A DISCRETE-ELEMENT METHOD FOR TRANSVERSE VIBRATIONS OF BEAM-COLUMNS RESTING ON LINEARLY ELASTIC OR INELASTIC SUPPORTS

by

Jack Hsiao-Chieh Chan
Hudson Matlock

Research Report Number 56-24

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 1972

PREFACE

This study describes a method developed to analyze beam-columns subjected to either static fixed loads or dynamic loads. The supports of the beam-column may be either linearly elastic or nonlinear and inelastic. The method incorporates previously developed discrete-element beam-column techniques.

This work was done under Research Project 3-5-63-56, "Development of Methods for Computer Simulation of Beam-Columns and Grid-Beam and Slab Systems," conducted at the Center for Highway Research, The University of Texas at Austin, as part of the Cooperative Highway Research Program sponsored by the Texas Highway Department and the Department of Transportation Federal Highway Administration.

The authors wish to acknowledge Mr. John J. Panak, Research Engineer, for his valuable suggestions in programming, writing, and other aspects of this study. Appreciation goes to Miss Darlene Neva for typing this report. Other personnel of the Center for Highway Research are gratefully acknowledged for their assistance. The excellent facilities of the Computation Center of The University of Texas and its cooperative staff made a significant contribution to this work.

Jack Hsiao-Chieh Chan
Hudson Matlock

June 1972

LIST OF REPORTS

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Report No. 56-24, "A Discrete-Element Method for Transverse Vibrations of Beam-Columns Resting on Linearly Elastic or Inelastic Supports" by Jack Hsiao-Chieh Chan and Hudson Matlock, presents a new approach to predict the hysteretic behavior of inelastic supports in dynamic problems. June 1972.

(P) indicates Preliminary Report.

ABSTRACT

A discrete-element method of analysis for transverse vibration of beam columns resting on linearly or nonlinearly-elastic, or nonlinearly-inelastic, supports is presented. The applied forces include static fixed loads and time-dependent dynamic loads. The program is an extension of programs BMCOL 43 (Research Report No. 56-4) and DBC1 (Research Report No. 56-8) to cover inelastic supports and time-dependent axial thrusts. Two multi-element models are used to simulate the inelastic characteristics of supports, one which allows the beam to lift off the support when it deflects, upward or downward, and the other which considers the resistance to either upward or downward deflection. An internal damping factor, which is related to the first derivative with respect to time of the curvature of the beam, has been included, in addition to the conventional external viscous damping factor.

The method is based on an implicit difference formulation of the Crank-Nicolson type. A computer program has been written to check the validities of the proposed multi-element models of tracing the loading paths of the nonlinearly-inelastic supports and of the implicit formulation of the Crank-Nicolson type. The results compare well with the theoretical results and with experimental data.

KEY WORDS: dynamic, static, nonlinearly-inelastic supports, multi-element model, beam column, implicit formulation, discrete-element method, computers, piles, bridges, earthquake, wave forces.

SUMMARY

A computer program, DBC5, is presented which can efficiently analyze a beam-column resting on linearly or nonlinearly-elastic, or nonlinearly-inelastic supports and subjected to either static fixed loads or dynamic loads.

The path-dependent history of loading of the nonlinearly-inelastic resistance-deflection curve of the support is considered in this study. Two multi-element models, which are used to simulate the nonlinear characteristics of the inelastic resistance-deflection curves, have been introduced. For problems with nonlinearly-elastic or nonlinearly-inelastic supports, the iteration process compares successively computed deflections until a specified tolerance is satisfied. An option available in the program allows a switch from a spring-load-iteration process (adjusting both the stiffness and the load from one iteration to the next, which is known as tangent modulus method) to a load-iteration technique (adjusting only the load) when the supports yield or disconnect from the beam-column. An internal damping factor, which is related to the first time derivative of the curvature of the beam, has been considered in addition to the external viscous damping factor which is normally encountered in a dynamic problem.

The results of an analysis can include

(1) solutions for the member under static fixed loads,

(2) solutions for the member under dynamic and static loads at each time station, and

(3) plots of computed deflections or moments along either the time or the beam axis as required.

Seven example problems typical of those encountered by highway and foundation designers illustrate the uses of the program and the options available. Included are a three-span beam loaded with an AASHO standard 2-D truck moving at a uniform speed of 60 mph, a simply supported steel rod loaded by axial pulses, a partially embedded steel pipe pile loaded by idealized wave forces, and a partially embedded steel pipe pile excited by sinusoidal, earthquake-induced forces.

A guide for data input is presented which allows routine application of the method of analysis with little necessary reference to the body of the main report. Any number of analyses may be run at the same time.

IMPLEMENTATION STATEMENT

The utilization of numerical methods to describe computer models of problems in structural dynamics has been an interesting subject to which many structural engineers have devoted their efforts in recent years.

In this study, an efficient computer program, DBC5, is developed for the analysis of beam-column problems, static or dynamic, which have either linearly-elastic or nonlinearly-inelastic supports. The path-dependent history of loading of the nonlinearly-inelastic resistance-deflection curve of the support is considered. Potential applications include study of the dynamic response of actual truck-loaded bridges, prediction of the response of offshore piles to wave forces, analysis of railroad loadings on continuous spans which are supported on soil foundations, analysis of transverse response of partially embedded piles to earthquake-induced forces, and prediction of the hysteresis effect of inelastic supports under pavement slabs.

Recommendations are made for further research in developing other better multi-element computer models for nonlinear supports so that buckling, fracture, softening, and relaxation (creep) of the support could also be considered in the program.

It is further 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 more usable for the practicing design engineer.

TABLE OF CONTENTS

CHAPTER 5. EXAMPLE PROBLEMS

APPENDICES

NOMENCLATURE

Symbol	Typical Units	Definition
a_{k+1}, a_{k-1}	----	Coefficients in stiffness matrix
b_{k+1}, b_{k-1}	----	Coefficients in stiffness matrix
C	in-lb	Concentrated applied couple
c_{k+1}, c_k, c_{k-1}	----	Coefficient in stiffness matrix
D	$lb\text{-}in^2$	Lumped internal damping factor divided by time increment length
(D^e)	lb-sec/in	Lumped external viscous damping factor
(D^i)	$lb\text{-}in^2\text{-}sec$	Lumped internal damping factor
d_{k+1}, d_{k-1}	----	Coefficient in stiffness matrix
e	----	Base of natural logarithms
E	lb/in^2	Modulus of elasticity
e_{k+1}, e_{k-1}	----	Coefficient in stiffness matrix
$f_{j,k}$	----	Coefficient in stiffness matrix
F	$lb\text{-}in^2$	Flexural stiffness, EI
h	in	Beam increment length
h_t	sec	Time increment length
I	in^4	Moment of inertia of cross section
j	----	Beam station number
k	----	Time station number
M_j	in-lb	Static bending moment at beam station j
$M_{j,k}$	in-lb	Dynamic bending moment at beam station j and time station k

Symbol	Typical Units	Definition
q^2	----	$2\rho h^3/h_t^2$
Q	lb	Concentrated applied static transverse load
Q^T	lb	Concentrated applied dynamic transverse load
Q_j^R , Q_j^S	lb	Static support reaction at beam station j
$Q_{j,k}^R$, $Q_{j,k}^S$	lb	Dynamic support reaction at beam station j and time station k
ΔQ_1^T, ΔQ_2^T, . . .	lb	Retained projected values of resistance of segments 1, 2, ... on support curve
R	in-lb/rad	Concentrated rotational restraint
R_1, R_2, . . .	lb	Resistances in the sub-springs 1, 2, ... of the nonlinear support
R_1^S, R_2^S	lb	Residual resistances in sub-springs 1, 2
R_A, R_B	lb	Resistances at points A and B on support curve
S_j^s	lb/in	Concentrated transverse linear spring restraint at beam station j
$S_{j,k}^N$	lb/in	Concentrated transverse nonlinear spring restraint at beam station j and time station k
S_1, S_2, . . .	----	Retained values of slopes of segments 1, 2, ... on support curve
T	lb	Static axial thrust
T^T	lb	Dynamic axial thrust
V_j	lb	Static shear of bar j
$V_{j,k}$	lb	Dynamic shear of bar j at time station k
W_j	in	Static transverse deflection at beam station j

CHAPTER 1. INTRODUCTION

In recent years, a great deal of interest has been focused on the utilization of numerical methods to describe computer models of problems in structural dynamics. Many computer programs (for instance, Refs 3 and 10) are available for solving for the dynamic response of beams or slabs which are either linearly or nonlinearly supported; no program has been found, however, which considers the path-dependent history of loading of nonlinearly-inelastic supports. As a result of the necessity to consider the important effects of energy lost due to the hysteretic behavior of the supports, much of the present work has been devoted to the development of multi-element models to simulate the nonlinearly-inelastic supports. With these models, general rules in FORTRAN logic can be observed and used to predict the loading paths of resistance-deflection curves of the supports. The models for the nonlinearly-inelastic supports described in this work are not time-dependent; therefore, relaxation (creep) of resistance of the support is not included in the model. The retardation, or delayed elasticity, of the support can be considered by installing an external viscous dashpot in parallel with the support model. The softening of the nonlinearly-inelastic support is also not included but strain-hardening may be considered.

Purpose and Scope of Program DBC5

The primary purpose of this investigation is to develop an efficient computer program for solving for the transverse dynamic response of a beam-column resting on linearly or nonlinearly-elastic or nonlinearly-inelastic supports which are simulated by the proposed multi-element models described in Chapter 3. When the hysteretic behavior of the supports is considered, the program is able to predict more accurately the dynamic response of beams, piles, slabs, or even bridges which are supported by soil foundations.

A marching method of solution is used which is based on an implicit formula introduced by Crank and Nicolson (Ref 2) to solve second-order heat flow problems. Salani (Ref 10) is credited with applying this implicit formula in determining the transverse time-dependent linear deflections of a beam or plate. Essentially, the beam is replaced by an arbitrary number of rigid bars and deformable joints, and time is divided into discrete, equal intervals. The representation readily permits the flexural stiffness, the elastic restraints, the mass densities, and the applied external loadings to be discontinuous and lumped at the deformable joints which connect the rigid bars. The governing partial differential equation at each joint is approximated by a difference equation that includes several unknown deflections of the joint, which occur at specified time intervals. All difference equations are based on the assumptions of linear elasticity and the elementary beam theory. The effects of transverse shear and rotatory inertia are neglected.

The nonlinear characteristics of the supports are considered by using either a spring-load iteration process (adjusting both the stiffness and the load from one iteration to the next, which is known as tangent modulus method) or a load-iteration technique (adjusting only the load). The iteration process compares successively computed deflections until a specified tolerance is satisfied. Only three nonlinear characteristics of support curves are considered: the first is exhibiting the same resistance to either upward to downward deflection, hereafter referred to as the symmetric resistance-deflection curve; the second is allowing the beam to lift off the support when it deflects upward, hereafter referred to as the negative one-way resistance-deflection curve; the third is allowing the beam to lift off the support when it deflects downward, hereafter referred to as positive one-way resistance-deflection curve. Two multi-element models to simulate the three types of support are introduced in this work.

Application

Computer Program DBC5 is versatile and efficient for

(1) solving for the transverse response of beam-columns with linear and nonlinear supports under free or forced vibration;

(2) computing slopes and shears of the bars, bending moments, and support reactions of the deformable joints, statically or dynamically; and

(3) plotting computed deflections or moments along either the time or beam axis for the requested monitor stations.

Applied forces include static fixed loads, time variant axial thrusts, and time variant lateral loads. Static solutions of beam-columns under fixed loads may also be obtained.

The computer program is intended to provide an efficient tool for analyzing many problems encountered by highway and foundation designers which are complicated and unsolvable using classical methods. A variety of highway structures, such as bridge girders, guard rails, or even a whole bridge floor under moving loads or suddenly applied impact, can be simulated by the computer model of Program DBC5 and solved efficiently. The capability to treat supports that behave nonlinearly and inelastically provides for direct solutions of transverse deflections of railroad rails under moving loads and the prediction of the responses of offshore piles to wave forces, as well as the study of transverse responses of piles to earthquake-induced forces, since the parts of rails and piles supported by the soil can be reasonably represented by the proposed multi-element models for considering the path-dependent history of loading of the soil supports.

CHAPTER 2. DEVELOPMENT OF THE IMPLICIT OPERATOR

Program DBC5 is developed for the dynamic analysis of beam-columns resting on linearly-elastic or nonlinear supports under time variant axial thrusts and lateral loads. The program uses a discrete-element model for developing the equation of motion of beams. An implicit formula of the Crank-Nicolson (Ref 2) type is then utilized to form a marching operator. At each point in time, a set of simultaneous equations for the unknown deflections at the deformable joints can be obtained by systematically applying the marching operator at all joints. A recursive procedure is then used to solve the simultaneous equations. A brief discussion of the method of the recursive solution procedure is included in Appendix B.

Discrete-Element Model for Dynamic Beam-Columns

Matlock and Taylor have developed a static model composed of rigid bars and springs (Fig 1) which can be used to simulate a beam-column. In Ref 5 the efficiency of this model has been proved by solving a variety of structures which can be simulated as beam-columns. By the addition of masses and damping factors lumped at the deformable joints, a dynamic model (Fig 2) is formed that can closely simulate the dynamic response of real beam-columns.

Equation of Motion of Beam-Columns

The equation of motion for transverse vibration of beams can be obtained by summing all the forces, internal and external, at a particular joint j and a particular time station k (see Fig 3). The concept is based on D'Alembert's principle. Thus an equation can be written in terms of the unknown deflections w, moments M, internal damping factors D^i ... ,

$$- M_{j-1} + 2M_j - M_{j+1} - \left(D^i\right)_{j-1} \frac{d}{dt} \left(\varphi_{j-1,k}\right) + 2\left(D^i\right)_j \frac{d}{dt} \left(\varphi_{j,k}\right)$$

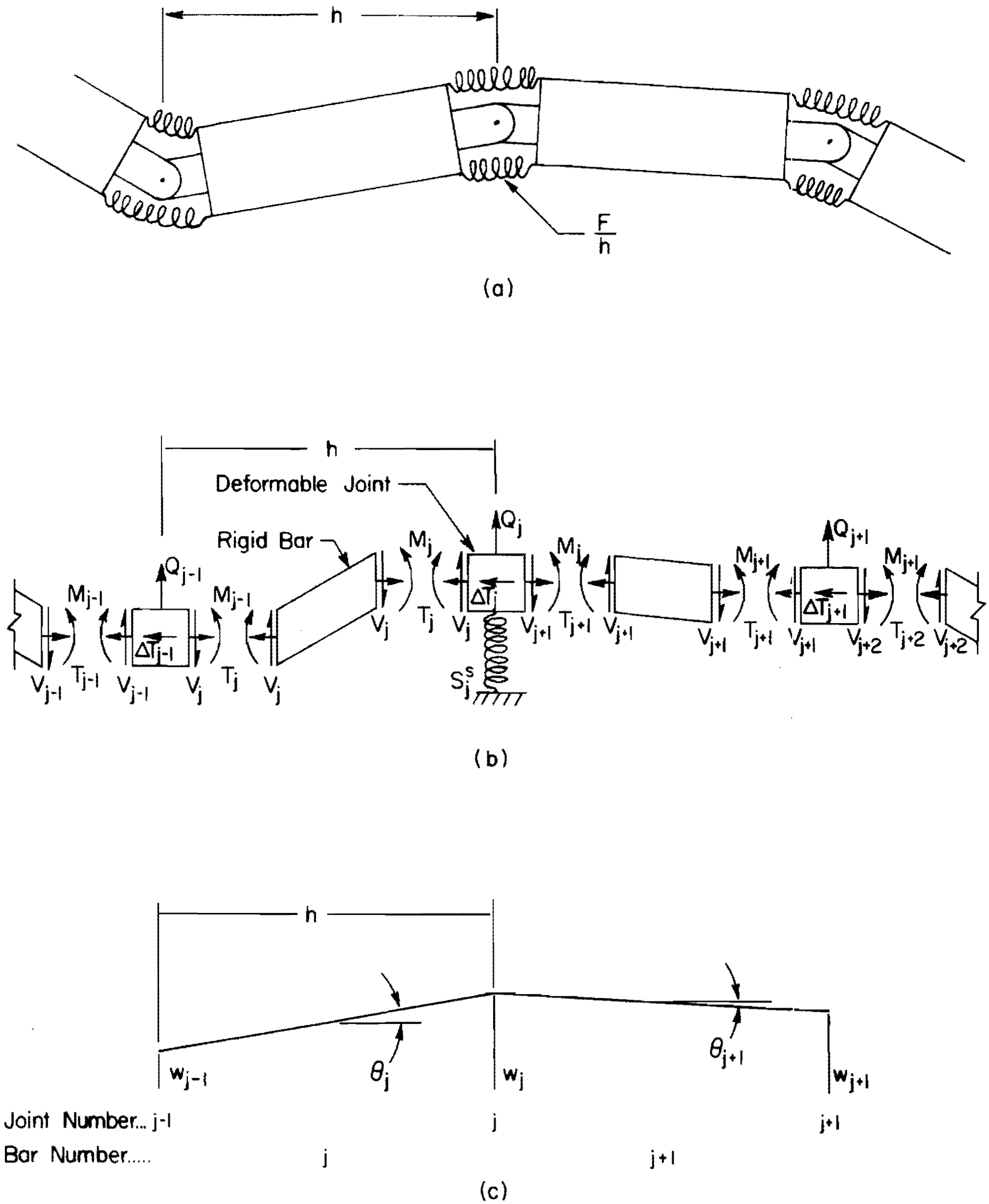


Fig 1. Mechanical model of beam-column.

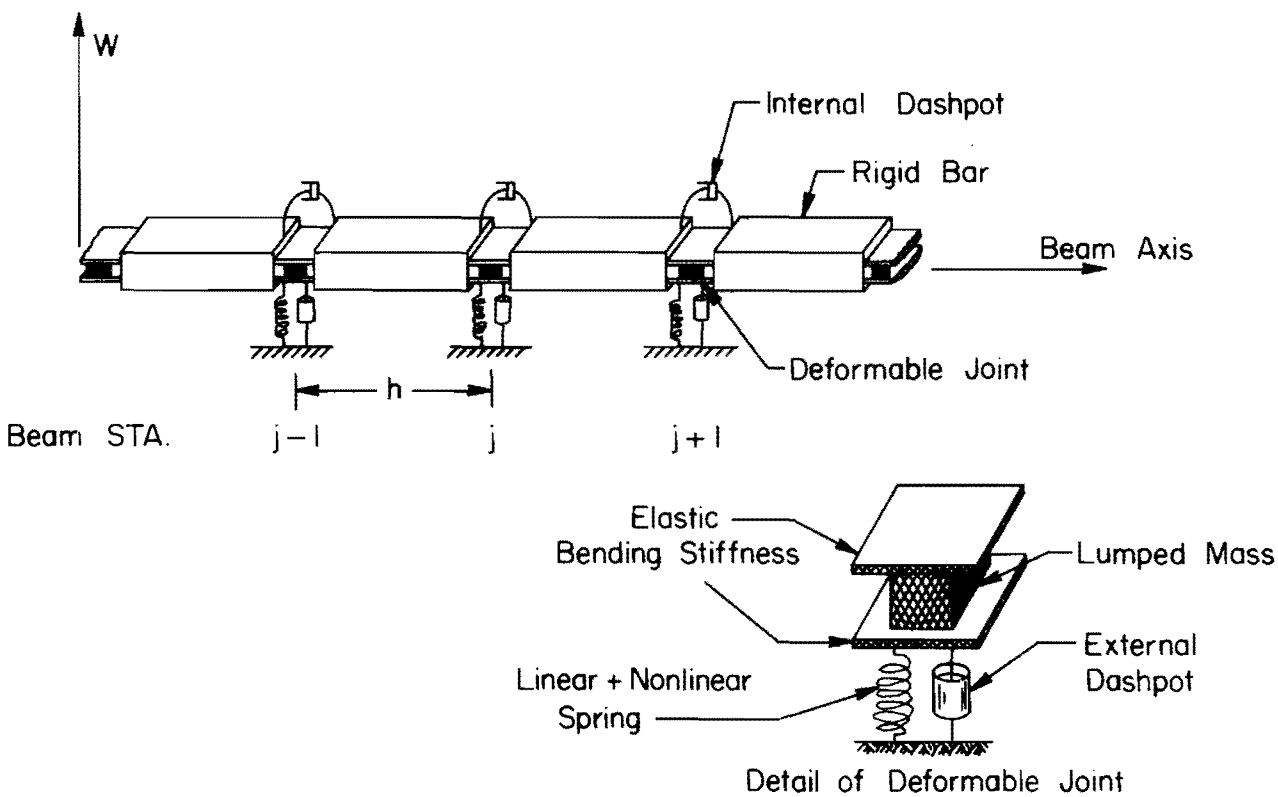


Fig 2. Dynamic model of beam-column.

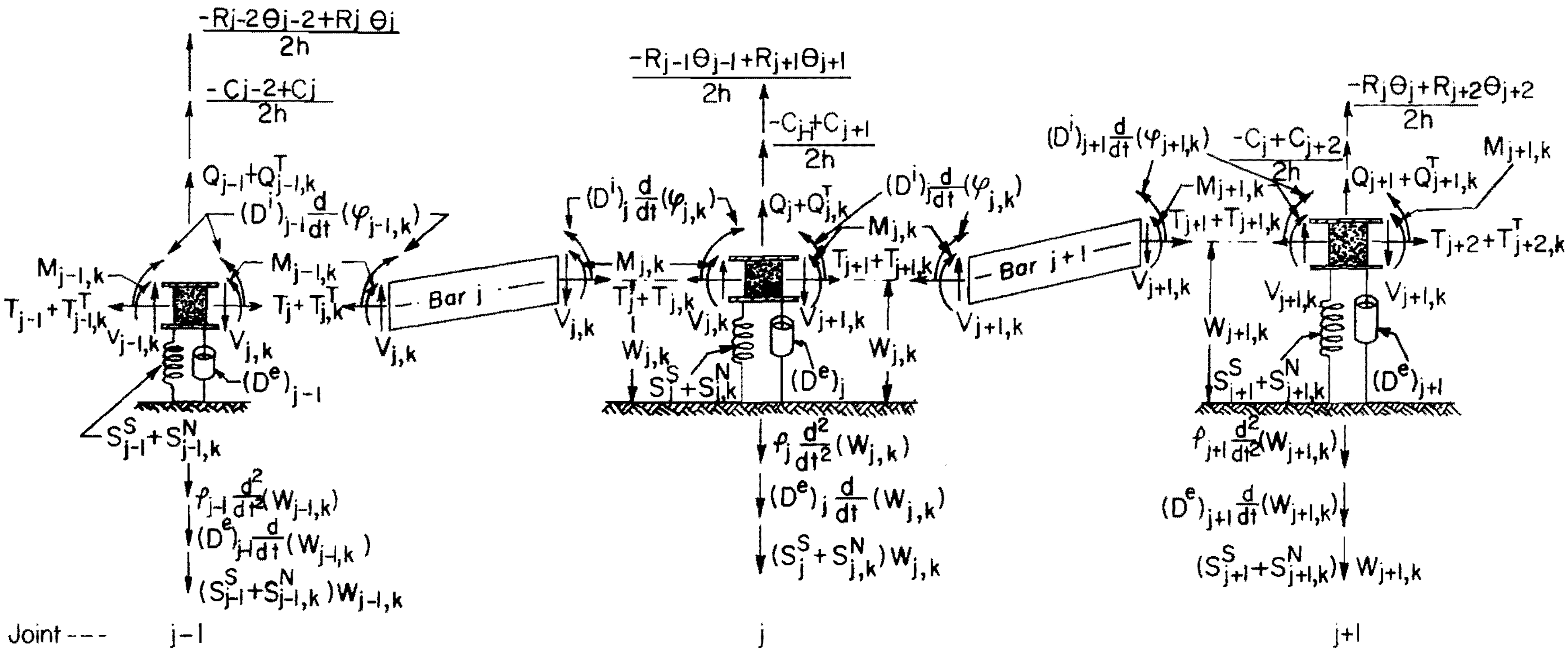


Fig 3. Free-body diagram of a portion of the dynamic beam-column model.

$$- \left(D^{i}\right)_{j+1} \frac{d}{dt} \left(\varphi_{j+1,k}\right) - \left(T_j + T^T_{j,k}\right) \left(-w_{j-1,k} + w_{j,k}\right)$$

$$+ \left(T_{j+1} + T^T_{j+1,k}\right) \left(-w_{j,k} + w_{j+1,k}\right) + hQ^T_{j,k} + hQ_j$$

$$+ 1/2\left(-R_{j-1}\theta_{j-1} + R_{j+1}\theta_{j+1}\right) + 1/2\left(-C_{j-1} + C_{j+1}\right) - hS^s_j w_{j,k}$$

$$- hS^N_{j,k} w_{j,k} - h\rho_j \frac{d^2}{dt^2} \left(w_{j,k}\right) - h\left(D^e\right)_j \frac{d}{dt} \left(w_{j,k}\right) = 0 \qquad (2.1)$$

By the use of Crank-Nicolson's implicit formula, Eq 2.1 can be further represented as

$$a_{k+1} w_{j-2,k+1} + b_{k+1} w_{j-1,k+1} + c_{k+1} w_{j,k+1} + d_{k+1} w_{j+1,k+1} + e_{k+1} w_{j+2,k+1}$$

$$= c_k w_{j,k} + a_{k-1} w_{j-2,k-1} + b_{k-1} w_{j-1,k-1} + c_{k-1} w_{j,k-1}$$

$$+ d_{k-1} w_{j+1,k-1} + e_{k-1} w_{j+2,k-1} + f_{j,k} \qquad (2.2)$$

where

$$a_{k+1} = F_{j-1} + \frac{1}{h_t} \left(D^{i}\right)_{j-1} - 0.25hR_{j-1}$$

$$b_{k+1} = -2\left(F_{j-1} + F_j\right) - \frac{2}{h_t} \left[\left(D^{i}\right)_{j-1} + \left(D^{i}\right)_j\right] - h^2 \left[T_j + 0.5\left(T^T_{j,k-1} + T^T_{j,k+1}\right)\right]$$

$$c_{k+1} = \left(F_{j-1} + 4F_j + F_{j+1}\right) + \frac{1}{h_t} \left[\left(D^{i}\right)_{j-1} + 4\left(D^{i}\right)_j + \left(D^{i}\right)_{j+1}\right]$$

$$+ h^2\left[T_j + T_{j+1} + 0.5\left(T^T_{j,k-1} + T^T_{j,k+1} + T^T_{j+1,k-1} + T^T_{j+1,k+1}\right)\right]$$

$$+ 0.25h\left(R_{j-1} + R_{j+1}\right) + 2h^3 \frac{\rho_j}{h_t^2} + h^3\left(D^e\right)_j/h_t + 0.5h^3\left[\left(S_j^s + S_{j,k-1}^N\right)\right.$$

$$\left. + \left(S_j^s + S_{j,k+1}^N\right)\right]$$

$$d_{k+1} = -2\left(F_j + F_{j+1}\right) - \frac{2\left[\left(D^i\right)_j + \left(D^i\right)_{j+1}\right]}{h_t}$$

$$- h^2\left[T_{j+1} + 0.5\left(T_{j+1,k-1}^T + T_{j+1,k+1}^T\right)\right]$$

$$e_{k+1} = F_{j+1} + \frac{\left(D^i\right)_{j+1}}{h_t} - 0.25hR_{j+1}$$

$$c_k = \frac{4h^3\rho_j}{h_t^2}$$

$$a_{k-1} = - a_{k+1} + \frac{2\left(D^i\right)_{j-1}}{h_t}$$

$$b_{k-1} = - b_{k+1} - \frac{4\left[\left(D^i\right)_{j-1} + \left(D^i\right)_j\right]}{h_t}$$

$$c_{k-1} = - c_{k+1} + \frac{2\left[\left(D^i\right)_{j-1} + 4\left(D^i\right)_j + \left(D^i\right)_{j+1}\right]}{h_t} + \frac{2h^3\left(D^e\right)_j}{h_t}$$

$$d_{k-1} = -d_{k+1} - \frac{4\left[\left(D^i\right)_j + \left(D^i\right)_{j+1}\right]}{h_t}$$

$$e_{k-1} = -e_{k+1} + \frac{2\left(D^i\right)_{j+1}}{h_t}$$

$$f_{j,k} = h^3\left[\left(Q_j + Q^T_{j,k-1}\right) + \left(Q_j + Q^T_{j,k+1}\right)\right] + h^2\left(-C_{j-1} + C_{j+1}\right)$$

Detailed derivations of Eqs 2.1 and 2.2 are included in Appendix A. In Fig 4, an implicit operator of the Crank-Nicolson (Ref 2) type is shown for Eq 2.2.

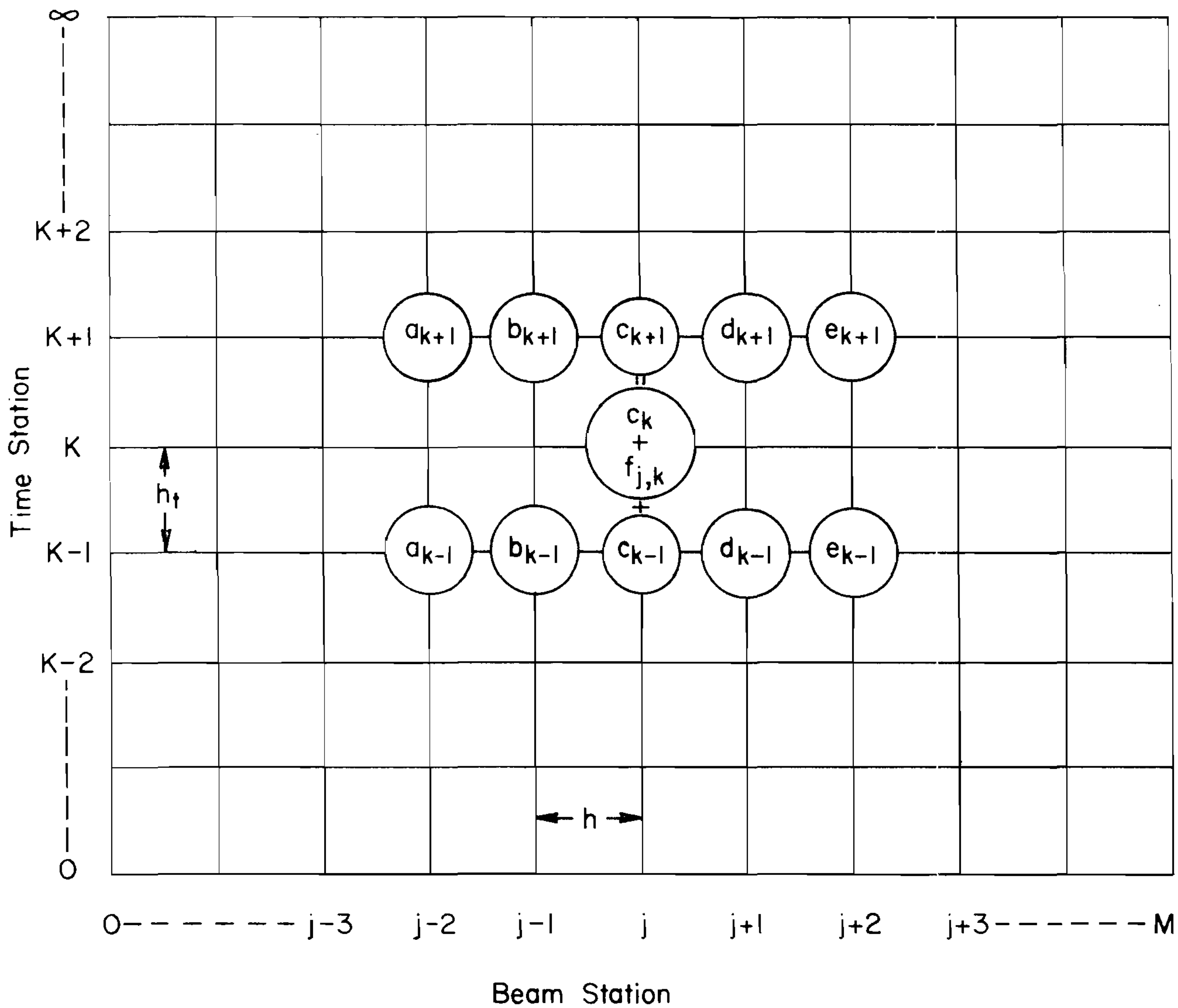
To start the dynamic solutions, a static model as described in Ref 2 is used twice, at time stations -2 and -1 , for solving the initial deflected shape of the beam-column due to static loads. Since the implicit operator requires the deflected shape at only the two previous time stations, there are no considerations of the initial velocities and initial accelerations of the deformable joints of the beam. This is consistent with normal practice, since deformable joints of a beam normally have no initial velocities or initial accelerations.

All deflections at time station k+1 are unknown. To solve for the unknown deflections at time station k+1 , the operator, which requires the deflected shapes of the beam at time stations k and k-1 to be known, is applied systematically at beam joints $j = -1, 1, 2 \ldots M+1$. This procedure establishes a set of simultaneous equations wherein each equation includes five unknown deflections. These equations are solved by a two-pass, recursive technique described in Ref 4 (see Appendix B) for the unknown deflection of every joint. Once the deflected shape of a member at time station k+1 is known, the slopes, bending moments, shears, and support reactions for the member at the previous time station k can be determined by using the procedures described below.

Slope. Equation 2.3 is the simple-difference expression for slope of the individual bar j in terms of the deflections of joints j-1 and j and the beam increment length h (see Fig 1(c)).

$$\theta_j = \frac{-w_{j-1} + w_j}{h} \tag{2.3}$$

The concept applied for both the static model and the dynamic model. It will be seen in results printed from the program that the slope is printed between the beam stations; this slope is that of the bar between the indicated beam stations.



$$a_{k+1}\, w_{j-2,k+1} + b_{k+1}\, w_{j-1,k+1} + c_{k+1}\, w_{j,k+1} + d_{k+1}\, w_{j+1,k+1} + e_{k+1}\, w_{j+2,k+1}$$

$$= c_k w_{j,k} + a_{k-1}\, w_{j-2,k-1} + b_{k-1}\, w_{j-1,k-1} + c_{k-1}\, w_{j,k-1} + d_{k-1}\, w_{j+1,k-1}$$

$$+ e_{k-1}\, w_{j+2,k-1} + f_{j,k}$$

Fig 4. Implicit operator of Crank-Nicolson type used in Program DBC5.

Bending Moment. In conventional beams, the bending moment is equal to the product of the flexural stiffness and the curvature. In the finite-element model the flexibility of the beam and the curvature are lumped at the beam station points. The corresponding relation for bending moment M in the static model is

$$M_j = \frac{F_j}{h}\left(\frac{w_{j-1} - 2w_j + w_{j+1}}{h}\right) \tag{2.4}$$

In the dynamic model, the internal dampling factor lumped at the joint contributes its effect in addition to the conventional bending moment. Thus,

$$M_{j,k} = \frac{F_j}{h}\left(\frac{w_{j-1,k} - 2w_{j,k} + w_{j+1,k}}{h}\right)$$

$$+ \frac{\left(D^i\right)_j}{2h^2h_t}\left(-w_{j-1,k-1} + 2w_{j,k-1} - w_{j+1,k-1} + w_{j-1,k+1}\right.$$

$$\left. - 2w_{j,k+1} + w_{j+1,k+1}\right) \tag{2.5}$$

Shear. Shear V_j in the static model is found from the equation of moment equilibrium of bar j (Fig 1(b)). Thus,

$$V_j = \frac{-M_{j-1} + M_j}{h} - T_j\left(\frac{-w_{j-1} + w_j}{h}\right) \tag{2.6}$$

For the dynamic model, in addition to the effects of conventional bending moments and static axial thrusts, the moments contributed by the internal damping factors $\left(D^i\right)_{j-1}$ and $\left(D^i\right)_j$, and the time dependent axial thrusts $T^T_{j,k}$ are also found in the equation of moment equilibrium of bar j (Fig 3). Thus,

$$V_{j,k} = \frac{-M_{j-1,k} + M_{j,k}}{h} - \left[T_j + T^T_{j,k}\right]\left(\frac{-w_{j-1,k} + w_{j,k}}{h}\right)$$

$$- \left(D^{i}\right)_{j-1} \frac{d}{dt}\left(\frac{w_{j-2,k} - 2w_{j-1,k} + w_{j,k}}{h^3}\right)$$

$$+ \left(D^{i}\right)_{j} \frac{d}{dt}\left(\frac{w_{j-1,k} - 2w_{j,k} + w_{j+1,k}}{h^3}\right) \tag{2.7}$$

Substituting

$$T^{T}_{j,k} = \frac{1}{2}\left(T^{T}_{j,k-1} + T^{T}_{j,k+1}\right),$$

$$\frac{d}{dt}\left(\frac{w_{j-2,k} - 2w_{j-1,k} + w_{j,k}}{h^3}\right) = \frac{1}{2h_t h^3}\left(-w_{j-2,k-1} + 2w_{j-1,k-1}\right.$$

$$\left. - w_{j,k-1} + w_{j-2,k+1} - 2w_{j-1,k+1} + w_{j,k+1}\right)$$

and

$$\frac{d}{dt}\left(\frac{w_{j-1,k} - 2w_{j,k} + w_{j+1,k}}{h^3}\right) = \frac{1}{2h_t h^3}\left(-w_{j-1,k-1} + 2w_{j,k-1}\right.$$

$$\left. -w_{j+1,k-1} + w_{j-1,k+1} - 2w_{j,k+1} + w_{j+1,k+1}\right)$$

into Eq 2.7, thus,

$$V_{j,k} = \frac{-M_{j-1,k} + M_{j,k}}{h} - \left[T_j + 0.5\left(T^{T}_{j,k-1} + T^{T}_{j,k+1}\right)\right]\left(\frac{-w_{j-1,k} + w_{j,k}}{h}\right)$$

$$- \frac{\left(D^{i}\right)_{j-1}}{2h_t h^3}\left(-w_{j-2,k-1} + 2w_{j-1,k-1} - w_{j,k-1} + w_{j-2,k+1}\right.$$

$$- 2w_{j-1,k+1} + w_{j,k+1}\Big) + \frac{\left(D^i\right)_j}{2h_t h^3}\Big(-w_{j-1,k-1} + 2w_{j,k-1} - w_{j+1,k-1}$$

$$+ w_{j-1,k+1} - 2w_{j,k+1} + w_{j+1,k+1}\Big) \tag{2.8}$$

As seen in Fig 1(b) (or Fig 3), V_j (or $V_{j,k}$) is the shear throughout the length of bar j. Therefore Program DBC5 is written such that the shear computed in each bar is printed between the adjacent beam stations. In the program, the rotational restraints and the applied couples, which conventionally are considered to be concentrated at a point, are acting on the beam as equal and opposite loads separated by two increments, as shown in Fig 5. Therefore, the shear for only the bars adjacent to beam stations with applied couples or rotational restraints is affected by these loads and is not the same as conventional shear.

Support Reaction. As described in Ref 5, the support reaction for the static model can be obtained by Eq 2.9 or Eq 2.10.

If joint j is supported on a linear spring S^s_j , the reaction Q^S_j is

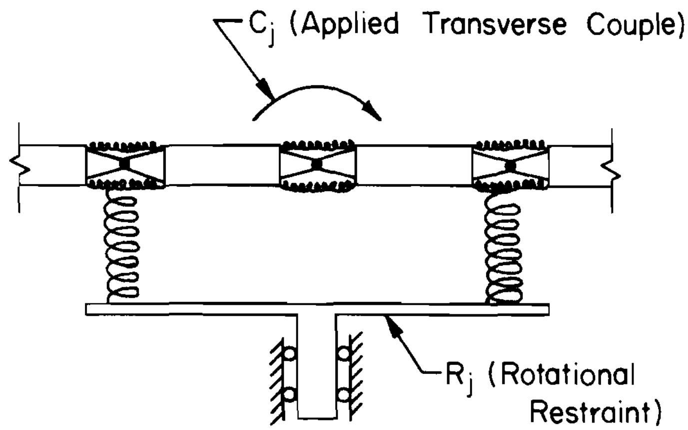
$$Q^S_j = - S^s_j w_j \tag{2.9}$$

If joint j is supported on a nonyielding support (deflection w_j equal to zero), the support reaction is

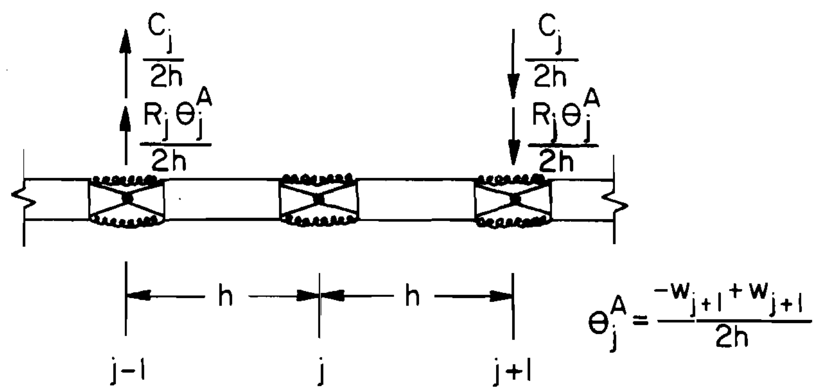
$$Q^R_j = \frac{M_{j-1} - 2M_j + M_{j+1}}{h} - Q_j + \frac{C_{j-1} - C_{j+1}}{2h}$$

$$- \frac{R_{j-1}w_{j-2} - R_{j-1}w_j - R_{j+1}w_j + R_{j+1}w_{j+2}}{4h^2}$$

$$- \frac{T_j w_{j-1} - T_j w_j - T_{j+1}w_j + T_{j+1}w_{j+1}}{h} \tag{2.10}$$



(a) Mechanical model.



(b) Equivalent forces.

Fig 5. Rotational resistance R and applied couple C acting on the mechanical model.

For the dynamic model, the support reaction can be obtained by Eq 2.11 or Eq 2.12.

If joint j is supported on a linear $\left(S^s_j\right)$ or nonlinear $\left(S^N_{j,k}\right)$ spring or both $\left(S^s_j + S^N_{j,k}\right)$, the support reaction $Q^S_{j,k}$ is

$$Q^S_{j,k} = - S^s_j w_{j,k}$$

or

$$S^N_{j,k} w_{j,k} + Q^S_{i,k} \quad \text{or} \; - \left(S^s_j + S^N_{j,k}\right) w_{j,k} + Q^S_{i,k} \tag{2.11}$$

where $Q^S_{i,k}$ is the iterative correction reaction of the nonlinear support at time station k .

If joint j is supported on a nonyielding support, the support reaction is

$$Q^R_{j,k} = \frac{M_{j-1,k} - 2M_{j,k} + M_{j+1,k}}{h} - Q_j + \frac{C_{j-1} - C_{j+1}}{2h}$$

$$- \left(\frac{Q^T_{j,k-1} + Q^T_{j,k+1}}{2}\right) - \frac{1}{4h^2}\left(R_{j-1} w_{j-2,k} - R_{j-1} w_{j,k} - R_{j+1} w_{j,k}\right.$$

$$\left. + R_{j+1} w_{j+2,k}\right) - \frac{1}{h}\left(T_j w_{j-1,k} - T_j w_{j,k} - T_{j+1} w_{j,k} + T_{j+1} w_{j+1,k}\right)$$

$$+ \frac{\left(D^i\right)_{j-1}}{h^3 2h_t}\left(-w_{j-2,k-1} + 2w_{j-1,k-1} - w_{j,k-1} + w_{j-2,k+1}\right.$$

$$\left. - 2w_{j-1,k+1} + w_{j,k+1}\right) - \frac{2\left(D^i\right)_j}{h^3 2h_t}\left(- w_{j-1,k-1} + 2w_{j,k-1}\right.$$

$$- w_{j+1,k-1} + w_{j-1,k+1} - 2w_{j,k+1} + w_{j+1,k+1}\Big)$$

$$+ \frac{\left(D^i\right)_{j+1}}{h^3 2h_t}\Big(- w_{j,k-1} + 2w_{j+1,k-1} - w_{j+2,k-1} + w_{j,k+1}$$

$$- 2w_{j+1,k+1} + w_{j+2,k+1}\Big) - \frac{1}{h}\Big[0.5\left(T^T_{j,k-1} + T^T_{j,k+1}\right)$$

$$\left(w_{j-1,k} - w_{j,k}\right) - 0.5\left(T^T_{j+1,k-1} + T^T_{j+1,k+1}\right)\left(w_{j,k} - w_{j+1,k}\right)\Big]$$

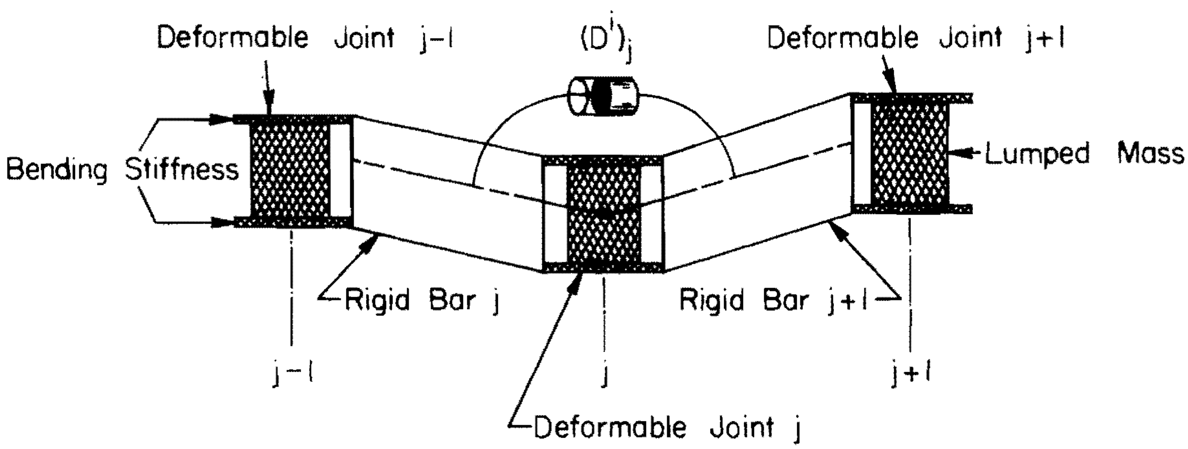
$$+ \frac{\rho_j}{h_t^2}\left(w_{j,k-1} - 2w_{j,k} + w_{j,k+1}\right) + \frac{\left(D^e\right)_j}{2h_t}\Big(- w_{j,k-1}$$

$$+ w_{j,k+1}\Big) \qquad (2.12)$$

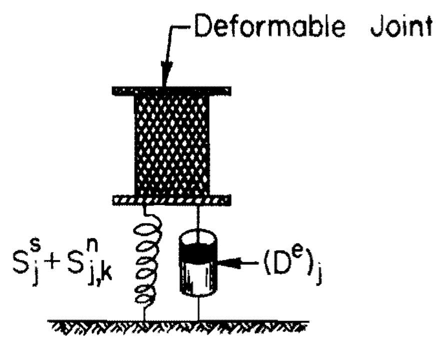
Internal and External Damping

In Eq 2.1, two symbols $\left(D^i\right)_j$ and $\left(D^e\right)_j$ are introduced to represent the internal damping coefficients and the external viscous damping coefficients, which are both lumped at joint j. The rheological models of the two damping constants are shown in Fig 6. The typical units of $\left(D^i\right)_j$ and $\left(D^e\right)_j$ are lb-in^2-sec/sta and lb-sec/in/sta. The internal damping is due to the internal dynamic viscosity of materials. Boltzmann first proposed the hereditary theory which attributed the loss of energy, due to internal damping, to the elastic delay by which the deformation lagged behind the applied force.

Coulomb also proposed a viscous theory which assumed that the viscosity effects are proportional to the first time derivative of strain. The coefficient of proportionality (constant for each material at constant temperature) is called the coefficient of viscosity. In Ref 13, Volterra has shown a mathematical relationship between the viscous and hereditary damping theories. The relationship of stress σ to strain ϵ for the material based on the hereditary theory can be assumed as



(a)



(b)

Fig 6. Rheological models of internal and external damping coefficients.

$$\sigma = E\epsilon + \sum_{n=1}^{\infty} Pn \frac{d^{n-1}\epsilon}{dt^{n-1}} \tag{2.13}$$

where

$$Pn = \frac{(-1)^{n-1}}{(n-1)!} \int_{o}^{To} \tau^{n-1} \phi(\tau) d\tau$$

τ is an instant of time between 0 and To , To is the period of heredity ($\phi(\tau) = 0$ for $\tau > To$), and $\phi(\tau)$ is the memory function which can be found from the experimental data.

If the coefficients Pn with $n > 1$ can be neglected, Eq 2.13 reduces to

$$\sigma = E\epsilon + \iota \frac{d\epsilon}{dt} \tag{2.14}$$

where $\iota = P_1$. Equation 2.14 is the stress-strain relationship of the material based on viscous theory. Therefore, viscous theory is included in hereditary theory.

