280E-02	-3.976E-03
148	4.608E+03	3.356E+03	2.996E-03	-6.044E-02	-4.334E-03
149	4.594E+03	3.375E+03	2.889E-03	-5.655E-02	-4.261E-03
150	4.579E+03	3.394E+03	2.455E-03	-5.111E-02	-3.745E-03
151	4.565E+03	3.414E+03	1.714E-03	-4.423E-02	-2.811E-03
152	4.551E+03	3.433E+03	7.156E-04	-3.622E-02	-1.531E-03
153	4.536E+03	3.452E+03	-4.549E-04	-2.750E-02	-1.193E-05
154	4.521E+03	3.471E+03	-3.129E-04	-1.854E-02	-2.132E-04
155	4.507E+03	3.490E+03	-2.466E-04	-9.352E-03	-3.132E-04
156	4.492E+03	3.509E+03	-2.494E-04	-3.705E-17	-3.154E-04

PROGRAM PCGR2 - DECK 1 - DAWKINS REVISION DATE 22 JULY 1970
PCGR 2 - EXAMPLE PROBLEMS FOR REPORT
CODED 7/69 - WPD

PROB (CONTD)
CG41 TYPICAL CURVED HIGHWAY GIRDER

TABLE - 6 (CONTD)

ELEMENT END FORCES IN NORMAL AND TANGENTIAL DIRECTIONS

ELEM		END(I-1)			END(I)	
NO. (I)	TWISTING MOMENT	SHEAR FORCE	BENDING MOMENT	TWISTING MOMENT	SHEAR FORCE	BENDING MOMENT
1	-3.110E-10	3.007E+03	1.788E-07	1.519E+02	-3.007E+03	7.217E+04
2	-1.519E+02	1.337E+03	-7.217E+04	5.234E+02	-1.337E+03	1.042E+05
3	-5.234E+02	-3.334E+02	-1.042E+05	9.455E+02	3.334E+02	9.624E+04
4	7.268E+03	6.487E+03	-9.608E+04	-6.536E+03	-6.487E+03	2.518E+05
5	6.536E+03	4.817E+03	-2.518E+05	-5.232E+03	-4.817E+03	3.675E+05
6	5.232E+03	3.147E+03	-3.675E+05	-3.525E+03	-3.147E+03	4.431E+05
7	3.525E+03	1.477E+03	-4.431E+05	-1.585E+03	-1.477E+03	4.785E+05
8	1.585E+03	-1.926E+02	-4.785E+05	4.207E+02	1.926E+02	4.739E+05
9	-4.207E+02	-1.863E+03	-4.739E+05	2.322E+03	1.863E+03	4.292E+05
10	-2.322E+03	-3.533E+03	-4.292E+05	3.951E+03	3.533E+03	3.444E+05
11	-3.951E+03	-5.203E+03	-3.444E+05	5.138E+03	5.203E+03	2.195E+05
12	-5.138E+03	-6.873E+03	-2.195E+05	5.715E+03	6.873E+03	5.451E+04
13	-5.715E+03	-8.543E+03	-5.451E+04	5.513E+03	8.543E+03	-1.506E+05
14	2.108E+03	6.505E+03	1.501E+05	-2.411E+03	-6.505E+03	6.083E+03
15	2.411E+03	4.835E+03	-6.083E+03	-2.141E+03	-4.835E+03	1.222E+05
16	2.141E+03	3.165E+03	-1.222E+05	-1.466E+03	-3.165E+03	1.981E+05
17	1.466E+03	1.495E+03	-1.981E+05	-5.565E+02	-1.495E+03	2.340E+05
18	5.565E+02	-1.748E+02	-2.340E+05	4.202E+02	1.748E+02	2.298E+05
19	-4.202E+02	-1.845E+03	-2.298E+05	1.295E+03	1.845E+03	1.855E+05
20	-1.295E+03	-3.515E+03	-1.855E+05	1.898E+03	3.515E+03	1.012E+05
21	-1.898E+03	-5.185E+03	-1.012E+05	2.062E+03	5.185E+03	-2.329E+04
22	-2.062E+03	-6.855E+03	2.329E+04	1.618E+03	6.855E+03	-1.878E+05
23	-1.618E+03	-8.525E+03	1.878E+05	3.961E+02	8.525E+03	-3.925E+05
24	-1.519E+04	-6.928E+03	3.937E+05	1.318E+04	6.928E+03	-5.601E+05
25	-1.318E+04	-8.666E+03	5.601E+05	1.038E+04	8.666E+03	-7.681E+05
26	-1.038E+04	-1.040E+04	7.681E+05	6.624E+03	1.040E+04	-1.018E+06
27	-6.624E+03	1.089E+04	1.018E+06	2.888E+03	-1.089E+04	-7.566E+05
28	-2.888E+03	9.148E+03	7.566E+05	1.642E+02	-9.148E+03	-5.371E+05
29	-1.642E+02	7.410E+03	5.371E+05	-1.723E+03	-7.410E+03	-3.592E+05
30	1.723E+03	5.706E+03	3.592E+05	-2.947E+03	-5.706E+03	-2.222E+05
31	2.947E+03	4.036E+03	2.222E+05	-3.679E+03	-4.036E+03	-1.253E+05
32	5.420E+03	2.366E+03	1.253E+05	-5.827E+03	-2.366E+03	-6.848E+04
33	4.875E+03	6.567E+02	6.856E+04	-5.134E+03	-6.567E+02	-5.251E+04
34	4.833E+03	6.966E+03	5.275E+04	-4.695E+03	-6.966E+03	1.173E+05
35	4.695E+03	5.217E+03	-1.173E+05	-3.921E+03	-5.217E+03	2.446E+05
36	3.921E+03	3.468E+03	-2.446E+05	-2.692E+03	-3.468E+03	3.292E+05
37	2.692E+03	1.719E+03	-3.292E+05	-1.193E+03	-1.719E+03	3.712E+05
38	1.193E+03	-2.952E+01	-3.712E+05	3.946E+02	2.952E+01	3.705E+05
39	-3.946E+02	-1.779E+03	-3.705E+05	1.888E+03	1.779E+03	3.271E+05
40	-1.888E+03	-3.528E+03	-3.271E+05	3.104E+03	3.528E+03	2.410E+05
41	-3.104E+03	-5.277E+03	-2.410E+05	3.860E+03	5.277E+03	1.122E+05
42	-3.860E+03	-7.026E+03	-1.122E+05	3.973E+03	7.026E+03	-5.922E+04