In the rheological model shown in Fig 6(a), the internal damping coefficients $\left(D^{i}\right)_j$ are related to the first time derivative of curvature. Thus

$$M_j = F_j \varphi_j + \left(D^{i}\right)_j \frac{d\varphi_j}{dt} \tag{2.15}$$

gives the relationship between the moment M_j and the curvature φ_j .

Equation 2.15 is used in Program DBC5 for calculating the bending moments contributed by the flexural stiffness and the internal damping coefficient at the deformable joint j.

It will be shown in problem 4 described in Chapter 5 that the internal damping factors have little effect on the solutions of lower frequencies of a vibrating steel beam. The vibrations at higher frequencies, however, are damped out with time due to the effects of internal damping and rapid changes of curvatures.

The external viscous damping force is defined as $f(w_{j,k}) = -(D^e)_j w_{j,k}$. The constant D^e (in tons per unit velocity, lb-sec/inch, or kip-sec/ft) is called the coefficient of viscous damping. This type of damping occurs for small velocities in lubricated sliding surfaces, dashpots, and hydraulic shock-absorbers. The so-called viscous resistances are produced by the slow motion of immersed bodies in fluid, either liquid or gas. The value of the coefficient $(D^e)_j$ depends essentially on the nature of the fluid, as well as on the form and the dimensions of the immersed body.

With these two types of damping factors, the Program DBC5 can solve the problems characterized by the so-called visco-elastic nonlinearity to a great extent.

<u>Linearly-Elastic and Nonlinearly-Inelastic Supports</u>

In the discrete-element model, lateral supports of various types can be represented by either an equivalent linearly-elastic spring or a nonlinearly-inelastic spring at each of the beam stations. For example, if the beam is supported by columns or piers, the axial stiffnesses of the columns or piers can be approximately estimated and included as equivalent linear spring constants. For more reality, the true behavior of many lateral supports can be better represented by the nonlinear characteristics of the axial resistance-deflection curves of columns, or piers, and soil supports.

If the beam is laterally supported by a soil foundation, better results are obtained by using the nonlinear characteristics of the resistance-deflection curves of the soil than by using the equivalent linear spring constants of the soil resistances, since these characteristics represent the true behavior of the soil supports. In Program DBC5, the nonlinear characteristics of each lateral support are described by a curve consisting of straight line segments. Only three types of the nonlinear characteristics of the lateral supports, symmetric, negative one-way, and positive one-way, are considered in this work.

The symmetrical nonlinear resistance-deflection curve is shown in Fig 7. The force developed against the beam-column model by the supports is plotted on the vertical axis and the model deflection is plotted on the horizontal axis. For both load and deflection, the positive sense is upward. The positive and negative one-way resistance-deflection curves are shown in Fig 8.

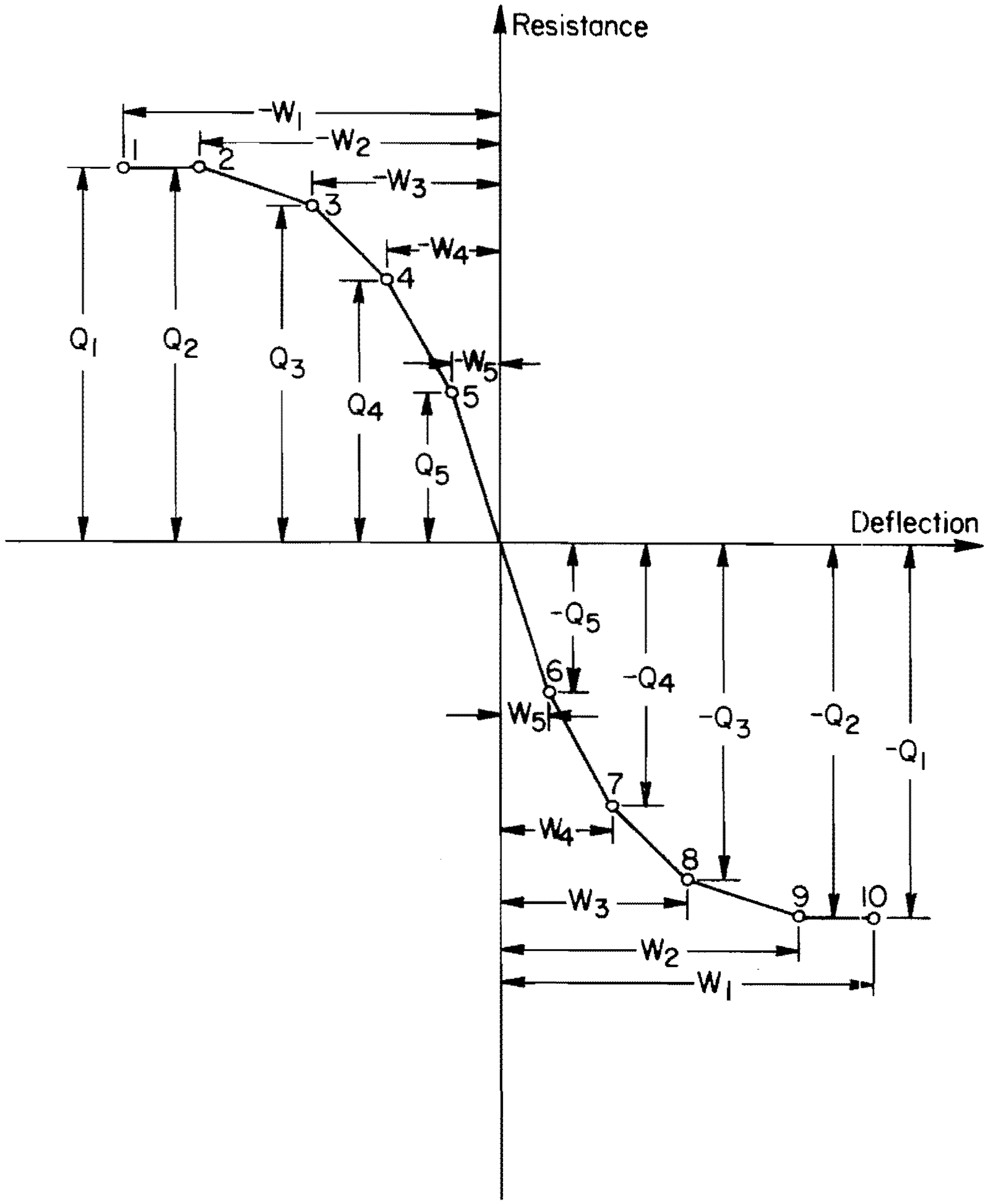
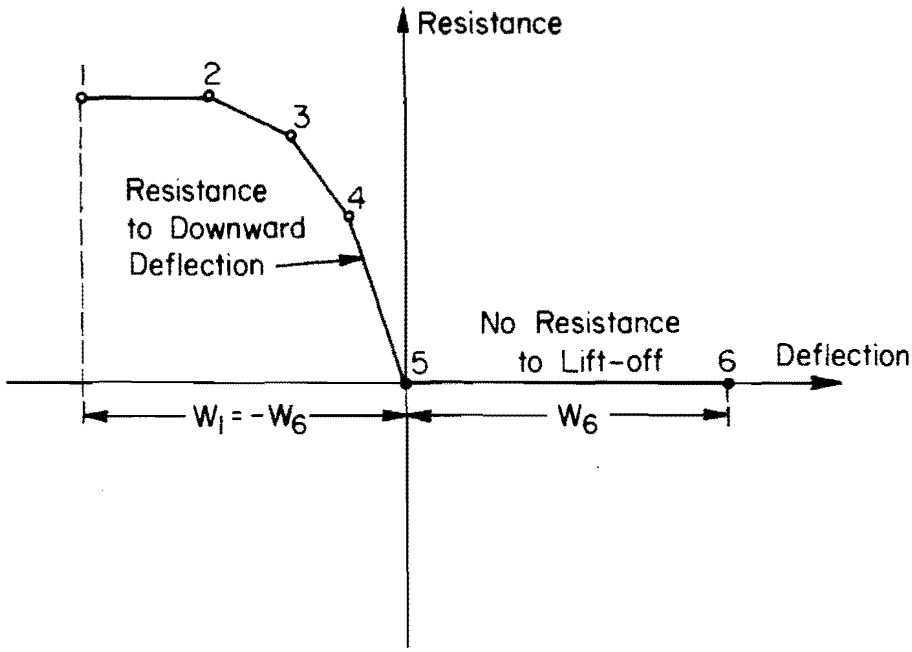
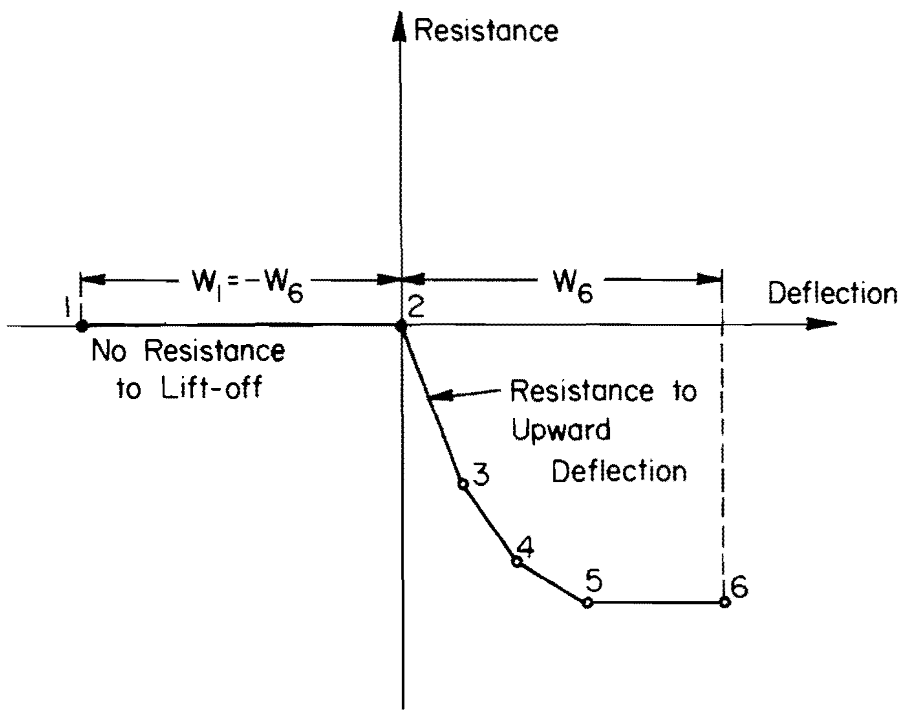


Fig 7. Symmetric resistance-deflection curve.



(a) Negative one-way resistance-deflection curve.



(b) Positive one-way resistance-deflection curve.

Fig 8. One-way resistance-deflection curves.

For the negative one-way support, resistance to deflection is developed only when deformable joints deflect in the negative or downward direction; for the positive one-way support, resistance to deflection is developed only when deformable joints deflect in the positive or upward direction. In order to be consistent with the multi-element model (see Chapter 3) used to simulate the nonlinear resistance-deflection curve of the supports, several limitations are placed on the nonlinear characterization:

(1) The curve must pass through the origin.

(2) The curve must be continuously concave as viewed from the horizontal axis, except that horizontal lines of zero stiffness can be input for representing ideally plastic behavior.

(3) No softening of supports is permitted; that is, no reversal of slope sign of the segments on the support curve is permitted.

Stability of the Implicit Operator

Reference 10 has shown that when a uniform beam with well-defined boundary conditions under free vibration is analyzed using the implicit operator of the Crank-Nicolson form, the solution is stable for all positive values of EI, ρ, h, and ht.

If the same beam, with internal damping $\left(D^i\right)_j$ lumped at joints, is under free vibration, the quadratic equation for evaluation of the stability criterion becomes

$$e^{2\phi} + e^{\phi}\left[\frac{2q^2}{4(F+D)(\cos\beta_n - 1)^2 + q^2}\right] + \left[\frac{4(F-D)(\cos\beta_n - 1)^2 + q^2}{4(F+D)(\cos\beta_n - 1)^2 + q^2}\right] = 0 \qquad (2.16)$$

where

$$F = EI$$

$$D = (D^i)_j/ht$$

$$q^2 = 2\rho h^3/h_t^2$$

The derivation of Eq 2.16 is included in Appendix C.

From Eq 2.16, the condition for bounded solutions as time approaches infinity becomes

$$16(F^2-D^2)(\cos \beta_n-1)^2 + 8Fq^2 \geq 0 \tag{2.17}$$

The above inequality is true, since D is usually less than F for a reasonable time increment length h_t , and the positive value of the term $8Fq^2$ is always greater than the negative value of the term $16(F^2 - D^2)(\cos \beta_n-1)^2$ when h_t is extremely small.

For more complicated cases, such as a beam with internal damping, nonlinear spring supports, and rotational restraints under forced vibration, the analytical proofs for the stability of the implicit operator are not feasible. However, stable numerical solutions have been obtained for most complex practical problems that are physically stable. For beams with nonlinear supports under forced vibration, cautious selection of a reasonably small time increment length (for instance, less than 1/10 of the fundamental period) must be made, since the basic assumption of the Crank-Nicolson implicit formula is that the time-dependent forcing function and the time variant nonlinear springs are smoothly varied with time. Extremely small time increment length is not possible for most practical problems due to the present limitation of a maximum of 1000 time stations provided in Program DBC5.

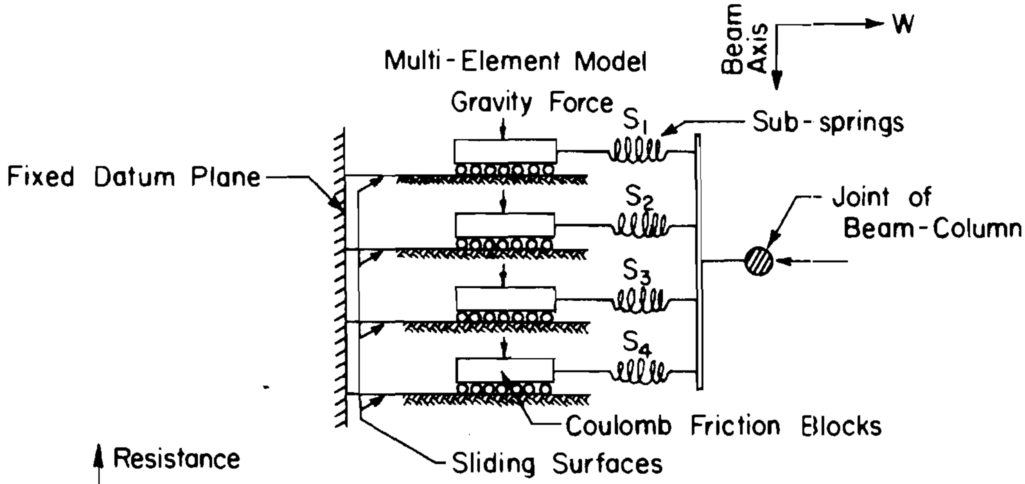
CHAPTER 3. RESISTANCE-DEFLECTION CURVES FOR THE LATERAL SUPPORTS

Three types of lateral supports are considered in this work: linearly-elastic, nonlinearly-elastic, and nonlinearly-inelastic. Chapter 2 discusses how the nonlinear support characteristics can be reasonably described by nonlinear resistance-deflection curves which are approximated by a series of straight-line segments. This chapter introduces two multi-element models each of which is made up of several sub-elements that can be used to simulate the nonlinearly-inelastic characteristics of either a symmetric or a one-way resistance-deflection curve. A short discussion of the Baushinger effect (Refs 9 and 11) as it relates to the formation of the loading paths of nonlinearly-inelastic resistance-deflection curves is included. Finally, a systematic approach to tracing the loading paths of nonlinearly-inelastic resistance-deflection curves in dynamic problems is explained.

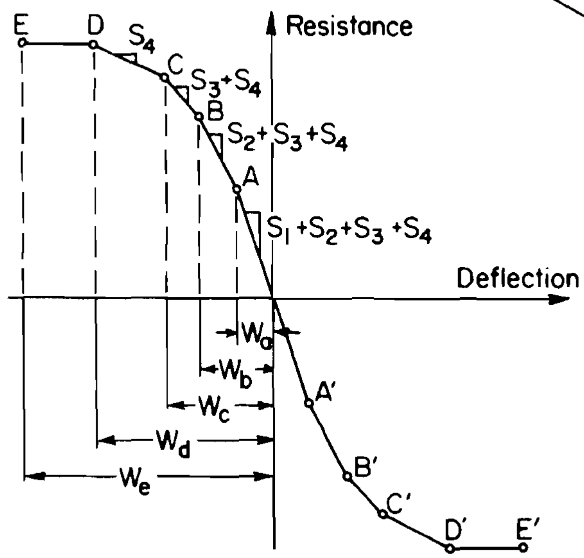
Multi-Element Models

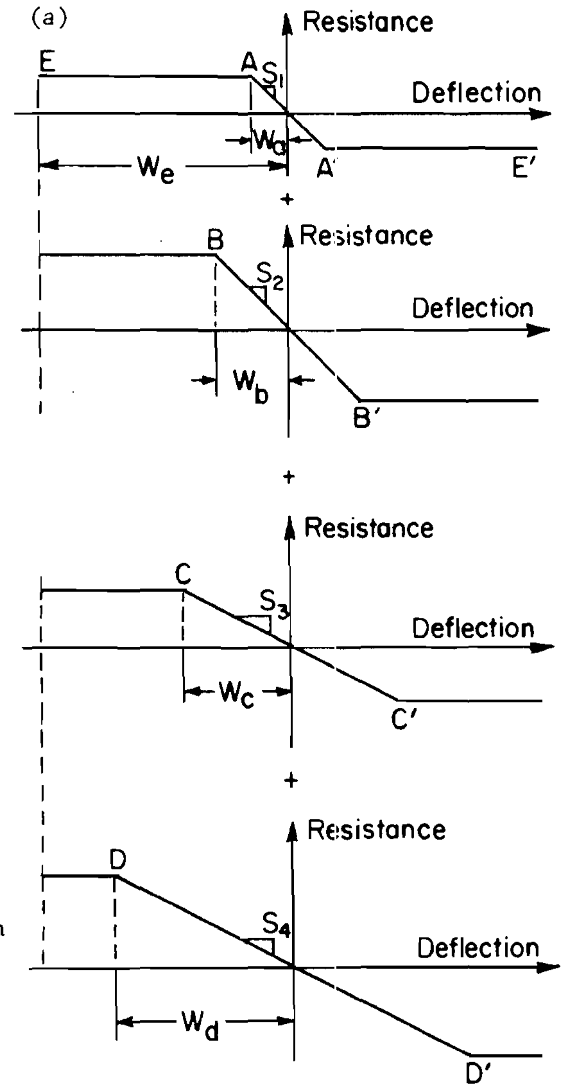
A multi-element model consisting of several parallel sub-elements for simulating the symmetric resistance-deflection curve is shown in Fig 9(a). Each sub-element has a linear spring connected in series with a Coulomb friction block. The sub-elements are assumed to behave as perfectly elastic-plastic and their resistance-deflection curves are shown in Fig 9(c). We see that it is possible to represent a symmetric resistance-deflection curve with a number of perfectly elastic-plastic simple elements in parallel. Buckling and fracture phenomena are not considered in this work. Now let us study the behavior of the sub-elements. If the multi-element model is starting to deform downward, all of the four sub-springs will deform elastically and the resistance will be built up to point A, as shown in Fig 9(b).

At this point the resistance force in the sub-spring S_1 is just equal to the friction force created at the sliding surface of the Coulomb friction block. Beyond the point A the entire sub-element 1 will slide and no resistance, therefore, will be taken by this sub-element. If the model continues to deform downward the resistance will be taken by sub-springs S_2 , S_3 , and S_4



(a)





<u>Procedure of Constructing the Above Curve From (c)</u>

1. Use slope $S_1 + S_2 + S_3 + S_4$ and deflection W_a to construct points A and A′;

2. Use slope $S_2 + S_3 + S_4$ and deflection W_b to construct points B and B′;

3. Use slope $S_3 + S_4$ and deflection W_c to construct points C and C′;

4. Use slope S_4 and deflection W_d to construct points D and D′;

5. Extend from point D to point E and from point D′ to point E′ by using zero slope and deflection W_e.

(b)

(c)

Fig 9. Multi-element model of symmetric nonlinear resistance-deflection curve of the support.

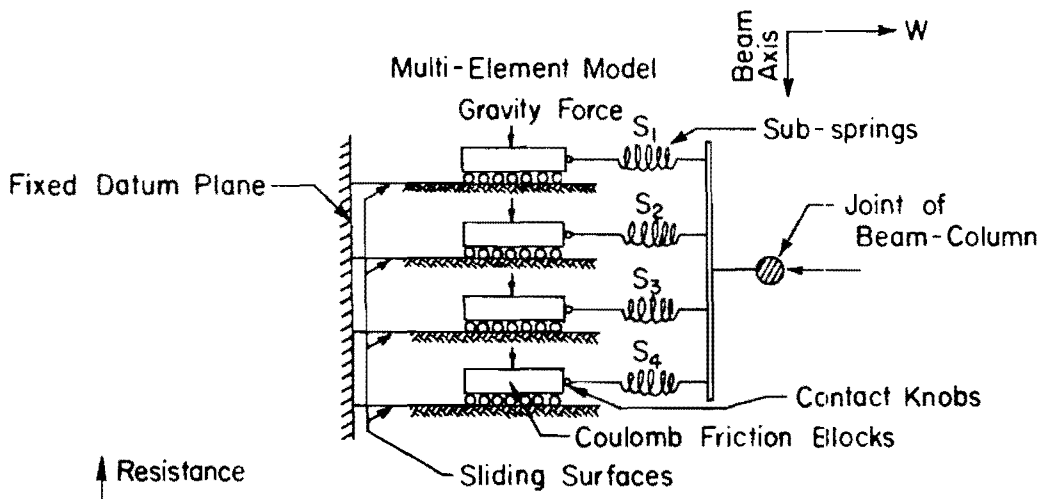
up to point B. At point B the sub-element 2 will start to slide. Beyond the point B the resistance will be taken by sub-springs S_3 and S_4 up to point C. At point C the sub-element 3 will also start to slide. Beyond point C the resistance will be taken only by sub-spring S_4 up to point D. Finally at point D the entire support will start to yield plastically and offer no more resistance to the deflection. Based on the above assumption, a continuously-straight-line-segment curve which represents the nonlinear characteristics of the support can be easily obtained by the summation of all ideally elastic-plastic resistance-deflection curves of the sub-elements. The procedure of constructing such a curve is shown in Fig 9(b). Theoretically, the more segments there are in a curve, the smoother the representation of the nonlinear characteristics will be. Practically, however, a symmetric curve that consists of a maximum of 19 straight-line segments (9 sub-elements) is suitable to represent the nonlinear characteristics.

A multi-element model, as shown in Fig 10(a), is used to simulate the negative one-way resistance-deflection curve. The model is similar to the one used in the symmetric case except that there is no connection between the springs and the friction blocks. The spring-blocks work the same way as the ones used in the symmetric case when the deflection is downward (negative). While the deflection is upward (positive), the springs lift off the friction blocks and therefore no resistances can be built up in the sub-springs. Once the sub-springs are contacting the friction blocks again, the resistances in the sub-springs will again begin to build up and the spring-blocks act exactly as if the model is deflecting downward. The procedure of constructing a negative one-way curve from the individual sub-elements is shown in Fig 10(b).

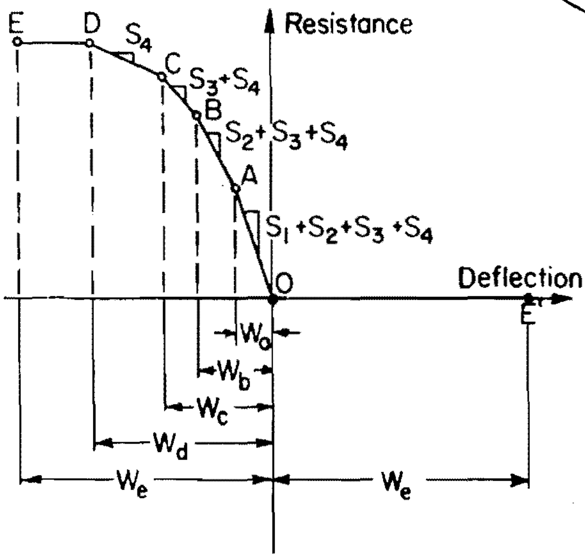
The same multi-element model as shown in Fig 10(a) can be used to simulate the positive one-way resistance-deflection curve. In this case, the support model is to the right of (or above) the joint of beam-column; therefore, the sub-springs disconnect from the friction blocks and exhibit no resistances while the deflection is downward (negative).

Baushinger Effect of Nonlinear Resistance-Deflection Curve

If a specimen of mild steel is subjected to compression after a previous loading in tension, the applied compression stress, combined with the residual stress induced by the preceding tensile test, will produce yielding in the most unfavorably oriented crystals before the average compressive stress



(a)



<u>Procedure of Constructing the Above Curve From (c)</u>

1. Use slope $S_1 + S_2 + S_3 + S_4$ and deflection W_a to construct point A;

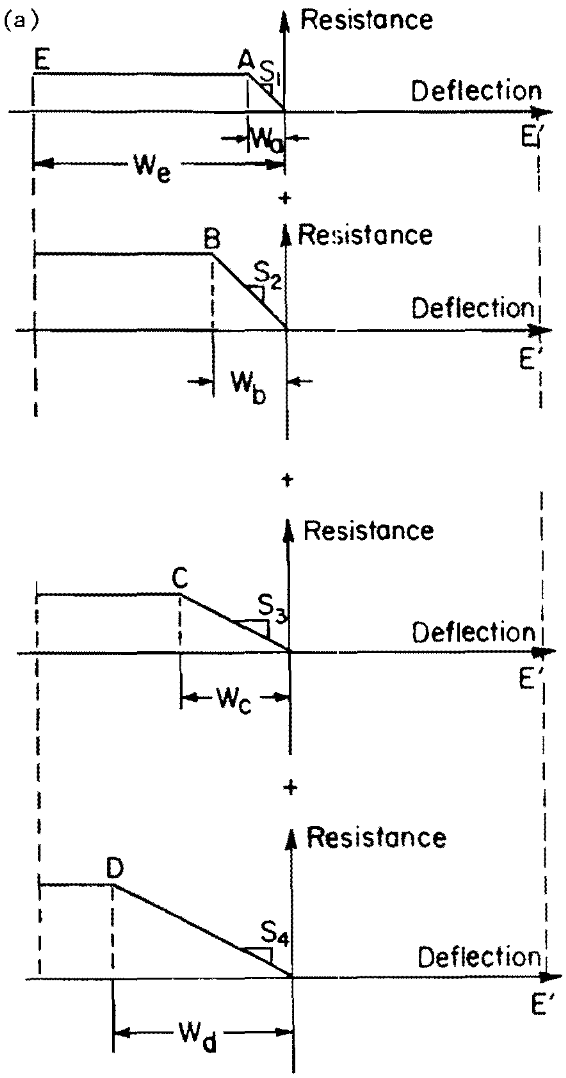
2. Use slope $S_2 + S_3 + S_4$ and deflection W_b to construct point B;

3. Use slope $S_3 + S_4$ and deflection W_c to construct point C;

4. Use slope S_4 and deflection W_d to construct point D;

5. Extend from point D to point E and from point O to point E′ by using zero slope and deflection W_e.

(b)



(c)

Fig 10. Multi-element model of one-way resistance-deflection curve of the support.

reaches the value at which slip bands would be produced in a specimen in its original state. Thus, the tensile test cycle raises the elastic limit in tension, but lowers the elastic limit in compression. This phenomen is called the Baushinger effect (Refs 9 and 11).

From the multi-element models shown in Fig 9(a) and Fig 10(a), we can see that each individual sub-element is allowed to slide during the loading-unloading process. As a result of sliding or plastic deformation produced on loading, a system of residual resistances is introduced on unloading. Obviously, these residual resistances will influence the deformation produced by subsequent loads. Now let us study the so-called Baushinger effect based on the multi-element models shown in Fig 9(a) and Fig 10(a). For simplicity, consider a single spring support which has a nonlinear symmetric resistance-deflection curve with only three segments of resistances as shown in Fig 11(b). The nonlinear spring can be constructed by a multi-element model consisting of only two sub-elements each with an ideally elastic-plastic resistance-deflection curve as shown in Fig 11(c) and Fig 11(d). If a vertical load Q_1 is applied downward to the spring, it will produce resistances R_1 and R_2 in the sub-springs S_1 and S_2, respectively. Thus,

$$R_1 = \frac{Q_1 S_1}{(S_1+S_2)} \tag{3.1}$$

$$R_2 = \frac{Q_1 S_2}{(S_1+S_2)} \tag{3.2}$$

By gradually increasing the load Q_1 we reach the condition at which the friction block in the sub-element 1 starts to slide while the sub-spring S_2 continues to deform elastically. This condition corresponds to point A in Fig 11b. If at point A the deflection is equal to a value w_1, then the corresponding resistance R_A is found from the equation

$$R_A = (S_1 + S_2)w_1 \tag{3.3}$$

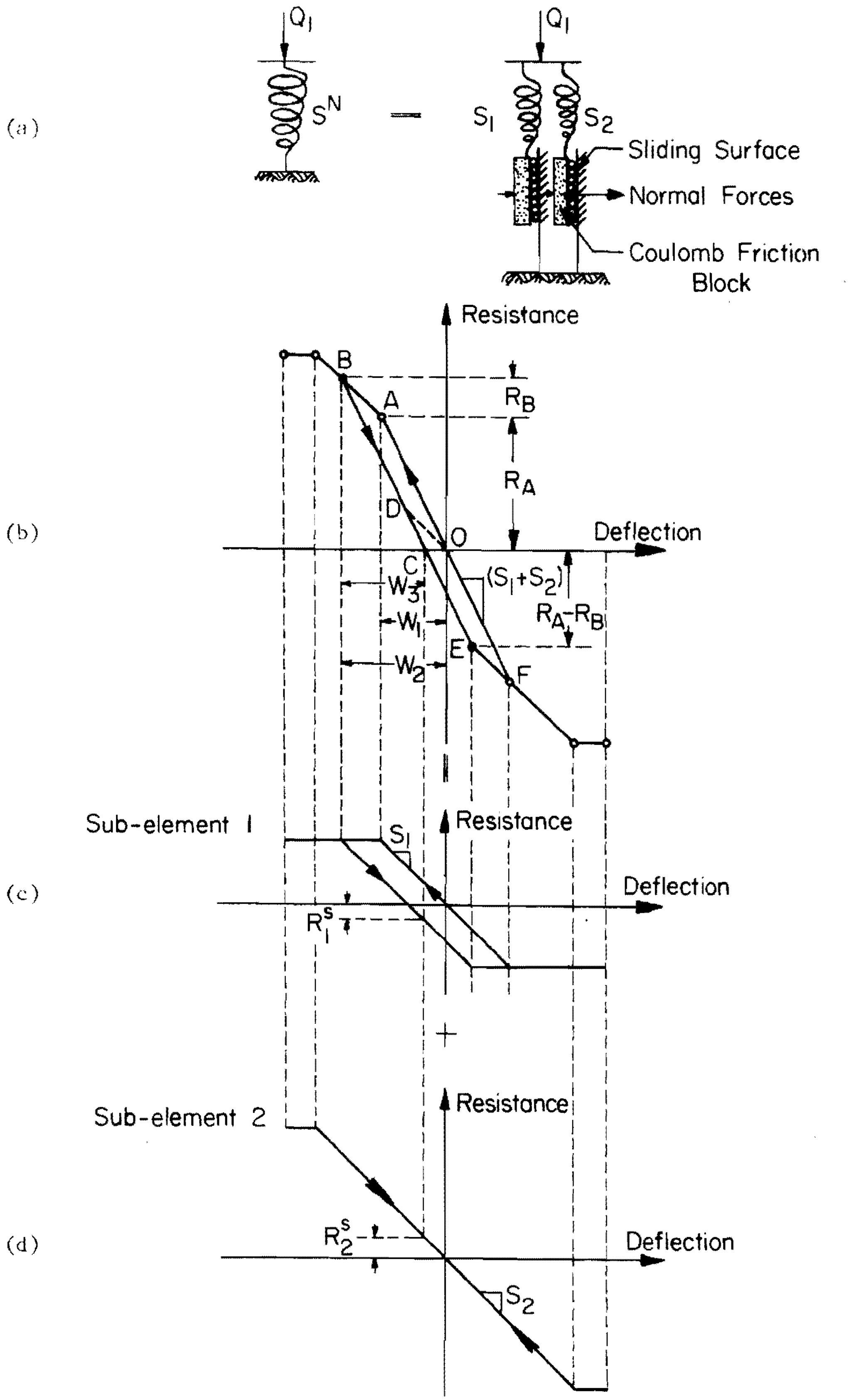


Fig 11. Baushinger effect of symmetric nonlinear resistance-deflection curve of the support.

If we continue to increase the load, the sub-element 1 will slide and exhibit no resistance, and the additional resistance R_B will be taken by the sub-spring S_2 . The additional resistance R_B corresponding to the deflection w_2 will be

$$R_B = S_2(w_2 - w_1) \tag{3.4}$$

The relation between R_B and w_2 is shown in Fig 11(b) by the inclined line AB . If we begin unloading the model after reaching point B on the diagram, both sub-springs S_1 and S_2 will behave elastically and the relation between the removed resistance and the upward displacement will be given by Eq 3.3. In the diagram we therefore obtain the line BC parallel to OA , and the total vertical displacement upward during unloading is

$$w_3 = (R_A + R_B)/(S_1 + S_2) \tag{3.5}$$

Substituting Eq 3.3 into Eq 3.5 yields

$$w_3 = w_1 + \frac{R_B}{S_1 + S_2} \tag{3.6}$$

From Eq 3.4 we obtain

$$w_2 = w_1 + \frac{R_B}{S_2} \tag{3.7}$$

Comparing Eqs 3.6 and 3.7, we find that w_2 is greater than w_3 . We see that because of the sliding of sub-element 1, the model does not return to its initial state and the permanent set $\overline{OC}$ is produced. The magnitude of the permanent set is found from the equation

$$\overline{OC} = w_2 - w_3 = R_B \left[\frac{S_1}{S_2(S_1 + S_2)} \right] \tag{3.8}$$

Because of this permanent set there will be positive residual resistance R_2^S in the sub-spring S_2 , and this resistance will be balanced by the negative residual resistance R_1^S in the sub-spring S_1 . The magnitudes of R_1^S and R_2^S can be shown graphically in Fig 11(c) and Fig 11(d), respectively.

To show the Baushinger effect let us consider a second cycle of loading. At small values of load both sub-springs deform elastically, and in Fig 11(b) the second loading process will begin at point C and proceed along the straight line CB . When we reach point D the sub-spring S_1 will be relieved of the residual negative resistance R_1^s and during further loading will have positive resistance. At point B the positive resistance in the sub-spring S_1 will equal the friction force created by the friction block, and sliding of the sub-element 1 will begin. It is seen that the sliding resistance of the sub-element 1 is raised because of the residual resistances. The sliding resistance was at point A with resistance R_A in the first cycle and at point B with resistance $R_A + R_B$ in the second cycle. The process of unloading in the second cycle is perfectly elastic and follows the line BC .

Let us now reverse the direction of the force and apply an upward load Q_1 . The deformation will then proceed along the straight line CE , which is a continuation of line BC . At point E the total negative resistance is $R_A - R_B$, and the negative resistance in the sub-spring S_1 is equal to the friction force created by the friction block. As the load is increased, the deformation proceeds along the line EF . If the model is unloaded after reaching point F, it will return to the initial state represented by point O . It is seen that by loading the model downward to point B , the positive sliding resistance in the sub-spring S_1 was increased from R_A to $R_A + R_B$. At the same time the negative sliding resistance in the sub-spring S_1 was diminished from R_A to $R_A - R_B$. This illustrates the Baushinger effect. The area of the parallelogram OABCEFO gives the amount of mechanical energy lost per cycle. The same concept discussed above can be expanded to a model consisting of any number of sub-elements.

For a negative one-way resistance-deflection curve as shown in Fig 12b, the Baushinger effect for this model can be illustrated by the loading paths indicated by the parallelogram OABCO and the area defined by OAB'DEFO . Notice that unless the model reaches the condition at which both sub-elements are sliding during the loading process (point D) there will be no permanent set after unloading from point B in the diagram. This is because the sub-spring

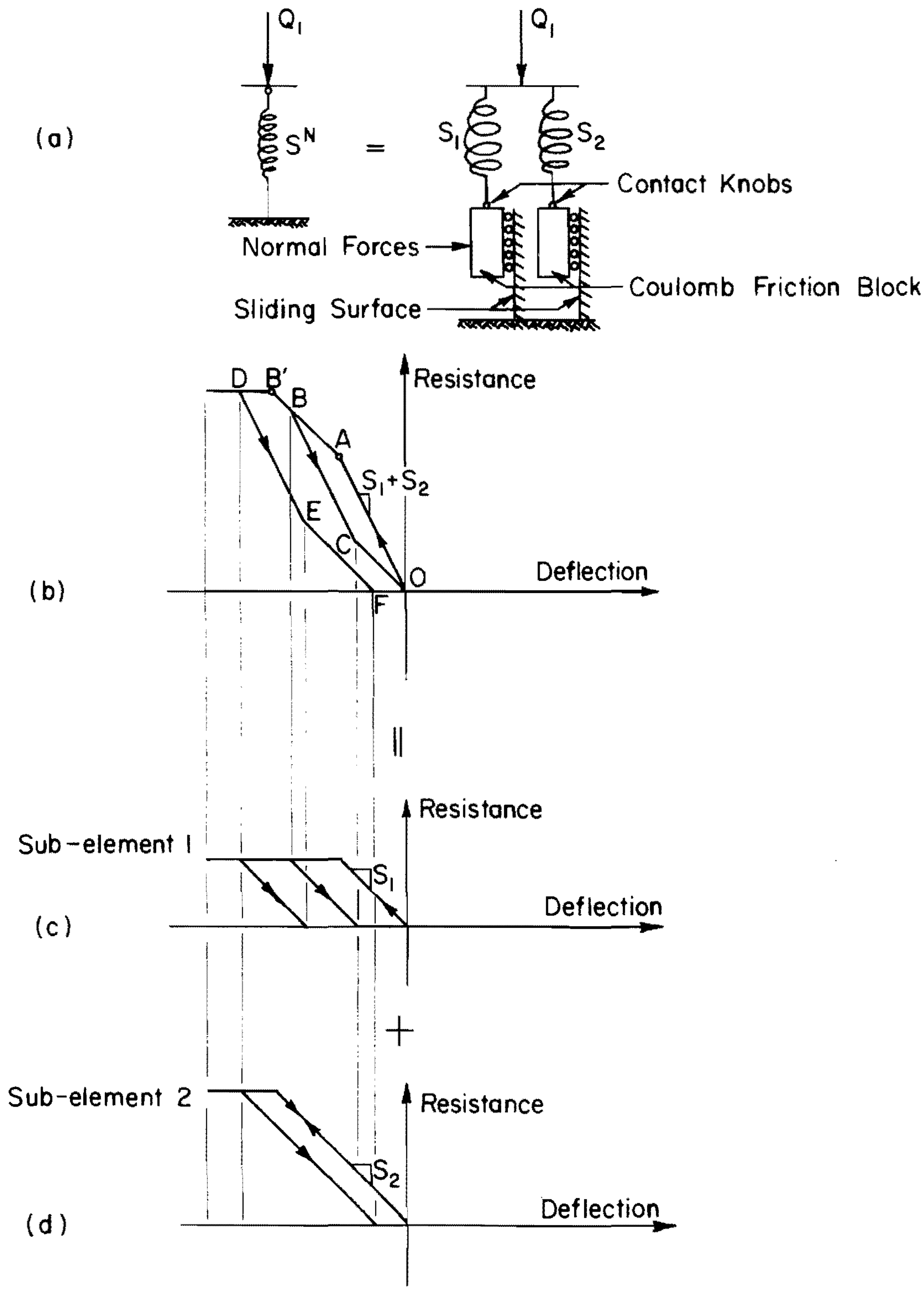


Fig 12. Baushinger effect of negative one-way resistance-deflection curve of the support.

S_1 and the friction block are disconnected after reaching the point C in the diagram, and hence no residual resistance can be built up in the sub-spring S_1 . With further unloading the deformation proceeds along the line CO and the model will return to the initial state represented by point O. At this point, if we reverse the direction of load, the deformation will proceed along the new curve line OCBB'D . This is because the sub-spring S_1 lifts off the friction block before reaching the point C.

It is seen that because the sub-springs are able to lift off the friction blocks, no negative resistances can be built up in the sub-springs and therefore the loading paths can generate only on the negative side of deflection. The above concept also can be expanded to the model which has more than two sub-elements. The Baushinger effect of a positive one-way resistance-deflection curve is similar to a negative one-way resistance-deflection curve, except that the loading paths can generate only on the positive side of the deflection.

A general procedure for tracing the loading paths of either a symmetric nonlinear or a one-way resistance-deflection curve of any support which has more than two sub-elements will be discussed below.

Systematic Approach for Following Loading Paths

In Figs 9(c) and 10(c), we see that the multi-element models for simulating the nonlinearly-inelastic supports can be represented by a number of ideally elastic-plastic sub-elements. Although it is possible to retain the ideally elastic-plastic resistance-deflection curves of each individual sub-element in the program, a more efficient and easier way is to retain the overall curve which is obtained by the summation of all ideally elastic-plastic resistance-deflection curves of the sub-elements as shown in Figs 9(b) and 10(b).

In Program DBC5, nonlinear supports can be described for any beam station. The nonlinear resistance-deflection curve of the support is described by a simple tabular input which generates a curve of straight line segments with a series of point numbers. After defining the resistance-deflection curve by a series of points, which are numbered in order, the resistance and deflection of each point must be retained sequentially in the variables of Q and W , respectively. The retained values of the deflection w must be increasing positively, while that of the resistance Q must be decreasing or equal for the consecutive points.

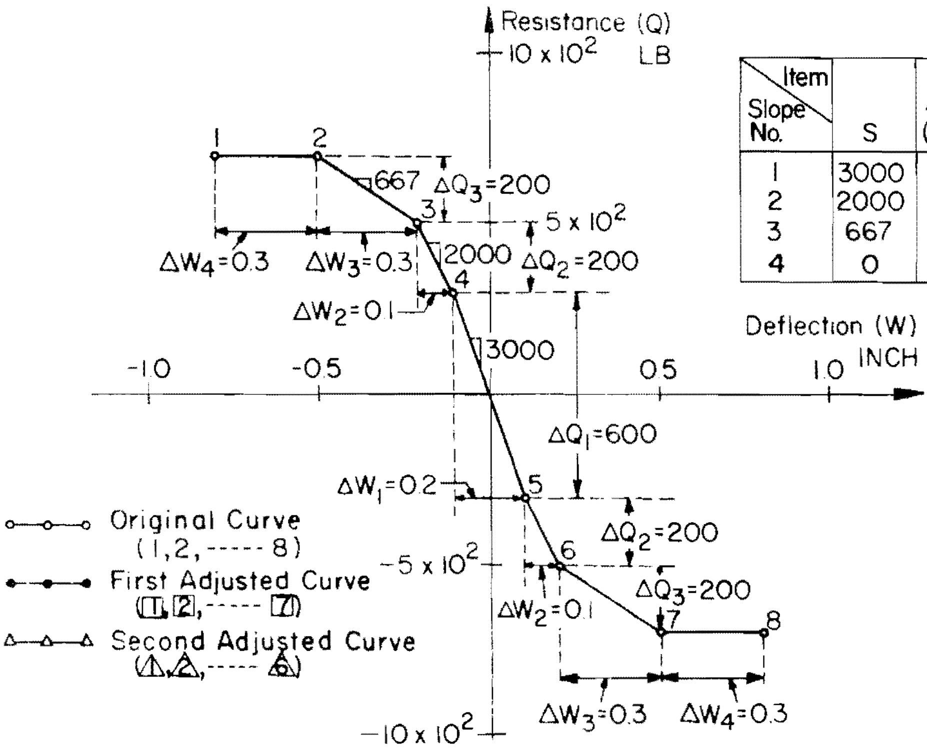
A typical symmetric nonlinear resistance-deflection curve is shown in Fig 13a.

In order to be able to systematically generate the loading paths of the curve during the loading-unloading process, the slope of each segment, the projected horizontal (deflection) value and the projected vertical (resistance) value of each segment must be retained sequentially in the variables of S , $\triangle w$, and $\triangle Q$, correspondingly. Notice that the retained values of the variable S must be in descending order.

Now let us study the procedure of constructing the new path of the original resistance-deflection curve shown in Fig 13(a), when the deformation of the support starts to reverse its direction at point A as shown in Fig 13(b). The systematic procedure consists of (1) drawing line AB parallel to segment 4-5 so that the projected value of line AB on the horizontal axis is equal to $\triangle w_1^T$ and the projected value on the vertical axis is equal to $\triangle Q_1^T$, (2) drawing line BC parallel to segment 3-4 so that the projected value of line BC on the horizontal axis is equal to $\triangle w_2^T$ and the projected value on the vertical axis is equal to $\triangle Q_2^T$, (3) connecting point C to point 7 on the original curve, and (4) renumbering the new path of the resistance-deflection curve as 1, 2, ... 7 as shown in Fig 13(b).

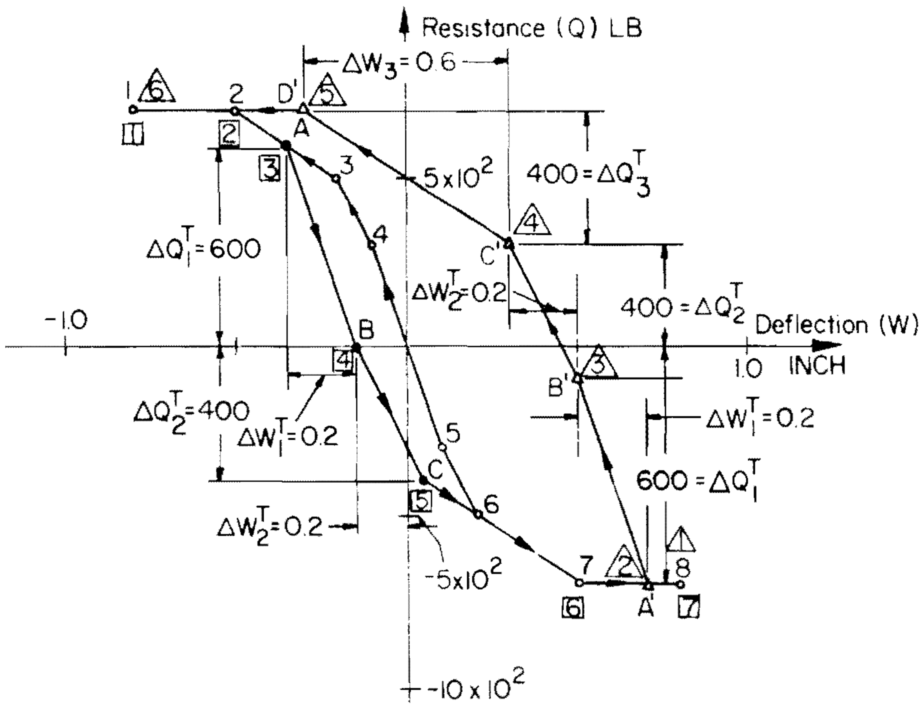
We see that the number of points on the new curve has been reduced to 7 from 8, which is the previous number of points on the original curve. If the deformation of the support again starts to reverse its direction at point A', shown in Fig 13(b), another new path of the resistance-deflection curve, numbered 1, 2, ... 6, will be generated by a procedure similar to that described above, except that three lines, A'B' , B'C' , and C'D' , are drawn before the new curve connects to the previous curve.

For a typical negative one-way resistance-deflection curve, as shown in Fig 14(a), the logic of tracing two new curves can be shown graphically in Fig 14(b). The procedure is similar to the one used in the symmetric case. It is seen that loading paths are generated only by downward (negative) deflections and positive resistances. We also see that the second adjusted curve is generated when the deformation of the support, after going back to the initial state at the end of the first loop, continues to proceed along the line 5CBA2A' and starts to reverse its direction at point A'. The deformation at point A' is greater than the deformation at point A, where the first



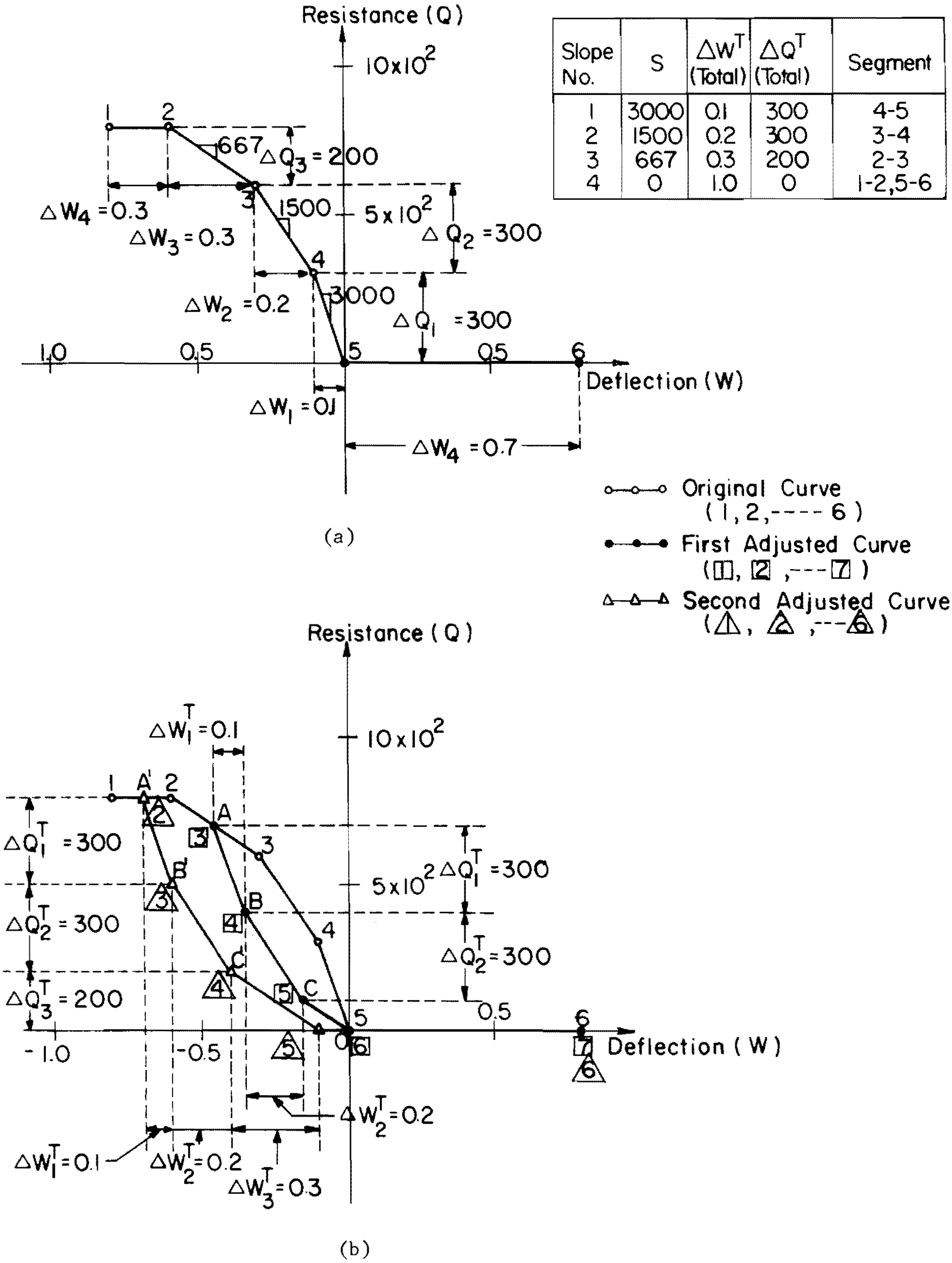
Item / Slope No.	S	ΔW^T (Total)	ΔQ^T (Total)	Segment
1	3000	0.2	600	4-5
2	2000	0.2	400	3-4, 5-6
3	667	0.6	400	2-3, 6-7
4	0	0.6	0	1-2, 7-8

(a)



(b)

Fig 13. Logic of tracing hysteresis loops for symmetric nonlinear resistance-deflection curve.



Slope No.	S	ΔW^T (Total)	ΔQ^T (Total)	Segment
1	3000	0.1	300	4-5
2	1500	0.2	300	3-4
3	667	0.3	200	2-3
4	0	1.0	0	1-2,5-6

Fig 14. Logic of tracing hysteresis loops for a negative one-way resistance-deflection curve.

adjusted curve started. The logic of tracing the loading paths of a positive one-way resistance-deflection curve is similar to the one used in a negative one-way resistance-deflection curve, except that the loading paths are on the positive side of the deflection.

A detailed flow chart relating to the FORTRAN logic, which is used in the program, of tracing the loading paths of the nonlinearly-inelastic resistance-deflection curves of the support will be found in Appendix F.

CHAPTER 4. DESCRIPTION OF PROGRAM DBC5

General

Program DBC5 is written in FORTRAN language for Control Data Corporation (CDC) 6600 computers. With minor changes, the program would be compatible with IBM 7090 computers and with other systems. Four available FORTRAN subroutines are included in the program:

(1) INTERP3 (Ref 5) for interpolating the input data,

(2) TICTOC (Ref 5) for evaluating the computation time,

(3) SPLOT9 for plotting the results by using the printer plotting method, and

(4) ZOT1 for plotting the results by using the microfilm or ball-point paper plotting method.

The program uses in-core storage which requires 58,500 words. Although the use of auxiliary tapes will reduce the storage, it raises the computation time to a great extent due to tape operations; therefore, the in-core solution method has been chosen rather than using many auxiliary tapes. A summary flow chart of the program is presented in Fig 15. The definitions of symbols used in the program and a listing of the program with several general flow charts are included in Appendix E and Appendix F. Subroutines SPLOT9 and ZOT1 were developed particularly for the highway research projects at The University of Texas at Austin.

Procedure for Data Input

A guide for data input is included in Appendix D. The guide is designed so that additional copies may be furnished as separately bound extracts for routine use. A parallel study of the guide will help the reader to understand the following discussion.

Any number of problems may be stacked and run together. The sequence of problems is preceded by two cards which describe the run. The first card of each problem contains the problem number and a brief description of the problem

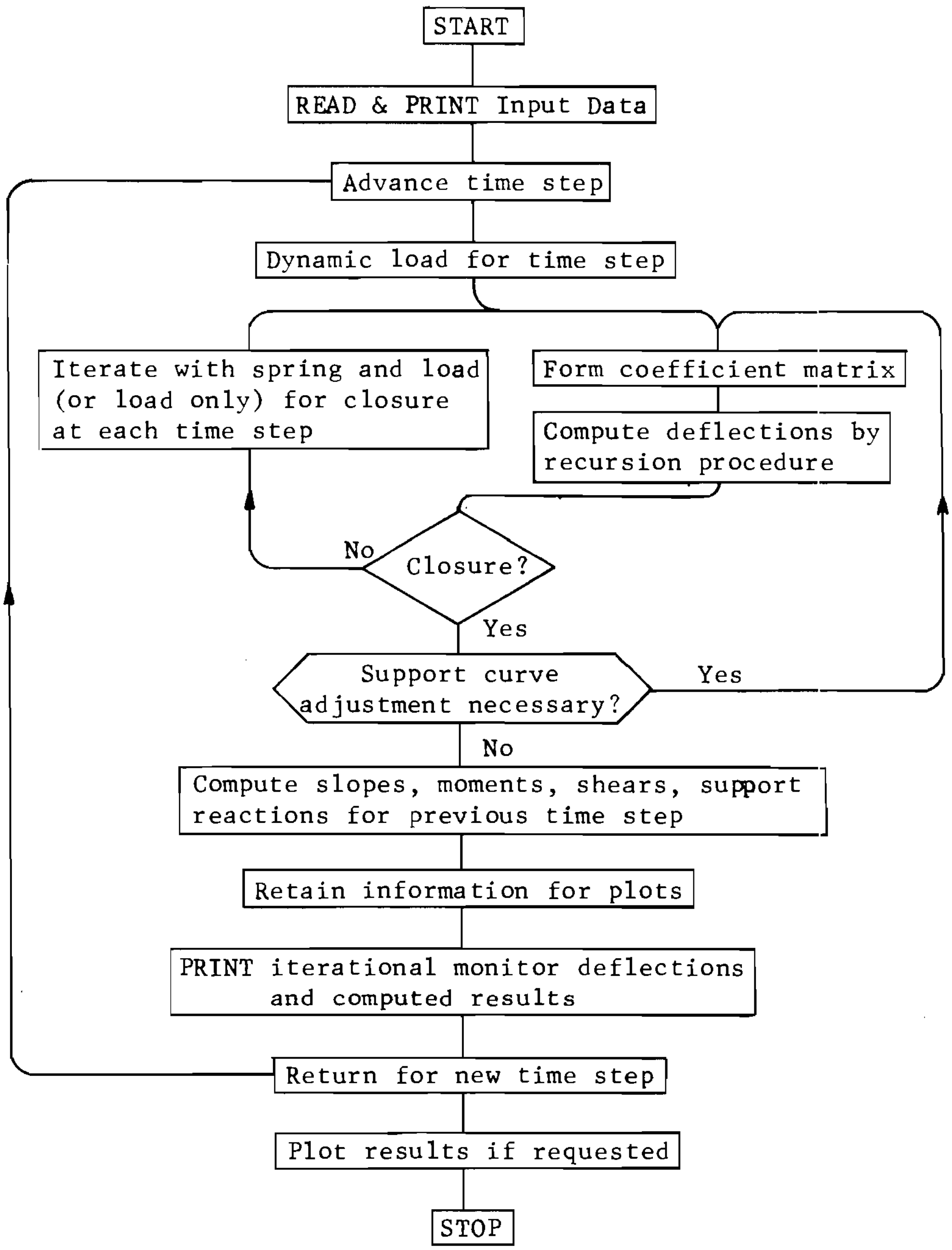


Fig 15. Summary flow chart of DBC5 program.

The program continues working problems until a blank problem number or an error is encountered; then the run is terminated.

Tables of Input Data

Table 1 is the data-control table. It consists of a single card which must be input for each problem. The number of cards in the remaining tables and the hold options of these tables are specified in this table. The hold options for the various tables are independent of each other, but care must be exercised to insure that the data in the various tables are compatible. For example, if a previous 40-increment problem had a distributed load from station 0 to station 40, then the user should not change the total number of increments in the new problem to some number less than 40 unless he erases the loads past the end of the new beam.

Table 2 contains

(1) number of increments into which the beam-column is divided,

(2) beam increment length,

(3) number of increments into which the time axis is divided,

(4) time increment length,

(5) printing option for the computed results,

(6) number of monitor beam stations which are requested for printing the computed results,

(7) iteration switch to show whether or not the problem has nonlinear supports,

(8) number of monitor beam stations which are requested for printing the iteration data,

(9) option to choose the method of plotting the results, and

(10) option of using lines or points for the plots.

If the number of time increments is 0, the problem is considered to be a static case and the complete results of the static solution will be printed at every beam station. In this case, two kinds of plots, which have either deflection or moments for the vertical axis and beam stations for the horizontal axis, may be requested by inputing "0" for the time station in Table 9.

For any station in the beam, a deflection, slope, or both, in either the initial or the permanent condition, may be specified in Table 3. If an initial condition of deflection, slope, or both is specified, it will be disregarded after the dynamic solutions are started. A specified deflection is equivalent to a single lateral support that is very stiff and is unable to deform freely.

A fixed-end support can be simulated in the computer by the specification of a permanent zero deflection and a permanent zero slope at the same beam station. The ability to specify a permanent deflection other than zero provides the user with a simple method of studying problems in which the supports settle. The ability to specify an initial deflection other than zero, on the other hand, provides the user with capability to study dynamic problems with initial displacements. Due to the method of simulation (see Fig 5), the specified slopes and deflections must conform to the following minimum spacing requirements:

(1) A slope may not be specified closer than three increments from another specified slope.

(2) A deflection may not be specified closer than two increments from a specified slope, except that both a slope and deflection may be specified at the same beam station.

Slope and deflection conditions may be specified at no more than 20 beam stations. Each specification requires a separate card. The cards may be stacked in any order within the table.

Fixed loads and restraints are described in Table 4. The input values are beam stiffness, fixed static loads, linear support springs, static axial thrusts, rotational restraints, and applied couples. Couples and rotational restraints appear only as concentrated effects, while axial thrusts are usually distributed. The remaining values may be either concentrated or distributed. The method used for the description of distributed data is illustrated in Appendix D. All of the input values of Table 4 are accumulated algebraically in storage. Therefore, there are no restrictions on the order of the cards, except that within a distribution sequence, the beam stations must be in ascending order. Axial thrusts must be described in the same manner as other values in this table because there is no provision in the program for automatically distributing the internal effects of an externally applied axial thrust. For example, an axial thrust applied to the ends of the beam-column must be specified as either an axial tension or an axial compression at each interior beam station. The number of cards accumulated in Table 4 cannot exceed 100.

Table 5 is used to describe the lumped mass densities, the lumped internal damping factors, and the lumped external damping factors at beam stations. Data in this table are input the same as in Table 4. The maximum allowable number of cards accumulated in this table is 100.

Time-dependent axial thrusts are input in Table 6 as values applying to designated bars. The values of time-dependent axial thrusts specified in this table may vary linearly both in the beam axis direction and in the time axis direction. There are no restrictions on the order of cards, except that beam stations which are stated as the starting station and the ending station in the same card must be in ascending order. A concentrated effect of time-dependent axial thrust at a beam station is not permitted to be stated in this table since it would have no physical meaning.

The method used for the description of distributed data is also illustrated in Appendix D. The number of cards accumulated in this table cannot exceed 100.

Table 7 is used to describe time-dependent lateral loadings applied at the station points. The variation and the distribution of the input data are the same as in Table 6, except that the concentrated effect of the lateral load at a single station is allowed in this table. The number of cards accumulated in this table cannot exceed 100.

Nonlinear resistance-deflection curves of the supporting beam stations are input in Table 8. Every particular nonlinear support curve is described by three consecutive cards. The values input on the first card are resistance-multiplier, deflection-multiplier, number of points, symmetry option, deflection-tolerance, and resistance-tolerance. The values input on the second card are resistance values which are multiplied by the resistance-multiplier to obtain the final resistances of each point on the curve. The values input on the third card are deflection values which are multiplied by the deflection-multiplier to obtain the final deflections of each point on the curve.

There are no restrictions on the order of support curves, except that within any distribution sequence, the beam stations must be in regular order. More than one curve may be placed at a beam station. The maximum number of support curves cannot exceed 20 (60 cards).

Four kinds of plots may be requested by inputing the name of the horizontal axis, the name of the vertical axis, the particular beam or time station, and the multiple plot switch in Table 9. As many as five of the same kinds of plots, each of which is described by one separate card, may be superimposed by using the multiple plot switch. There are no restrictions on the order of cards, except that beam or time stations must be in regular order within a sequence of the same kind of plots. Superimposed plots must all be of the same kind. The maximum number of cards input in this table cannot exceed 10.

Three kinds of plotting methods, namely printer plots, microfilm plots, and ball-point paper plots, are built into the program. The switch which tells the program to choose one of the above three methods for plots is input in Table 2. Various plot options are illustrated in example problems described in Chapter 5.

Error Messages

Program DBC5 provides many checks for common types of data errors as well as for particular errors which occur due to either violations of FORTRAN logic or solution errors considered by the program.

Conditions which are considered to be of the type of data errors are

(1) the allowable number of cards for an input table is exceeded;

(2) a slope or deflection is specified too close to another slope or deflection;

(3) data are input at stations beyond the end of the beam-column;

(4) the station numbers in a distribution sequence are out of order;

(5) the symmetry option is not equal to 1 when only one point is input on a support curve;

(6) the final values of deflection and resistance, which are input for defining the points on a support curve, are improperly specified;

(7) the allowable number of nonlinearly supported beam stations is exceeded;

(8) the number of cards input in Table 8 is not zero when the problem is a linear case; and

(9) repeated data are input in Table 9.

The conditions which are considered solution errors are

(1) calculated displacements exceed maximum allowable deflection specified by the user,

(2) calculated displacements exceed limits of support curves during the iteration process, and

(3) solution does not close within the specified number of iterations.

An error message which defines the error will be printed if any of the above conditions is encountered.

In addition to the specific error messages, a general purpose error message is provided for a number of unlikely errors. If the message "UNDESIGNATED ERROR STOP" is printed, the user must investigate the program to determine what caused the error. Any error detected by the program will cause the entire run to be abandoned.

Description of Problem Results

The output of results is arranged so that the input quantities of Tables 1 through 9 are available for all problems and are printed with explanatory headings.

Table 10 presents the calculated results which are tabulated according to the following order:

(1) monitor deflections during the iteration process of the static solutions (none if the problem is a linear case or if the number of monitor beam stations for printing the iteration data is zero),

(2) complete results of the static solutions,

(3) monitor deflections during the iteration process of the dynamic solutions at time station 0 (see explanation in the parentheses of procedure 1,

(4) complete results of the dynamic solutions at time station 0,

(5) monitor deflections during the iteration process of the dynamic solutions at this time station (see explanation in the parentheses of procedure 1),

(6) monitor or complete results of the dynamic solutions at this time station, and

(7) repeat outputs of procedures 5 and 6 until the last time station specified in this problem is encountered.

The proper headings are printed at the top of the outputs of each procedure described above.

If printout of the calculated results are not requested, the message "PRINTING RESULTS IS NOT REQUESTED" will be printed under the headings of Table 10.

Plots of Results

Options are available which allow the user to obtain plots of the deflections or moments along either beam or time axis. Three kinds of plotting methods, namely printer plots, mircofilm plots, and ball-point plots, are available in the program. Both microfilm and ball-point plots fit in an 8-inch by 9-inch space. The optimum scales for the plots, both horizontal and vertical, are automatically selected by the program. Two fictitious points, one with the minimum horizontal and vertical values of all the points to be plotted on a single frame and the other with the maximum horizontal and vertical values, are plotted on the microfilm or ball-point plots for the purpose of choosing the proper vertical scale. These two fictitious points are not in the stored values of the points to be plotted on this frame and, therefore, should be disregarded. An example plot of the deflections along the time axis for inelastically supported mass under free vibration is shown in Fig 16. The plot in Fig 16 is made using the ball-point plotting method; the problem number and the identification of the plot variables are printed beneath the plot. The plot variables which identify either a microfilm plot or a ball-point plot include three sets of characters. The first set to the right of the problem number is one of the following four symbols: DVT or MVT (deflection or moment along time axis for a particular beam station), DVB or MVB (deflection or moment along beam axis for a particular time station). In the center is either BEAM STA = or TIME STA =. On the right are the station numbers for which the deflections or moments are plotted. The plot in Fig 16 is from Example Problem 1, described in Chapter 5. Another example plot, which is plotted using the microfilm plotting method, is shown in Fig 17. In this example, the moments along the time axis for the mid-point of a three-span beam on which an AASHO standard 2-D truck is moving with a speed of 60 mph is plotted on the microfilm, which then can be developed on an enlarged magnetic print. The plot is from Example Problem 3, described in Chapter 5. Many more ball-point plots which have more than one curve plotted on one frame can be found in Example Problem 5, described in Chapter 5.

A typical example plot which is plotted by using the printer plotting method is shown in Fig 18. The printer plotting method plots the horizontal axis vertically on the sheet. The plot is from Example Problem 6, described in Chapter 5. Different symbols (as many as five) are used on each frame of

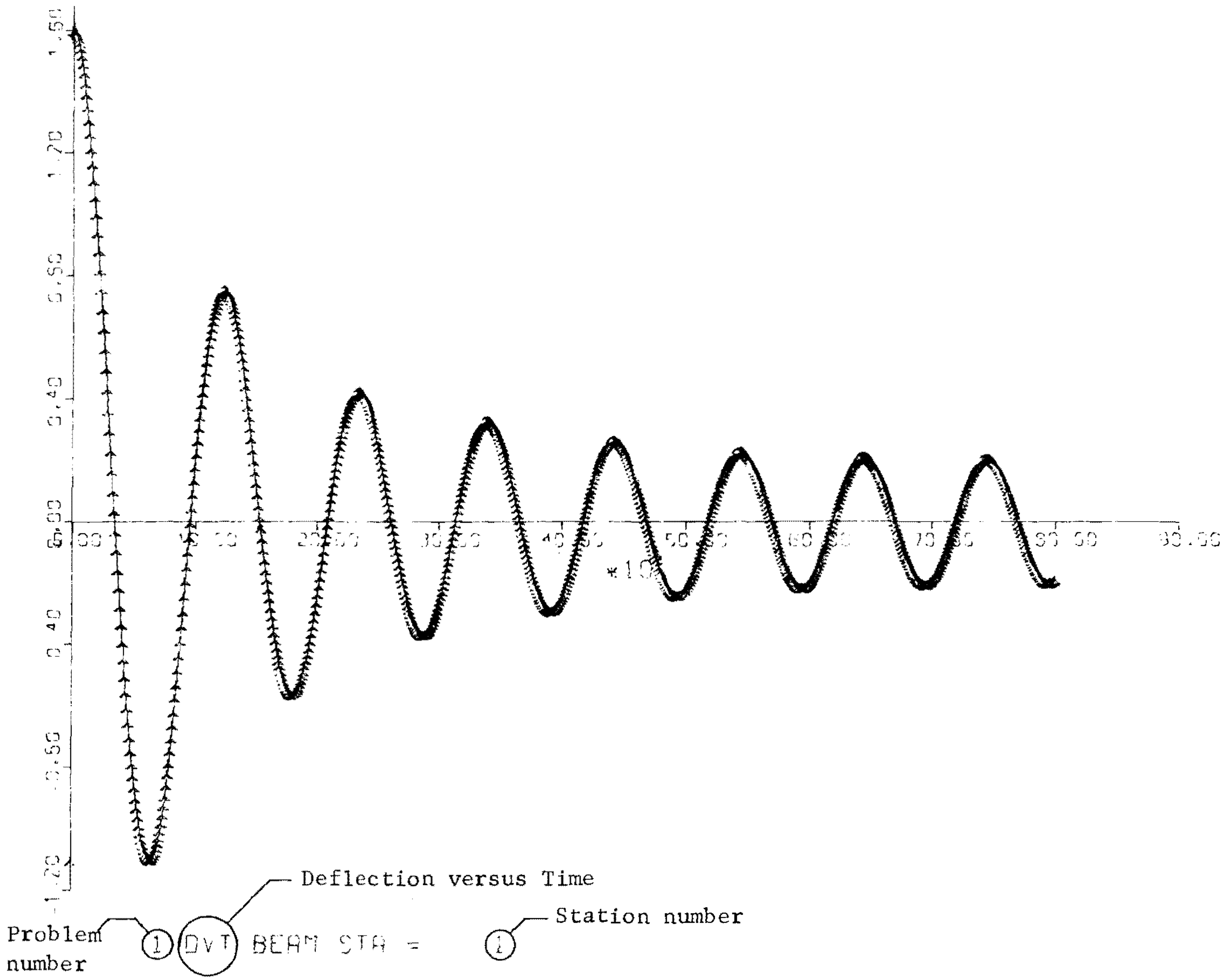


Fig 16. A typical ball-point paper plot.

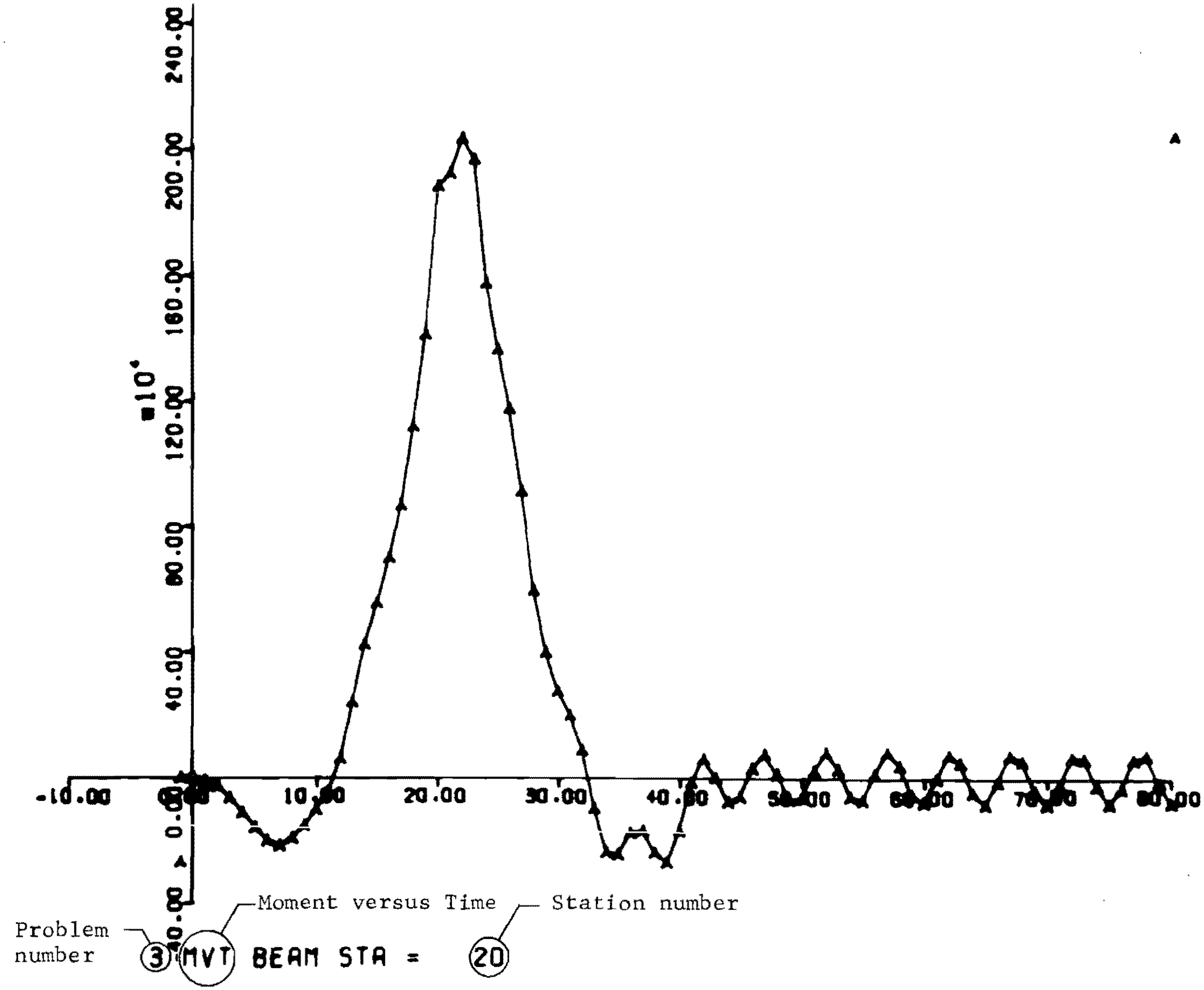


Fig 17. A typical microfilm plot.

```
PROGRAM DBC5 - MASTER - JACK CHAN - MATLOCK -  DECK1-REVISION DATE = 26 JUN 71
         EXAMPLE PROBLEMS FOR PROGRAM DBC5         BY JACK CHAN JUNE 1971
         DYNAMIC BEAM-COLUMN PROGRAM ( 5-1-5 IMPLICIT OPERATOR )


PROB (CONTD)
    6      THREE-SPAN BEAM WITH ONE-WAY AND SYMMETRIC NONLINEAR SUP LOADED BY T.P
***** PLOT OF DEFLECTION VS TIME FOR BEAM STATIONS OF, *****

      1 CURVE (*) =    8
      2 CURVE (+) =   17
```

PT.NO	*VALUE*
-1	-1.313E-16
0	-6.601E-17
1	-6.665E-03
2	-1.613E-02
3	-2.991E-02
4	-4.576E-02
5	-3.474E-02
6	-1.719E-02
7	-2.686E-04
8	-3.031E-03
9	-1.485E-02
10	-1.738E-02
11	-2.036E-02
12	-3.566E-02
13	-3.996E-02
14	-3.422E-02
15	-1.095E-02
16	7.612E-03
17	-3.977E-03
18	-3.483E-02
19	-3.644E-02
20	-2.729E-02
21	-1.945E-02
22	-5.084E-03
23	8.561E-03
24	3.095E-03
25	-2.837E-02
26	-3.069E-02
27	1.662E-02
28	4.137E-02
29	-1.882E-02
30	-8.241E-02
31	-1.368E-02
32	6.972E-02
33	4.049E-02
34	-6.450E-02
35	-8.346E-02
36	9.599E-03
37	7.121E-02
38	4.240E-02
39	-6.159E-02
40	-7.584E-02

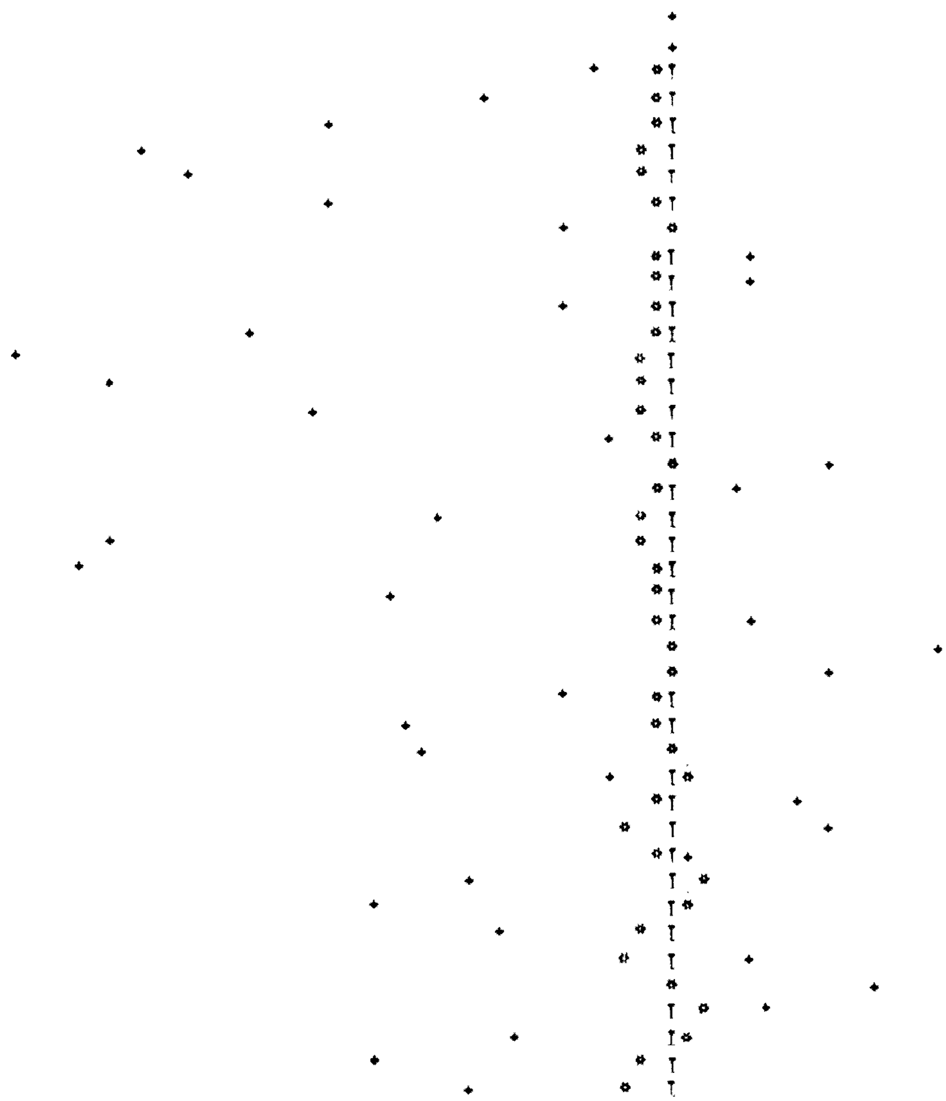


Fig 18. A typical printer plot.

the printer plots for identifying different curves superimposed on this frame. The identifications of the plot variables (such as description of program and run, problem number and problem description, description of the type of the plots, and beam stations or time stations) are printed on the top of each frame of plots. The numerical values printed vertically to the left of the plots are those of the first plot on this frame. The scale of the vertical (deflection or moment) axis is not plotted on the plots, and the horizontal (beam or time station) axis is scaled equally for each point on the plots and plotted by the symbols I. A series of numbers corresponding to the beam or time stations is printed vertically on the left end of the plots for the purpose of indexing. The printer plots fit on 8-1/2-inch by 11-inch standard letter-size paper.

CHAPTER 5. EXAMPLE PROBLEMS

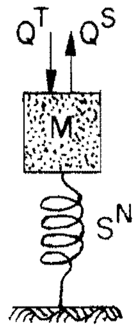
In this chapter seven example problems are solved by Program DBC5. Problems 1 and 2 each have two different cases and Problem 4 has three different cases. Problems 1 and 1A demonstrate the validity of the program in predicting the formation of hysteresis loops on the nonlinear resistance-deflection curve of the spring which supports a freely vibrating mass.

Problems 2-1 and 2-2 present a comparison between the numerical solutions solved by DBC5 and the theoretical solutions of vibrating beams illustrated in Ref 12, pages 375 and 378. Problem 3 demonstrates the capability to use the computed dynamic tire forces of a moving truck from another available computer program as input data in Program DBC5 to predict the dynamic responses of a highway structure. Problem 4 compares the experimental data with the computed results of a simply supported steel rod under axial pulses. Problem 5 demonstrates the capability to predict the response of off-shore piles to wave forces. The solution of a three-span beam (30 beam increments) which is simply supported at the ends and loaded by a transient pulse at station 17 is illustrated in Problem 6. Finally, Problem 7 demonstrates the capability to predict the response of a partially embedded pile to earthquake-induced forces. A listing of input data is included in Appendix G, and the sample computer output listing is included in Appendix H.

Example Problem 1. Inelastically Supported Mass Under Free Vibration

Figure 19 shows a mass of density 1.0 $lb\text{-}sec^2/in.$ supported by a nonlinearly inelastic spring; the mass is loaded by a static load of 100 pounds for the initial deflection and then released by applying a constant dynamic load of 100 pounds. The weight of the mass is neglected. The nonlinear characteristics of the resistance-deflection curve of the spring are also shown in Fig 19. Time increment length is equal to 6.283×10^{-3} second, which is approximately 1/100 of the natural period. The vibration of the mass is solved at 800 time stations. This first problem is intended to provide confidence in the proposed multi-element models to predict the loading paths of the nonlinear-inelastic

Problem 1



Mass density = 1.0 lb-sec^2/in

Q^S 100 lb

Q^T -100 lb/each time sta

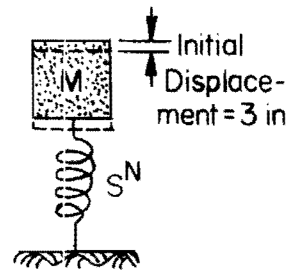
Number of beam increments = 1

Beam increment length = 1 inch

Number of time increments = 800

Time increment length = 6.283×10^{-3} seconds

Problem 1A



Nonlinearly-Inelastic Resistance-Deflection Curve of S^N

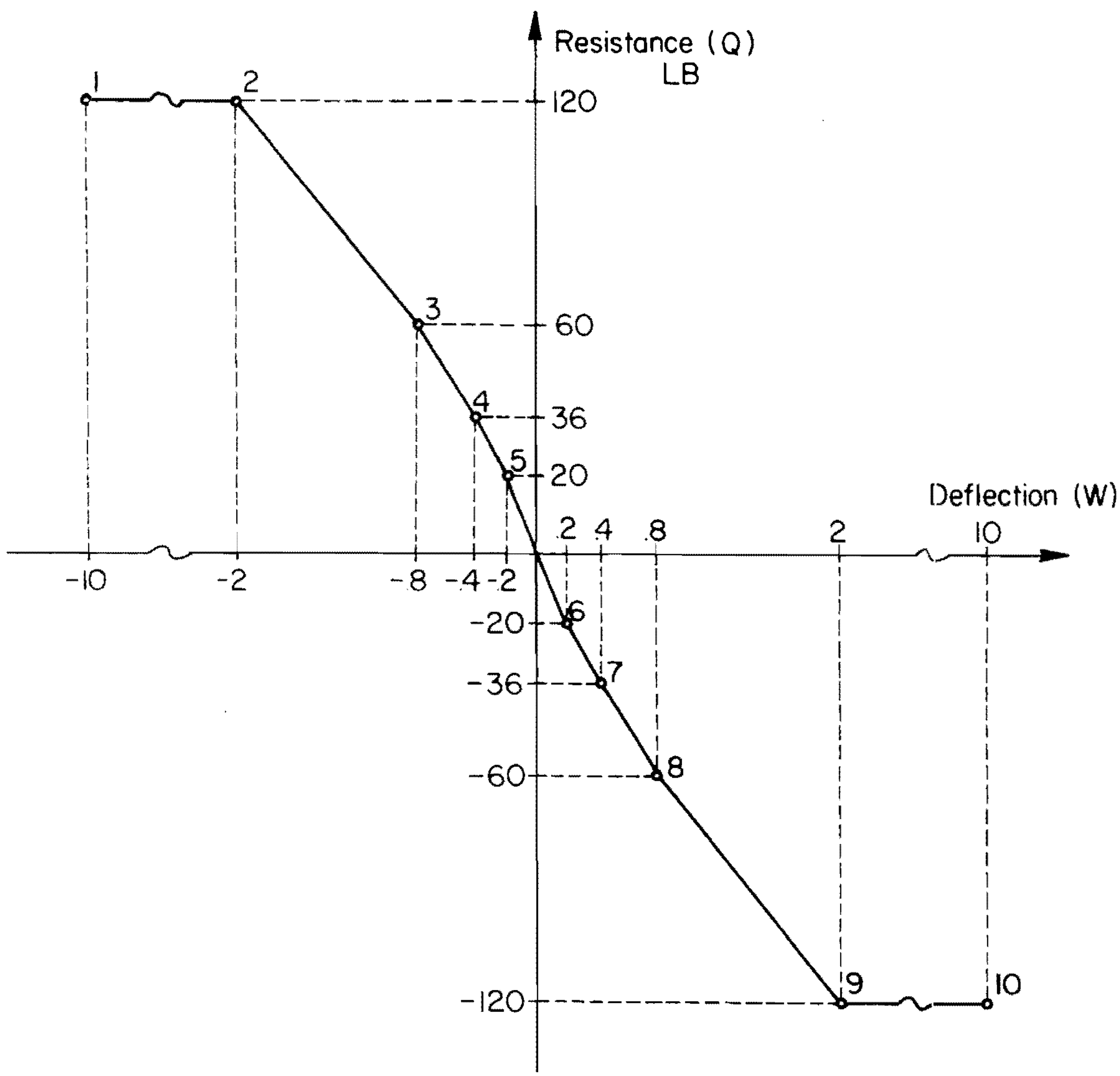


Fig 19. Example Problems 1 and 1A. Inelastically supported mass under free vibration.

support. From the computer output, a plot of deflections versus support reactions can be obtained, as shown in Fig 20.

It is seen that due to partial yielding of the support at the beginning, a hysteresis loop is formed in each cycle of vibration and mechanical energy is lost in each loop. The mechanical energy lost from point A to point J in Fig 20 is equal to the area defined by JKEFGHIJ, which is equivalent to the difference between the summation of the areas defined by ALDCBA and DEFPD and the summation of the areas defined by FPNHGF and JMNIJ. Therefore, the deflections are damping out with time until the response finally becomes a free elastic vibration within the range of greatest stiffness. This can be proved from the tabular output of the program when large time increment lengths (6.283×10^{-2} second) are used. The computer plot of deflections versus time is shown in Fig 21.

Example Problem 1A. Free Vibration of Mass by Specifying Initial Displacements

An additional run on the preceding problem was made by specifying an initial displacement of 3 inches instead of applying a static load for the initial deflection. From the plot of support reactions versus deflections (Fig 22), it is seen that a permanent set is obtained because of initial yielding of the support. The mass is finally freely vibrated at a position about a mean permanent upward deflection of approximately 1 inch. This can be shown in the computer plot of deflections versus time in Fig 23.

Example Problem 2-1. Lateral Vibration of a Simply Supported Beam with Axial Compression Force

Figure 24 shows a simply supported beam which is compressed with an axial force of 3.70×10^{5} pounds and placed under free vibration by specifying an initially deflected sine curve for which the maximum deflection at the center is 3.952 inches. The beam is 120 inches long and has a uniform flexural stiffness of 1.08×10^{9} lb-in^{2}. The beam is divided into 10 elements, each is 12 inches long. The mass density of the beam is 1.085×10^{-1} lb-sec^{2}/in./sta. The number of time increments is 200, and the time increment length is 3.752×10^{-4} seconds. The theoretical natural period of the vibration is 3.752×10^{-2} seconds (Ref 9, p 375).

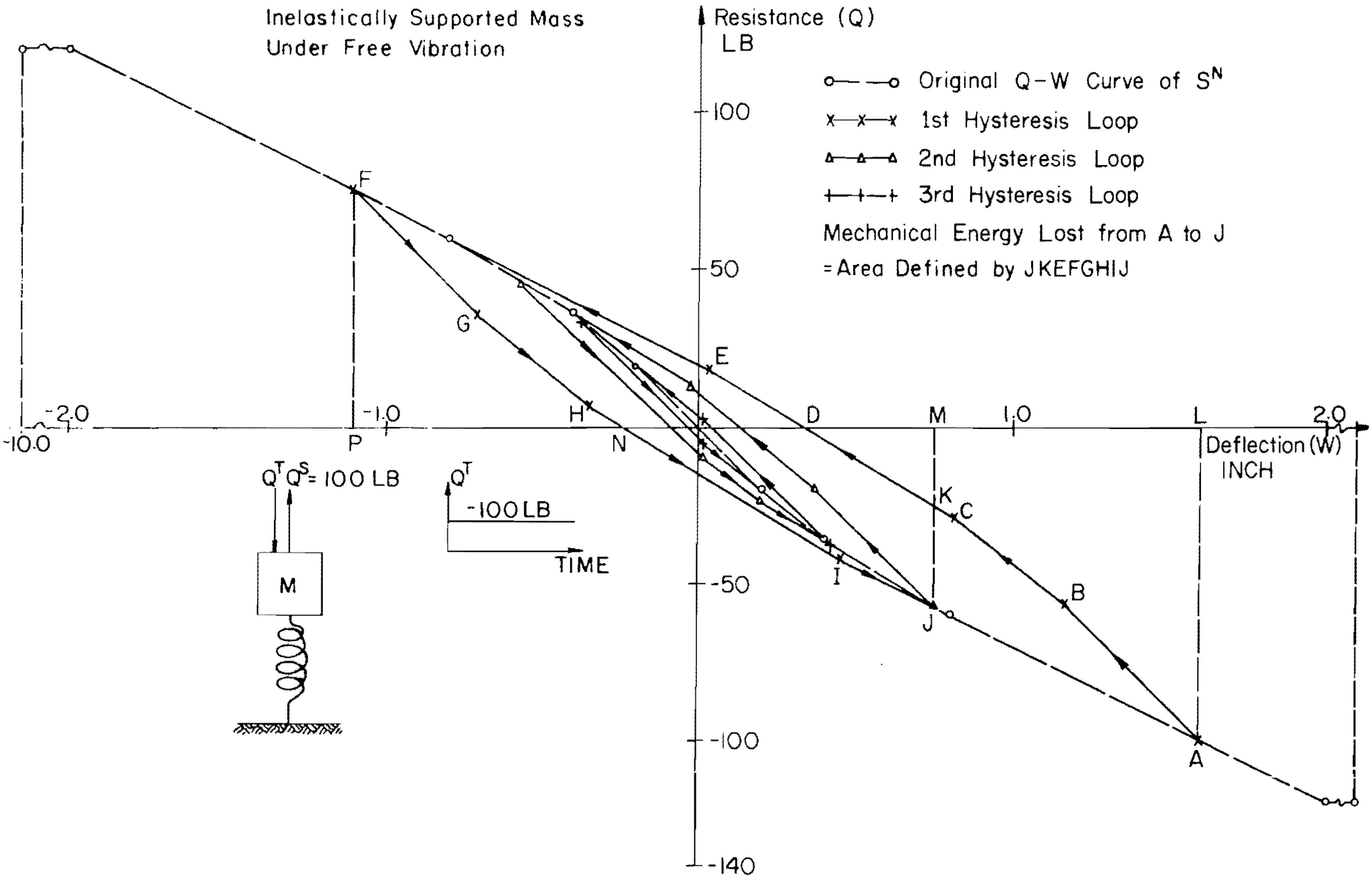


Fig 20. Hysteresis loops of computed resistance-deflection curve of Example Problem 1.

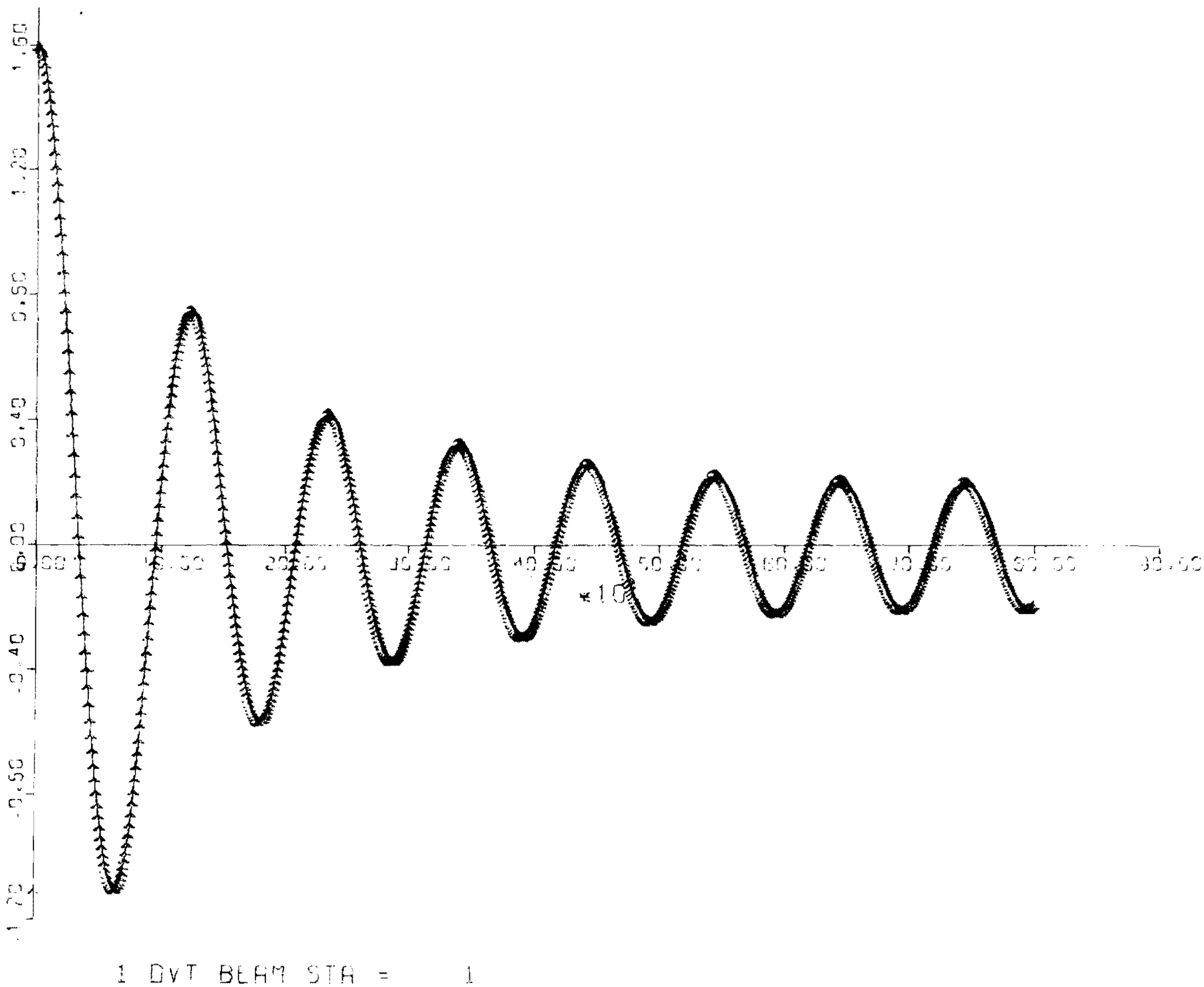


Fig 21. Example Problem 1. Response of the nonlinearly supported mass.