43	-3.974E+03	-8.775E+03	5.922E+04	3.262E+03	8.775E+03	-2.733E+05
44	1.998E+03	8.049E+03	2.724E+05	-2.744E+03	-8.049E+03	-7.599E+04
45	2.744E+03	6.300E+03	7.599E+04	-2.740E+03	-6.300E+03	7.776E+04
46	2.740E+03	4.551E+03	-7.776E+04	-2.169E+03	-4.551E+03	1.888E+05
47	2.169E+03	2.802E+03	-1.888E+05	-1.214E+03	-2.802E+03	2.572E+05
48	1.214E+03	1.053E+03	-2.572E+05	-5.814E+01	-1.053E+03	2.829E+05
49	5.814E+01	-6.958E+02	-2.829E+05	1.117E+03	6.958E+02	2.659E+05
50	-1.117E+03	-2.445E+03	-2.659E+05	2.127E+03	2.445E+03	2.063E+05
51	-2.127E+03	-4.194E+03	-2.063E+05	2.792E+03	4.194E+03	1.039E+05
52	-2.792E+03	-5.943E+03	-1.039E+05	2.926E+03	5.943E+03	-4.109E+04
53	-2.926E+03	-7.692E+03	4.109E+04	2.348E+03	7.692E+03	-2.288E+05
54	1.959E+03	7.877E+03	2.277E+05	-2.523E+03	-7.877E+03	-3.552E+04
55	2.523E+03	6.128E+03	3.552E+04	-2.355E+03	-6.128E+03	1.140E+05
56	2.355E+03	4.379E+03	-1.140E+05	-1.638E+03	-4.379E+03	2.209E+05
57	1.638E+03	2.630E+03	-2.209E+05	-5.547E+02	-2.630E+03	2.851E+05
58	5.547E+02	8.814E+02	-2.851E+05	7.118E+02	-8.814E+02	3.066E+05
59	-7.118E+02	-8.676E+02	-3.066E+05	1.979E+03	8.676E+02	2.854E+05
60	-1.979E+03	-2.617E+03	-2.854E+05	3.064E+03	2.617E+03	2.216E+05
61	-3.064E+03	-4.366E+03	-2.216E+05	3.785E+03	4.366E+03	1.150E+05
62	-8.518E+02	-6.115E+03	-1.151E+05	1.025E+03	6.115E+03	-3.443E+04
63	-1.468E+02	-7.917E+03	3.445E+04	-3.968E+02	7.917E+03	-2.242E+05
64	-1.407E+04	-3.804E+03	2.280E+05	1.292E+04	3.804E+03	-3.192E+05
65	-1.292E+04	-5.660E+03	3.192E+05	1.129E+04	5.660E+03	-4.549E+05
66	-1.129E+04	-7.516E+03	4.549E+05	8.998E+03	7.516E+03	-6.351E+05
67	-8.998E+03	-9.372E+03	6.351E+05	5.856E+03	9.372E+03	-8.597E+05
68	-5.856E+03	-1.123E+04	8.597E+05	1.676E+03	1.123E+04	-1.129E+06
69	-1.676E+03	-1.308E+04	1.129E+06	-3.729E+03	1.308E+04	-1.442E+06
70	3.729E+03	1.328E+04	1.442E+06	-9.124E+03	-1.328E+04	-1.124E+06
71	9.124E+03	1.142E+04	1.124E+06	-1.327E+04	-1.142E+04	-8.503E+05
72	1.327E+04	9.568E+03	8.503E+05	-1.637E+04	-9.568E+03	-6.209E+05
73	1.637E+04	7.712E+03	6.209E+05	-1.859E+04	-7.712E+03	-4.361E+05