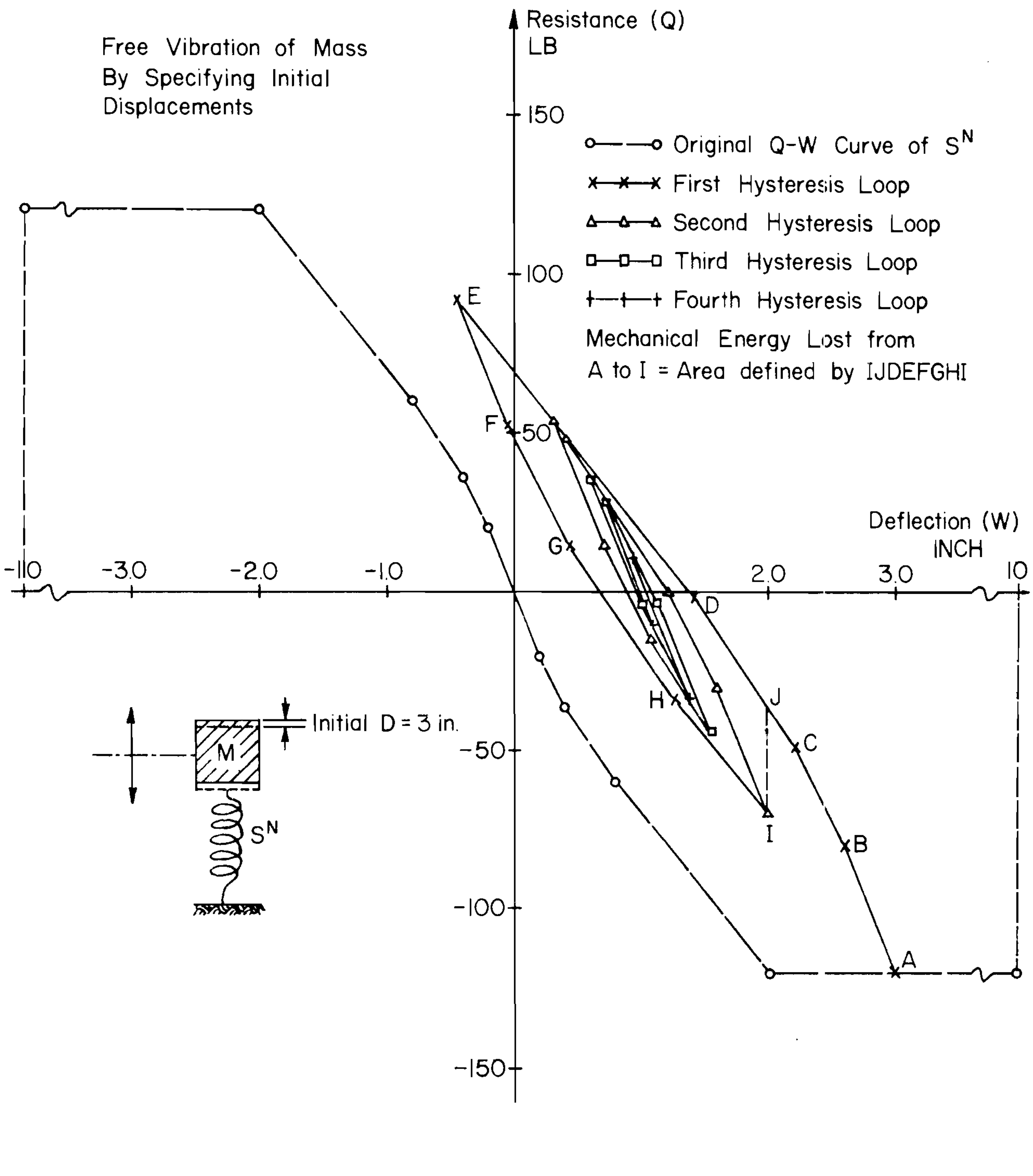


Fig 22. Hysteresis loops of computed resistance-deflection curves of Example Problem 1A.

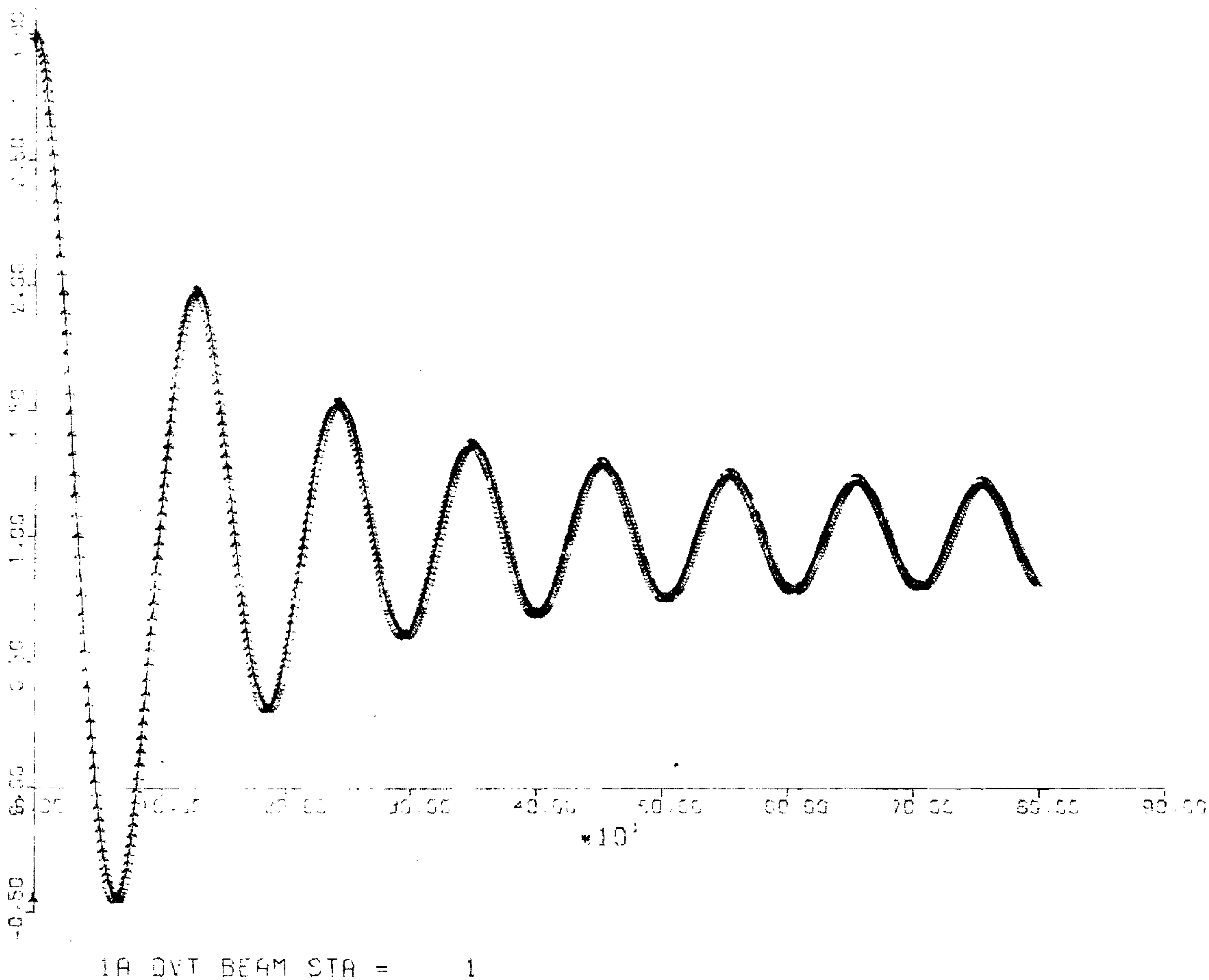
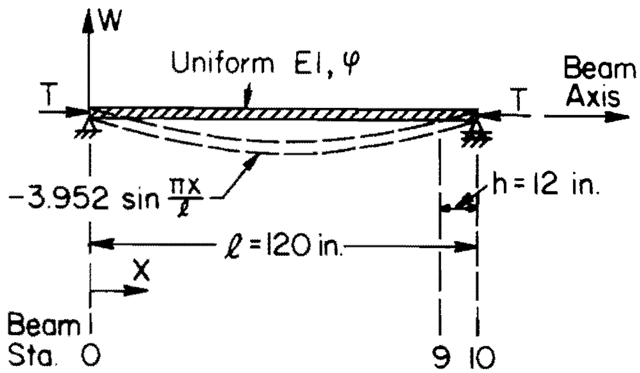


Fig 23. Example Problem 1A. Response of the nonlinearly supported mass.



EI 1.08×10^{9} lb-in^{2}

Mass density 1.085×10^{-1} lb-sec^{2}/in/sta

T = -3.70×10^{5} lb

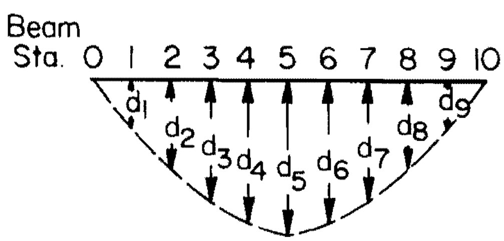
Number of beam increments = 10

Beam increment length = 12 inches

Number of time increments = 200

Time increment length = 3.752×10^{-4} seconds

Initially Deflection Sine Curve



$d_1 = d_9 = -3.952 \times \sin 18^{\circ}$ -1.221 inches

$d_2 = d_8 = -3.952 \times \sin 36^{\circ} = -2.323$ inches

$d_3 = d_7 = -3.952 \times \sin 54^{\circ} = -3.197$ inches

d_4 $d_6 = -3.952 \times \sin 72^{\circ} = -3.759$ inches

d_5 $-3.952 \times \sin 90^{\circ} = -3.952$ inches

Fig 24. Example Problem 2-1. Lateral vibration of a simple supported beam with axial compression force.

The theoretical responses (Eq d, p 375, Ref 12) and the computed responses based on a time increment length of 3.752×10^{-3} seconds (1/10 of the natural period) are plotted for the center of the beam on the computer plot of deflections versus time for beam station 5, as shown in Fig 25. The responses of the small time increment length (1/100 of the natural period) are almost perfectly matched with the theoretical responses. The responses of the large time increment length (1/10 of the natural period) show more variation when compared to the theoretical responses in the first period, and after the first period are shifted with a phase angle. The more increments, however, the beam is divided into, the better the results. The computed moments, based on both small and large time increment lengths along the time axis for the center of the beam, are shown in Fig 26.

Example Problem 2-2. Lateral Vibration of a Beam on Elastic Foundation

Figure 27 shows the beam in Problem 2-1 resting on an elastic foundation which has a spring constant of 1.2×10^{4} lb/in./sta. The beam is under free vibration with an initially deflected shape of sine curve, in which the maximum deflection at the center is 6.672 inches. The number of time increments is 200, and the time increment length is 1.540×10^{-4} seconds. The theoretical natural period is 1.540×10^{-2} seconds (Ref 12, p 378).

The comparisons between the computed responses, based on both small and large time increment lengths, and the theoretical responses (Eq c, p 378, Ref 12) for the center of the beam are shown in Fig 28. The difference between the computed responses of the small time increment length (1/100 of the natural period) and the theoretical responses is slight. The computed moments, based on both small and large time increment lengths, along the time axis are shown in Fig 29.

Example Problem 3. Three-Span Beam Loaded with an AASHO Standard 2-D Truck Moving at a Speed of 60 MPH

This problem demonstrates the capability to input the dynamic tire forces interpreted from the computer output of the program described in Ref 1 into Table 7 of Program DBC5 to predict the responses of a three-span beam; the beam is loaded with an AASHO standard 2-D truck which is moving at a uniform speed of 60 mph, as shown in Fig 30.

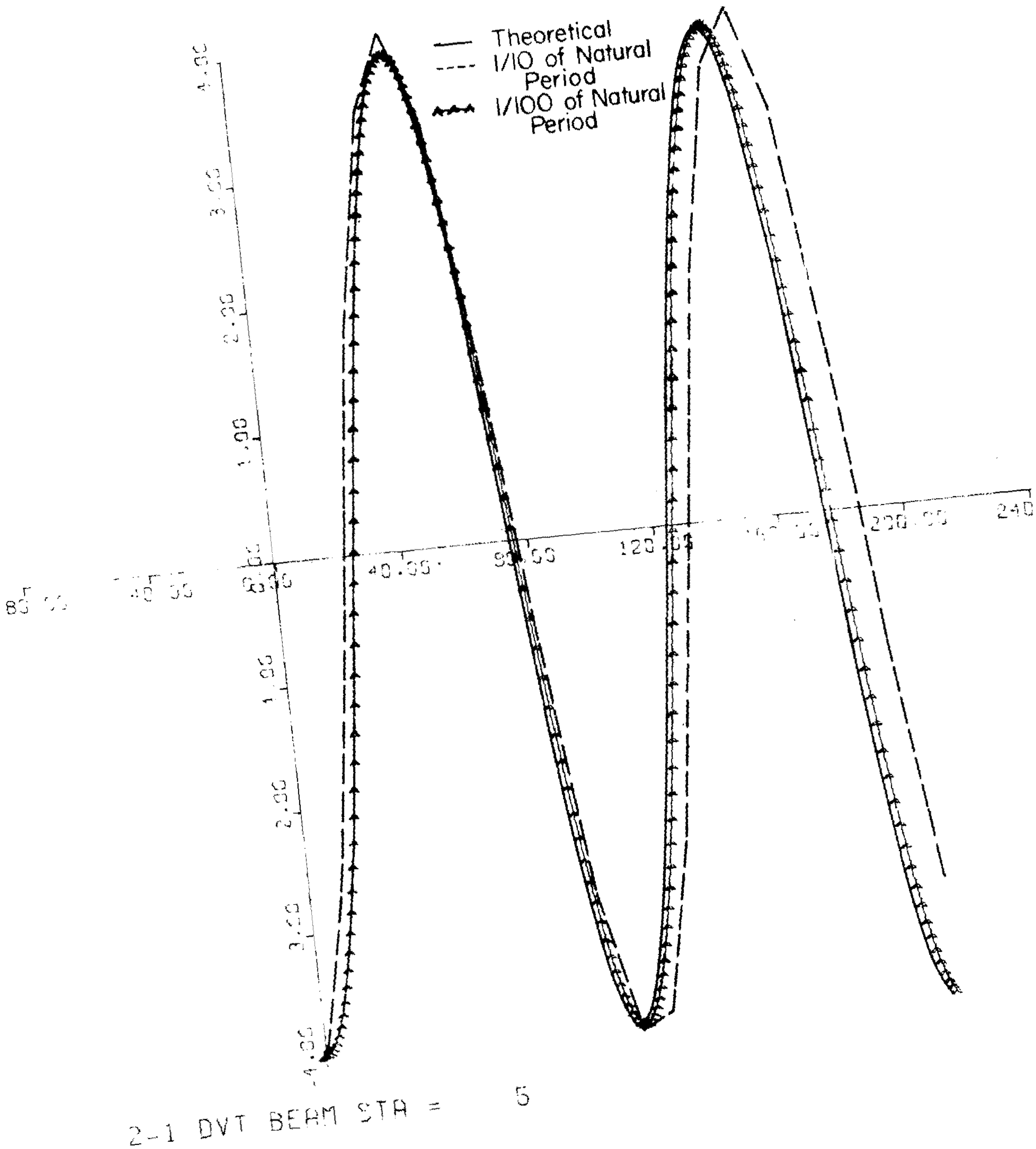


Fig 25. Example Problem 2-1. Deflection vs time for the center of beam.

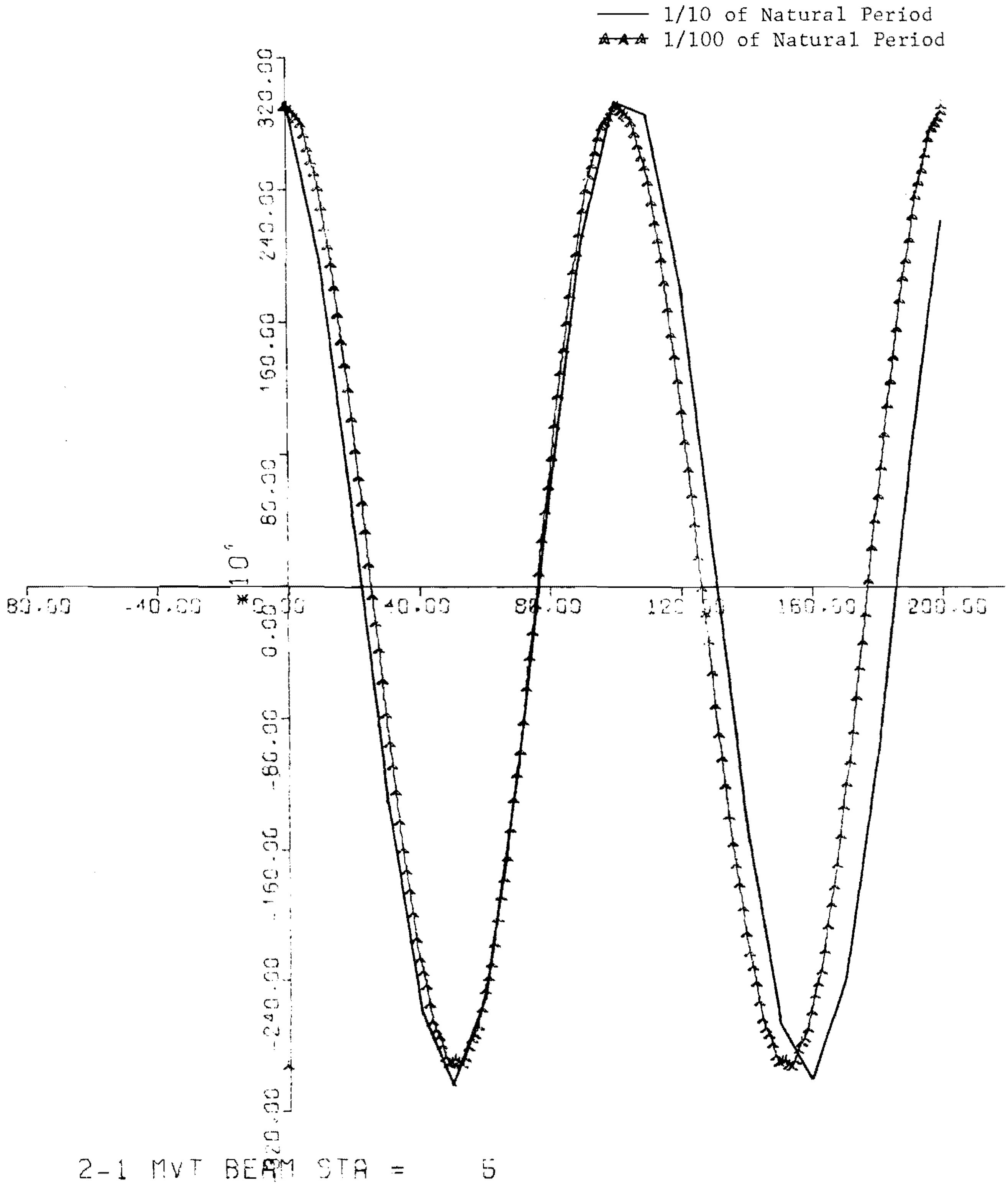
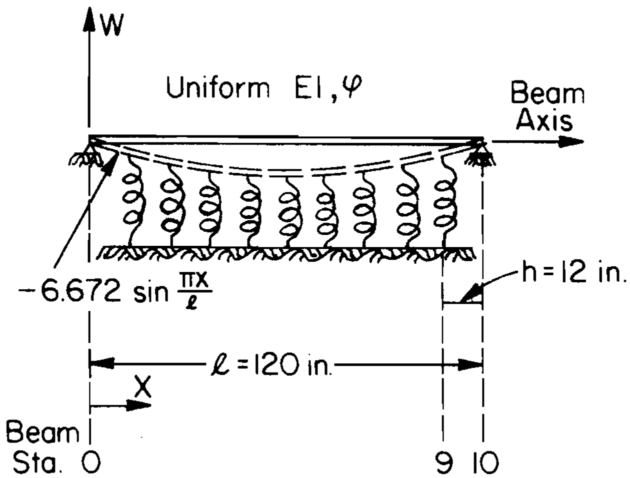


Fig 26. Example Problem 2-1. Moment vs time for the center of beam.



EI = 1.08×10^9 lb-in^2

Mass density 1.085×10^{-1} lb-sec^2/in/sta

Elastic spring constant 1.2×10^4 lb/in/sta

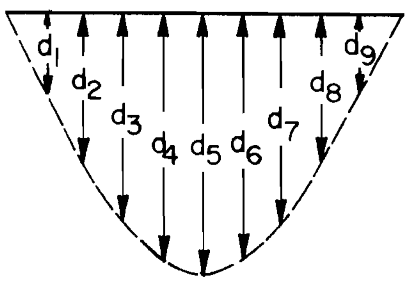
Number of beam increments = 10

Beam increment length = 12 inches

Number of time increments = 200

Time increment length = 1.540×10^{-4} seconds

Initially Deflected Sine Curve



$d_1 = d_9 = -6.672 \times \sin 18^\circ = -2.061$ inches

$d_2 = d_8 = -6.672 \times \sin 36^\circ = -3.922$ inches

$d_3 = d_7 = -6.672 \times \sin 54^\circ = -5.398$ inches

$d_4 = d_6 = -6.672 \times \sin 72^\circ = -6.345$ inches

$d_5 = -6.672 \times \sin 90^\circ = -6.672$ inches

Fig 27. Example Problem 2-2. Lateral vibration of a beam on elastic foundation.

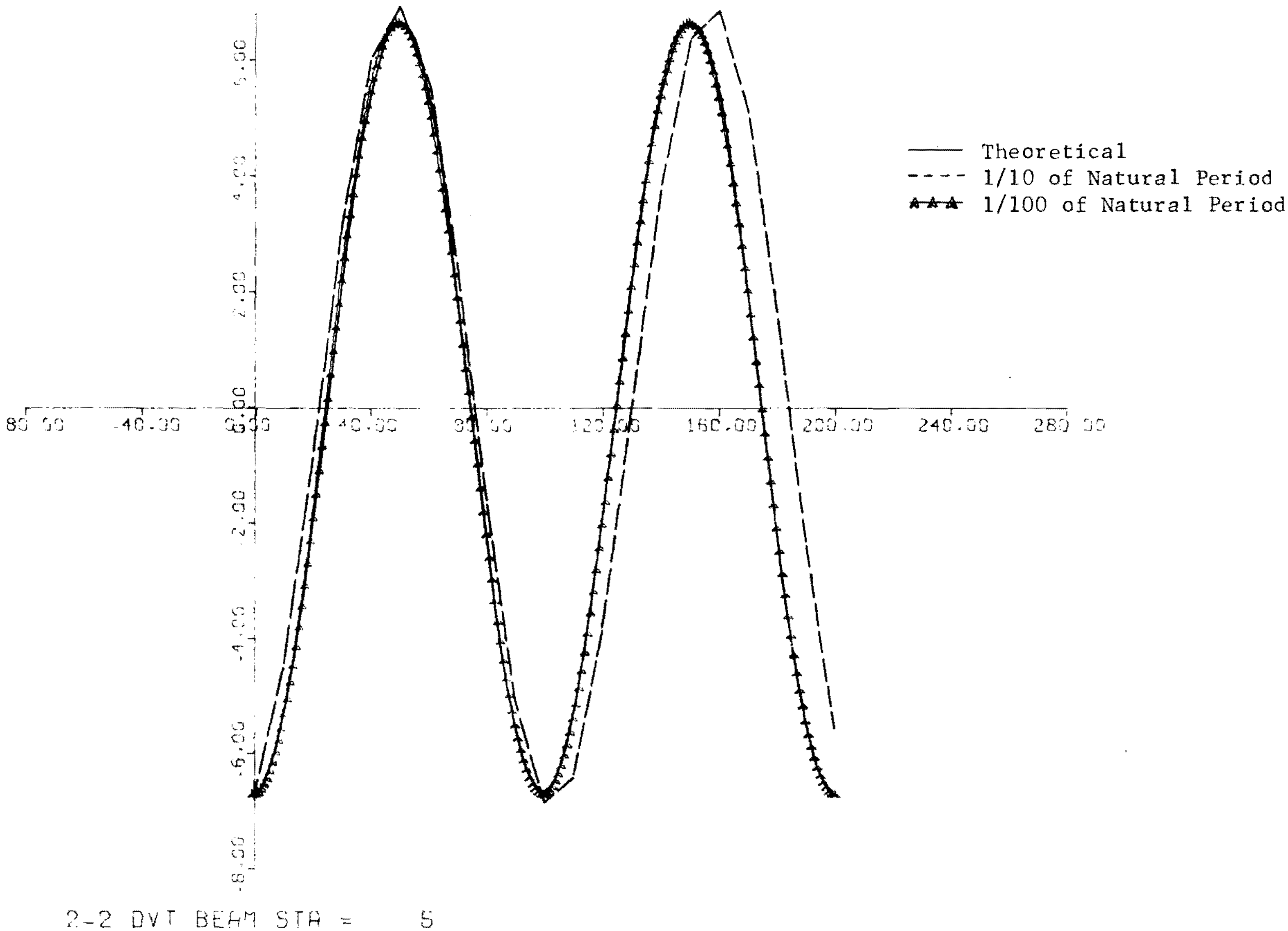


Fig 28. Example Problem 2-2. Deflection vs time for the center of beam.

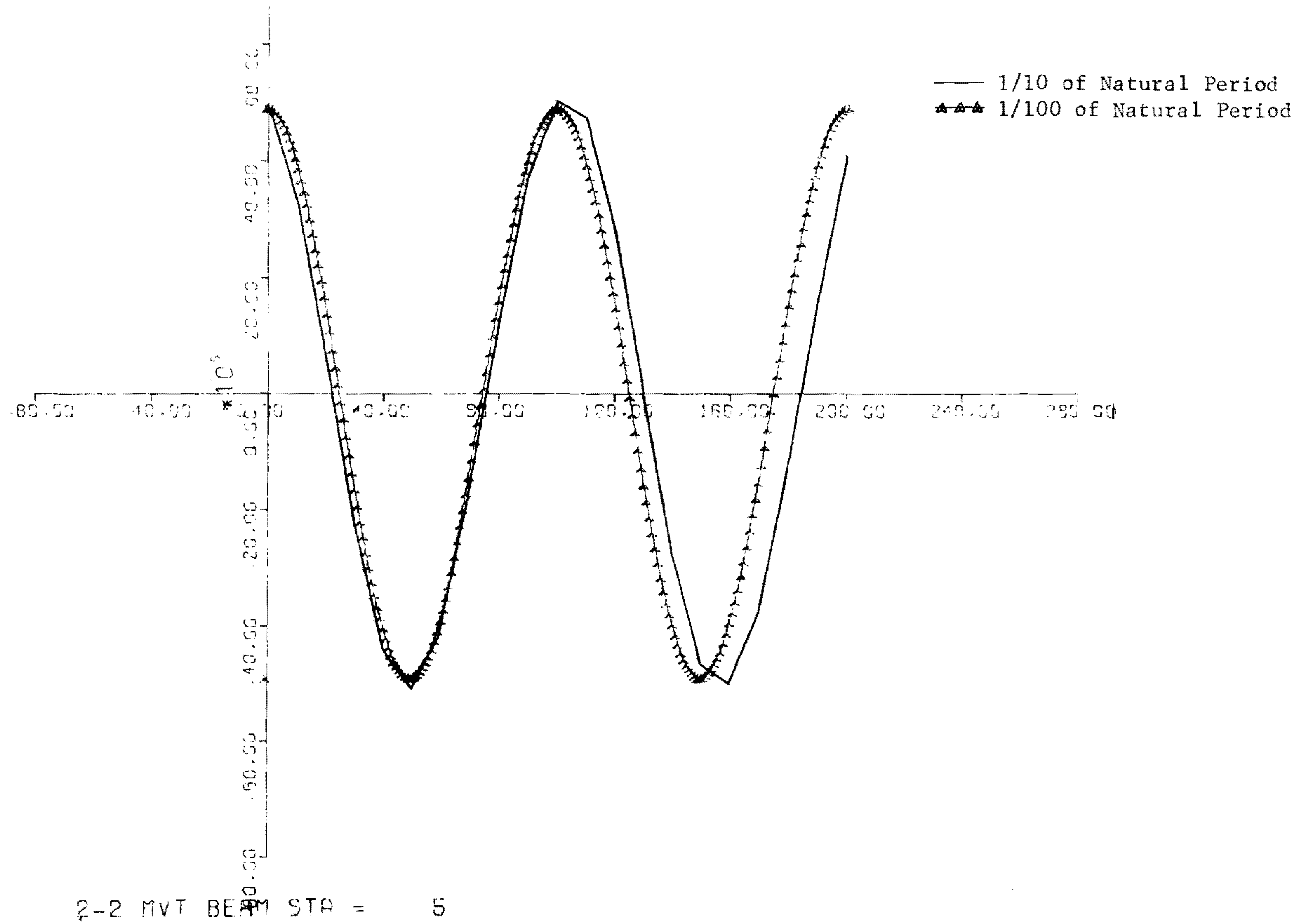
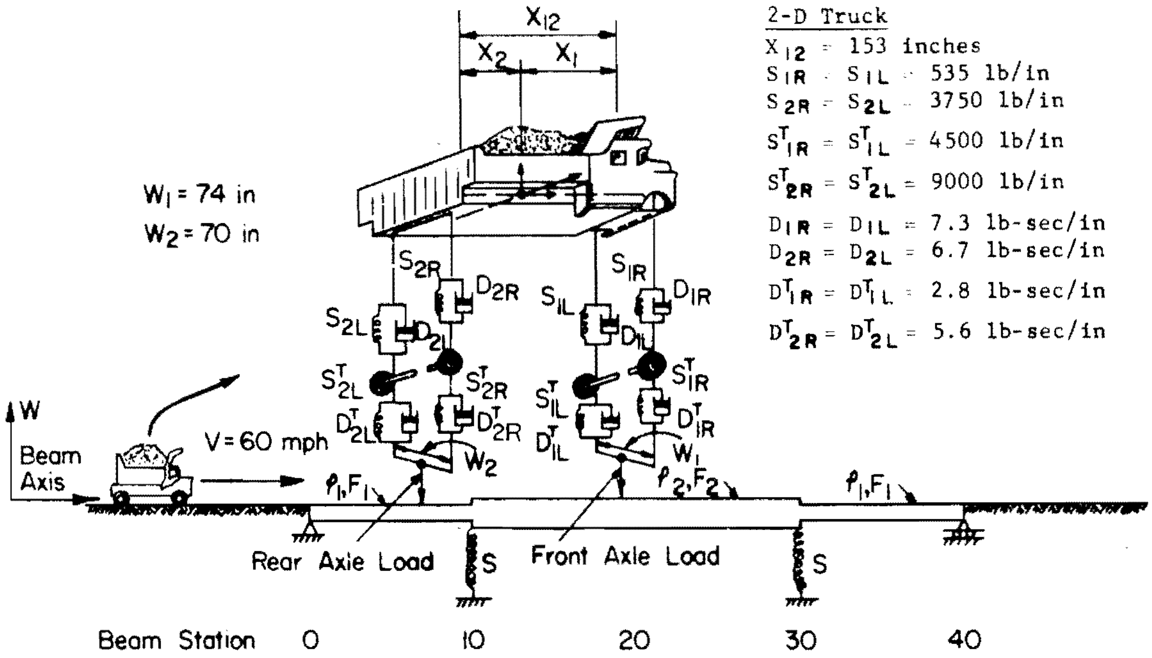


Fig 29. Example Problem 2-2. Moment vs time for the center of beam.



Static Weights of Wheels

Axle 1 right	3139 lb
Axle 1 left	3012 lb
Axle 2 right	7780 lb
Axle 2 left	7103 lb

Static Loads of Axles

Front	3075 lb
Rear	7441 lb

Dynamic Forces of the Front and Rear Axles

Beam Properties

F_1 = 4.5 x 10 in. lb-in
F_2 = 9.0 x 10 in lb-in
S = 2.0 x 10 lb/in
ρ_1 = 0.5964 lb-sec /in/sta
ρ_2 = 0.2982 lb-sec /in/sta
Beam increment length = 60 inches
Time increment length = 5.666 x 10^{-2} sec

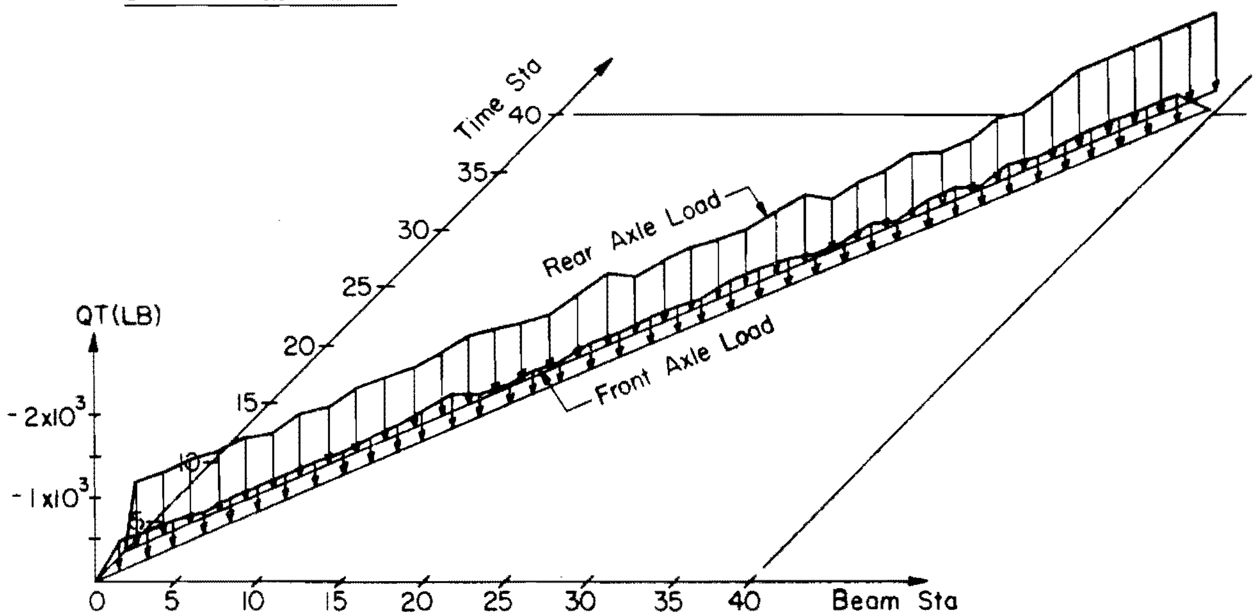


Fig 30. Example Problem 3. Three-span beam loaded by an AASHO standard 2-D truck moving at a speed of 60 mph.

The beam is simply supported at the ends and has a length of 200 feet. The beam is divided into 40 increments, each of which is 60 inches long. The two linear springs are located at beam stations 10 and 30 and have a value of 2×10^5 lb/in. The first and third spans of the beam have a uniform flexural stiffness of 4.5×10^{11} lb-in.^{2} and a uniform mass density of 0.5964 lb-sec^2/in./sta. The second span of the beam has a uniform flexural stiffness of 9.0×10^{11} lb-in.^{2} and a uniform mass density of 0.2982 lb-sec^2/in./sta. The computer model used in Ref 1 for simulating the AASHO standard 2-D truck is shown in Fig 30. The input data for the springs and dashpots which simulate the tires of the truck and the static weights of the wheels are also shown in Fig 30. The computed dynamic forces of the four tires are averaged to give the two axle forces which then are input into Table 7 of Program DBC5. The distribution of these two axle forces on both the beam and time axes is shown in Fig 30. The time axis is divided into 80 increments, each of which has a length of 5.666×10^{-2} seconds so that the front axle will move one beam increment length per time station.

The computed deflections and moments along the time axis for the center of the beam are plotted by the program as shown in Figs 31 and 32, respectively. The plots are produced on microfilm which then can be enlarged.

A comparison of the dynamic response to the static response of the deflections along the beam axis is shown in Fig 33. This static response of the plot in Fig 33 is computed by specifying the static load of the front axle at beam station 21 and the static load of the rear axle at the center of the bar, between beam stations 18 and 10; the dynamic response of the plot, therefore, is the computed deflection along the beam axis for time station 21. The dynamic effect on the responses of the beam produced by a moving 2-D truck is fairly small compared to the static responses produced by the same truck. This is because the dynamic forces generated by the 2-D truck, which is moving on a smooth pavement, are smoothly varied with time, and therefore there are small dynamic effects. Any other AASHO standard truck or semi-trailer can be used in the program described in Ref 1 to generate the corresponding dynamic tire forces, which then can be input with a limited amount of interpretation into Table 7 of Program DBC5 to predict the dynamic responses of highway structures that can be simulated by beam-columns.

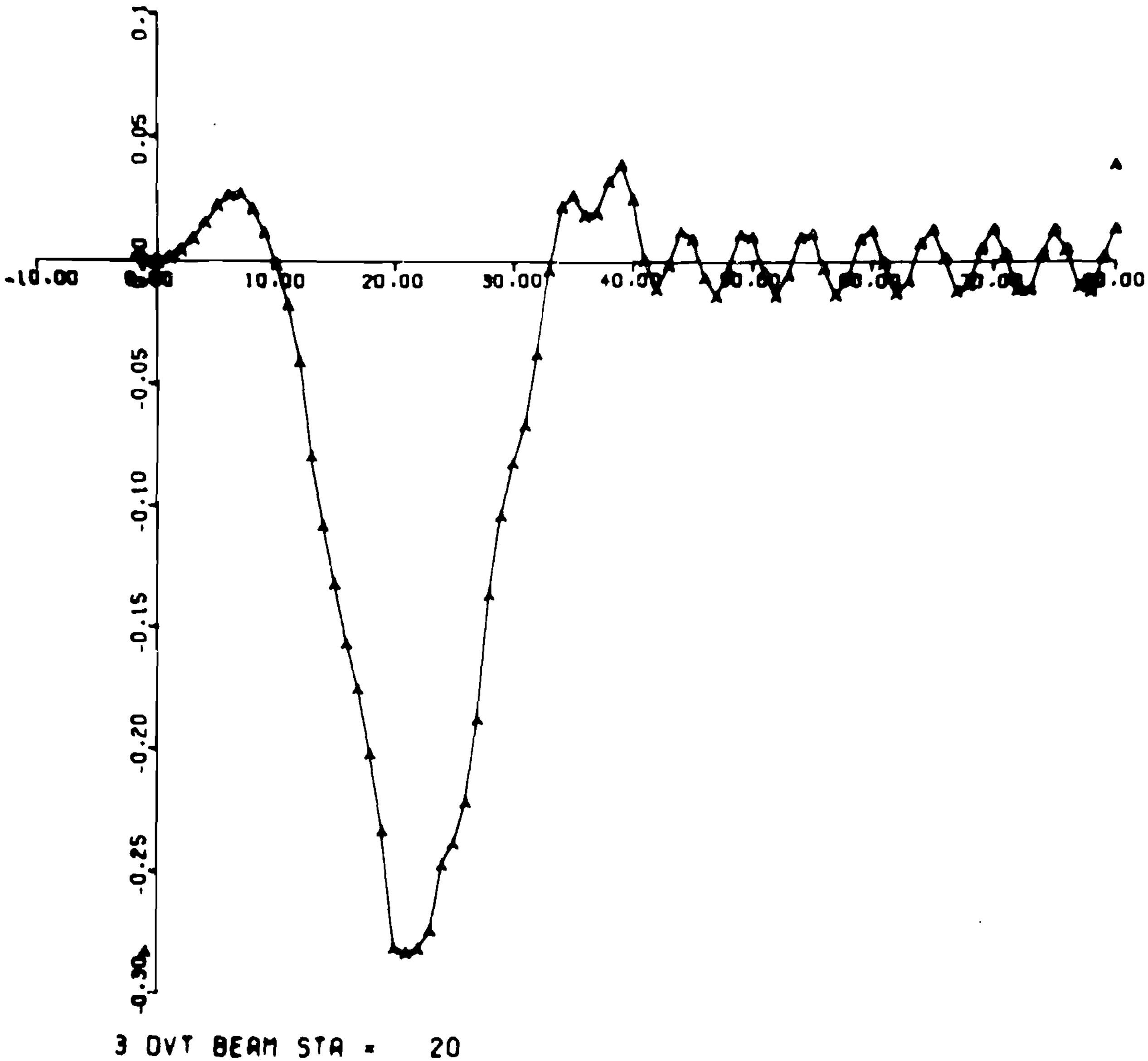


Fig 31. Example Problem 3. Deflection vs time for the center of beam.

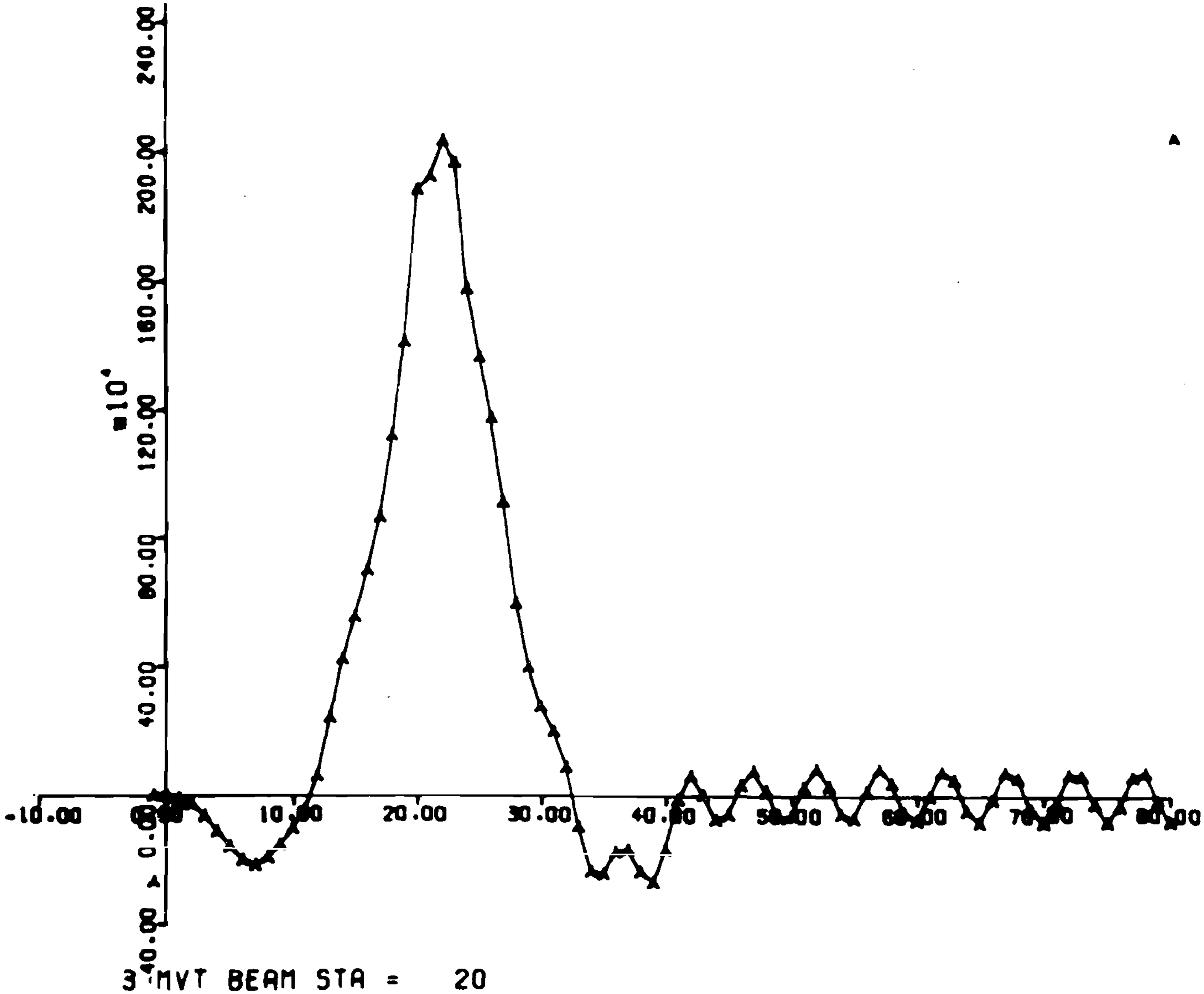


Fig 32. Example Problem 3. Moment vs time for the center of beam.

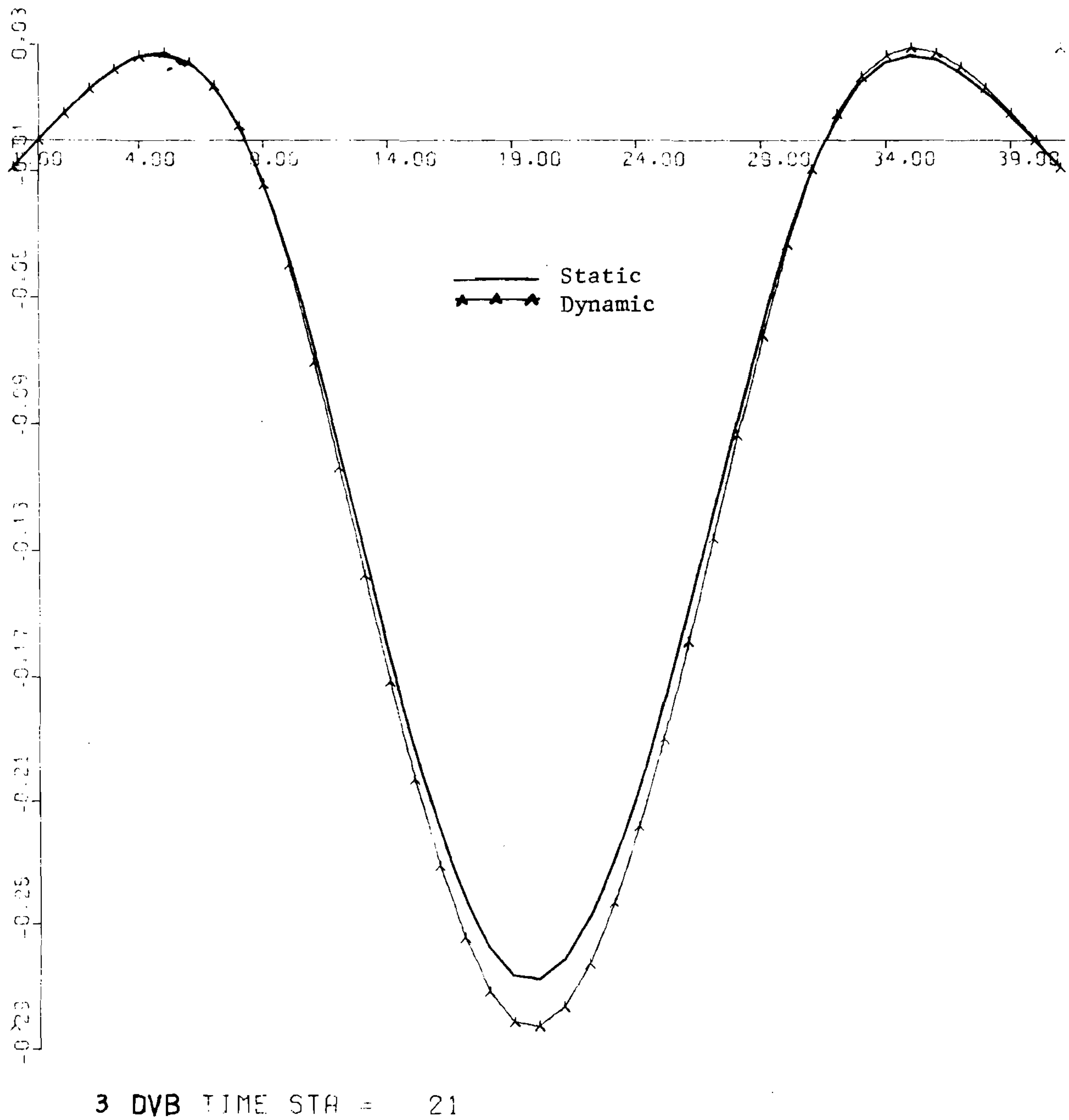


Fig 33. Example Problem 3. Comparison of dynamic to static response (deflection along the beam axis).

<u>Example Problem 4-1. Simply Supported Steel Rod - Axial Pulse Base Time = 0.10 Second</u>

In the following three problems, a simply supported steel rod is loaded by three axial pulses with different peak loads and base time, as shown in Fig 34. The problem is a real experiment which was done by Matlock and Vora (Ref 7). The steel rod is 153.75 inches long and 11/16 of an inch in diameter. The steel rod is divided into 41 increments, each of which has a length of 3.75 inches. The mass density of the rod is 1.023×10^{-3} $\text{lb-sec}^2\text{/in./sta.}$ The static weight of the rod is 3.95×10^{-1} lb/sta. An internal damping factor of 20 $\text{lb-in.}^2\text{-sec}$ is input at each station.

The first axial pulse input for this problem has a peak value of 175 pounds and a base time of 0.10 seconds. The axial pulse was recorded on the oscilloscope in the experiment by Matlock and Vora described in Ref 7. The true axial pulse is described at 20 points by scaling from the recorded output of strain gages, which then can be input in Table 6 of Program DBC5. The time increment length is set equal to 5×10^{-3} seconds and 40 time stations are solved for this problem.

Figure 35 shows the comparison of the computed bending moments along the time axis to the measured bending moments in the experiment for the center station of the steel rod. It is seen that good agreement exists between the predicted results and the measured results before 0.9 second, while the measured bending moments are smaller than the predicted bending moments after 0.9 second. This deviation is mainly due to the assumption that the beam properties are fully elastic in the dynamic model of Program DBC5. Other factors, such as the errors obtained by scaling from the recorded output, the difficulty in establishing the ideal hinged supports, and failure to consider the axial deformation of the rod, also affect the accuracy of the predicted results.

An additional curve of the bending moment along the time axis for the center of the rod, which is computed without inputting the internal damping factor, is also plotted on Fig 35. Little is changed by ignoring the effect of the internal damping factor, since the change of the curvature at this point is very smooth along the time axis. The computed deflections along the time axis for the center station of the steel rod are plotted by the program, as shown in Fig 36.

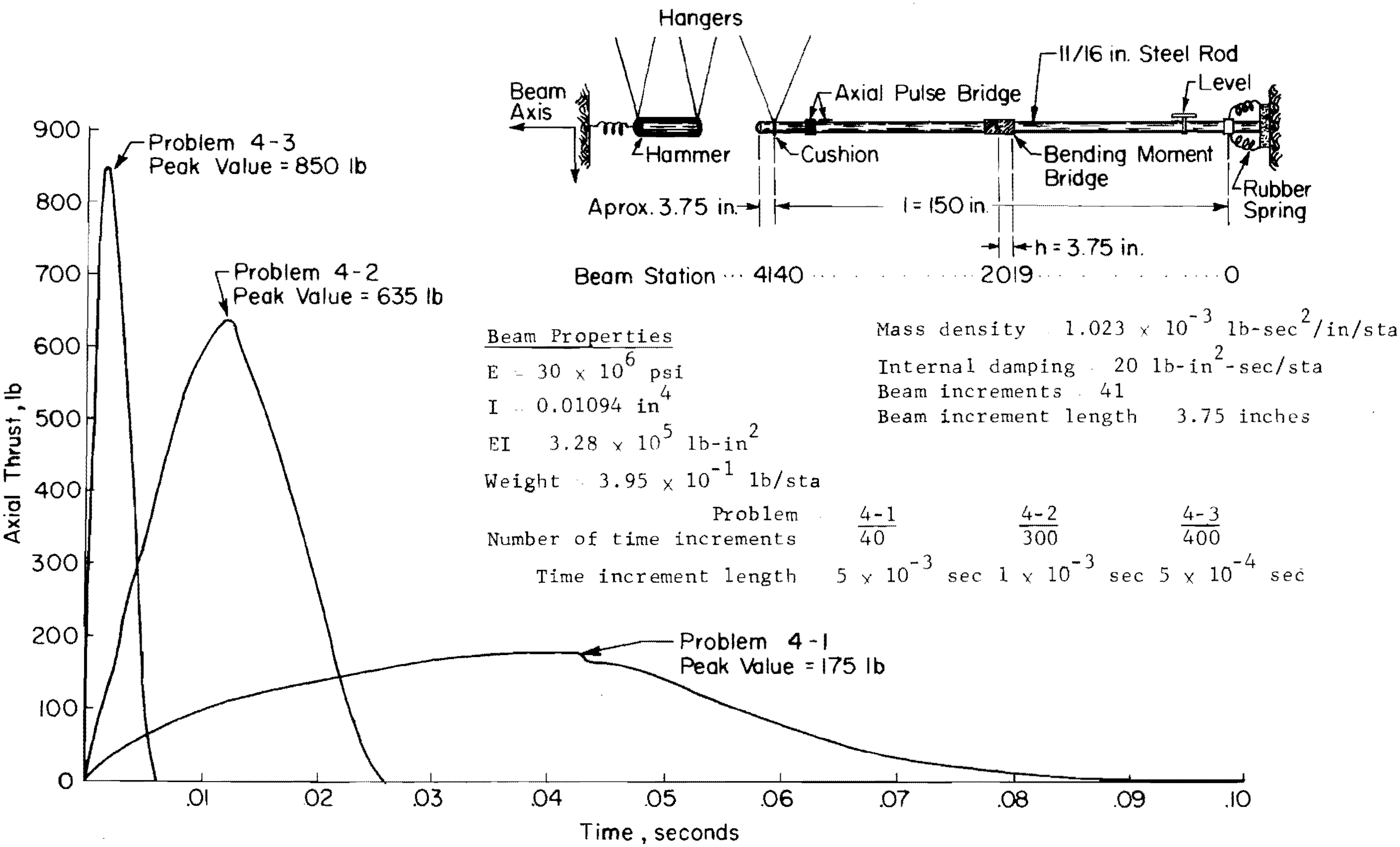


Fig 34. Example Problems 4-1, 4-2, and 4-3. Simply supported steel rod loaded by axial pulses.

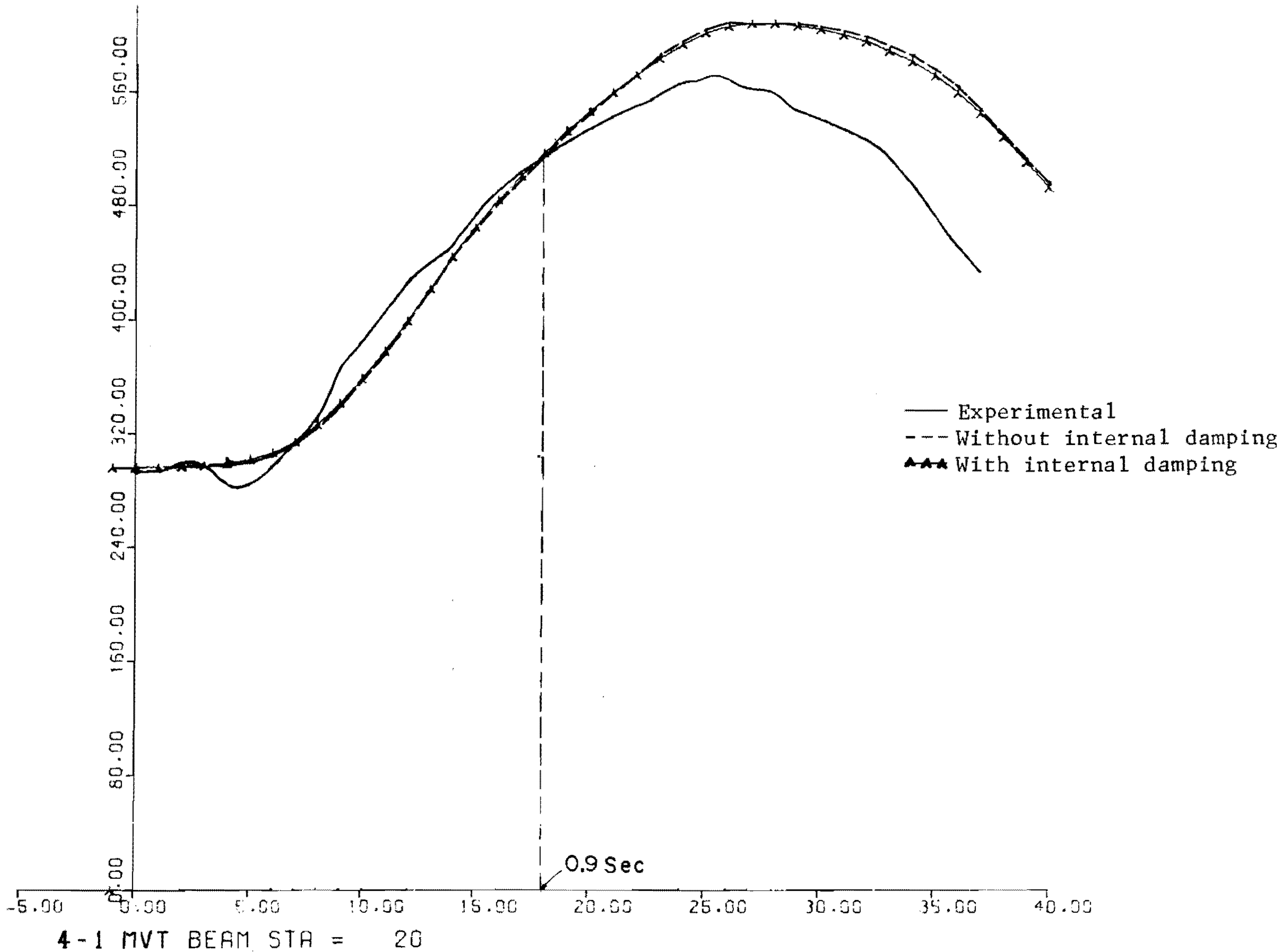


Fig 35. Example Problem 4-1. Comparison of moments vs time for the center of beam.

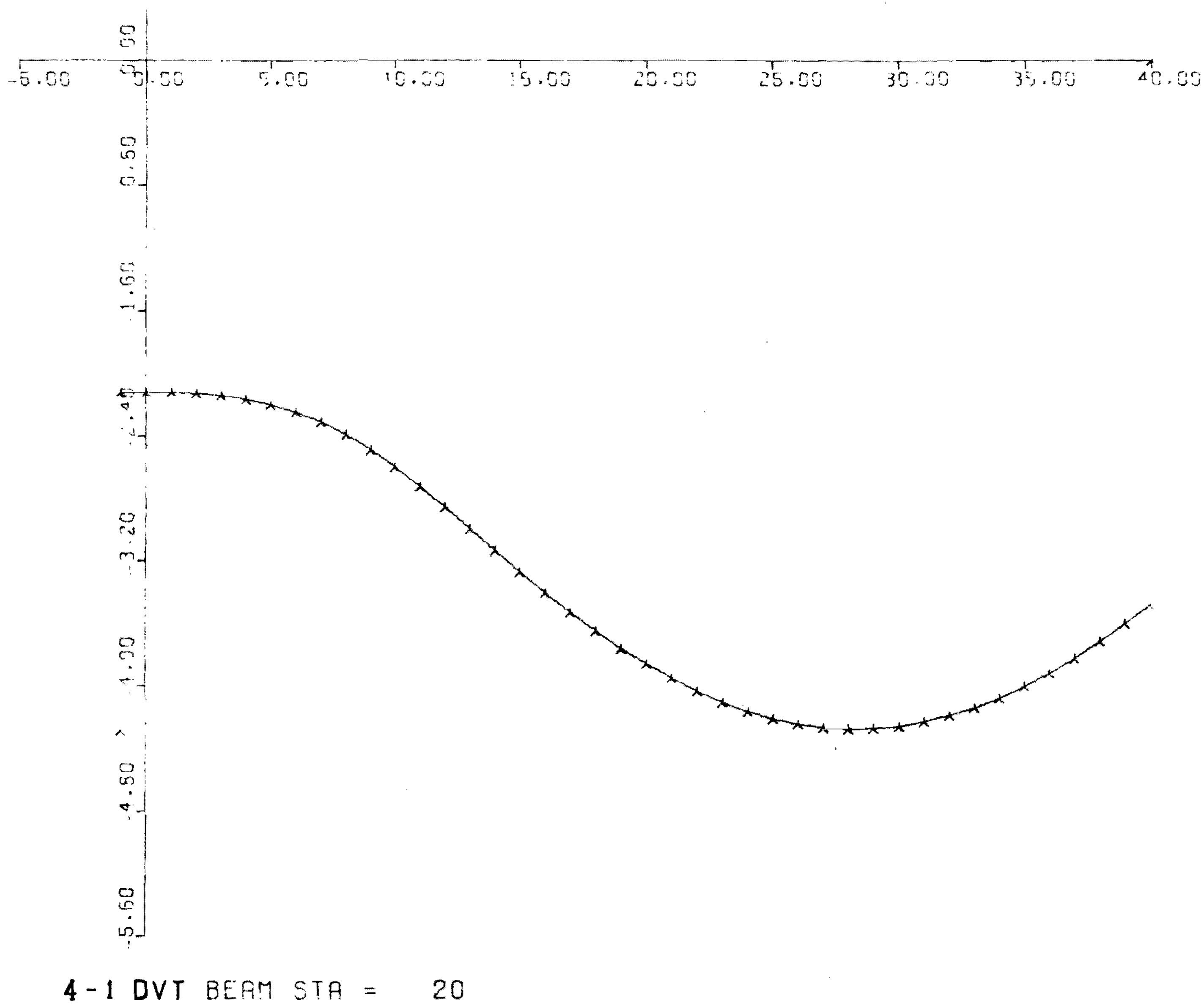


Fig 36. Example Problem 4-1. Deflection vs time for the center of beam.

Example Problem 4-2. Simply Supported Steel Rod - Axial Pulse Base Time = 0.026 Second

In this problem, the steel rod in the preceding problem is loaded by another pulse with a shorter base time but larger peak value. The base time of the pulse is 0.026 second and the peak value of the pulse is increased to approximately 635 pounds. The axial pulse is described at 26 points by scaling from the recorded output of the experiment.

The computed bending moments along the time axis, with and without internal damping effect, and the measured bending moments are plotted for comparison, as shown in Fig 37. Results similar to those for the preceding problem are observed, but the effect of the internal damping factor is a little greater than in the preceding problem. Figure 38 shows the computed deflections along the time axis for the center station of the steel rod.

Example Problem 4-3. Simply Supported Steel Rod - Axial Pulse Base Time = 0.006 Second

In this problem the loaded axial pulse has a base time of 0.006 seconds and a peak value of 850 pounds. Again the computed bending moments along the time axis, with and without internal damping factor, and the measured bending moments are plotted as shown in Fig 39. Because of the higher frequency of vibrations, the mode shapes of the beam vary rapidly with time and cause large variation of curvature; therefore, the effect of the internal damping factor is much greater than in the preceding two cases. The estimated value of 20 lb-in.^{2} sec/sta input for the internal damping factor is higher than the real value. Figure 40 shows the computed deflections along the time axis for the center station of the steel rod.

Example Problem 5. Partially Embedded Steel Pipe Pile Loaded by Wave Forces

This problem shows how DBC5 can be used to solve the dynamic response of laterally loaded piles to wave forces. Figure 41 presents a steel pipe of 30-inch outside diameter and 28-inch inside diameter which is partially embedded in the soil to a depth of 80 feet and extends slightly above the surface of the water which is 40 feet deep. The steel pipe is divided into 31 increments, each of which has a length of 48 inches. The flexural stiffness of the pipe is 2.877 x 10 inch lb-in.^{2}. The mass density of the pipe is 3.21

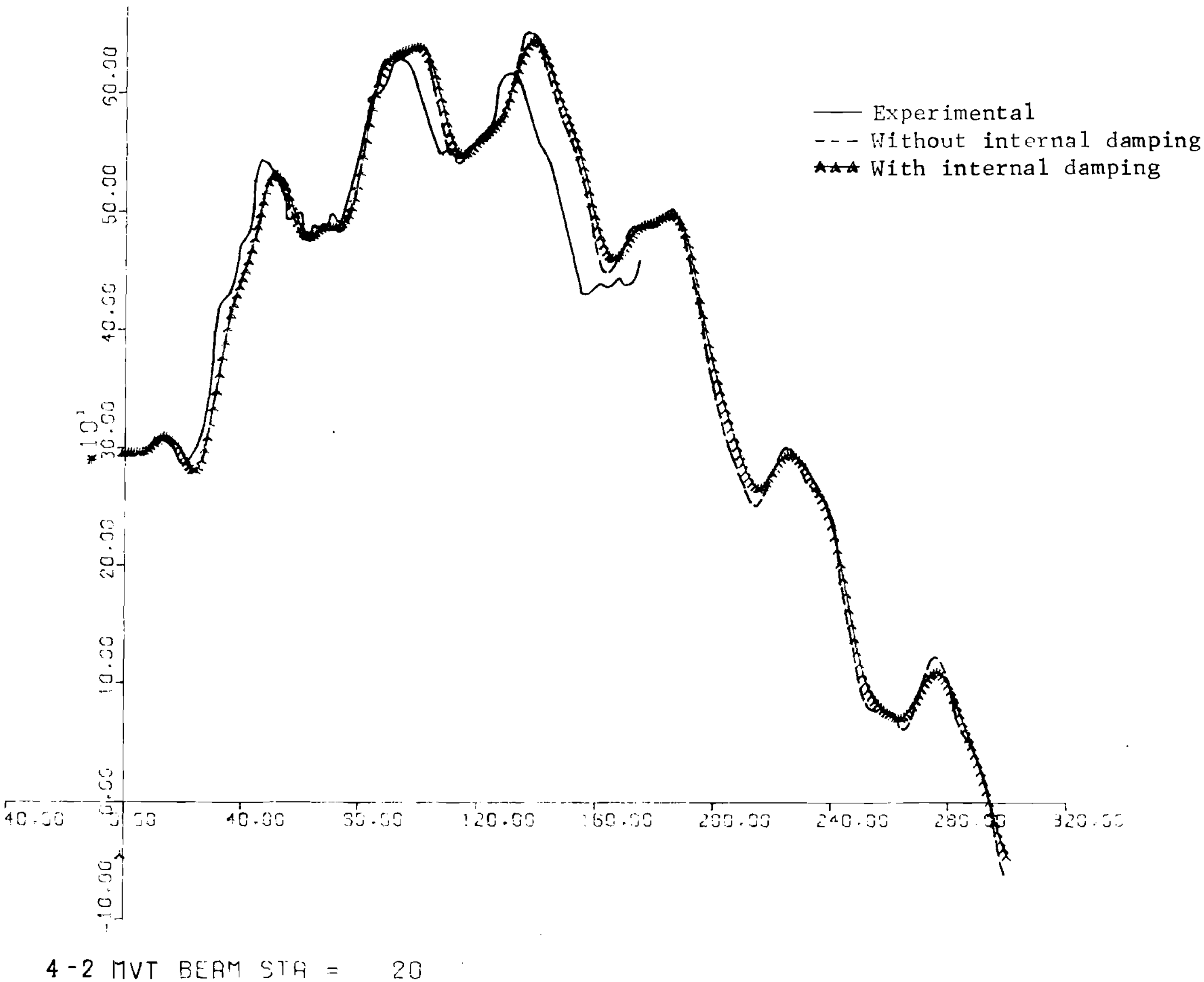


Fig 37. Example Problem 4-2. Comparison of moments vs time for the center of beam.

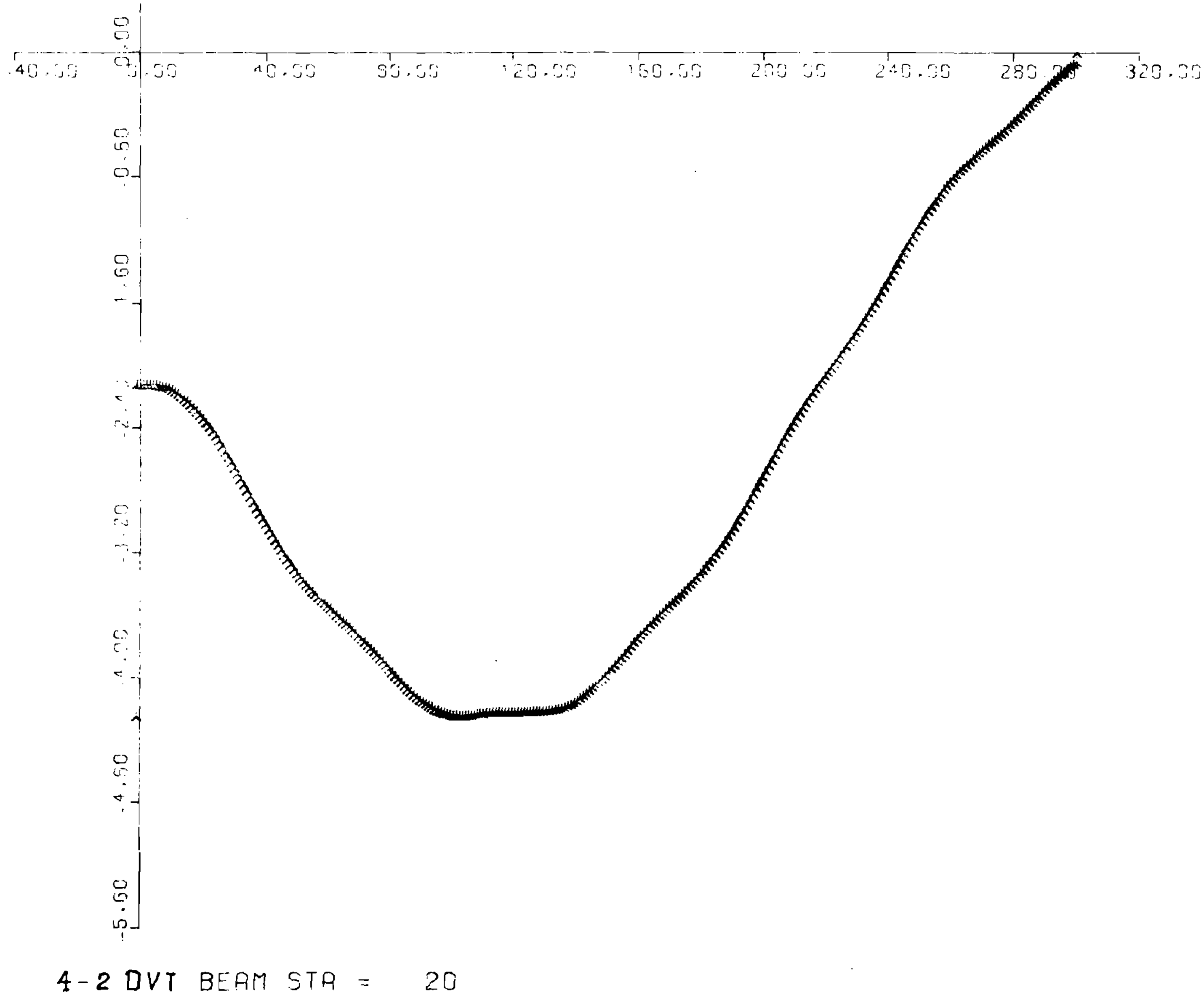


Fig 38. Example Problem 4-2. Deflection vs time for the center of beam.

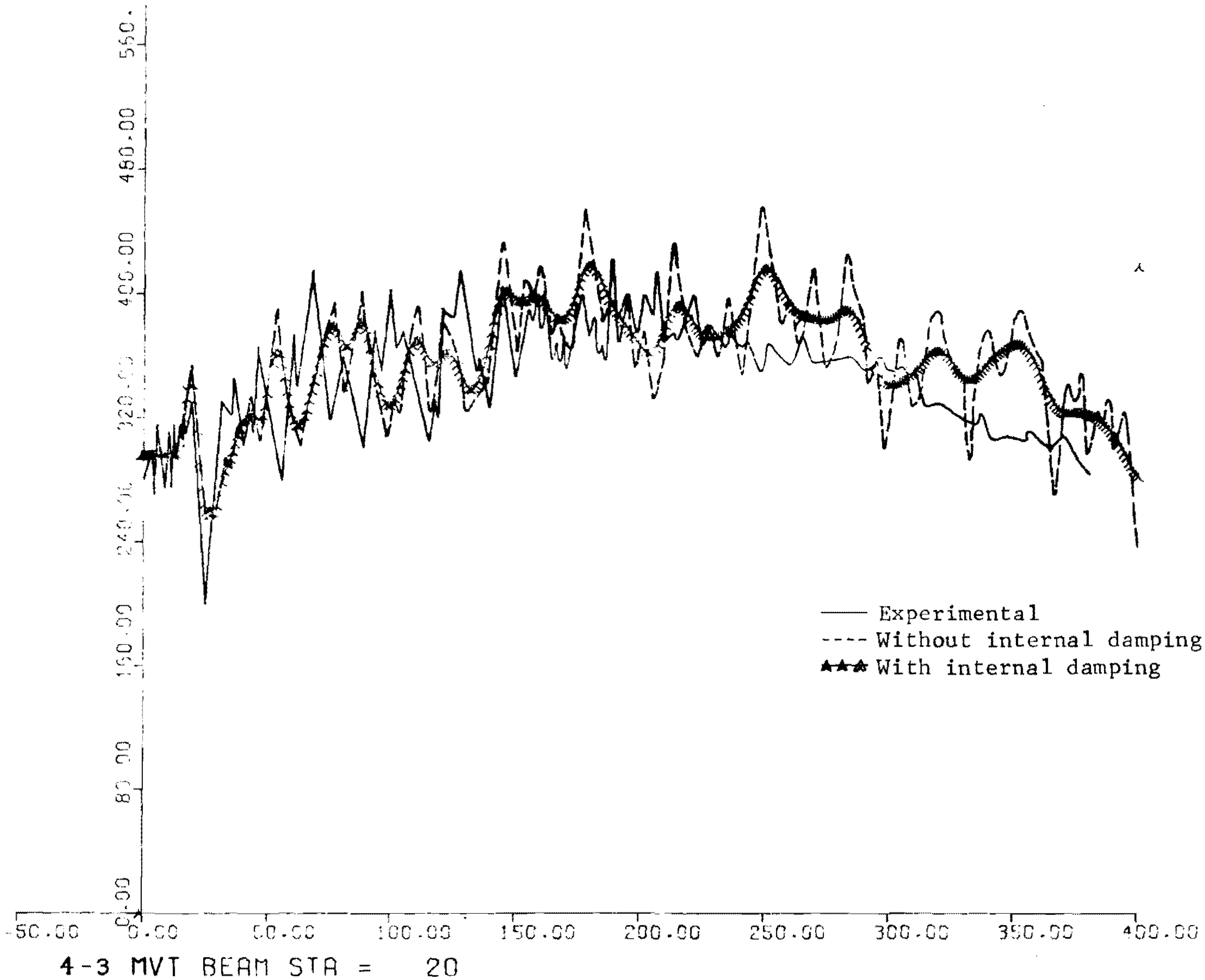


Fig 39. Example Problem 4-3. Comparison of moments vs time for the center of beam.

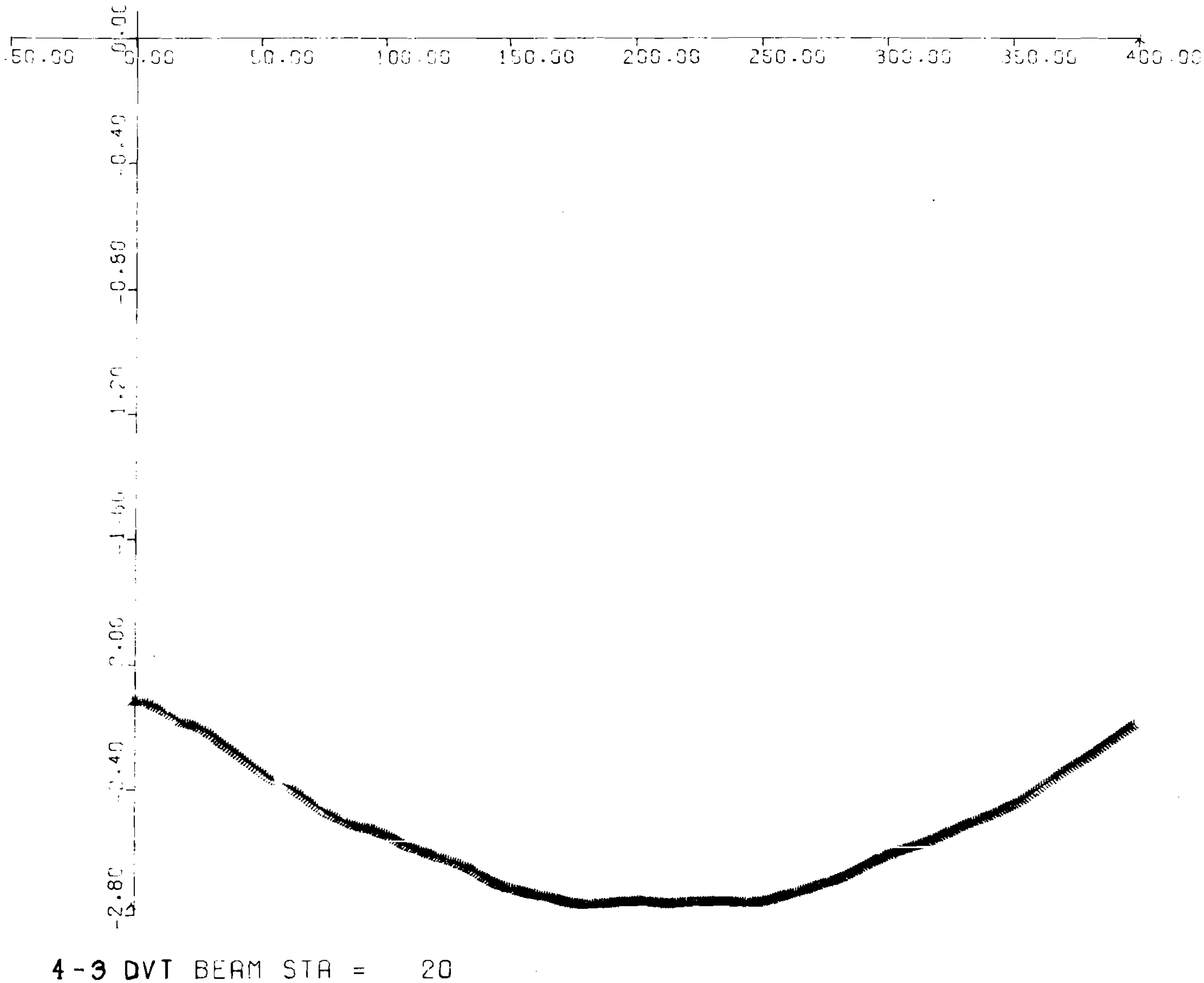
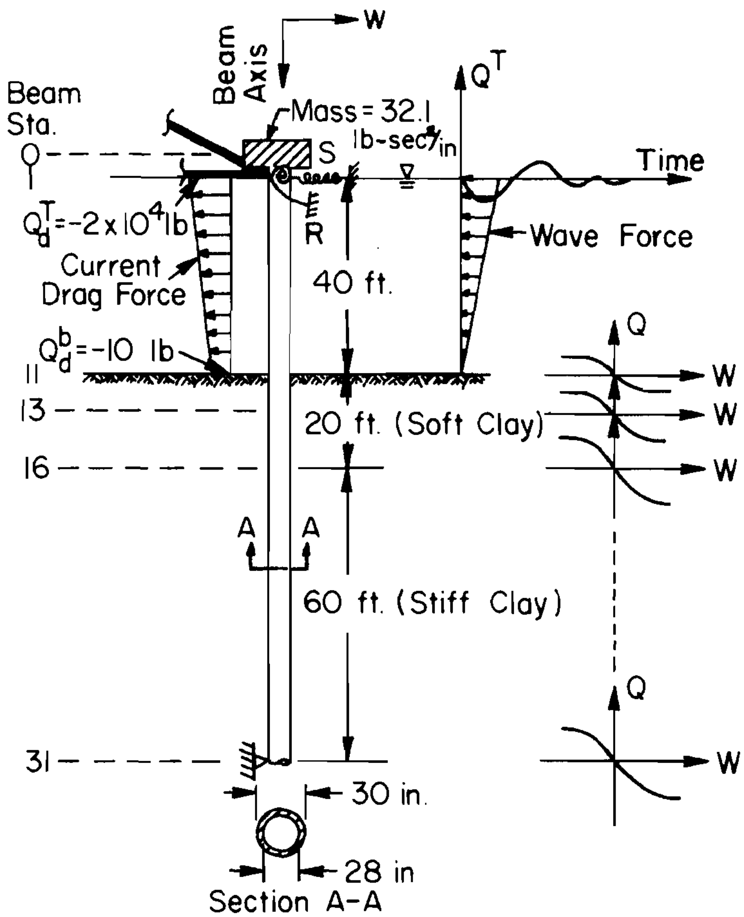


Fig 40. Example Problem 4-3. Deflection vs time for the center of beam.



EI = 2.877 x 10" lb-in^2

Mass density = 3.21 lb-sec^2/in/sta

Internal damping factor = 1.918 x 10^6 lb-in^2-sec/sta

S = 3 x 10^7 lb/in

R = 2.1 x 10^{10} lb-in/rad

Q_d^T = -2 x 10^4 lb

Q_d^b = -1 x 10^4 lb

Beam increments = 31

Beam increment length = 48 in.

Time increments = 400

Time increment length = 1.0 x 10^{-2} seconds

Idealized Wave Force at Beam Station 1

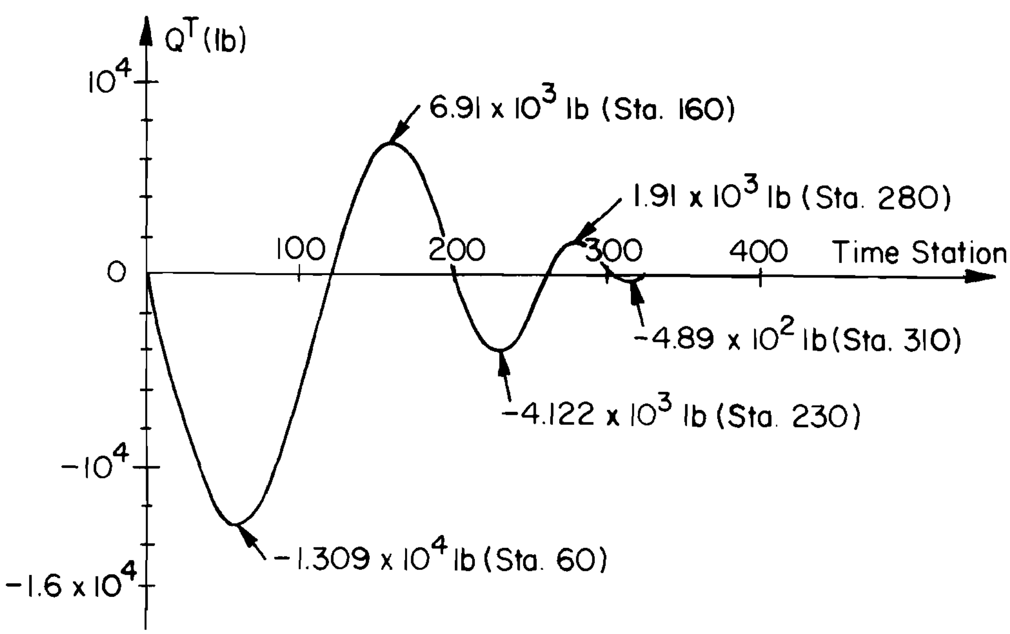


Fig 41. Example Problem 5. Partially embedded steel pipe loaded by idealized wave forces.

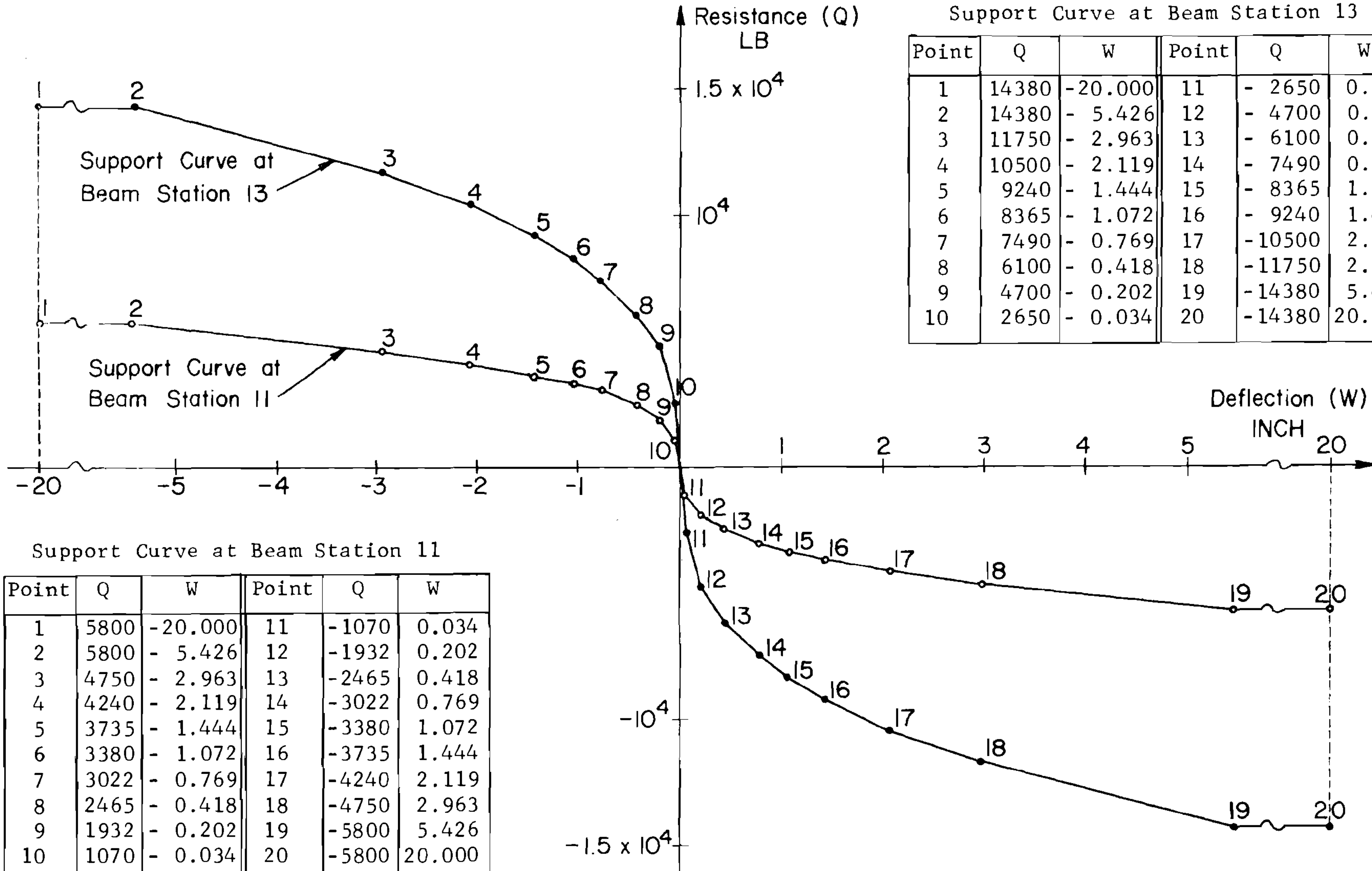
$lb\text{-}sec^2/in.$ from station 1 to station 31. A large mass, which is arbitrarily set at 32.1 $lb\text{-}sec^2/in.$, is lumped at station 0 to represent the weights of the structure, equipment, etc. The static weights of the pipe and the large mass lumped at station 0 are considered to be the axial compression forces, which are distributed from 1.220×10^4 pound at station 1 to 4.924×10^4 pound at station 31. An estimated value of 1.918×10^6 $lb\text{-}in.^2\text{-}sec/sta$ is input for the internal damping factor.

The pipe is assumed to be simply supported at station 31 and assumed to have a linear spring support of 3×10^7 lb/in. as well as a rotational restraint of 2.1×10^{10} lb-in./rad at station 1. From station 11 to station 31, the pipe is laterally supported by soil. The soil from station 11 to station 16 is assumed to be a soft clay which has a shear strength that varies from 200 lb/ft^2 at the top to 333.4 lb/ft^2 at the bottom. The soil below station 16 is assumed to be a stiff clay which has a shear strength of approximately 475 lb/ft^2. Generation of the resistance-deflection curves for the soil supports at stations 11 and 13 is based on a technique presented by Matlock (Ref 6). The resistances and deflections for both support curves are described at 20 points as shown in Fig 42. The remaining support curves between stations 11 and 16 are linearly distributed.

The nonlinear characteristics of the resistance-deflection curves for the soil supports from station 16 to station 31 are obtained from the data for the experiment done by Matlock and Vora in Ref 8. The nonlinear resistance-deflection curves are also described at 20 points, as shown in Fig 43.

Current drag forces are assumed to vary from -2×10^4 pound at station 1 to -1×10^4 pound at station 11. Idealized wave forces are shown at the bottom of Fig 41. The wave forces are assumed to vary linearly from station 1 to station 11. The time increment length is equal to 1.0×10^{-2} seconds. Four hundred time stations are solved for this problem.

The computed deflections and moments versus time for stations 10 and 21 are plotted by the program, as shown in Figs 44 and 45, respectively. Figure 46 shows the computed deflections along the beam axis for time stations 60 and 160. Figure 47 shows the computed deflection along the beam axis for time stations 230 and 280. Figure 48 shows the computed moments along the beam axis for time stations 60 and 320. All plots in this problem are automatically plotted using the ball-point plotting method.



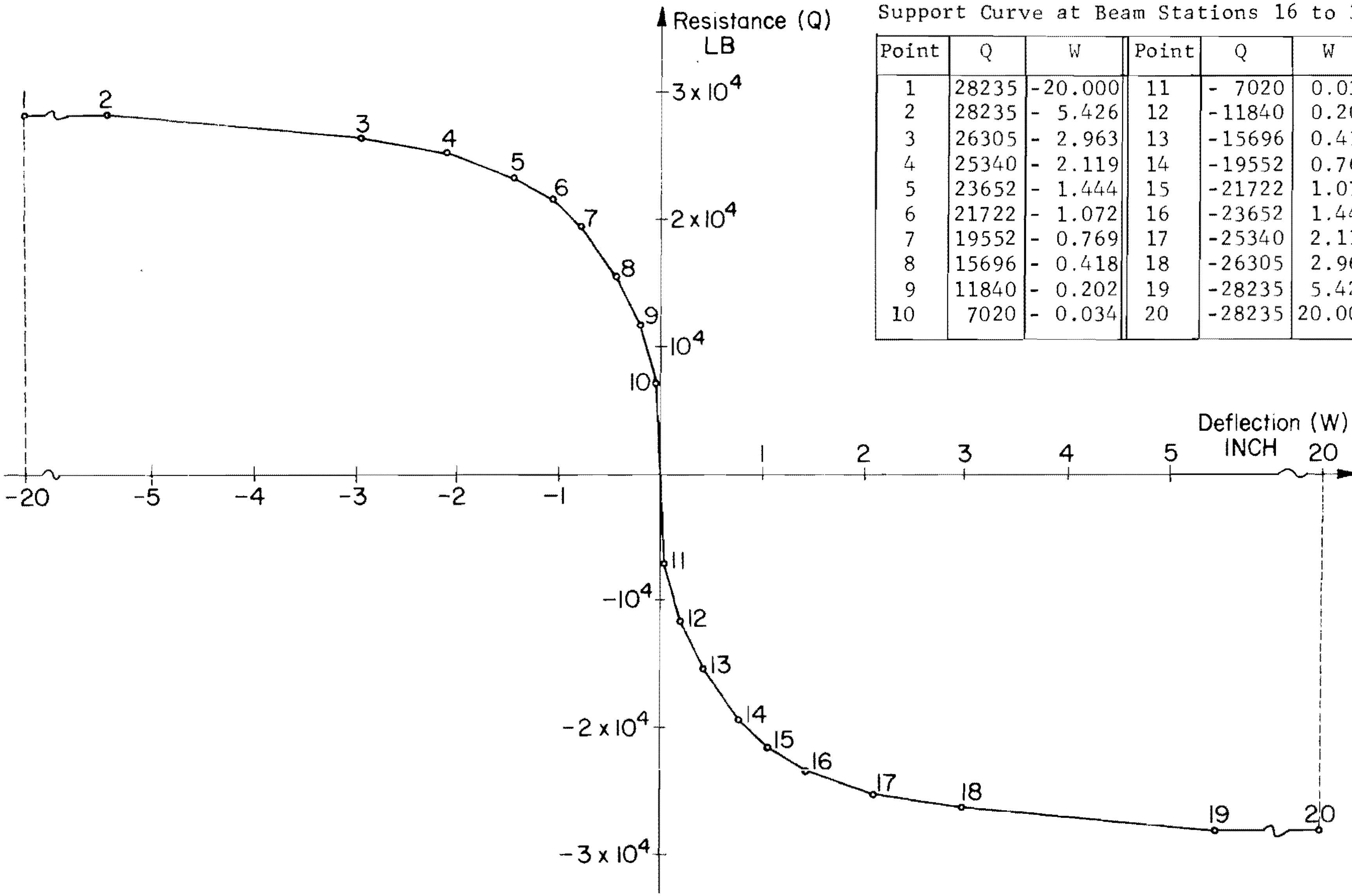
Support Curve at Beam Station 13

Point	Q	W	Point	Q	W
1	14380	-20.000	11	- 2650	0.034
2	14380	- 5.426	12	- 4700	0.202
3	11750	- 2.963	13	- 6100	0.418
4	10500	- 2.119	14	- 7490	0.769
5	9240	- 1.444	15	- 8365	1.072
6	8365	- 1.072	16	- 9240	1.444
7	7490	- 0.769	17	-10500	2.119
8	6100	- 0.418	18	-11750	2.963
9	4700	- 0.202	19	-14380	5.426
10	2650	- 0.034	20	-14380	20.000

Support Curve at Beam Station 11

Point	Q	W	Point	Q	W
1	5800	-20.000	11	-1070	0.034
2	5800	- 5.426	12	-1932	0.202
3	4750	- 2.963	13	-2465	0.418
4	4240	- 2.119	14	-3022	0.769
5	3735	- 1.444	15	-3380	1.072
6	3380	- 1.072	16	-3735	1.444
7	3022	- 0.769	17	-4240	2.119
8	2465	- 0.418	18	-4750	2.963
9	1932	- 0.202	19	-5800	5.426
10	1070	- 0.034	20	-5800	20.000

Fig 42. Symmetric resistance-deflection curves of soft clay at beam stations 11 and 13.



Support Curve at Beam Stations 16 to 31

Point	Q	W	Point	Q	W
1	28235	-20.000	11	- 7020	0.034
2	28235	- 5.426	12	-11840	0.202
3	26305	- 2.963	13	-15696	0.418
4	25340	- 2.119	14	-19552	0.769
5	23652	- 1.444	15	-21722	1.072
6	21722	- 1.072	16	-23652	1.444
7	19552	- 0.769	17	-25340	2.119
8	15696	- 0.418	18	-26305	2.963
9	11840	- 0.202	19	-28235	5.426
10	7020	- 0.034	20	-28235	20.000

Fig 43. Symmetric resistance-deflection curves of stiff clay at beam stations 16 to 31.

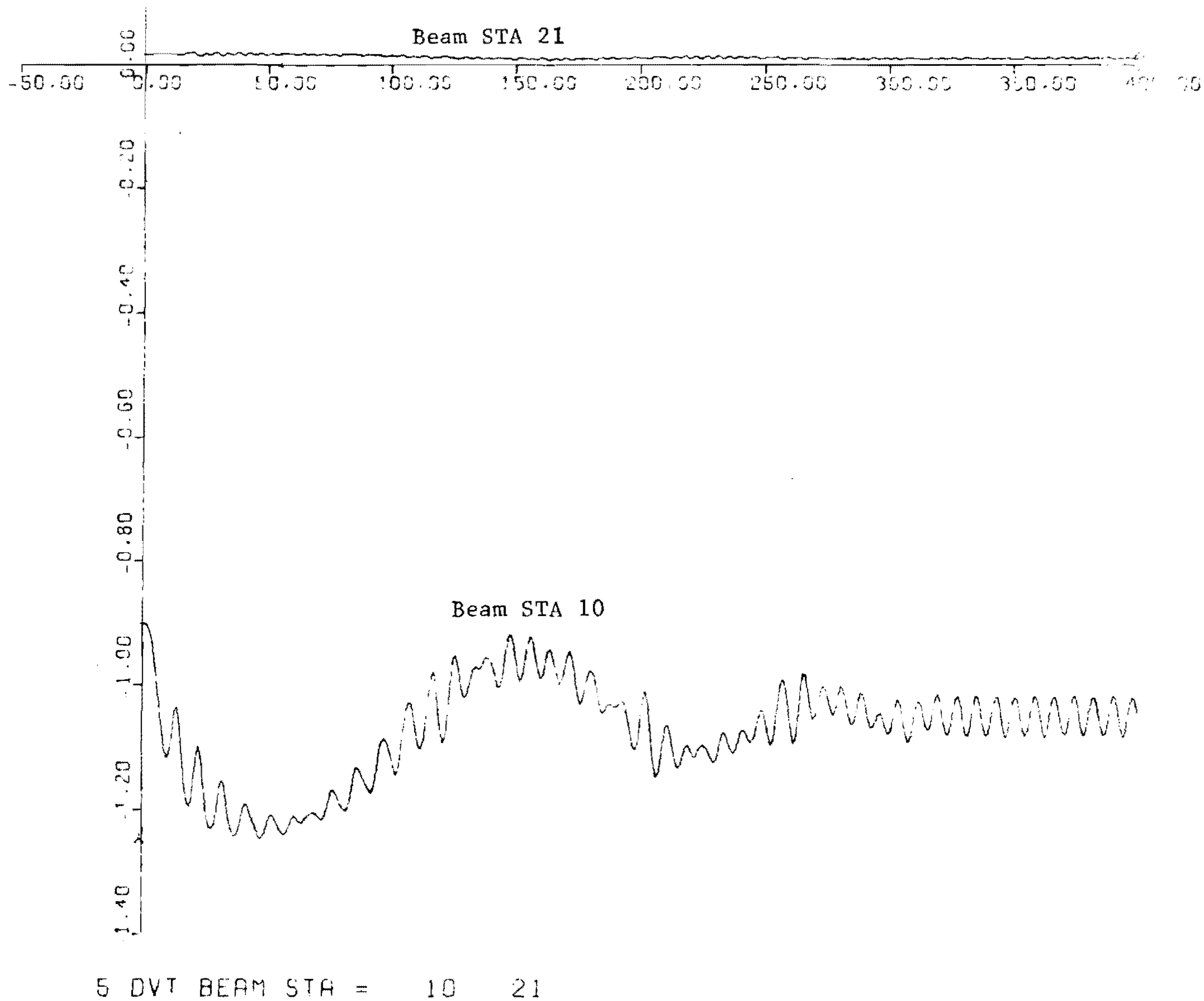


Fig 44. Example Problem 5. Deflection vs time for beam stations 10 and 21.