74	5.925E+02	9.343E+03	4.420E+05	-1.980E+03	-9.343E+03	-2.180E+05
75	1.980E+03	7.487E+03	2.180E+05	-2.519E+03	-7.487E+03	-3.861E+04
76	2.519E+03	5.631E+03	3.861E+04	-2.398E+03	-5.631E+03	9.635E+04
77	2.398E+03	3.843E+03	-9.635E+04	-1.799E+03	-3.843E+03	1.885E+05
78	1.799E+03	2.123E+03	-1.885E+05	-9.001E+02	-2.123E+03	2.393E+05
79	9.001E+02	4.032E+02	-2.393E+05	1.265E+02	-4.032E+02	2.490E+05
80	-1.265E+02	-1.317E+03	-2.490E+05	1.107E+03	1.317E+03	2.175E+05
81	-1.107E+03	-3.037E+03	-2.175E+05	1.868E+03	3.037E+03	1.447E+05
82	-1.924E+03	-4.757E+03	-1.447E+05	2.292E+03	4.757E+03	3.067E+04
83	-2.281E+03	-6.529E+03	-3.067E+04	2.069E+03	6.529E+03	-1.292E+05
84	3.515E+03	7.294E+03	1.273E+05	-3.678E+03	-7.294E+03	5.136E+04
85	3.678E+03	5.469E+03	-5.136E+04	-3.170E+03	-5.469E+03	1.853E+05
86	3.170E+03	3.644E+03	-1.853E+05	-2.182E+03	-3.644E+03	2.745E+05
87	2.182E+03	1.819E+03	-2.745E+05	-9.071E+02	-1.819E+03	3.191E+05
88	9.071E+02	-5.926E+00	-3.191E+05	4.634E+02	5.926E+00	3.190E+05
89	-4.634E+02	-1.831E+03	-3.190E+05	1.737E+03	1.831E+03	2.741E+05
90	-1.737E+03	-3.656E+03	-2.741E+05	2.723E+03	3.656E+03	1.846E+05
91	-2.723E+03	-5.481E+03	-1.846E+05	3.227E+03	5.481E+03	5.035E+04
92	-3.227E+03	-7.306E+03	-5.035E+04	3.059E+03	7.306E+03	-1.286E+05
93	-3.059E+03	-9.131E+03	1.286E+05	2.027E+03	9.131E+03	-3.522E+05
94	4.904E+02	8.285E+03	3.511E+05	-1.563E+03	-8.285E+03	-1.483E+05
95	1.563E+03	6.460E+03	1.483E+05	-1.860E+03	-6.460E+03	9.941E+03
96	1.860E+03	4.635E+03	-9.941E+03	-1.574E+03	-4.635E+03	1.234E+05
97	1.574E+03	2.810E+03	-1.234E+05	-8.955E+02	-2.810E+03	1.923E+05
98	8.955E+02	9.849E+02	-1.923E+05	-1.782E+01	-9.849E+02	2.164E+05
99	1.782E+01	-8.401E+02	-2.164E+05	8.675E+02	8.401E+02	1.958E+05
100	-8.675E+02	-2.665E+03	-1.958E+05	1.568E+03	2.665E+03	1.305E+05
101	-1.568E+03	-4.490E+03	-1.305E+05	1.893E+03	4.490E+03	2.057E+04
102	-1.893E+03	-6.315E+03	-2.057E+04	1.649E+03	6.315E+03	-1.341E+05
103	-1.649E+03	-8.140E+03	1.341E+05	6.451E+02	8.140E+03	-3.334E+05
104	4.689E+03	9.292E+03	3.309E+05	-5.622E+03	-9.292E+03	-1.034E+05