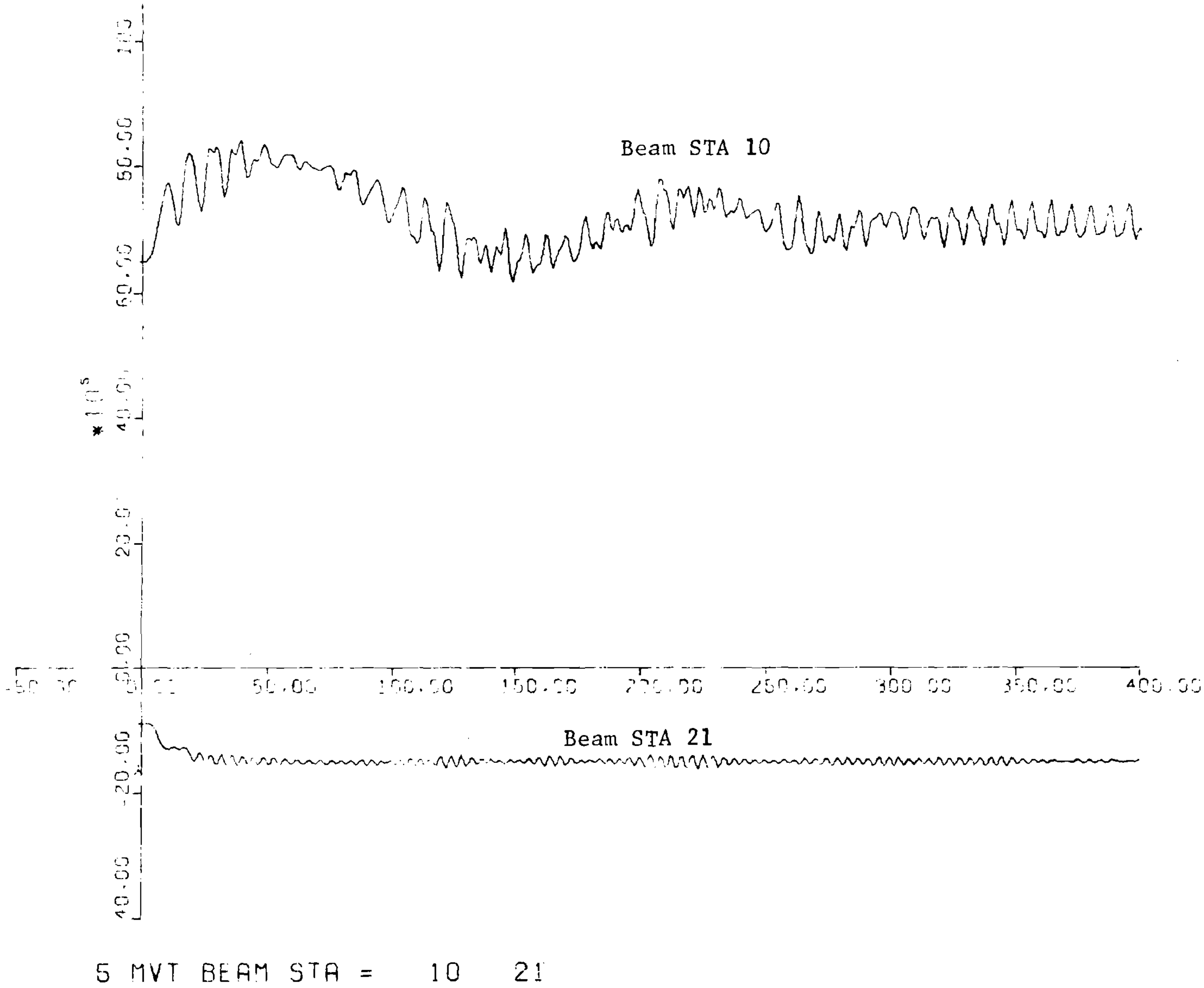


Fig 45. Example Problem 5. Moment vs time for beam stations 10 and 21.

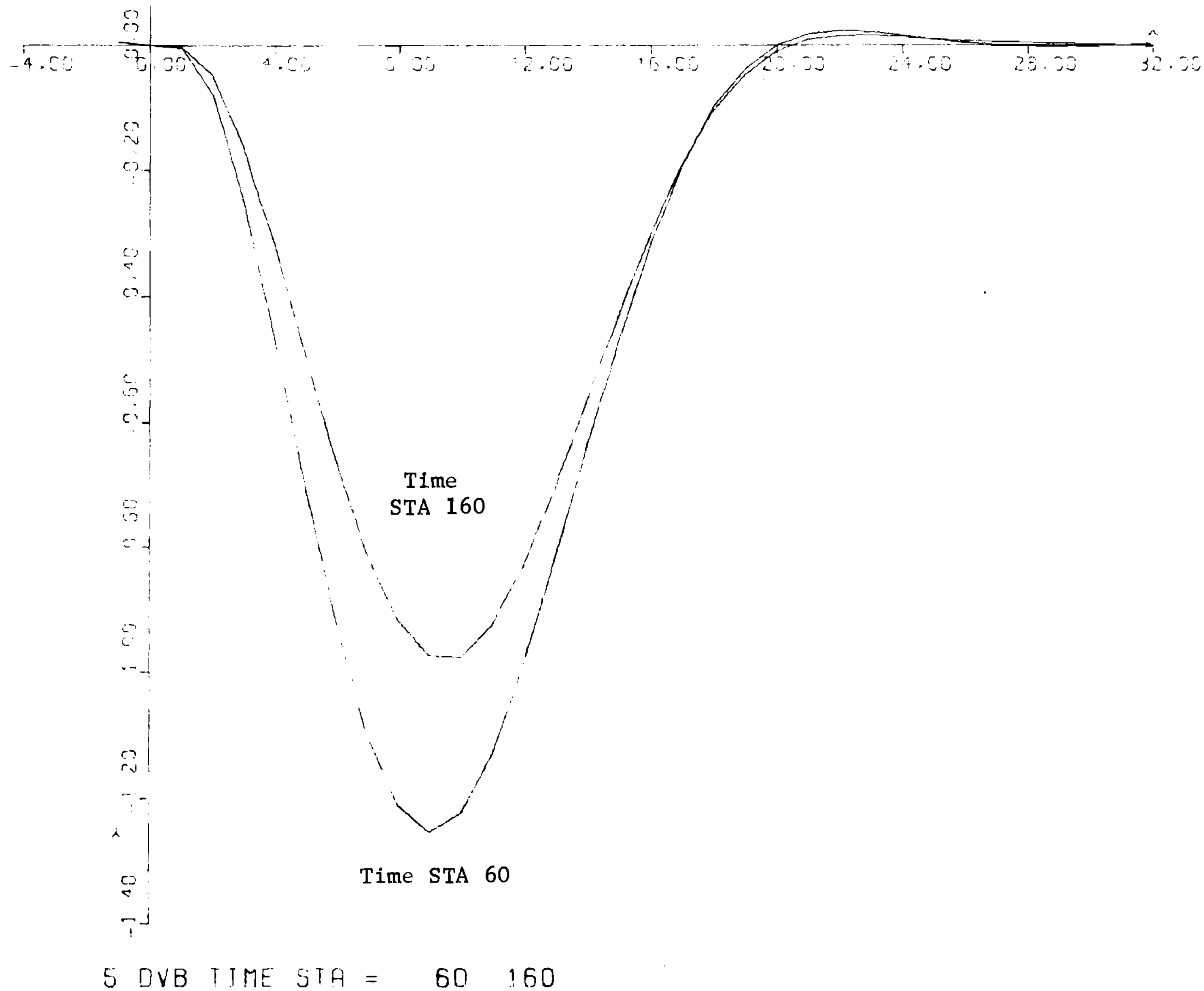


Fig 46. Example Problem 5. Deflection along the beam axis for time stations 60 and 160.

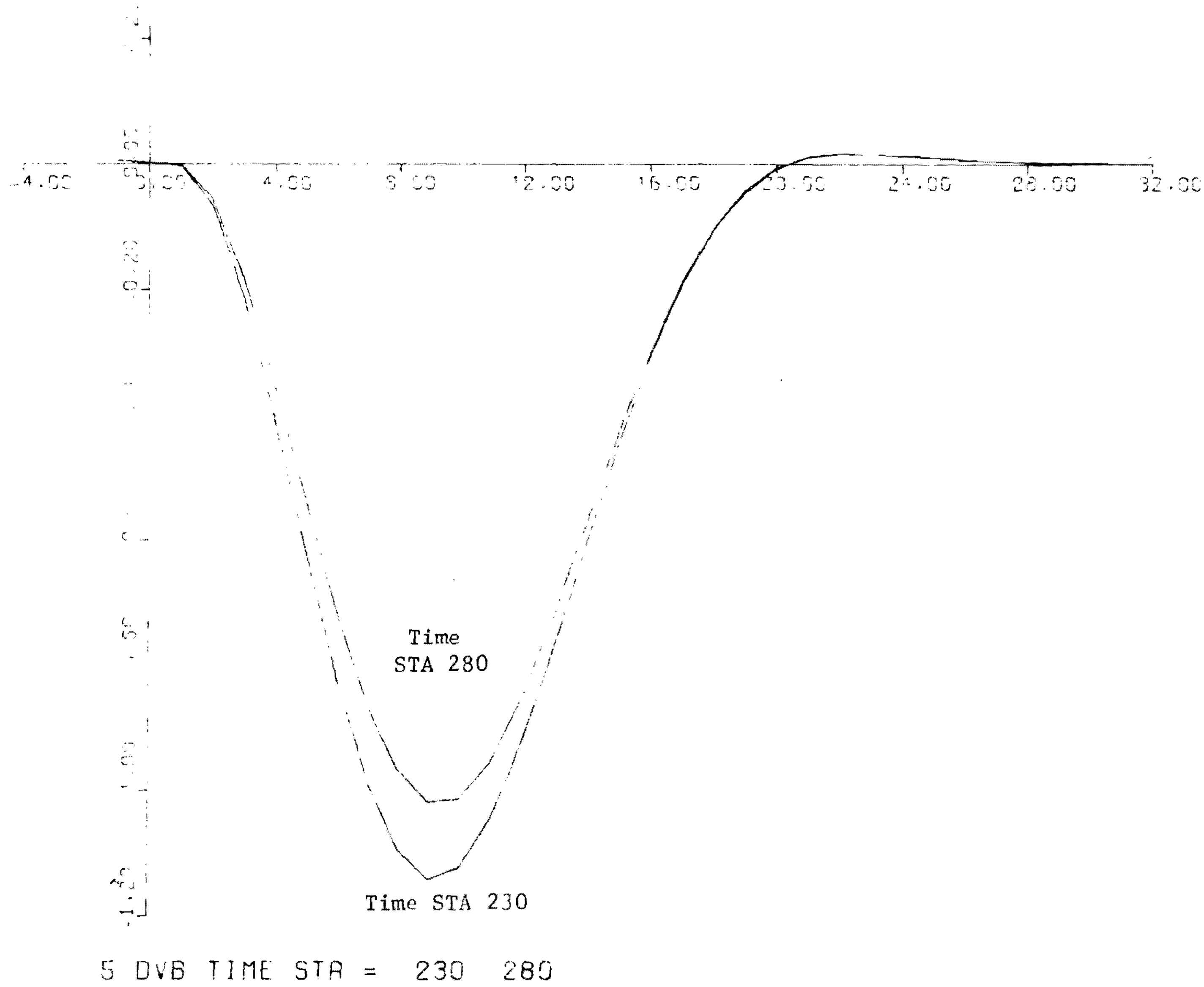


Fig 47. Example Problem 5. Deflection along the beam axis for time stations 230 and 280.

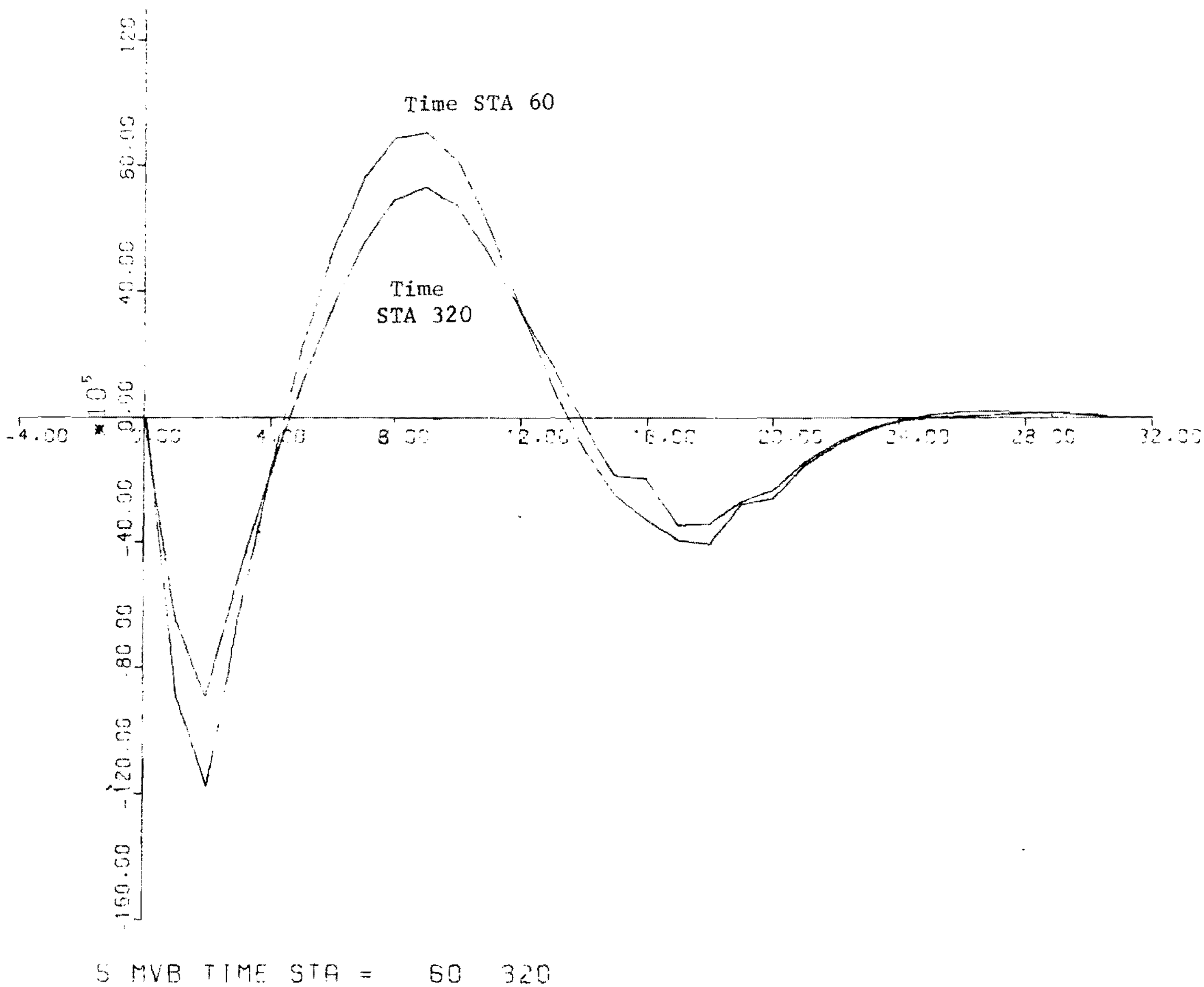
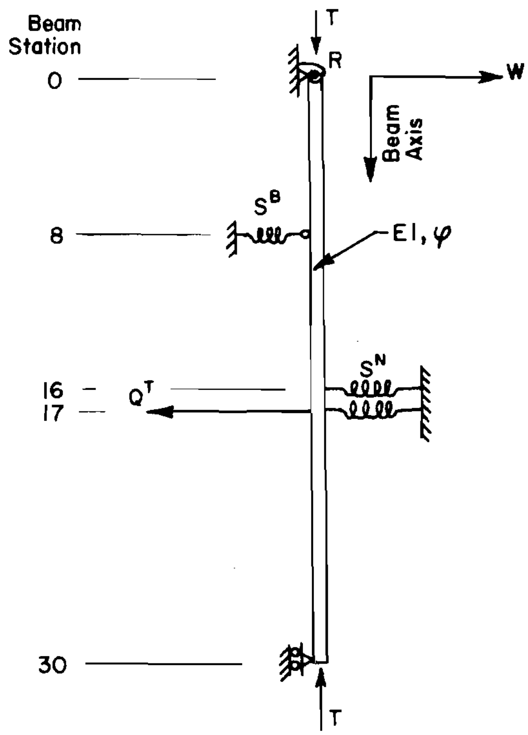


Fig 48. Example Problem 5. Moment along the beam axis for time stations 60 and 320.

Example Problem 6. Three-Span Beam with One-Way and Symmetric Nonlinear Supports Loaded with a Transient Pulse

This problem is intended to demonstrate that the option of switching from a spring-load (tangent modulus method) iteration to a load iteration technique which is built into Program DBC5 is useful when the tangent modulus method fails because of lift-off of the one-way support or yielding of the nonlinear supports. Figure 49 shows a three-span beam (30 beam stations) which is simply supported at the ends, one-way supported at station 8 and nonlinearly supported at stations 16 and 17 and is loaded with a transient pulse at station 17. The beam has a uniform flexural stiffness of 2.4×10^{10} lb-in.^{2} and a uniform mass density of 5.184×10^{-1} lb-sec^2/in./sta. A rotational restraint of 3.0×10^{10} is applied at beam station 0 and a constant axial compression force of 10^5 pounds is assumed. The negative one-way resistance-deflection curve of the support at beam station 8 is shown in Fig 50. The symmetric resistance-deflection curve of the support at beam station 17 is also shown in Fig 50. The nonlinear characteristic of the support at beam station 16 is linearly distributed between beam station 15, which has no resistance to deflection, and beam station 17. The applied transient pulse at beam station 17 is shown at the bottom of Fig 49. The time increment length is equal to 4×10^{-2} seconds and 40 time stations are solved for this problem.

The computed results and the monitor deflections at beam stations 8, 15, 16, and 17 during the iteration process are printed on the computer output. It is seen that the tangent modulus method failed at time stations 5, 9, 13, 16, and 24 due to abrupt changes of time-dependent loads or lift-off of the support at beam station 8 at these time stations; therefore the program automatically switches to the load iteration method and succeeds in obtaining the closed solutions. If the time increment length is reduced to 4×10^{-3} seconds and the same problem is rerun for 400 time stations, the tangent modulus method works nicely at each time station except three at which the beam starts to lift off the support at beam station 8. This is because smoother changes of time-dependent loads are obtained due to the small time increment length and, therefore, the tangent modulus method only fails at some of the critical time stations at which lift-off of the support occurred. The computed deflections and moments versus time for beam stations 8 and 17 are plotted using the printer plotting method, as shown in Figs 51 and 52,



$EI = 2.4 \times 10^{10}$ lb-in^2

$\varphi = 0.5184$ lb-sec^2/in/sta

$T = 10^5$ lb

$R = 3 \times 10^{10}$ lb-in/rad

S^B and S^N see Fig 50

Beam increments = 30

Beam increment length = 48 inches

Time increments = 40

Time increment length = 4×10^{-2} seconds

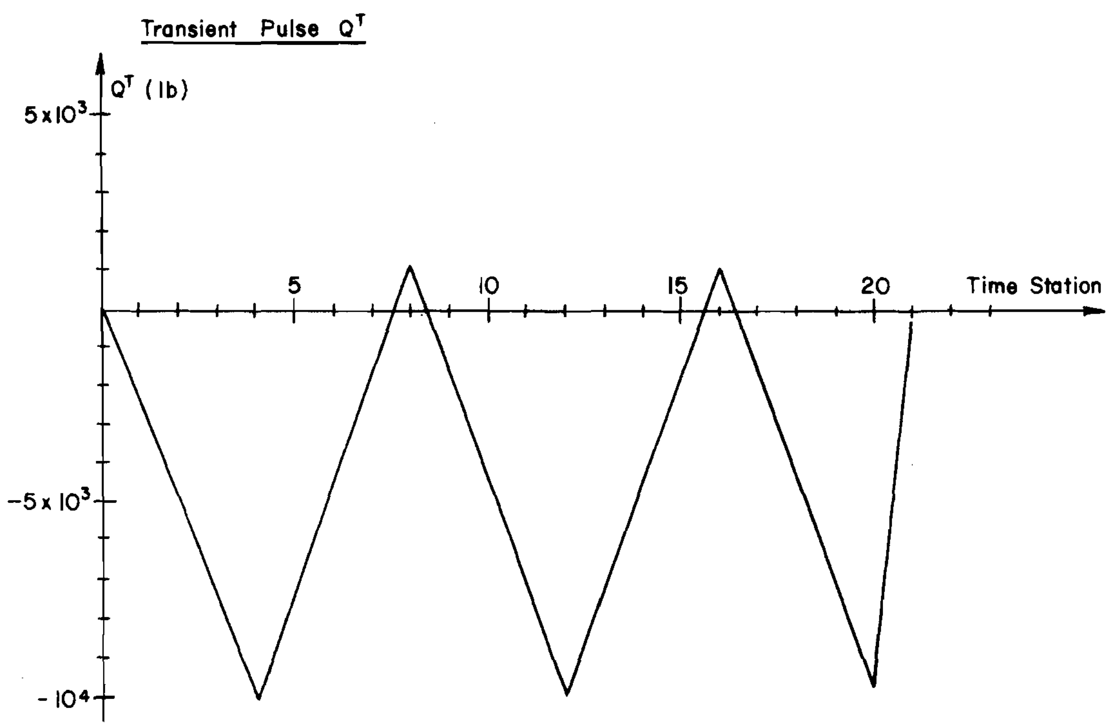
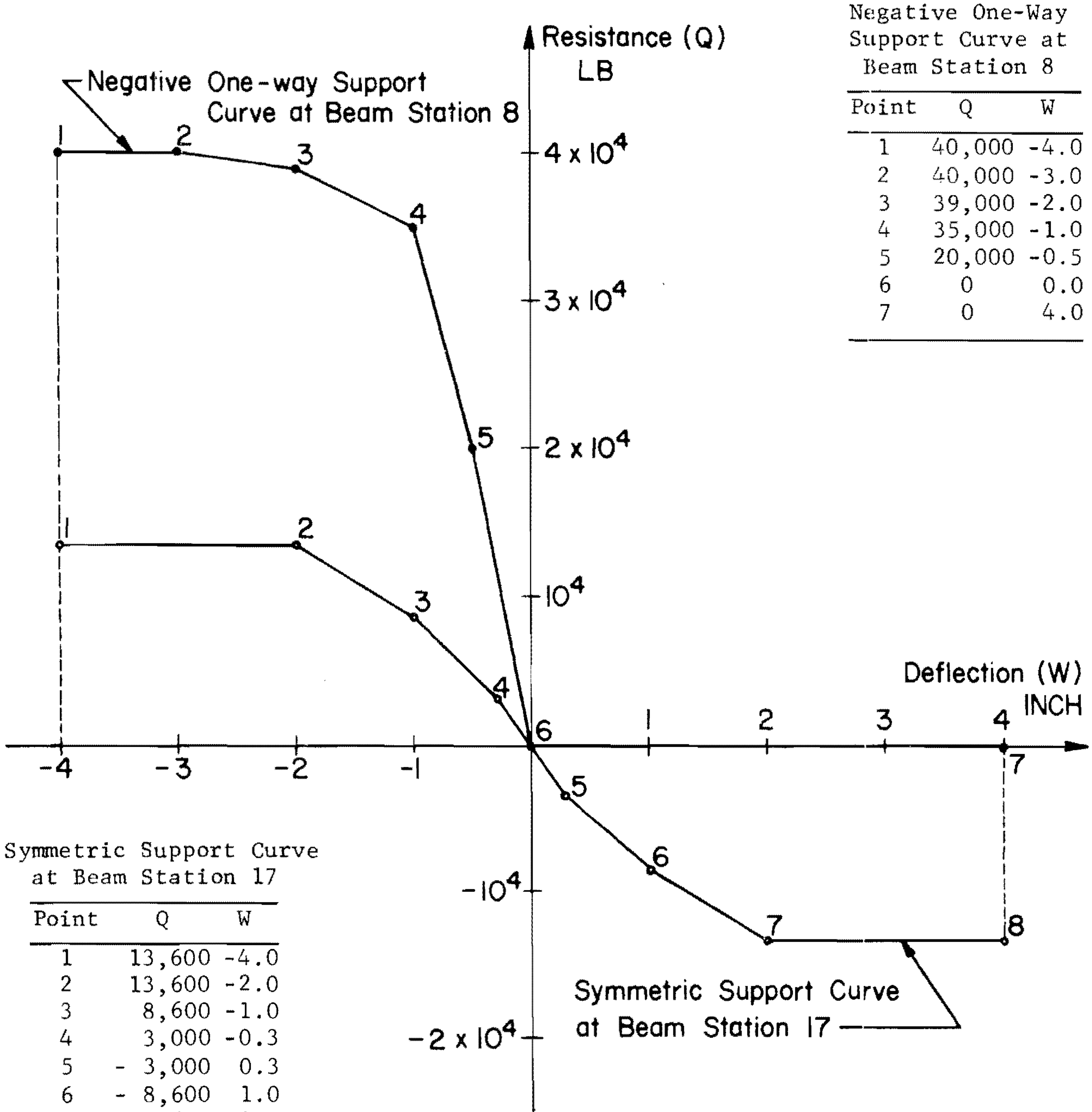


Fig 49. Example Problem 6. Three-span beam loaded by transient pulse.

Negative One-Way Support Curve at Beam Station 8

Point	Q	W
1	40,000	-4.0
2	40,000	-3.0
3	39,000	-2.0
4	35,000	-1.0
5	20,000	-0.5
6	0	0.0
7	0	4.0



Symmetric Support Curve at Beam Station 17

Point	Q	W
1	13,600	-4.0
2	13,600	-2.0
3	8,600	-1.0
4	3,000	-0.3
5	- 3,000	0.3
6	- 8,600	1.0
7	-13,600	2.0
8	-13,600	4.0

Fig 50. Resistance-deflection curves of the supports at beam stations 8 and 17.

```
PROGRAM DBC5 - MASTER - JACK CHAN - MATLOCK -  DECK1-REVISION DATE = 26 JUN 71
        EXAMPLE PROBLEMS FOR PROGRAM DBC5          BY JACK CHAN JUNE 1971
        DYNAMIC BEAM-COLUMN PROGRAM ( 5-1-5 IMPLICIT OPERATOR )


PROB (CONTD)
   6       THREE-SPAN BEAM WITH ONE-WAY AND SYMMETRIC NONLINEAR SUP LOADED BY T.P
***** PLOT OF DEFLECTION VS TIME FOR BEAM STATIONS OF, *****

      1 CURVE  (*) =    8
      2 CURVE  (+) =   17
```

PT.NO	*VALUE*
-1	-1.313E-16
0	-6.601E-17
1	-6.665E-03
2	-1.613E-02
3	-2.991E-02
4	-4.576E-02
5	-3.474E-02
6	-1.719E-02
7	-2.686E-04
8	-3.031E-03
9	-1.485E-02
10	-1.738E-02
11	-2.036E-02
12	-3.566E-02
13	-3.996E-02
14	-3.422E-02
15	-1.095E-02
16	7.612E-03
17	-3.977E-03
18	-3.483E-02
19	-3.644E-02
20	-2.729E-02
21	-1.945E-02
22	-5.084E-03
23	8.561E-03
24	3.095E-03
25	-2.837E-02
26	-3.069E-02
27	1.662E-02
28	4.137E-02
29	-1.882E-02
30	-8.241E-02
31	-1.388E-02
32	6.972E-02
33	4.049E-02
34	-6.450E-02
35	-8.346E-02
36	9.599E-03
37	7.121E-02
38	4.240E-02
39	-6.159E-02
40	-7.584E-02

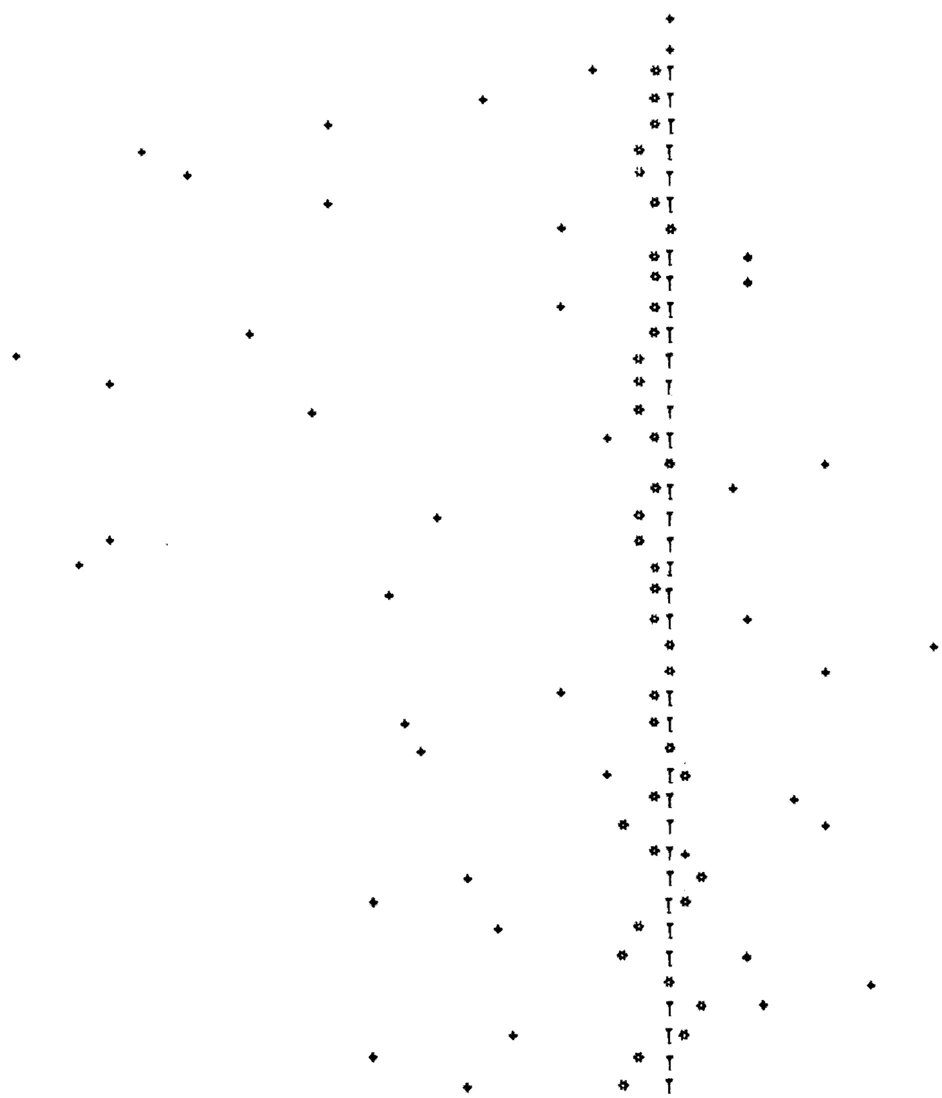


Fig 51. Example Problem 6. Deflection vs time for beam stations 8 and 17.

```
PROGRAM DBC5 - MASTER - JACK CHAN - MATLOCK -  DECK1-REVISION DATE = 26 JUN 71
        EXAMPLE PROBLEMS FOR PROGRAM DBC5        BY JACK CHAN JUNE 1971
        DYNAMIC BEAM-COLUMN PROGRAM ( 5-1-5 IMPLICIT OPERATOR )


PROB (CONTD)
   6      THREE-SPAN BEAM WITH ONE-WAY AND SYMMETRIC NONLINEAR SUP LOADED BY T.P
***** PLOT OF BEND. MOM. VS TIME FOR BEAM STATIONS OF: *****

     1 CURVE (*) =   8
     2 CURVE (+) =  17
```

PT.NO	*VALUE*
-1	-3.358E-10
0	-3.891E-10
1	-3.578E+04
2	-9.538E+04
3	-1.812E+05
4	-2.722E+05
5	-2.115E+05
6	-1.409E+05
7	-4.657E+04
8	1.139E+04
9	-5.331E+03
10	-6.771E+04
11	-1.828E+05
12	-2.875E+05
13	-2.433E+05
14	-1.828E+05
15	-5.922E+04
16	3.178E+04
17	1.222E+04
18	-9.157E+04
19	-2.589E+05
20	-2.965E+05
21	-1.227E+05
22	7.166E+04
23	1.018E+05
24	-1.266E+04
25	-8.175E+04
26	-3.985E+04
27	-1.949E+04
28	-4.340E+04
29	-3.052E+04
30	2.709E+04
31	1.262E+04
32	-5.033E+04
33	-7.626E+04
34	-5.714E+04
35	-1.049E+04
36	2.866E+04
37	4.163E+04
38	-4.764E+04
39	-9.793E+04
40	-7.125E+04

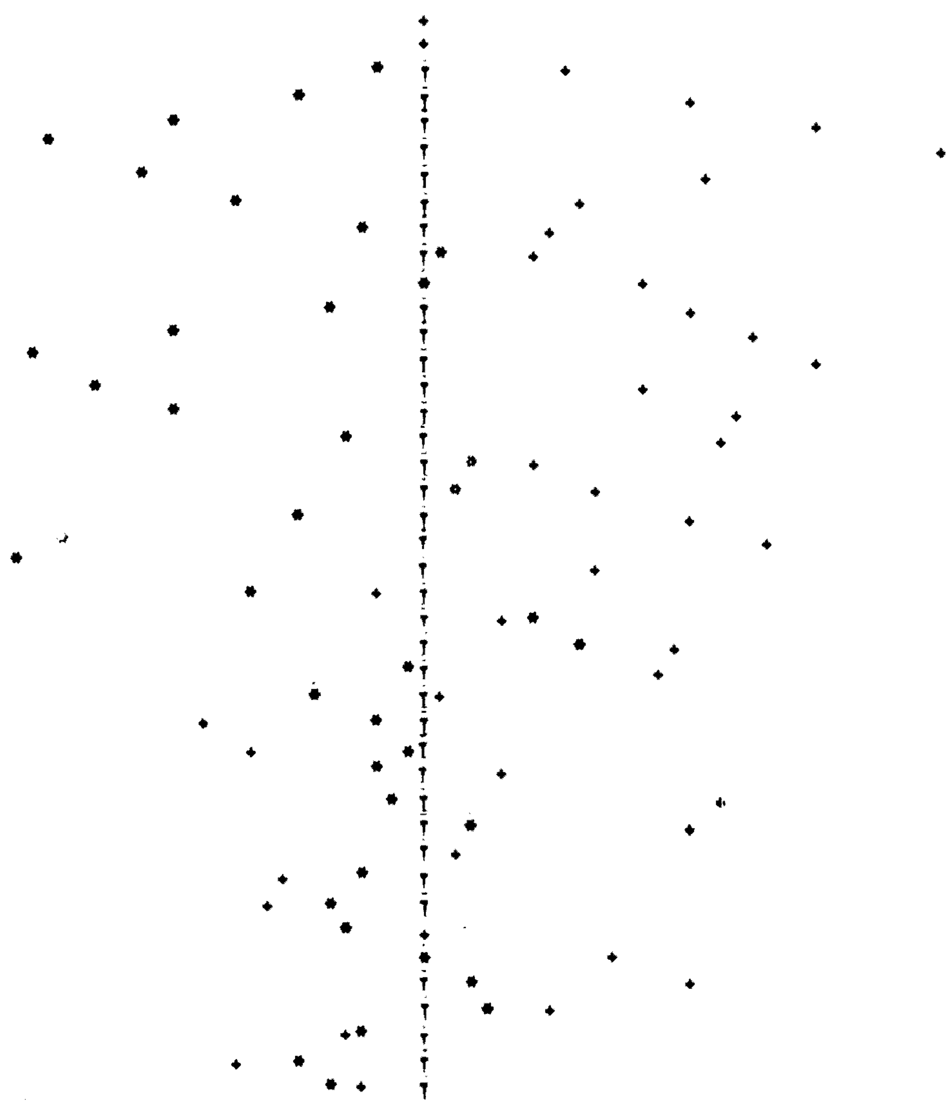


Fig 52. Example Problem 6. Moment vs time for beam stations 8 and 17.

respectively. Figure 53 shows the computed deflections along the beam axis for time stations 4, 8, and 20. Figure 54 shows the computed moments along the beam axis for time stations 12, 16, and 30.

Example Problem 7. Partially Embedded Steel Pipe Pile Excited by Sinusoidal Earthquake-Induced Forces

The capability of Program DBC5 to analyze the response of a partially embedded steel pipe pile which is excited by sinusoidal earthquake-induced forces is illustrated with problem 7. Figure 55(a) shows a 12.75-inch outside diameter $\times$ 0.5-inch wall steel pipe pile embedded in the soil to a depth of 40 feet and extending 10 feet above the ground surface. The pile has a flexure stiffness of 10.9×10^9 lb-in.^{2} and is divided into 50 beam increments. Each beam increment has a length of 12 inches. An axial compression force of 10,000 pounds is assumed in the pile. From beam station 0 to beam station 40, the lumped mass density of soil and pile is assumed to be 5.184 lb-sec^2/in./sta. From beam station 40 to beam station 50, the lumped mass density of soil and lateral load is assumed to be 2.592 lb-sec^2/in./sta. The negative and positive one-way resistance-deflection curves, which describe the lateral soil supports from beam station 0 to beam station 40, are shown in Fig 55(b) and (c), respectively. The time increment length is 5×10^{-3} seconds and 160 time stations are solved for this problem.

The pile is excited by a sinusoidal earthquake-induced force, as shown in Fig 55(d). The sinusoidal earthquake induced force has a base time of 0.1 second (equivalent to 20 time stations) and is induced from an assumed sinusoidal acceleration with a maximum value of 1/10 G (G = 386 in./sec^2) and a base time of 0.1 second. Based on the discrete-element beam-column model, the applied transverse load Q^T is equal to the product of deflection W and spring force S^N. By double integration of the equation of sinusoidal acceleration and evaluation of the constants of integration, the relation between the maximum deflection (W_{max}) and the maximum acceleration ($\ddot{W}_{max}$) is found to be

$$W_{max} = \ddot{W}_{max} \, t_c^{\,2} / \pi^2$$

where t_c is the base time and π is equal to 3.1416. If the nonlinear spring

```
PROGRAM DBC5 - MASTER - JACK CHAN - MATLOCK -  DECK1-REVISION DATE = 26 JUN 71
         EXAMPLE PROBLEMS FOR PROGRAM DBC5          BY JACK CHAN  JUNE 1971
         DYNAMIC BEAM-COLUMN PROGRAM ( 5-1-5 IMPLICIT OPERATOR )


PROB (CONTD)
    6       THREE-SPAN BEAM WITH ONE-WAY AND SYMMETRIC NONLINEAR SUP LOADED BY T.P
***** PLOT OF DEFLECTIONS ALONG BEAM AXIS AT TIME STATIONS OF. *****

      1 CURVE (*) =    4
      2 CURVE (+) =    8
      3 CURVE (X) =   20
```

PT.NO	*VALUE*
-1	5.388E-03
0	0.
1	5.759E-03
2	1.787E-02
3	3.146E-02
4	4.173E-02
5	4.379E-02
6	3.293E-02
7	4.549E-03
8	-4.576E-02
9	-1.222E-01
10	-2.203E-01
11	-3.353E-01
12	-4.625E-01
13	-5.970E-01
14	-7.339E-01
15	-8.684E-01
16	-9.957E-01
17	-1.111E+00
18	-1.192E+00
19	-1.238E+00
20	-1.250E+00
21	-1.229E+00
22	-1.178E+00
23	-1.098E+00
24	-9.927E-01
25	-8.640E-01
26	-7.155E-01
27	-5.510E-01
28	-3.743E-01
29	-1.892E-01
30	0.
31	1.892E-01

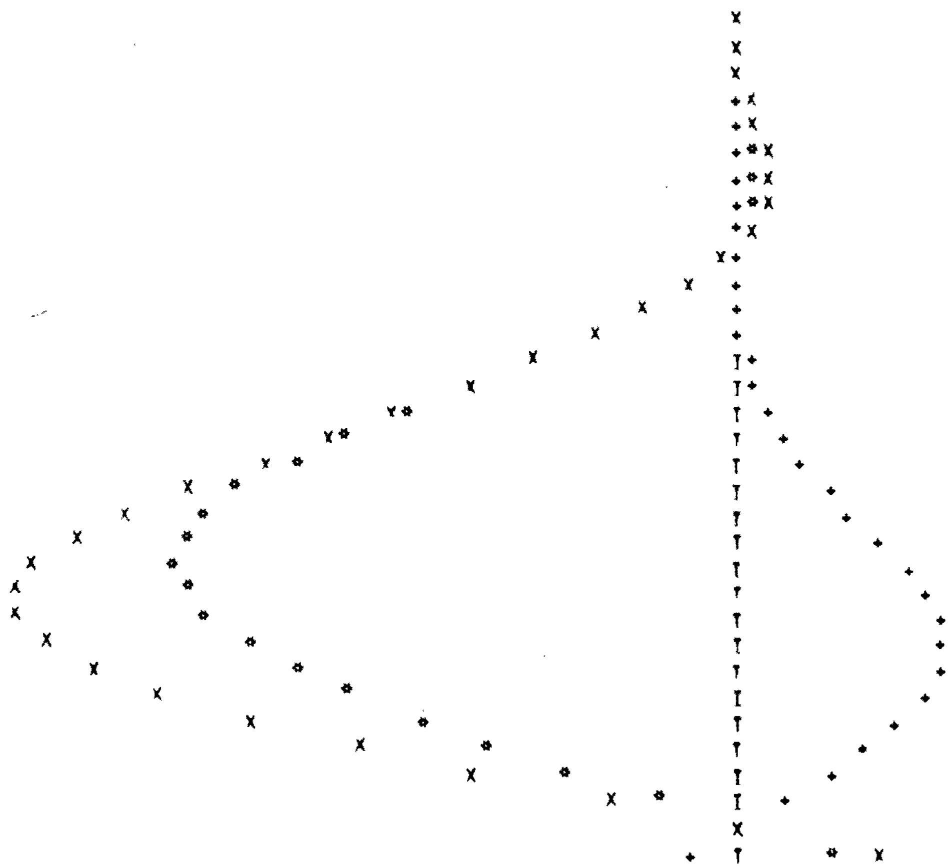


Fig 53. Example Problem 6. Deflection along the beam axis for time stations 4, 8, and 20.

PROGRAM DBC5 - MASTER - JACK CHAN - MATLOCK - DECK1-REVISION DATE = 26 JUN 71
EXAMPLE PROBLEMS FOR PROGRAM DBC5 BY JACK CHAN JUNE 1971
DYNAMIC BEAM-COLUMN PROGRAM (5-1-5 IMPLICIT OPERATOR)

PROB (CONTD)
6 THREE-SPAN BEAM WITH ONE-WAY AND SYMMETRIC NONLINEAR SUP LOADED BY T.P
***** PLOT OF BEND. MOM. ALONG BEAM AXIS AT TIME STATIONS OF, *****

1 CURVE (*) = 12
2 CURVE (+) = 16
3 CURVE (X) = 30

PT.NO	*VALUE*
-1	0.
0	6.563E+04
1	7.673E+04
2	2.150E+04
3	-3.385E+04
4	-8.865E+04
5	-1.422E+05
6	-1.937E+05
7	-2.424E+05
8	-2.875E+05
9	-2.600E+05
10	-2.283E+05
11	-1.930E+05
12	-1.548E+05
13	-1.153E+05
14	-7.640E+04
15	-4.068E+04
16	-1.077E+04
17	2.700E+05
18	3.585E+05
19	4.323E+05
20	4.891E+05
21	5.271E+05
22	5.446E+05
23	5.407E+05
24	5.149E+05
25	4.679E+05
26	4.012E+05
27	3.173E+05
28	2.197E+05
29	1.123E+05
30	-9.252E-09
31	0.

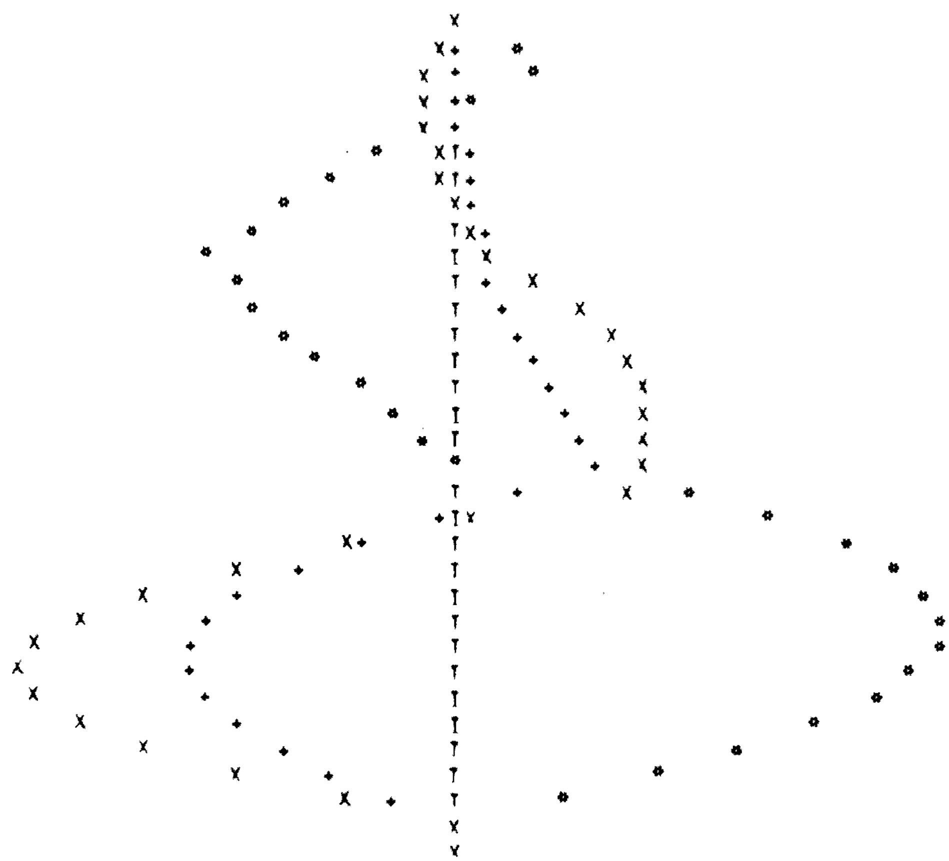
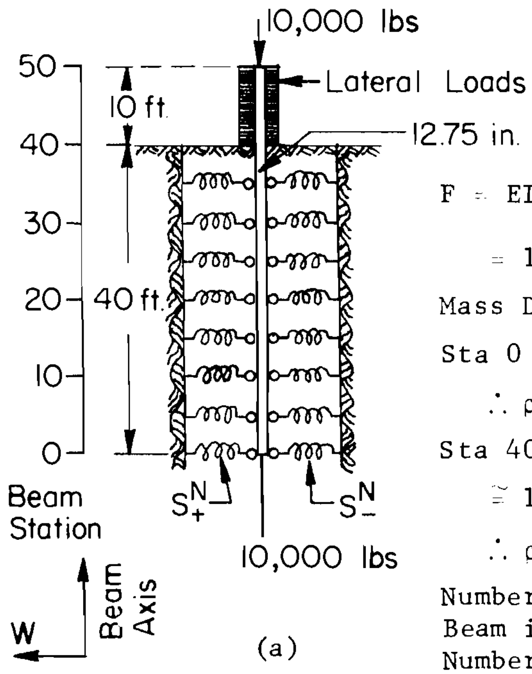


Fig 54. Example Problem 6. Moment along the beam axis for time stations 12, 16, and 30.



(a)

$$F = EI = 30 \times 10^6 \times \frac{\pi}{64}\left[(12.75)^4 - (11.75)^4\right]$$

$$= 10.9 \times 10^9 \text{ lb-in}^2$$

Mass Density:

Sta 0 to 40: Weight of soil + pile $\cong$ 200 lbs/ft

$$\therefore \rho = 200/386.4 = 5.184 \text{ lb-sec}^2\text{/in/sta}$$

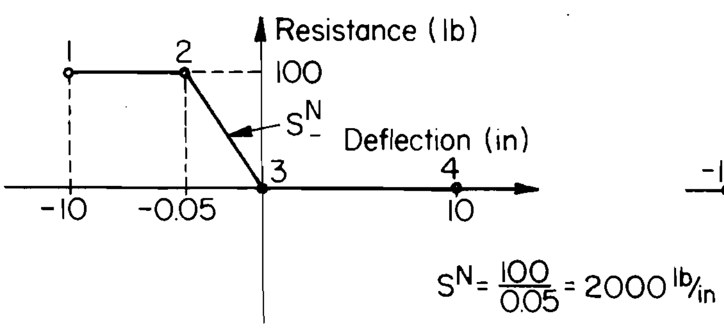
Sta 40 to 50: Weight of pile + lateral load

$\cong$ 10,000 lbs. Distributing on 10' length.