105	5.622E+03	7.467E+03	1.034E+05	-5.673E+03	-7.467E+03	7.951E+04
106	5.673E+03	5.642E+03	-7.951E+04	-5.035E+03	-5.642E+03	2.177E+05
107	5.035E+03	3.817E+03	-2.177E+05	-3.899E+03	-3.817E+03	3.112E+05
108	3.899E+03	1.992E+03	-3.112E+05	-2.457E+03	-1.992E+03	3.600E+05
109	-5.533E+03	1.667E+02	-3.599E+05	7.087E+03	-1.667E+02	3.640E+05
110	9.948E+02	-1.654E+03	-3.640E+05	5.224E+02	1.654E+03	3.224E+05
111	-5.224E+02	-3.470E+03	-3.224E+05	1.754E+03	3.470E+03	2.349E+05
112	-1.754E+03	-5.286E+03	-2.349E+05	2.498E+03	5.286E+03	1.017E+05
113	-2.498E+03	-7.102E+03	-1.017E+05	2.553E+03	7.102E+03	-7.721E+04
114	-2.079E+02	4.410E+03	7.583E+04	1.183E+02	-4.410E+03	3.530E+04
115	-1.183E+02	2.594E+03	-3.530E+04	4.188E+02	-2.594E+03	1.007E+05
116	-4.188E+02	7.783E+02	-1.007E+05	9.072E+02	-7.783E+02	1.203E+05
117	-9.072E+02	-1.038E+03	-1.203E+05	1.381E+03	1.038E+03	9.412E+04
118	1.028E+02	-2.854E+03	-9.413E+04	1.544E+02	2.854E+03	2.219E+04
119	-5.042E+02	-4.673E+03	-2.218E+04	3.613E+02	4.673E+03	-9.004E+04
120	-3.613E+02	-6.495E+03	9.004E+04	-3.467E+02	6.495E+03	-2.460E+05
121	3.467E+02	-8.317E+03	2.460E+05	-1.804E+03	8.317E+03	-4.458E+05
122	1.804E+03	-1.014E+04	4.458E+05	-4.195E+03	1.014E+04	-6.893E+05
123	4.195E+03	-1.196E+04	6.893E+05	-7.704E+03	1.196E+04	-9.765E+05
124	-1.733E+04	-1.339E+04	9.909E+05	1.248E+04	1.339E+04	-1.313E+06
125	-1.248E+04	1.278E+04	1.313E+06	7.593E+03	-1.278E+04	-1.006E+06
126	-7.593E+03	1.096E+04	1.006E+06	3.911E+03	-1.096E+04	-7.424E+05
127	-3.911E+03	9.137E+03	7.424E+05	1.245E+03	-9.137E+03	-5.230E+05
128	-1.245E+03	7.315E+03	5.230E+05	-5.881E+02	-7.315E+03	-3.473E+05
129	5.881E+02	5.493E+03	3.473E+05	-1.773E+03	-5.493E+03	-2.153E+05
130	1.773E+03	3.671E+03	2.153E+05	-2.495E+03	-3.671E+03	-1.271E+05
131	2.495E+03	1.900E+03	1.271E+05	-2.934E+03	-1.900E+03	-8.148E+04
132	2.934E+03	1.805E+02	8.148E+04	-3.268E+03	-1.805E+02	-7.713E+04
133	3.268E+03	-1.540E+03	7.713E+04	-3.671E+03	1.540E+03	-1.141E+05
134	4.087E+03	7.007E+03	1.141E+05	-4.214E+03	-7.007E+03	5.424E+04
135	4.214E+03	5.287E+03	-5.424E+04	-3.717E+03	-5.287E+03	1.812E+05
136	3.717E+03	3.567E+03	-1.812E+05	-2.773E+03	-3.567E+03	2.669E+05
137	2.773E+03	1.872E+03	-2.669E+05	-1.554E+03	-1.872E+03	3.119E+05
138	1.554E+03	2.020E+02	-3.119E+05	-2.297E+02	-2.020E+02	3.167E+05
139	2.297E+02	-1.468E+03	-3.167E+05	1.031E+03	1.468E+03	2.815E+05
140	-1.031E+03	-3.138E+03	-2.815E+05	2.058E+03	3.138E+03	2.061E+05
141	-2.058E+03	-4.808E+03	-2.061E+05	2.683E+03	4.808E+03	9.062E+04
142	-2.683E+03	-6.478E+03	-9.062E+04	2.737E+03	6.478E+03	-6.497E+04
143	-2.737E+03	-8.148E+03	6.497E+04	2.051E+03	8.148E+03	-2.607E+05
144	3.817E+03	8.918E+03	2.566E+05	-4.447E+03	-8.918E+03	-4.240E+04
145	4.447E+03	7.248E+03	4.240E+04	-4.259E+03	-7.248E+03	1.317E+05
146	4.259E+03	5.578E+03	-1.317E+05	-3.421E+03	-5.578E+03	2.657E+05
147	3.421E+03	3.908E+03	-2.657E+05	-2.104E+03	-3.908E+03	3.596E+05
148	2.104E+03	2.238E+03	-3.596E+05	-4.759E+02	-2.238E+03	4.133E+05
149	4.759E+02	5.684E+02	-4.133E+05	1.294E+03	-5.684E+02	4.270E+05
150	-1.294E+03	-1.102E+03	-4.270E+05	3.038E+03	1.102E+03	4.005E+05
151	-3.038E+03	-2.772E+03	-4.005E+05	4.585E+03	2.772E+03	3.339E+05
152	-4.585E+03	-4.442E+03	-3.339E+05	5.747E+03	4.442E+03	2.272E+05
153	-5.767E+03	-6.112E+03	-2.272E+05	6.416E+03	6.112E+03	8.044E+04
154	9.839E+02	4.696E+02	-9.647E+04	-5.988E+02	-4.696E+02	9.776E+04
155	5.958E+02	-1.200E+03	-9.776E+04	-2.446E+02	1.200E+03	6.893E+04
156	1.452E+02	-2.870E+03	-6.893E+04	-5.472E-08	2.870E+03	-3.575E-07

TIME FOR THIS PROBLEM = 0 MINUTES 2.529 SECONDS

ELAPSED CPU TIME = 0 MINUTES 13.876 SECONDS

THE AUTHOR

William P. Dawkins is an Associate Professor of Civil Engineering at Oklahoma State University. While at The University of Texas at Austin, he was an Assistant Professor of Civil Engineering. His research activities included the study of reinforced concrete and computer simulation of bridge floor systems. His research and industrial experience includes work on Project MOHOLE. He is the author of several publications and is a member of both professional and honorary societies.