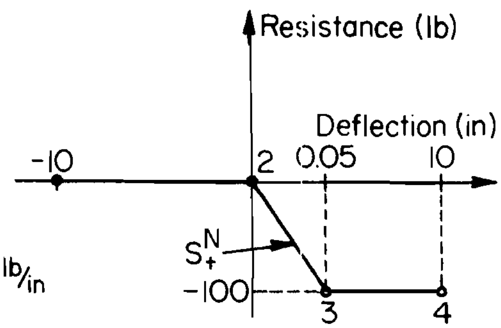
$$\therefore \rho = 10{,}000/(10 \times 386.4) = 2.592 \text{ lb-sec}^2\text{/in/sta}$$

Number of beam increments = 50
Beam increment length = 12 inches
Number of time increments = 160
Time increment length = 5×10^{-3} seconds

One-Way Resistance-Deflection Curves S_-^N and S_+^N

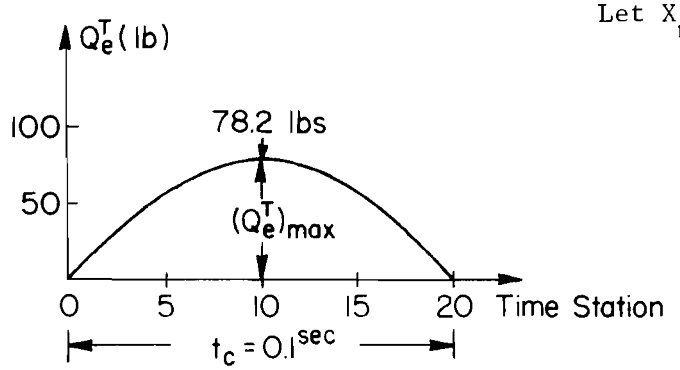


(b)



(c)

Earthquake-Induced Forces



(d)

Let $\ddot{X}_{max} = 1/10\ G = 38.6 \text{ in/sec}^2$

$$(Q_e^T)_{max} \cong \frac{S^N t_c^2}{\pi^2} \ddot{X}_{max}$$

$$= \frac{2000 \times 0.1^2}{\pi^2} \times 38.6$$

$$= 78.2 \text{ lbs}$$

Fig 55. Example Problem 7. Partially embedded pile excited by sinusoidal earthquake-induced forces.

force S^N can be assumed to be constant, then the maximum sinusoidal earthquake-induced force can be obtained by the equation

$$Q^T_{max} = S^N t_c^2 \ddot{W}_{max}/\pi^2$$

The earthquake-induced forces are applied at beam stations 0 to 40 to approximately describe the ground movements.

The computed resistance-deflection curves of the negative and positive one-way supports at beam station 20 are shown in Fig 56. The first loading path is seen to form a loop which starts from point A and follows the path of ABCDAEFGA. The mechanical energy lost in the first loop is equal to the area defined by the loading path. The second loading path follows the path of ADHDAGIGA; no mechanical energy is lost in this path because the energy is absorbed by or transformed to adjacent supports. Between points D and G in the second loading path, the supports at beam station 20 exhibit no resistance and hence a hole is produced around the pile at this station. The third loading path is similar to the second loading path except that in the third the maximum positive deflection increases from point H to point J, and the maximum negative deflection decrease from point I to point K. The succeeding paths are similar but have progressively smaller maximum positive and maximum negative deflections until finally no more energy is absorbed by or transformed to adjacent supports and the entire pile exists in a state of free vibration since no damping factor has been included. Figure 57 shows the plot of deflection versus time for beam station 20. Here the response is tapering down to the two limits at which the entire pile is in a state of free vibration.

A similar computed resistance-deflection curve can be constructed for any other support, with a similar result expected unless the support (for instance, at beam station 40) has not yet reached the yielding condition; then the computed resistance-deflection curve will be a straight line. Figure 58 shows the computer plot of deflection versus time for beam stations 10 and 30. Figure 59 shows the computer plot of deflection versus time for beam stations 40 and 50. Figure 60 shows the computer plot of deflection along the beam axis at time stations 10 and 20. Figure 61 shows the computer plot of deflection along the beam axis at time stations 50 and 150. Figure 62 shows the computer plot of moment along the beam axis at time stations 30 and 100.

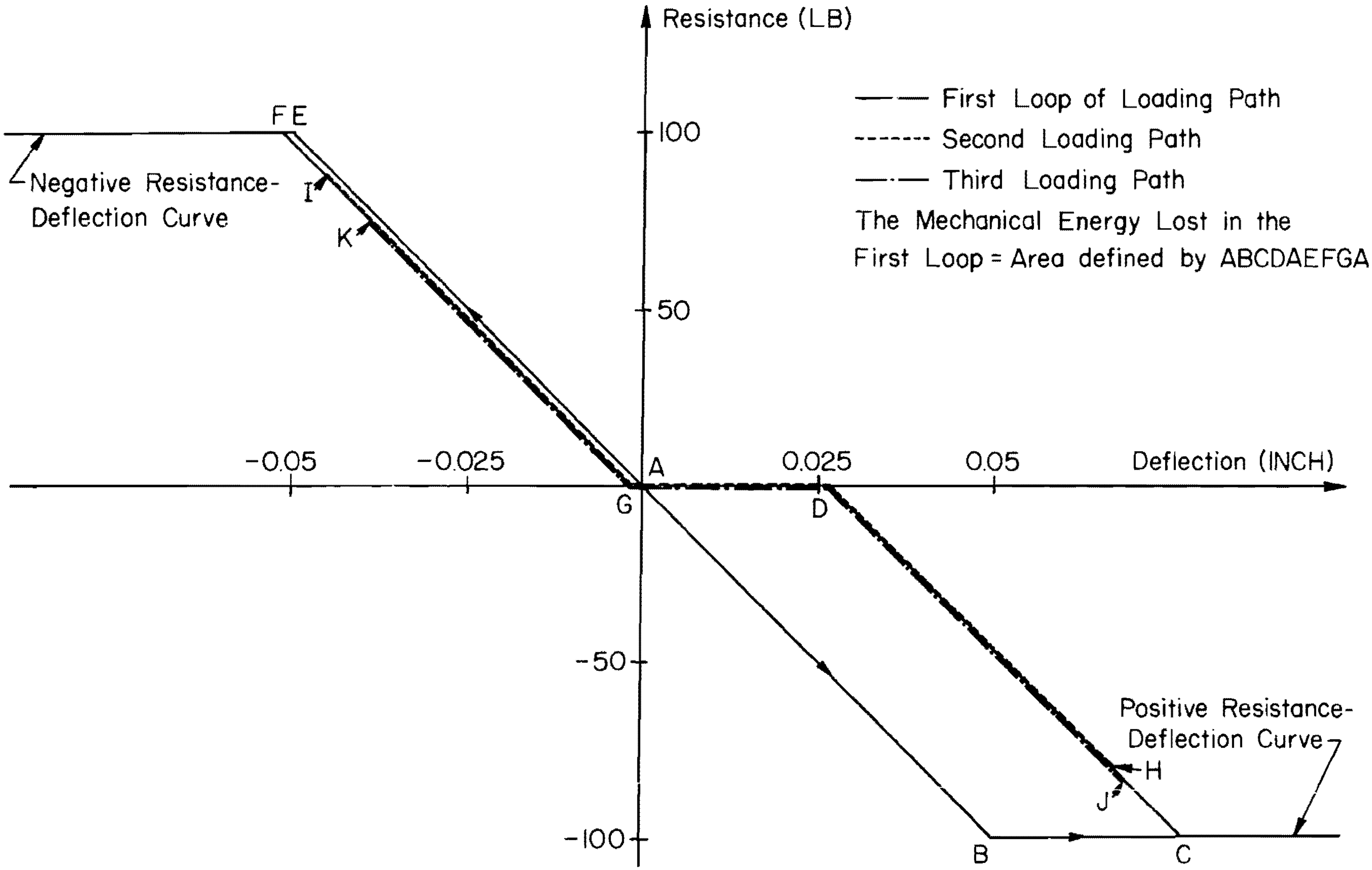


Fig 56. Computed resistance-deflection curves of the one-way supports at beam station 20 of Example Problem 7.

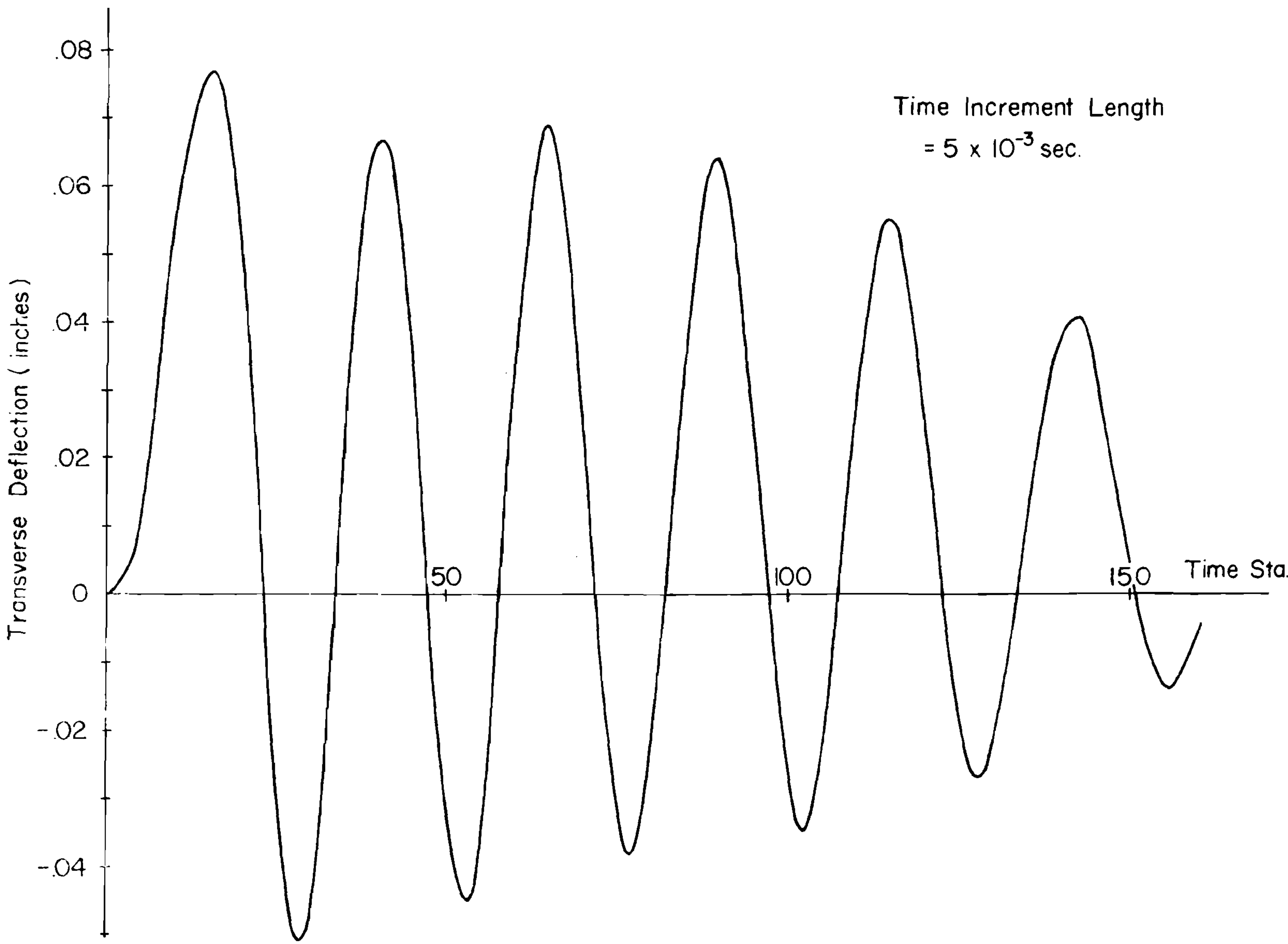


Fig 57. Example Problem 7. Deflection vs time for beam station 20.

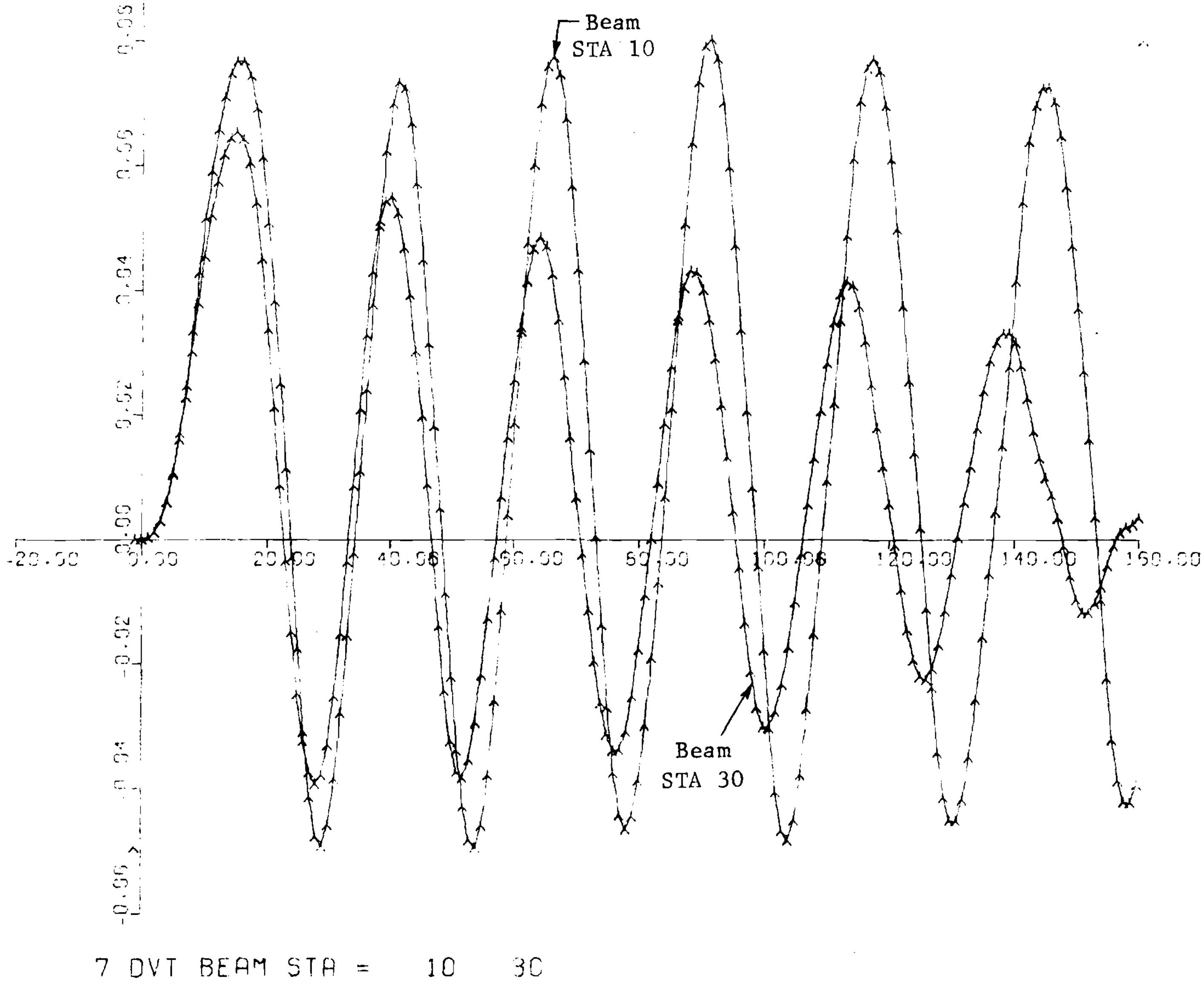


Fig 58. Example Problem 7. Deflection vs time for beam stations 10 and 30.

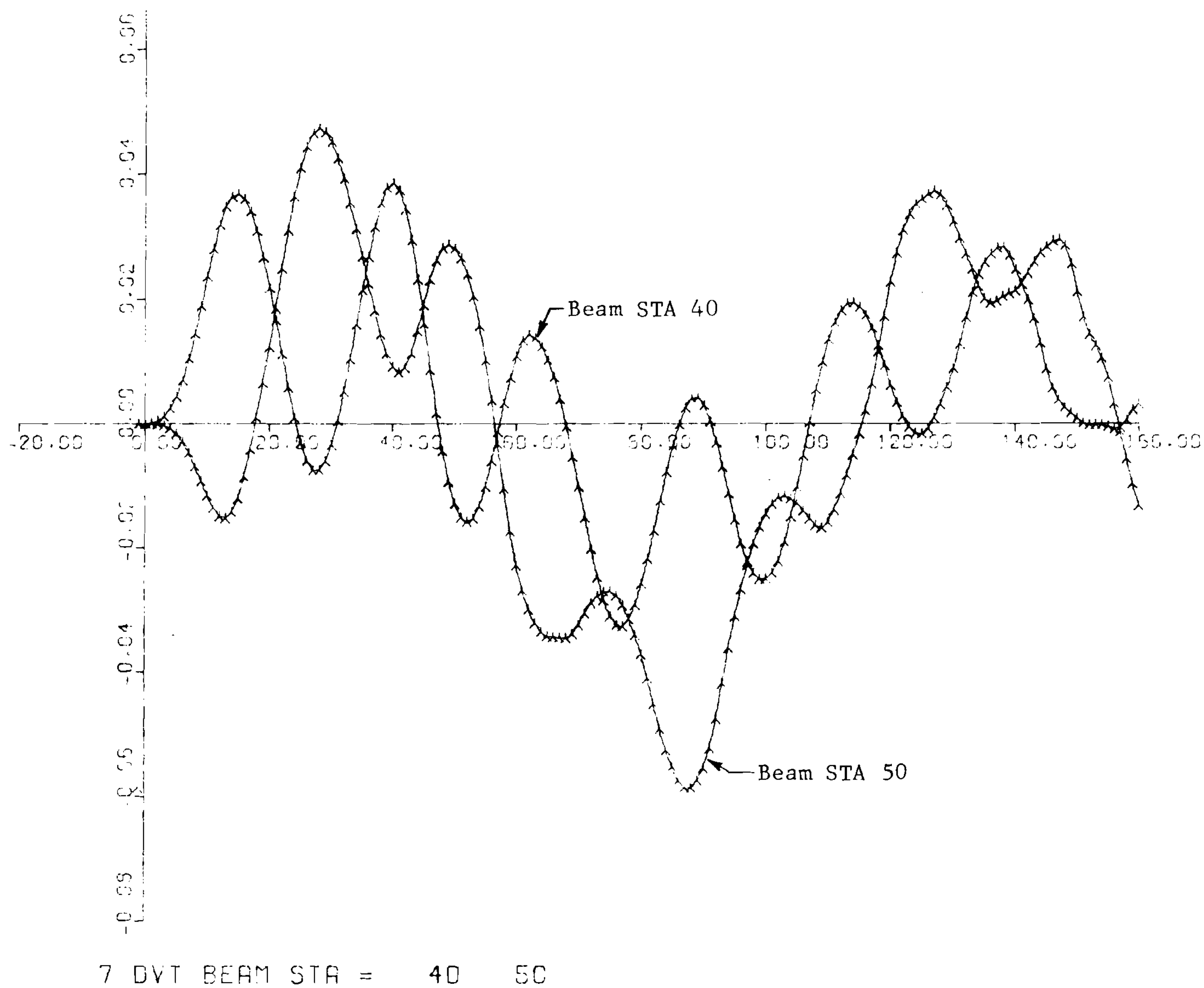


Fig 59. Example Problem 7. Deflection vs time for beam stations 40 and 50.

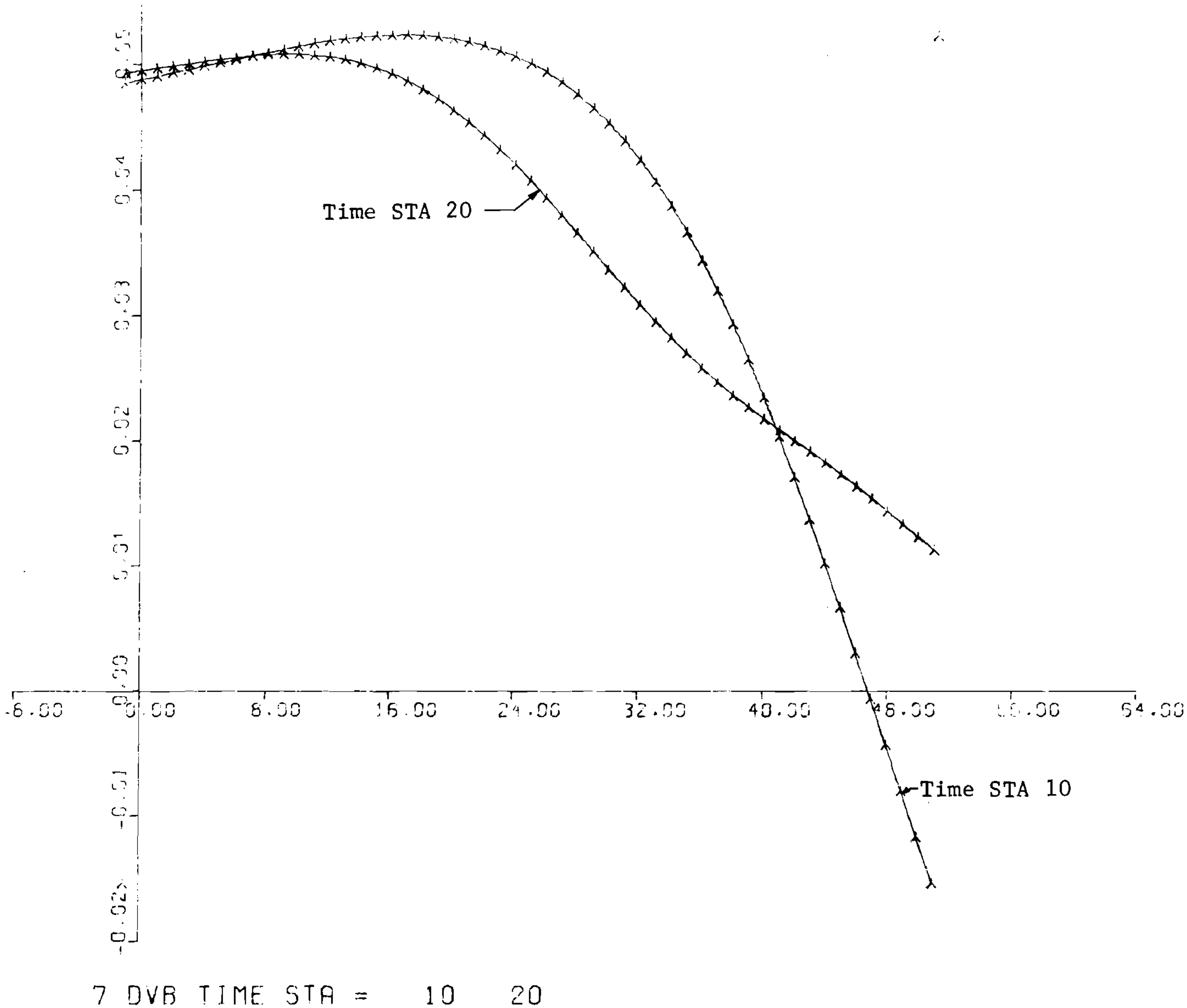


Fig 60. Example Problem 7. Deflection along the beam axis for time stations 10 and 20.

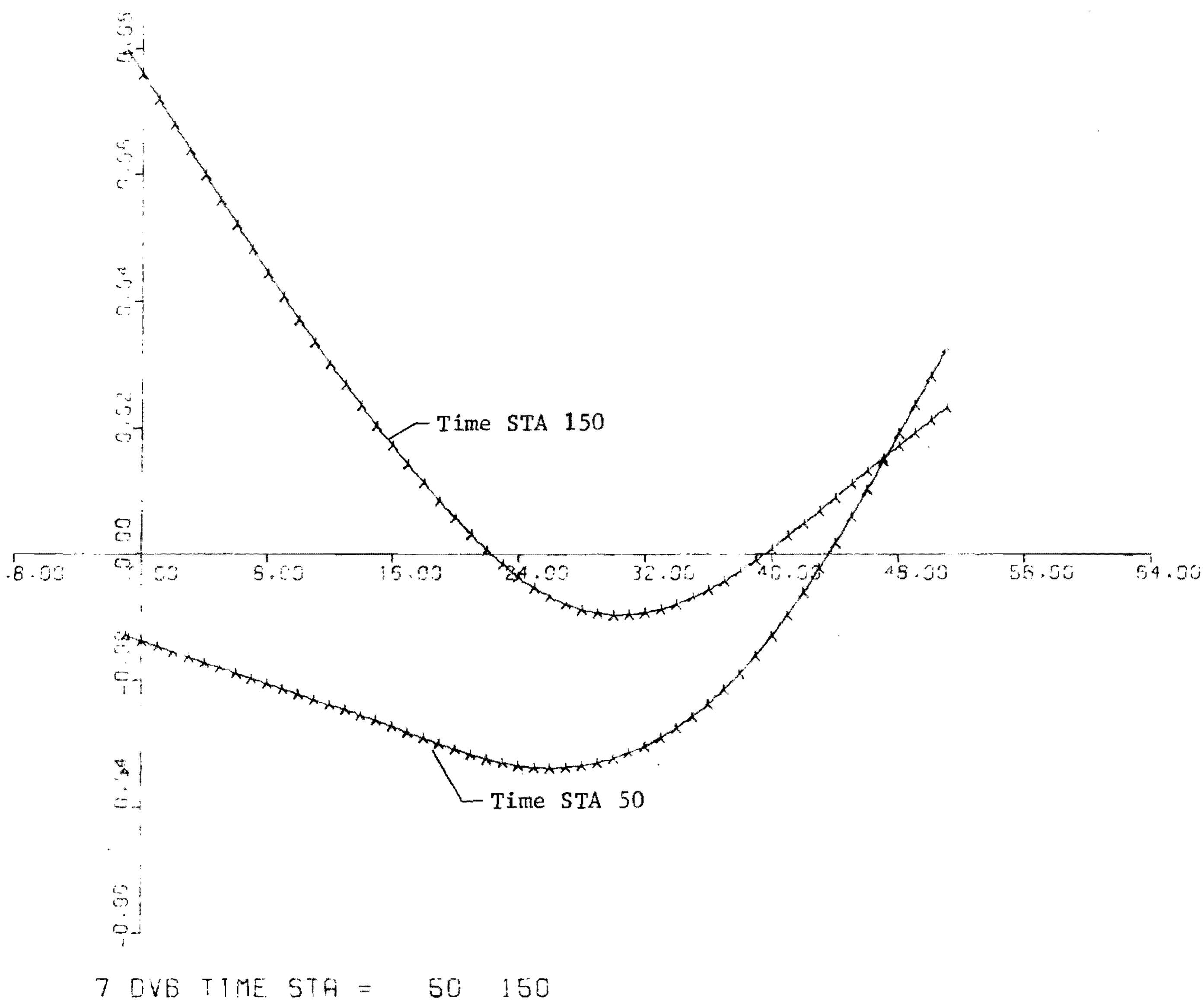


Fig 61. Example Problem 7. Deflection along the beam axis for time stations 50 and 150.

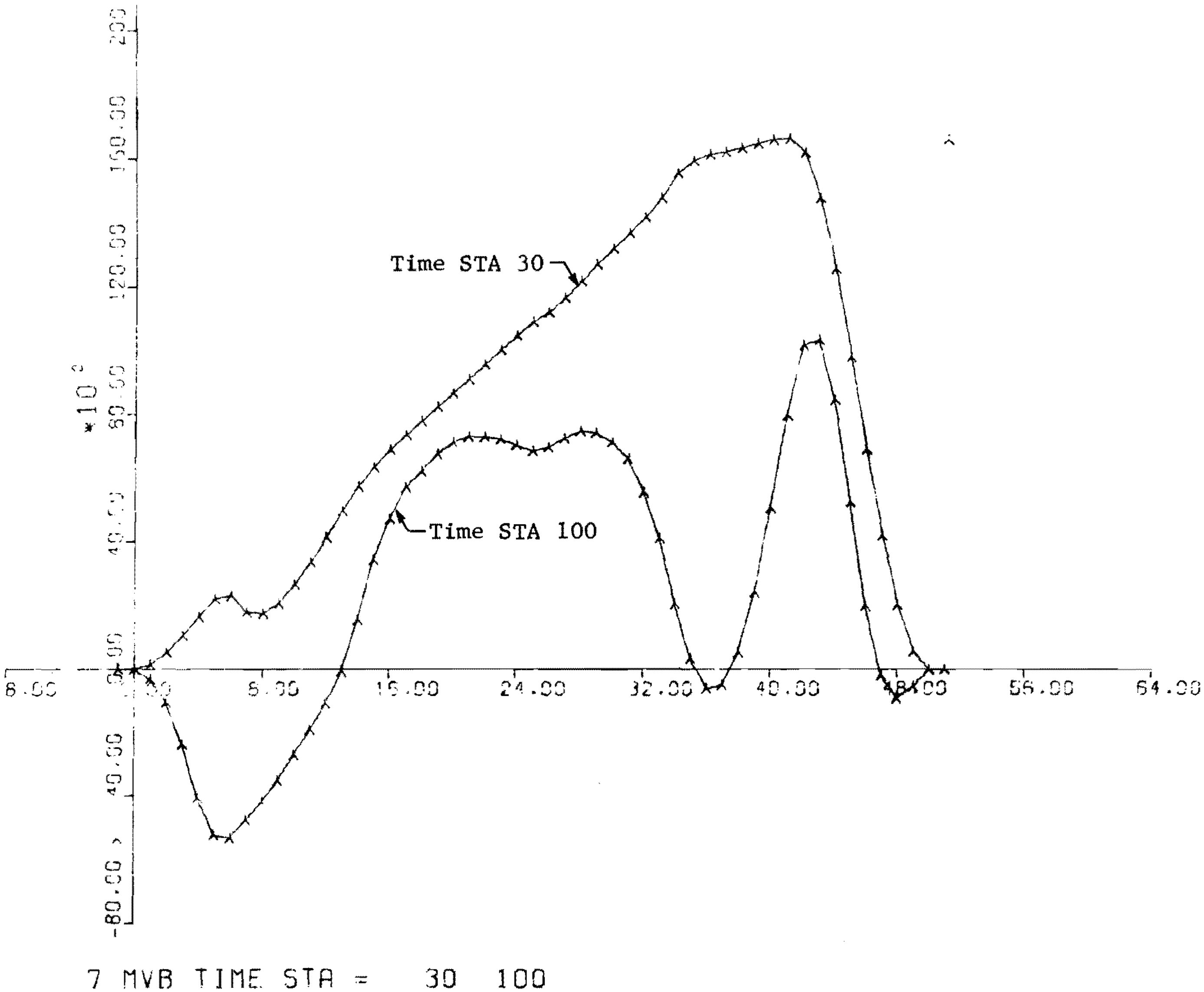


Fig 62. Example Problem 7. Moment along the beam axis for time stations 30 and 100.

CHAPTER 6. SUMMARY AND CONCLUSIONS

In this study, the dynamic solution of the discrete-element beam-columns of Ref 10 (DBC1) and the static solution of the discrete-element beam-columns of Ref 5 (BMCOL 43) have been modified and extended to cover nonlinear supports and loads with time-dependent axial thrusts; the program has the added capability of producing plots of the deflections or moments along either beam or time axis of any requested monitor stations.

The path-dependent history of loading of the nonlinearly-inelastic resistance-deflection curve of the support is considered in the study. Two multi-element models, which are used to simulate the nonlinear characteristics of symmetric and one-way resistance-deflection curves, have been introduced. An internal damping factor, which is related to the first time derivative of the curvature of the beam, has been considered in addition to the external viscous damping factor which is normally encountered in a dynamic problem. A computer program which has been presented, DBC5, allows the user to obtain a variety of results and plots. All of the uses and capabilities of DBC1 and BMCOL 43, except construction of the envelopes of maximums provided in BMCOL 43, have been incorporated in the DBC5 program.

This method is based on an implicit difference formula of the Crank-Nicolson type. Problems in which only linear spring supports are specified are not subject to the instability of dynamic solutions. Problems in which nonlinearly-inelastic supports are specified, however, require cautious selection of a time increment length, to pick one reasonably but not extremely small (for instance, less than 1/10 of the fundamental period), since the basic assumption of the Crank-Nicolson implicit formula is that the time dependent forcing function and the time variant nonlinear springs are smoothly varied with time. For problems with nonlinear supports, the iteration process compares the successively computed deflections until a specified tolerance is satisfied. The option of switching from the spring-load iteration technique (tangent modulus method) to the load iteration technique for problems with nonlinear supports is useful when the support yields or disconnects from the beam-column since the spring-load iteration method fails in these cases.

This report is intended to encourage use of DBC5 as a tool in computer aided design. Highway structural and foundation designers can use it to solve many problems, static or dynamic, which they encounter and which presently are solved by rough approximations or by tedious hand calculations. A very important use would be for a study of the dynamic response of actual truck loaded beam-columns, as illustrated in Example Problem 3 described in Chapter 5. A highly sophisticated computer program (Ref 1) is available to compute the time variant dynamic forces of the tires of a truck moving at a uniform speed on highway pavements. With limited interpretation, the computed dynamic tire forces could be input in the table provided for the time dependent lateral loads in Program DBC5.

Further application to design problems that are difficult to solve by conventional means is possible. The possible variations include analyses of a bridge structure as foundation supports settle, railroad loadings on continuous spans supported on soil foundations, the effect of axial loads induced from tractive forces or temperature changes, approach slabs connected integrally with the bridge structure and supported on soil foundations, offshore piles loaded with wave forces and partially embedded in the soil, and transverse response to earthquake-induced forces.

Future extensions to the model and the program might include, for highway pavement analysis, the coupling of a vehicle model and pavement roughness characteristics to the beam-column model for generation of dynamic loads (similar to the model described in Ref 1) and the inelastic analysis of beam properties.

The nonlinear solution capabilities should be extended to the beam bending stiffness variable. Nonlinear moment-curvature relations could be incorporated in the iterative procedure, thereby permitting analysis of the beam material for stresses in the nonlinear range. The hysteresis effect of the nonlinear moment-curvature relations should also be considered.

Studies of the nonlinear closure procedure should be continued. Methods for accelerating closure in the load iteration technique should be developed. In Program DBC5, the iteration process is performed at each time step. It is possible, however, to iterate only at the critical time stations; at the rest of the time stations, the support stiffness can be assumed to be unchanged since a small time increment length must be used in these problems. The existing discrete-element model requires the user to know and specify the distribution of axial thrust throughout the beam. A valuable extension of this work would be modification of the model to include axial deformations and development of the force-deformation equations for axial thrust.

Finally, experimental data are required for further evaluation of the method, especially in predicting the path-dependent behavior of the supports. Research of this nature will furnish additional data on the nonlinear behavior of the supports, which could be applied to modification of the existing multi-element models for nonlinear supports so that buckling, fracture, softening, and relaxation (creep) of the support could also be considered in the program.

REFERENCES

1. Al-Rashid, Nasser I., "A Theoretical and Experimental Study of Dynamic Highway Loading," Ph.D. Dissertation, The University of Texas at Austin, May 1970.

2. Crank, J., and P. Nicolson, "A Practical Method for Numerical Evaluation of Solutions of Partial Differential Equations of Heat Conduction Type," Proceedings, Cambridge Philosophical Society, Vol 43, 1947, pp 50-67.

3. Kelly, Allen E., and Hudson Matlock, "Dynamic Analysis of Discrete-Element Plates on Nonlinear Foundations," Research Report 56-17, Center for Highway Research, The University of Texas at Austin, January 1970.

4. Matlock, Hudson, and Allan T. Haliburton, "A Finite-Element Method of Solution for Linearly Elastic Beam-Columns," Research Report 56-1, Center for Highway Research, The University of Texas, Austin, September 1966.

5. Matlock, Hudson, and Thomas P. Taylor, "A Computer Program to Analyze Beam-Columns Under Movable Loads," Research Report 56-4, Center for Highway Research, The University of Texas at Austin, June 1968.

6. Matlock, Hudson, "Correlations for Design of Laterally Loaded Piles in Soft Clay," Paper No. OTC 1204, Offshore Technology Conference, 6200 North Central Expressway, Dallas, Texas.

7. Matlock, Hudson, and Mahendra Vora, unpublished paper on axially loaded steel rod, The University of Texas at Austin, 1971.

8. Matlock, Hudson, and Mahendra Vora, unpublished paper on cyclic load-deformation curves of stiff clay, The University of Texas at Austin, 1971.

9. Reiner, M., "Building Materials, Their Elasticity and Inelasticity," North-Holland Publishing Company, 1954.

10. Salani, Harold, and Hudson Matlock, "A Finite-Element Method for Transverse Vibrations of Beams and Plates," Research Report 56-8, Center for Highway Research, The University of Texas at Austin, June 1967.

11. Timoshenko, S., "Strength of Materials," Part II, pp 411-416, D. Van Nostrand Company, Inc., 1956.

12. Timoshenko, S., "Vibration Problems in Engineering," pp 324-380, D. Van Nostrand Company, Inc., 1955.

13. Volterra, Enrico, and E. C. Zachmanoglou, "Dynamics of Vibrations," Charles E. Merrill Books, Inc., Columbus, Ohio, 1965.

APPENDIX A

DERIVATION OF THE DYNAMIC IMPLICIT OPERATOR BASED ON THE CRANK-NICOLSON IMPLICIT FORMULA

APPENDIX A. DERIVATION OF THE DYNAMIC IMPLICIT OPERATOR BASED ON THE CRANK-NICOLSON IMPLICIT FORMULA

The dynamic model used in Program DBC5 is discussed in Chapter 2 and the free-body diagram of the model is shown in Fig 3.

Since the rigid bars connected between the deformable joints are only responsible for transferring the bending moments, the shears, and the axial thrusts from one joint to another, the equation of motion of the beam-column can be obtained by summing up all the forces, internal or external, at any deformable joint where the beam properties are lumped. For the convenience of the reader, the free-body diagram of a portion of the dynamic beam-column model is shown in Fig A1.

If we take equilibriums for the moments in Bar j and Bar j+1 and for the vertical forces at joint J, then

for Bar j

$$M_{j-1} - M_j + (D^i)_{j-1} \frac{d}{dt} (\varphi_{j-1,k}) - (D^i)_j \frac{d}{dt} (\varphi_{j,k})$$

$$+ V_j h + (T_j + T^T_{j,k})(-w_{j-1,k} + w_{j,k}) = 0 \tag{A.1}$$

for Bar j+1

$$M_j - M_{j+1} + (D^i)_j \frac{d}{dt} (\varphi_{j,k}) - (D^i)_{j+1} \frac{d}{dt} (\varphi_{j+1,k})$$

$$+ V_{j+1} h + (T_{j+1} + T^T_{j+1,k})(-w_{j,k} + w_{j+1,k}) = 0 \tag{A.2}$$

for Joint j

$$V_j - V_{j+1} + Q^T_{j,k} + Q_j + \frac{-R_{j-1}\theta_{j-1} + R_{j+1}\theta_{j+1}}{2h}$$

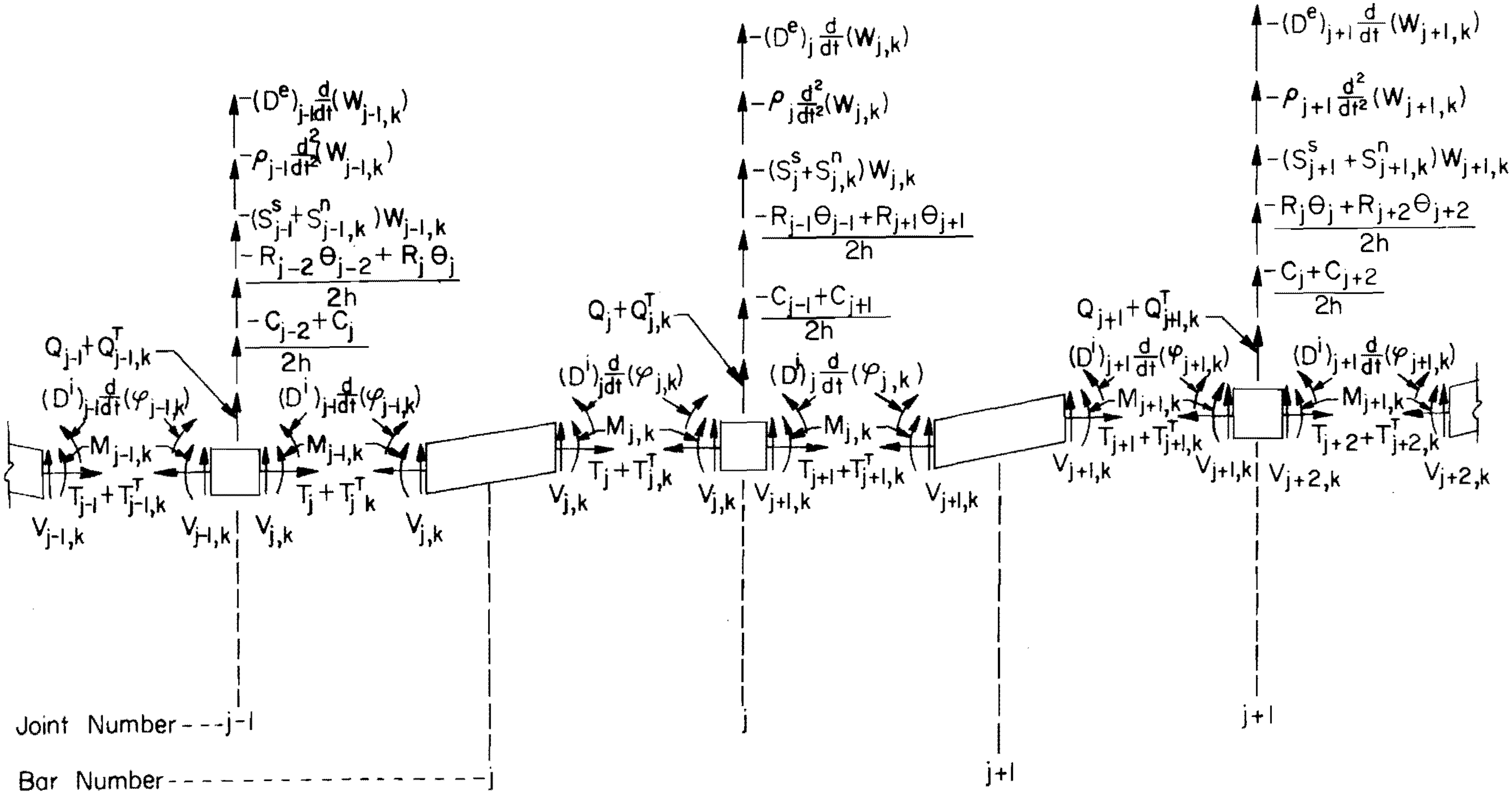


Fig A1. Free-body diagram of a portion of the dynamic beam-column model.

$$+ \frac{-C_{j-1} + C_{j+1}}{2h} - S^N_{j,k} w_{j,k} - S^S_j w_{j,k} - \rho_j \frac{d^2}{dt^2} (w_{j,k})$$

$$- (D^e)_j \frac{d}{dt} (w_{j,k}) = 0 \tag{A.3}$$

Solving for the shears V_j and V_{j+1} in Eqs A.1 and A.2 and substituting into Eq A.3 and multiplying by h yields

$$- M_{j-1} + 2M_j - M_{j+1} - (D^i)_{j-1} \frac{d}{dt} (\varphi_{j-1,k}) + 2(D^i)_j \frac{d}{dt} (\varphi_{j,k})$$

$$- (D^i)_{j+1} \frac{d}{dt} (\varphi_{j+1,k}) - (T_j + T^T_{j,k})(-w_{j-1,k} + w_{j,k})$$

$$+ (T_{j+1} + T^T_{j+1,k})(-w_{j,k} + w_{j+1,k}) + hQ^T_{j,k} + hQ_j$$

$$+ \frac{(-R_{j-1}\theta_{j-1} + R_{j+1}\theta_{j+1})}{2} + \frac{(-C_{j-1} + C_{j+1})}{2} - hS^S_j w_{j,k}$$

$$- hS^N_{j,k} w_{j,k} - h\rho_j \frac{d^2}{dt^2} (w_{j,k}) - h(D^e)_j \frac{d}{dt} (w_{j,k}) = 0 \tag{A.4}$$

Based on the Crank-Nicolson implicit formula, we can assume that

$$M_{j-1} = F_{j-1} \frac{1}{2h^2} \Big[w_{j-2,k-1} - 2w_{j-1,k-1} + w_{j,k-1} + w_{j-2,k+1}$$

$$- 2w_{j-1,k+1} + w_{j,k+1} \Big] ,$$

$$M_j = F_j \frac{1}{2h^2} \Big[w_{j-1,k-1} - 2w_{j,k-1} + w_{j+1,k-1} + w_{j-1,k+1} - 2w_{j,k+1}$$

$$+ w_{j+1,k+1} \Big] ,$$

$$M_{j+1} = F_{j+1} \frac{1}{2h^2} \left[w_{j,k-1} - 2w_{j+1,k-1} + w_{j+2,k-1} + w_{j,k+1} \right.$$

$$\left. - 2w_{j+1,k+1} + w_{j+2,k+1} \right] ,$$

$$\frac{d}{dt}(\varphi_{j-1,k}) = \frac{1}{h^2 2h_t} \left[-w_{j-2,k-1} + 2w_{j-1,k-1} - w_{j,k-1} + w_{j-2,k+1} \right.$$

$$\left. - 2w_{j-1,k+1} + w_{j,k+1} \right] ,$$

$$\frac{d}{dt}(\varphi_{j,k}) = \frac{1}{h^2 2h_t} \left[-w_{j-1,k-1} + 2w_{j,k-1} - w_{j+1,k-1} + w_{j-1,k+1} \right.$$

$$\left. - 2w_{j,k+1} + w_{j+1,k+1} \right] ,$$

$$\frac{d}{dt}(\varphi_{j+1,k}) = \frac{1}{h^2 2h_t} \left[-w_{j,k-1} + 2w_{j+1,k-1} - w_{j+2,k-1} + w_{j,k+1} \right.$$

$$\left. - 2w_{j+1,k+1} + w_{j+2,k+1} \right] ,$$

$$\theta_{j-1} = \frac{1}{4h} \left[-w_{j-2,k-1} - w_{j-2,k+1} + w_{j,k-1} + w_{j,k+1} \right] ,$$

$$\theta_{j+1} = \frac{1}{4h} \left[-w_{j,k-1} - w_{j,k+1} + w_{j+2,k-1} + w_{j+2,k+1} \right] ,$$

$$S^N_{j,k} = \frac{1}{2} \left[S^N_{j,k-1} + S^N_{j,k+1} \right] ,$$

$$\frac{d^2}{dt^2} (w_{j,k}) = \frac{1}{h_t^{\,2}} \left[w_{j,k-1} - 2w_{j,k} + w_{j,k+1} \right] ,$$

$$\frac{d}{dt}(w_{j,k}) = \frac{1}{2h_t}\left[-w_{j,k-1} + w_{j,k+1}\right],$$

$$w_{j-1,k} = \frac{1}{2}\left[w_{j-1,k-1} + w_{j-1,k+1}\right],$$

$$w_{j,k} = \frac{1}{2}\left[w_{j,k-1} + w_{j,k+1}\right],$$

$$w_{j+1,k} = \frac{1}{2}\left[w_{j+1,k-1} + w_{j+1,k+1}\right],$$

$$Q^T_{j,k} = \frac{1}{2}\left[Q^T_{j,k-1} + Q^T_{j,k+1}\right],$$

$$T^T_{j,k} = \frac{1}{2}\left[T^T_{j,k-1} + T^T_{j,k+1}\right],$$

and

$$T^T_{j+1,k} = \frac{1}{2}\left[T^T_{j+1,k-1} + T^T_{j+1,k+1}\right] \qquad \text{(A.5)}$$

Substituting Eq A.5 into Eq A.4 and rearranging the order, we obtain

$$\left[F_{j-1} + \frac{(D^i)_{j-1}}{h_t} - 0.25hR_{j-1}\right] w_{j-2,k+1} + \Big\{- 2(F_{j-1} + F_j)$$

$$- \frac{2}{h_t}\left[(D^i)_{j-1} + (D^i)_j\right] - h^2\left[T_j + 0.5(T^T_{j,k-1} + T^T_{j,k+1})\right]\Big\}$$

$$w_{j-1,k+1} + \Big\{(F_{j-1} + 4F_j + F_{j+1}) + \frac{1}{h_t}\Big[(D^i)_{j-1} + 4(D^i)_j$$

$$+ (D^i)_{j+1}\Big] + h^2\Big[T_j + T_{j+1} + 0.5(T^T_{j,k-1} + T^T_{j,k+1} + T^T_{j+1,k-1}$$

$$+ T^T_{j+1,k+1})\Big] + 0.25h(R_{j-1} + R_{j+1}) + \frac{h^3}{2}\Big[(S^S_j + S^N_{j,k-1})$$

$$+ (S^S_j + S^N_{j,k+1})\Big] + \frac{2h^3\rho_j}{h_t^2} + \frac{h^3(D^e)_j}{h_t}\Big\} w_{j,k+1} + \Big\{-2(F_j + F_{j+1})$$

$$- \frac{2}{h_t}\Big[(D^i)_j + (D^i)_{j+1}\Big] - h^2\Big[T_{j+1} + 0.5(T^T_{j+1,k-1} + T^T_{j+1,k+1})\Big]\Big\}$$

$$w_{j+1,k+1} + \Big[F_{j+1} + \frac{(D^i)_{j+1}}{h_t} - 0.25hR_{j+1}\Big] w_{j+2,k+1}$$

$$= \Big[\frac{4h^3\rho_j}{h_t^2}\Big] w_{j,k} + \Big[-F_{j-1} + \frac{(D^i)_{j-1}}{h_t} + 0.25hR_{j-1}\Big] w_{j-2,k-1}$$

$$+ \Big\{2(F_{j-1} + F_j) - \frac{2}{h_t}\Big[(D^i)_{j-1} + (D^i)_j\Big] + h^2\Big[T_j + 0.5(T^T_{j,k-1}$$

$$+ T^T_{j,k+1})\Big]\Big\} w_{j-1,k-1} + \Big\{-(F_{j-1} + 4F_j + F_{j+1})$$

$$+ \frac{1}{h_t}\Big[(D^i)_{j-1} + 4(D^i)_j + (D^i)_{j+1}\Big] - h^2\Big[T_j + T_{j+1} + 0.5(T^T_{j,k-1}$$

$$+ T^T_{j,k+1} + T^T_{j+1,k-1} + T^T_{j+1,k+1})\Big] - 0.25h(R_{j-1} + R_{j+1})$$

$$- \frac{h^3}{2}\Big[(S^S_j + S^N_{j,k-1}) + (S^S_j + S^N_{j,k+1})\Big] - \frac{2h^3\rho_j}{h_t^2} + \frac{h^3(D^3)_j}{h_t}\Big\} w_{j,k-1}$$

$$+ \Big\{2(F_j + F_{j+1}) - \frac{2}{h_t}\Big[(D^i)_j + (D^i)_{j+1}\Big] + h^2\Big[T_{j+1} + 0.5(T^T_{j+1,k-1}$$

$$+ T^T_{j+1,k+1}) \Big] \Big\} w_{j+1,k-1} + \Big[- F_{j+1} + \frac{(D^i)_{j+1}}{h_t} + 0.25hR_{j+1} \Big]$$

$$w_{j+2,k-1} + h^3 \Big[(Q^T_{j,k-1} + Q^T_{j,k+1}) + 2Q_j \Big] + h^2(- C_{j-1}$$

$$+ C_{j+1}) \tag{A.6}$$

Collecting the terms and rearranging the order in Eq A.6, we obtain a dynamic implicit operator:

$$a_{k+1}w_{j-2,k+1} + b_{k+1}w_{j-1,k+1} + c_{k+1}w_{j,k+1} + d_{k+1}w_{j+1,k+1}$$

$$+ e_{k+1}w_{j+2,k+1}$$

$$= c_k w_{j,k} + a_{k-1}w_{j-2,k-1} + b_{k-1}w_{j-1,k-1} + c_{k-1}w_{j,k-1}$$

$$+ d_{k-1}w_{j+1,k-1} + e_{k-1}w_{j+2,k-1} + f_{j,k}$$

where

$$a_{k+1} = F_{j-1} + \frac{(D^i)_{j-1}}{h_t} - 0.25hR_{j-1} ,$$

$$b_{k+1} = -2(F_{j-1} + F_j) - \frac{2}{h_t} \Big[(D^i)_{j-1} + (D^i)_j \Big] - h^2 \Big[T_j +$$

$$0.5(T^T_{j,k-1} + T^T_{j,k+1}) \Big] ,$$

$$c_{k+1} = (F_{j-1} + 4F_j + F_{j+1}) + \frac{1}{h_t} \Big[(D^i)_{j-1} + 4(D^i)_j + (D^i)_{j+1} \Big]$$

$$+ h^2 \Big[T_j + T_{j+1} + 0.5(T^T_{j,k-1} + T^T_{j,k+1} + T^T_{j+1,k-1} + T^T_{j+1,k+1}) \Big]$$

$$+ 0.25h(R_{j-1} + R_{j+1}) + \frac{2h^3\rho_j}{h_t^2} + \frac{h^3(D^e)_j}{h_t} + \frac{h^3}{2}\left[(S_j^S + S_{j,k-1}^N)\right.$$

$$\left. + (S_j^S + S_{j,k+1}^N)\right] ,$$

$$d_{k+1} = -2(F_j + F_{j+1}) - \frac{2}{h_t}\left[(D^i)_j + (D^i)_{j+1}\right] - h^2\left[T_{j+1}\right.$$

$$\left. + 0.5(T_{j+1,k-1}^T + T_{j+1,k+1}^T)\right] ,$$

$$e_{k+1} = F_{j+1} + \frac{(D^i)_{j+1}}{h_t} - 0.25hR_{j+1} ,$$

$$c_k = \frac{4h^3\rho_j}{h_t^2} ,$$

$$a_{k-1} = -a_{k+1} + \frac{2(D^i)_{j-1}}{h_t} ,$$

$$b_{k-1} = -b_{k+1} - \frac{4}{h_t}\left[(D^i)_{j-1} + (D^i)_j\right] ,$$

$$c_{k-1} = -c_{k+1} + \frac{2}{h_t}\left[(D^i)_{j-1} + 4(D^i)_j + (D^i)_{j+1}\right] + \frac{2h^3(D^e)_j}{h_t} ,$$

$$d_{k-1} = -d_{k+1} - \frac{4}{h_t}\left[(D^i)_j + (D^i)_{j+1}\right] ,$$

$$e_{k-1} = -e_{k+1} + \frac{2(D^i)_{j+1}}{h_t} ,$$

$$f_{j,k} = h^3 \left[(Q^T_{j,k-1} + Q_j) + (Q^T_{j,k+1} + Q_j) \right] + h^2(-C_{j-1} + C_{j+1})$$

APPENDIX B

DERIVATION FOR RECURSIVE SOLUTION OF EQUATIONS
(Extracted from Appendix 2 of Ref 4)

APPENDIX B. DERIVATION FOR RECURSIVE SOLUTION OF EQUATIONS
(Extracted from Appendix 2 of Ref 4)

Any of the fourth-order difference equations for beams or beam-columns can be written in the following form:

$$a_j w_{j-2} + b_j w_{j-1} + c_j w_j + d_j w_{j+1} + e_j w_{j+2} = f_j \tag{B.1}$$

Definitions of the coefficients a_j through f_j will vary according to the particular beam formulation considered. The general process of simultaneous solution of a complete system of such equations will be the same in any case. The matrix formed by writing coefficients a_j through e_j at all stations has non-zero terms along only the five main diagonals, and the most efficient method of solutions, therefore, is a direct process that amounts to simple Gaussian elimination. In a forward pass, two unknowns are eliminated from each equation, resulting in a triangularized coefficient matrix of only three diagonals. On the reverse pass, the solution is completed by back substitution. The necessary recursion equations for the process are derived below.

Assume, temporarily, that w_{j-2} and w_{j-1} can be eliminated so that w_j can be written in terms of deflections at two stations to the right. In general

$$w_j = A_j + B_j w_{j+1} + C_j w_{j+2} \tag{B.2}$$

Writing equations of this form for w_{j-2} and w_{j-1},

$$w_{j-2} = A_{j-2} + B_{j-2} w_{j-1} + C_{j-2} w_j \tag{B.3}$$

$$w_{j-1} = A_{j-1} + B_{j-1} w_j + C_{j-1}, w_{j+1} \tag{B.4}$$

Substituting Eqs B.3 and B.4 into Eq B.1,

$$a_j \left[A_{j-2} + B_{j-2} (A_{j-1} + B_{j-1} w_j + C_{j-1} w_{j+1}) + C_{j-2} w_j \right]$$

$$+ b_j(A_{j-1} + B_{j-1}w_j + C_{j-1}w_{j+1}) + c_jw_j + d_jw_{j+1} + e_jw_{j+2}$$

$$= f_j \quad (B.5)$$

Multiplying and collecting terms,

$$(a_jB_{j-2}B_{j-1} + a_jC_{j-2} + b_jB_{j-1} + c_j)w_j$$

$$+ (a_jB_{j-2}C_{j-1} + b_jC_{j-1} + d_j)w_{j+1}$$

$$+ (e_j)w_{j+2} = f_j - (a_jA_{j-2} + a_jB_{j-2}A_{j-1} + b_jA_{j-1}) \quad (B.6)$$

Equation B.6 can be rewritten in the form assumed in Eq B.2:

$$w_j = A_j + B_jw_{j+1} + C_jw_{j+2} \quad (B.7)$$

where

$$A_j = D_j(E_jA_{j-1} + a_jA_{j-2} - f_j) \quad (B.7a)$$

$$B_j = D_j(E_jC_{j-1} + d_j) \quad (B.7b)$$

$$C_j = D_j(e_j) \quad (B.7c)$$

and where

$$D_j = -1/(E_jB_{j-1} + a_jC_{j-2} + c_j) \quad (B.7d)$$

$$E_j = a_jB_{j-2} + b_j \quad (B.7e)$$

For beam and beam-column problems, the coefficients A_j, B_j, and C_j can be thought of as expressing the physical continuity of the system. In these coefficients all of the known input data are digested and stored. The coefficients at any one station depend not only on the load and stiffness data at that station but also on effects from all previous stations. These coefficients have therefore been termed "Continuity Coefficients."

APPENDIX C

STABILITY ANALYSIS FOR THE DYNAMIC IMPLICIT OPERATOR WITH INTERNAL DAMPING COEFFICIENT

APPENDIX C. STABILITY ANALYSIS FOR THE DYNAMIC IMPLICIT OPERATOR WITH INTERNAL DAMPING COEFFICIENT

In studying the stability criterion for the dynamic solutions of a beam with hinged ends and M increments, a solution to the equation of motion described in Chapter 2 (Eq 2.1 or 2.2) can be assumed to be

$$w_{j,k} = A \sin(j\beta_n)e^{k\phi} \tag{C.1}$$

in which A is a constant, $j = 0, 1, 2, \ldots M$, and $k = 1, 2, 3, \ldots, \infty$.

If we consider only the flexibility of the beam F_j , the mass density of the beam ρ_j , and the internal damping coefficient of the beam $(D^i)_j$, then Eq 2.2, becomes

$$\left[F_{j-1} + \frac{(D^i)_{j-1}}{h_t}\right] w_{j-2,k+1} - 2 \left\{(F_{j-1} + F_j) + \frac{1}{h_t} \left[(D^i)_{j-1}\right.\right.$$

$$\left.\left. + (D^i)_j\right]\right\} w_{j-1,k+1} + \left\{(F_{j-1} + 4F_j + F_{j+1}) + \frac{1}{h_t} \left[(D^i)_{j-1}\right.\right.$$

$$\left.\left. + 4(D^i)_j + (D^i)_{j+1}\right] + \frac{2h^3\rho_j}{ht^2}\right\} w_{j,k+1} - 2 \left\{(F_j + F_{j+1})\right.$$

$$\left. + \frac{1}{h_t} \left[(D^i)_j + (D^i)_{j+1}\right]\right\} w_{j+1,k+1} + \left[F_{j+1} + \frac{(D^i)_{j+1}}{h_t}\right] w_{j+2,k+1}$$

$$= \left(\frac{4h^3\rho_j}{h_t^2}\right) w_{j,k} - \left[F_{j-1} - \frac{(D^i)_{j-1}}{h_t}\right] w_{j-2,k-1} + 2 \left\{(F_{j-1} + F_j) - \right.$$

$$\left. \frac{1}{h_t}\left[(D^i)_{j-1} + (D^i)_j\right]\right\} w_{j-1,k-1} - \left\{(F_{j-1} + 4F_j + F_{j+1})\right.$$

$$\left. - \frac{1}{h_t}\left[(D^i)_{j-1} + 4(D^i)_j + (D^i)_{j+1}\right] + \frac{2h^3\rho_j}{h^2}\right\} w_{j,k-1}$$

$$+ 2\left\{(F_j + F_{j+1}) - \frac{1}{h_t}\left[(D^i)_j + (D^i)_{j+1}\right]\right\} w_{j+1,k-1}$$

$$- \left[F_{j+1} - \frac{(D^i)_{j+1}}{h_t}\right] w_{j+2,k-1} \tag{C.2}$$

Assuming that the beam has a uniform cross section, uniform elastic properties, uniform mass density, and a uniform internal damping coefficient, Eq C.2 can be simplified as

$$(F + D)w_{j-2,k+1} - 4(F + D)w_{j-1,k+1} + 6(F + D)w_{j,k+1} - 4(F + D)$$

$$w_{j+1,k+1} + (F + D)w_{j+2,k+1} + (F - D)w_{j-2,k-1} - 4(F - D)w_{j-1,k-1}$$

$$+ 6(F - D)w_{j,k-1} - 4(F - D)w_{j+1,k-1} + 6(F - D)w_{j,k-1}$$

$$- 4(F - D)w_{j+1,k-1} + (F - D)w_{j+2,k-1}$$

$$= - \frac{2\rho h^3}{h_t^2} (w_{j,k+1} + 2w_{j,k} + w_{j,k-1}) \tag{C.3}$$

where

$$F = \text{all } F \text{ terms (EI)}$$

$$D = \text{all } (D^i) \text{ terms divided by } h_t$$

$$\rho = \text{all } \rho \text{ terms}$$

Substituting Eq C.1 into Eq C.3, we obtain

$$(F + D)\ f\ (\beta_n, j) e^{(k+1)\phi} + (F - D)\ f\ (\beta_n, j) e^{(k-1)\phi}$$

$$= -\frac{2\rho h^3}{h_t^2}\Big[\sin \beta_n j e^{(k+1)\phi} + 2 \sin \beta_n j e^{k\phi}$$

$$+ \sin \beta_n j e^{(k-1)\phi}\Big] \tag{C.4}$$

where

$$f(\beta_n, j) = \sin \beta_n(j-2) - 4 \sin \beta_n(j-1) + 6 \sin \beta_n j$$

$$- 4 \sin \beta_n(j+1) + \sin \beta_n(j+2)$$

Let

$$q^2 = \frac{2\rho h^3}{h_t^2}$$

Then, dividing Eq C.4 by $e^{(k-1)\phi}$, we obtain

$$\left\{(F + D)\left[f(\beta_n, j) + q^2 \sin \beta_n j\right]\right\} e^{2\phi} + (2q^2 \sin \beta_n j)e^{\phi}$$

$$+ \left\{(F - D)\left[f(\beta_n j) + q^2 \sin \beta_n j\right]\right\} = 0 \qquad (C.5)$$

Substituting the following trigonometric identities,

$$\sin \beta_n(j-2) = \sin \beta_n j \cos 2\beta_n - \cos \beta_n j \sin 2\beta_n$$

$$4 \sin \beta_n(j-1) = 4(\sin \beta_n j \cos \beta_n - \cos \beta_n j \sin \beta_n)$$

$$4 \sin \beta_n(j+1) = 4(\sin \beta_n j \cos \beta_n + \cos \beta_n j \sin \beta_n)$$

$$\sin \beta_n(j+2) = \sin \beta_n j \cos 2\beta_n + \cos \beta_n j \sin 2\beta_n$$

into Eq C.5 and simplifying the equation, we obtain

$$\left[2(F + D)(\cos 2\beta_n - 4 \cos \beta_n + 3) + q^2\right] e^{2\phi} + 2q^2 e^{\phi}$$

$$+ \left[2(F - D) (\cos 2\beta_n - 4 \cos \beta_n + 3) + q^2\right] = 0 \qquad (C.6)$$

We can simplify Eq C.6 by using the trigonometric identities

$$\cos 2\beta_n = 2 \cos^2 \beta_n - 1 , \quad (\cos \beta_n - 1)^2 = \cos^2 \beta_n - 2 \cos \beta_n + 1 ,$$

and dividing by the coefficient of $e^{2\phi}$; thus

$$e^{2\phi} + \left[\frac{2q^2}{4(F + D)(\cos \beta_n - 1)^2 + q^2}\right] e^{\phi}$$

$$+ \left[\frac{4(F - D)(\cos \beta_n - 1)^2 + q^2}{4(F + D)(\cos \beta_n - 1)^2 + q^2} \right] = 0 \qquad (C.7)$$

Let

$$B = \frac{q^2}{\left[4(F + D)(\cos \beta_n - 1)^2 + q^2\right]} \quad \text{and}$$

$$C = \frac{4(F - D)(\cos \beta_n - 1)^2 + q^2}{4(F + D)(\cos \beta_n - 1)^2 + q^2}$$

Hence Eq C.7 becomes

$$e^{2\phi} + 2Be^{\phi} + C = 0 \qquad (C.8)$$

Equation C.8 is the quadratic equation which can be used to evaluate the stability criterion of the dynamic solutions of the beam. The criterion for the solution of $w_{j,k}$ in Eq C.1, which is to be bounded as time approaches infinity, is that the roots of the quadratic, e^{ϕ_1} and e^{ϕ_2}, must satisfy the condition that

$$|e^{\phi_1}| , |e^{\phi_2}| \leq 1 \qquad (C.9)$$

The two roots of Eq C.8 are

$$e^{\phi_1} = - B + \sqrt{B^2 - C}$$

and

$$e^{\phi_2} = -B - \sqrt{B^2 - C} \qquad (C.10)$$

The conditions of Eq C.9 are satisfied if the following inequality is true

$$B^2 - C \le 0 \qquad (C.11)$$

Substituting the equalities of B and C into Eq C.11 yields

$$\frac{q^2}{\left[4(F + D)(\cos \beta_n - 1)^2 + q^2\right]^2} \le \frac{4(F - D)(\cos \beta_n - 1)^2 + q^2}{4(F + D)(\cos \beta_n - 1)^2 + q^2} \qquad (C.12)$$

The above inequality can be reduced to

$$16\ (F^2 - D^2)(\cos \beta_n - 1)^4 + 8F\ (\cos \beta_n - 1)^2 q^2 \ge 0 \qquad (C.13)$$

By omitting the positive term $(\cos \beta_n - 1)^2$, the criterion for the stability of the dynamic solution of a uniform beam with hinged ends and internal damping coefficient becomes

$$16\ (F^2 - D^2)(\cos \beta_n - 1)^2 + 8Fq^2 \ge 0 \qquad (C.14)$$

Since $\frac{(D^i)_j}{h_t}$ is usually less than F_j for a reasonable time increment length h_t and the positive value of the term $8Fq^2$ is always greater than the negative value of the term $16(f^2 - D^2)(\cos \beta_n - 1)^2$ when the time increment length is extremely small, the above inequality is true.

APPENDIX D

GUIDE FOR DATA INPUT FOR DBC5

IDENTIFICATION OF PROGRAM AND RUN (Two alphanumeric cards per run)

Columns 1–80

Columns 1–80

IDENTIFICATION OF PROBLEM (One card for each problem)

Prob. No. (1–5)		Description of problem (11–80)

TABLE 1. PROGRAM CONTROL DATA (One card for each problem)

Enter "1" to keep data from prior tables / Number of cards input for tables

Keep 2	Keep 3	Keep 4	Keep 5	Keep 6	Keep 7	Keep 8	Keep 9	Cards 2	Cards 3	Cards 4	Cards 5	Cards 6	Cards 7	Cards 8	Cards 9
1–5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80

TABLE 2. CONSTANTS (One, two, or three cards; none if preceding Table 2 is held)

NUM of beam increments M	Beam increment length H	NUM of time increments MT	Time increment length HT	Printing Switch IPS*	NUM of monitor STA (printing) MONS	Iteration switch ITSW**	NUM of monitor STA (iteration) MONI	Plotting method switch MOP	Option for line or point plots LOP
6–10	20	26–30	40	46–50	55	60	65	70	75

* If printing switch is -1, use the following card, otherwise ignore:

Field	Description	Columns
KPS	Complete print out at time sta interval	6–10
Monitor stations		21–25, 25–30, 30–35, 35–40, 40–45, 45–50, 50–55, 55–60, 60–65, 65–70

** If iteration switch is not zero, use the following card, otherwise ignore:

Field	Description	Columns
MAXIT	Max num of iterations for any time step	6–10
WMAX	Maximum allowable deflection	10–20
WTOL	Deflection closure tolerance	20–30
Monitor stations		41–45, 45–50, 50–55, 55–60, 60–65

TABLE 3. SPECIFIED DEFLECTIONS AND SLOPES (The number of cards as shown in Table 1, none if preceding Table 3 is held)

Field	Description	Columns
STA		6–10
Case ***		16–20
Deflection		20–30
Slope		30–40
IOPS #	Initial or permanent switch	46–50

*** If case = 1, specified deflection
= 2, specified slope
= 3, specified both

\# If IOPS = 1, initial deflection or slope (or both) is specified.
= 2, permanent deflection or slope (or both) is specified.

TABLE 4. STIFFNESS AND FIXED-LOAD DATA (The number of cards as shown in Table 1)

From STA	To STA	Enter "1" if con't on next card	Bending stiffness F	Transverse static load QF	Static spring support S	Static axial thrust T	Rotational restraint R	Transverse couple CP
6–10	10–15	15–20	20–30	30–40	40–50	50–60	60–70	70–80

TABLE 5. MASS AND DAMPINGS (The number of cards as shown in Table 1)

From STA	To STA	Enter "1" if con't on next card	Mass density RHO	Internal damping DI	External damping DE
6–10	10–15	15–20	31–40	40–50	50–60

TABLE 6. TIME DEPENDENT AXIAL THRUST (The number of cards as shown in Table 1)

Beam STA from	Beam STA to	Time STA from	Time STA to	Axial thrust values (see page 7) TT1	TT2	TT3
6–10	10–15	21–25	25–30	36–45	45–55	55–65

TABLE 7. TIME DEPENDENT LATERAL LOADING (The number of cards as shown in Table 1)

Beam STA From	Beam STA To	Time STA From	Time STA To	Lateral Loads (see page 9) QT1	QT2	QT3
6–10	10–15	21–25	25–30	36–45	45–55	55–65

TABLE 8. NONLINEAR SUPPORT CURVES (Three cards per curve, the number of cards as shown in Table 1)

From Beam STA	To Beam STA	Enter "1" if cont'd on next card	Resistance Multiplier QMP	Deflection Multiplier WMP	Num Points NPOC	Symmetry Option KSYM	Deflection Tolerance WNTOL	Resistance Tolerance QNTOL
6–10	10–15	15–20	20–30	30–40	40–45	45–50	50–60	60–70

Resistance Values Q	31–35	35–40	40–45	45–50	50–55	55–60	60–65	65–70	70–75	75–80
Deflection Values W	31–35	35–40	40–45	45–50	50–55	55–60	60–65	65–70	70–75	75–80

TABLE 9. PLOTTING SWITCHES (One card for each plot, the number of cards as shown in Table 1)

Horizontal axis	Vertical axis	Beam or time STA	Multiple plot switch
△	⬡	▭	#
7–10	17–20	26–30	36–40

△ Enter either "TIME" or "BEAM"
⬡ Enter either "DEFL" or "MOMT"
▭ Enter either a beam station number if TIME horizontal axis was specified or a time station number if BEAM horizontal axis was specified.

[#]The consecutive plots, which are entered 1 for Multiple Plot Switch, will superimpose on common axes. The last plot of the group of plots which are superimposed on common axes must be entered 0 for Multiple Plot Switch.

For consecutive plots which are entered 0 for Multiple Plot Switch, each plot is plotted separately on different axes.

STOP CARD (One blank card of the end of each run)

The data cards must be stacked in proper order for the program to run.
A consistent system of units must be used for all input data, for example, lbs and inches.
All words of 5-spaces or less are understood to be right justified integers, whole decimal numbers, or alphanumeric words. [34] or [TIME]
All words of 10-spaces are right justified floating-point decimal numbers. [-4.231E+01]

Table 1. Program-Control Data

For each of Tables 2 and 3, a choice must be made between holding all the data from the preceding problem or entering entirely new data. If the hold option for any of these Tables is set equal to 1, the number of cards input for that Table must be zero.
For Tables 4 through 9, the data is accumulated in storage by adding to previously stored data.
The number of cards input is independent of the hold option, except that the cumulative total of cards cannot exceed 100 in Tables 4 through 7; 60 in Table 8; and 10 in Table 9. Card counts entered in Table 1 should be rechecked carefully after the coding of each problem is completed.

Table 2. Constants

Variables:	H	HT	WMAX	WTOL
Typical Input Units:	in	sec	in	in

The maximum number of increments into which the beam-column may be divided is 200. Typical units for the value of beam increment length are inches. The maximum number of increments into which the time axis may be divided is 1000. Typical units for the value of time increment length are seconds. If the printing switch (IPS) is set equal to -1, only results at monitor beam stations will be printed, except at every time station interval specified (KPS) where results at all beam stations will be printed. If the printing switch (IPS) is set equal to +1, the complete results of all beam stations will be printed at every time station and the second card therefore is not necessary. If the printing switch is equal to zero or left blank, no intermediate results will be printed. MONS is the number of specified monitor beam stations which are entered on the second card from column 21 to column 70, for printing the monitor stations results at every time station. The maximum number of monitor beam stations which may be used is 10.

The second input card should be omitted when the printing switch (IPS) is set equal to zero, blank, or +1.

For nonlinear support curves, which are stated in Table 8, the switch (ITSW) is set equal to either a negative or positive integer, for example, -1 or +1. If ITSW is set equal to zero or left blank, no nonlinear support curves may be entered in Table 8 and the third input card must be omitted.

MONI is the number of monitor beam stations, which are entered on the third input card from column 41 to column 65, for printing monitor deflections during the iteration process. The maximum number of monitor beam stations which may be requested is 5.

MAXIT is the number of iterations to be allowed for this problem. The maximum number is 50.

WMAX is the maximum allowable deflection for this problem.

WTOL is the closure tolerance for the iteration process.

MOP is a switch for selecting the method of plotting the results of beam or time stations which are stated in Table 9.

If MOP is set equal to -1, microfilm plots are made.

If MOP is set equal to zero or left blank, printer plots are made.

If MOP is set equal to 1, 12-inch standard ball-point paper plots are made.

LOP is an optional switch for choosing point or line plots for the microfilm or paper plots.

If LOP = -j, point plots are made at every jth point.

If LOP = 0 or blank, line plots are made. If LOP = j, line plots with a point plot at every jth point are made.

If no cards are entered for Table 9, MOP and LOP may be left blank.

If MOP is set equal to zero or left blank, LOP may be left blank.

Table 3. Specified Deflections and Slopes

The maximum number of beam stations at which deflections and slopes may be specified is 20.

A slope may not be specified closer than 3 increments from another specified slope.

A deflection may not be specified closer than 2 increments from a specified slope, except that both a deflection and a slope may be specified at the same beam station.

IOPS is a switch for specifying either an initial deflection (or slope) or a permanent deflection (or slope) at the beam station stated on the same card.

If IOPS is set equal to 1, initial deflection or slope (or both) are specified for the static solutions only.

If IOPS is set equal to 2, permanent deflection or slope (or both) are specified, both for the static solutions and the dynamic solutions.

Table 4. Stiffness and Fixed-Load Data

Variables:	F	QF	S	T	R	CP
Typical Input Units:	lb × in^2	lb	lb/in	lb	in×lb/rad	in×lb

Axial tension or compression values T must be stated at each beam station in the same manner as any other distributed data; there is no mechanism in the program to automatically distribute the internal effects of an externally applied axial force.

Data should not be entered in this table (nor held from the preceding problem) which would express effects at fictitious stations beyond the ends of the real beam-column.

The left end of the beam-column must be located at station 0.

For the interpolation and distribution process, there are four variations in the beam station numbering and referencing for continuation to succeeding cards. These variations are explained and illustrated on page 11. There are no restrictions on the order of cards in Tables 4 and 5, except that within a distribution sequence the beam stations must be in regular order.

Table 5. Mass and Damping Data

Variables:	RHO	DI	DE
Typical Input Units:	lb × sec^2/in	lb × in^2 × sec	lb × sec/in

See description in Table 4.

Table 6. Time Dependent Axial Thrust

Variables:	TT1	TT2	TT3
Typical Input Units:	lb	lb	lb

Time dependent axial thrust values "TT1" and "TT2" are the distributed values entered at beam stations "FROM" and "TO", respectively, of time station "FROM". The values "TT3" are the distributed values entered at beam stations "FROM" of time stations "TO".

All the values of time dependent axial thrusts at the beam stations within the two limits of "FROM" and "TO" of the time stations between the two limits of "FROM" and "TO" will be linearly

interpolated by the program. There are no restrictions on the order of cards, except that beam stations which are entered as "FROM" and "TO" in the same card must be in ascending order, or in other words, the same beam station is not allowed to be entered as "FROM" and "TO" in the same card.

See page 12 for illustrated examples of interpolation and distribution.

Table 7. Time Dependent Lateral Loading

Variables:	QT1	QT2	QT3
Typical Input Units:	lb	lb	lb

All restrictions stated in Table 6 are also true in this Table, except that same beam station is allowed to be entered as "FROM" and "TO" in the same input card.

See page 13 for illustrated examples of interpolation and distribution.

Table 8. Nonlinear Support Curves

QMP is a constant which is multiplied by Q-VALUES to obtain the vertical resistance values of the corresponding points of the resistance-deflection curve.

WMP is a constant which is multiplied by W-VALUES to obtain the horizontal deflection values of the corresponding points of the resistance-deflection curve.

NPOC is the number of points input on the resistance-deflection curves.

KSYM is the symmetry option of the input resistance-deflection curve.

If KSYM is set equal to 1, then the total number of points on the curve will be twice the value of NPOC. In this case, the point of origin of the curve should not be specified.

If KSYM is set equal to 0 (or left blank) or -1, the point of origin of the curve must be specified. In this case, the deflections which are stated as the first point and the last point on the curve must be equal but opposite in sign.

If KSYM is set equal to 0, the support is a negative one-way support; that is the beam will lift off the support when it deflects upward.

If KSYM is set equal to -1, the support is a positive one-way support; that is the beam will lift off the support when it deflects downward.

There are no restrictions on the order of support curves, except that within any distribution sequence the beam stations must be in regular order. More than one curve may be placed at a beam station.

The maximum number of points which may be input on any given curve is 10, although additional points up to a total of 20 may be created internally if the curve symmetry option is exercised.

WNTOL is the closure tolerance of deflections for matching up the unadjusted part of the resistance-deflection curve when the original curve needs to be adjusted.

QNTOL is the closure tolerance of resistances for matching up the unadjusted part of the resistance-deflection curve when the original curve needs to be adjusted.

For any particular resistance-deflection curve, the final deflections of the points in storage (WMP times W-values) must be increasing positively, while the final resistances (QMP times Q-values) must be in descending or equaling order. In other words, the resistance-deflection curves must be continuously concave as viewed from the horizontal axis, except that horizontal lines of zero stiffness can be input for representing the plastic regions of the curve. Softening of the support is not permitted; that is, no reversal of slope sign of the segment on the support curve is permitted.

For both one-way (negative and positive) supports, the input order of the points on the curve is the same, e.g., the final deflections of the points in storage must be increasing positively; internally, the program reverses the order of the points on the positive one-way support curve after the necessary information for tracing the loading paths has been retained.

If continuing on next curves, the deflections must be equal for the corresponding points of each curve in the sequence of continuation. In this case, WNTOL, NPOC, and KSYM also must be equal.

The resistance-deflection curve at every nonlinearly supported beam station within the two limits of "FROM" and "TO" will be linearly interpolated by the program.

The maximum number of beam stations which can be nonlinearly supported is 100.

Table 9. Plotting Switches

Four kinds of plots, deflection or moment along time axis, and deflection or moment along beam axis may be requested.

If the horizontal axis is TIME, a beam station must be entered from column 26 to column 30.

If the horizontal axis is BEAM, a time station must be entered from column 26 to column 30.

As many as five plots may be superimposed by using the multiple plot switch.

Superimposed plots must all be of the same kind.

There are no restrictions on the order of cards except that beam or time stations must be in regular order within a sequence of the same kind of plots.

	FROM STA	TO STA	CONT'D TO NEXT CARD ?	F	Q	etc...
Individual — card Input						
Case a.1 Data concentrated at one sta	7	7	0=NO		3.0	
Case a.2. Data uniformly distributed	5	15	0=NO	2.0		
	15	20	0=NO	4.0	1.0	
	10	20	0=NO		2.0	
Multiple — card Sequence						
Case b. First — of — sequence	25		1=YES	0.0	2.0	
Case c. Interior — of — sequence		30	1=YES	4.0	2.0	
		35	1=YES	2.0	0.0	
Case d. End — of — sequence		40	0=NO	2.0		

Resulting Distribution of Data

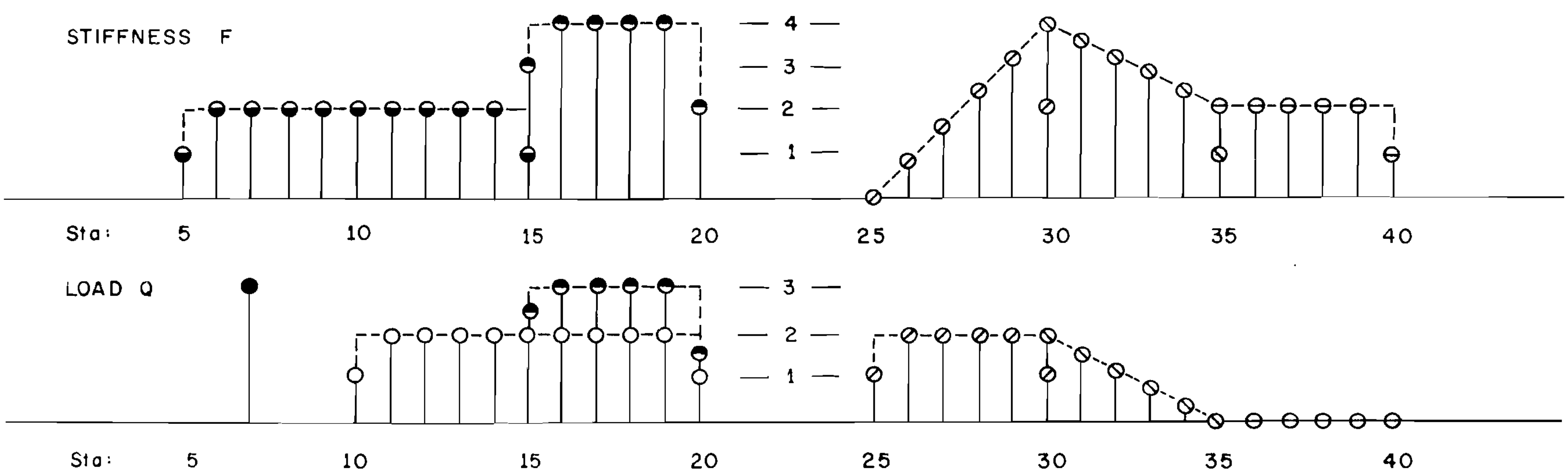


TABLE 6. TIME DEPENDENT AXIAL THRUST (CONTINUED)

The variable TT(J,K) is input at any bar-number and time station by specifying the value of axial thrust distributed at beam station "FROM" and time station "FROM" in the columns of inputting TT1 , the value of axial thrust distributed at beam station "TO" and time station "FROM" in the columns of inputting TT2 , and the value of axial thrust distributed at beam station "FROM" and time station "TO" in the columns of inputting TT3 .

Beam From	Sta To	Time From	Sta To	TT1	TT2	TT3	
0	5	0	5	4.0E+00	3.0E+00	2.0E+00	●
10	15	2	2	2.0E+00	3.0E+00	2.0E+00	○
8	9	7	9	2.0E+00	2.0E+00	3.0E+00	△
8	12	9	9	3.0E+00	1.0E+00	3.0E+00	●
15	20	6	7	2.0E+00	-2.0E+00	1.0E+00	●

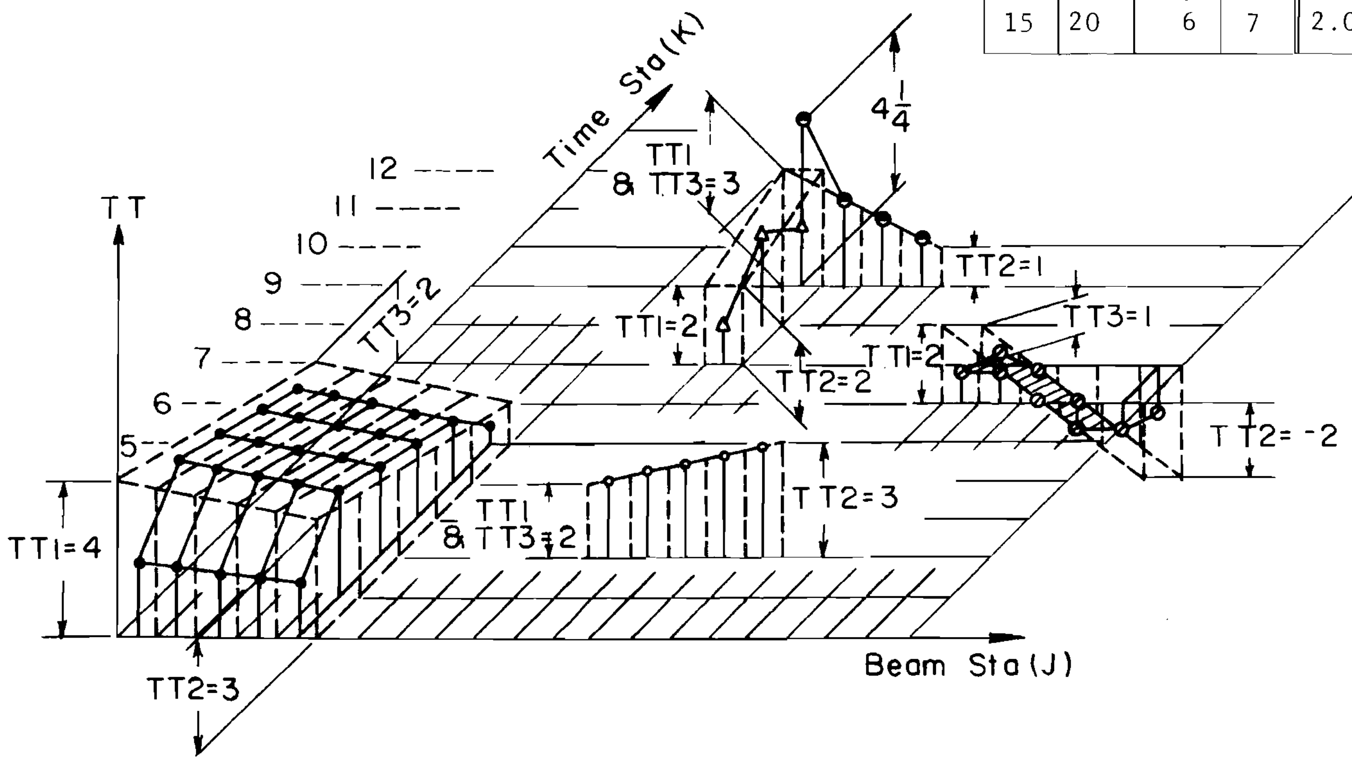
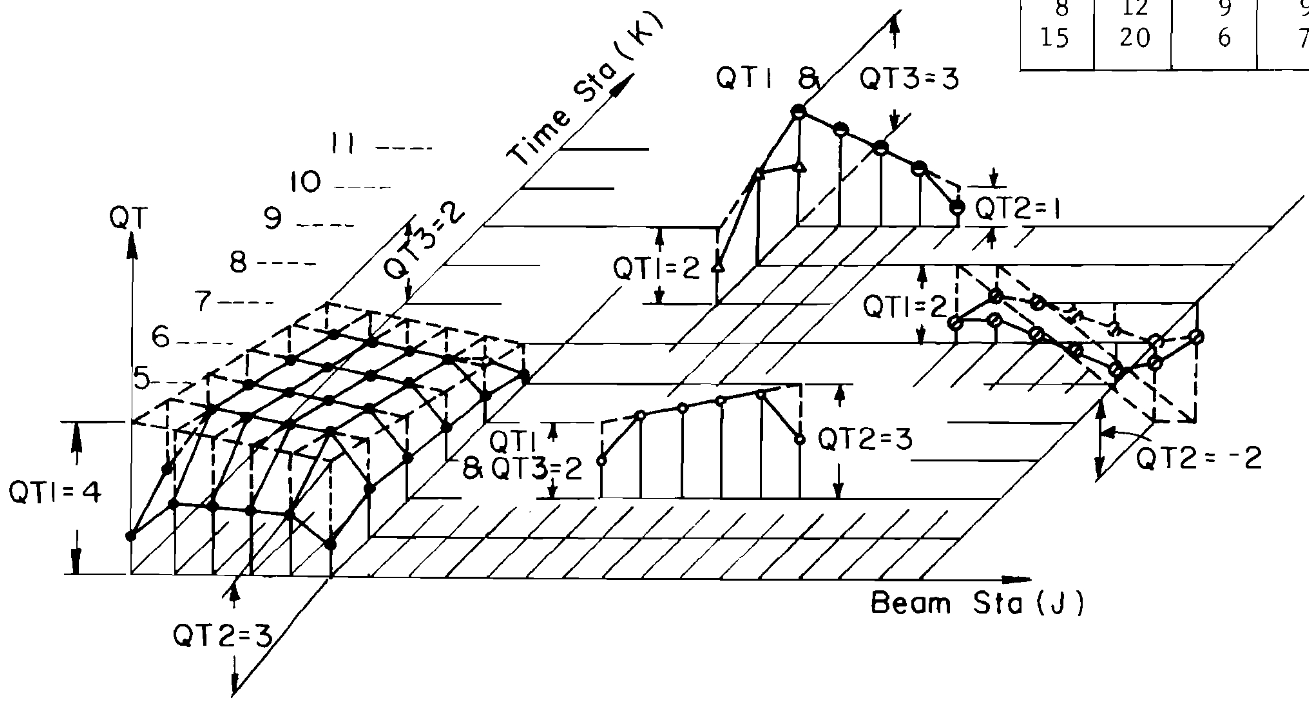


TABLE 7. TIME DEPENDENT LATERAL LOADING (CONTINUED)

The variable QT(J,K) is input at any beam station and time station by specifying the value of lateral load distributed at beam station "FROM" and time station "FROM" in the columns of inputting QT1 , the value of lateral load distributed at beam station "TO" and time station "FROM" in the columns of inputting QT2 , and the value of lateral load distributed at beam station "FROM" and time station "TO" in the columns of inputting QT3 .

Beam Sta From	Beam Sta To	Time Sta From	Time Sta To	QT1	QT2	QT3	
0	5	0	5	4.0E+00	3.0E+00	2.0E+00	●
10	15	2	2	2.0E+00	3.0E+00	2.0E+00	○
8	8	7	9	2.0E+00	2.0E+00	3.0E+00	Δ
8	12	9	9	3.0E+00	1.0E+00	3.0E+00	●
15	20	6	7	2.0E+00	-2.0E+00	1.0E+00	●



APPENDIX E

GLOSSARY OF NOTATION FOR DBC5

```
C-----NOTATION FOR JRC5                                                    07JU1
C         A( ), ATEMP, AREV    CONTINUITY COEFFICIENT                      07JU1
C         AN1( ), AN2( ),      IDENTIFICATION AND REMARKS (2 PHANUMN)      07JU1
C         A(J), B(J), C(J)     RECURSION OR CONTINUITY COEFFICIENTS AT     07JU1
C                                   BEAM STA J                             07JU1
C         B( ), BTEMP, BREV    CONTINUITY COEFFICIENT                      07JU1
C         BDENOM               BEAM INCREMENTS DENOMINATOR                 07JU1
C         BINC                 BEAM INCREMENTS FOR INTERPOLATION IN        07JU1
C                                   TABLES 6 AND 7                         07JU1
C         BM( )                BENDING MOMENT                              07JU1
C         C( ), CTEMP, CREV    CONTINUITY COEFFICIENT                      07JU1
C         CN2( ), CP(J)        STATIC TRANSVERSE TORQUE (INPUT AND TOTAL)07JU1
C         D, DTEMP, DREV       MULTIPLIER IN CONTINUITY COEFF EQS          07JU1
C         DBM( )               SHEAR BETWEEN ADJACENT STATIONS             07JU1
C         DENOM                DENOMINATOR                                 07JU1
C         DEN2( ), DE(J)       LUMPED EXTERNAL DAMPING COEFFICIENT (INPUT07JU1
C                                   AND TOTAL)                             07JU1
C         DIFF                 DIFFERENCE                                  07JU1
C         DIN2( ), DI(J)       LUMPED INTERNAL DAMPING COEFFICIENT (INPUT07JU1
C                                   AND TOTAL)                             07JU1
C         DW( )                FIRST DERIVATIVE OF BMCOL DEFL (SLOPE)      07JU1
C         DWS(JS)              SPECIFIED VALUE OF SLOPE AT STA JS          07JU1
C         DWSAV( )             TEMPORARY VALUE OF DWS( )                   07JU1
C         E                    TERM IN CONTINUITY COEFF EQS                07JU1
C         ESH, ESM, EST        FACTORS FOR DISTRIBUTING HALF VALUES AT     07JU1
C                                   END STAS                               07JU1
C         ESM                  MULTIPLIER FOR HALF VALUES AT END STAS      07JU1
C         FN2( ), F(J)         FLEXURAL STIFFNESS (EI) (INPUT AND TOTAL)  07JU1
C         H                    BEAM INCREMENT LENGTH                       07JU1
C         HE2                  H SQUARED                                   07JU1
C         HE3                  H CUBED                                     07JU1
C         HT                   TIME INCREMENT LENGTH                       07JU1
C         HT2                  H TIMES 2                                   07JU1
C         HTE2                 HT SQUARED                                  07JU1
C         H3T1                 H CUBED DIVIDED BY HT                       07JU1
C         H3T2                 H CUBED DIVIDED BY HT SQUARED               07JU1
C         IA                   NUM OF PLOTS TO BE PLOTTED ON ONE FRAME     07JU1
C         IA2                  IA DIVIDED BY 2 (INTEGER)                   07JU1
C         ID( ), IS( ), ISS( )VARIABLES FOR STORING THE PLOT TITLES       07JU1
C         IDX(J)               NUM OF POINTS IN JTH PLOT                   07JU1
C         IFLS( )              SWITCH FOR FIRST UNLOADING CASE             07JU1
C         IN13( )              BEAM STA WHICH IS SPECIFIED FOR DISPLACE-   07JU1
C                                  MENT IN TABLE 3                         07JU1
C         IN14( ), IN15( )     INITIAL EXTERNAL BEAM STA(TABLES 4 AND 5)   07JU1
C         IN18( ), IN28( )     INITIAL AND FINAL EXTERNAL STA (TABLE 8)    07JU1
C         IN24( ), IN25( )     FINAL EXTERNAL BEAM STA(TABLES 4 AND 5)     07JU1
C         INSAV                TEMPORARY VALUE OF IN13( )                  07JU1
C         IOCNT                NUM OF NONLINEAR SUPPORTS WHERE COMPUTED    07JU1
C                                   DEFL ARE OSCILLATING BETWEEN PRIOR     07JU1
C                                   AND ADJUSTED Q-W CURVES WHEN UNLOAD-   07JU1
C                                   ING CASE OCCURS                        07JU1
C         IOP( )               ROUTING SWITCH FOR INITIALLY AND PERMA-     07JU1
C                                   NENTLY SPECIFIED CONDITIONS            07JU1
C         IOPS( )              SPECIFIED SWITCH INPUT IN TABLE 3 TO INDI-07JU1
C                                   CATE THAT THE SPECIFIED CONDITIONS OF07JU1
C                                   DISPLACEMENTS ARE PERMANENT OR INITIA07JU1
C         IOPSAV               TEMPORARY VALUE OF IOPS( )                  07JU1
C         IOSW( )              ROUTING SWITCH(LOAD ITERATION METHOD)       07JU1
C         IPS                  OPTIONAL SWITCH FOR PRINTING THE RESULTS    07JU1
C                                   OF MONITOR STAS (-1, BLANK, OR +1)     07JU1
C         IQS                  INDICATOR THAT IA2 IS EVEN OR ODD           07JU1
C         IQ2( ), IQ2( )       INITIAL AND FINAL EXTERNAL STA (TABLE 7)    07JU1
C         IRCLL                OPTION TO MOVE TO A NEW PLOT FRAME          07JU1
C         ISTA( )              INTERNAL BEAM STA WHERE A NONLINEAR         07JU1
C                                   SUPPORT EXISTS                         07JU1
C         ISW(J)               ROUTING SWITCH FOR HALF VALUES              07JU1
C         ITCS                 ROUTING SWITCH(1ST CYCLE OF ITERATIONS)     07JU1
C         ITCSR                ROUTING SWITCH(2ND CYCLE OF ITERATIONS)     07JU1
C         IT1( ), IT2( )       INITIAL AND FINAL EXTERNAL STA (TABLE 6)    07JU1
C         ITSW                 ROUTING SWITCH TO INDICATE THAT THE PRO-    07JU1
C                                   BLEM HAS LINEAR (0 OR BLANK), NONLI-   07JU1
C                                   NEAR OR BOTH(OTHER THAN 0) SUPPORTS    07JU1
C         IUS(J)               ROUTING SWITCH TO INDICATE THAT THE Q-W     07JU1
C                                   CV AT STA NEEDS TO BE ADJUSTED         07JU1
C         IX( )                INDEPENDENT VARIABLE (INDEXING)             07JU1
C         IYSW( )              EXTERNAL TIME OR BEAM STA INPUT IN TABLE 907JU1
C         J                    INTERNAL BEAM STA                           07JU1
C         JIMS( )              ARRAY CONTAINING THE MONITOR STA FOR        07JU1
C                                   PRINTING THE ITERATION DATA            07JU1
C         JM                   INTERNAL MONITOR STA NUM                    07JU1
C         JN                   INDEX OF NUM OF POINTS OF THE PREVIOUS      07JU1
C                                   PLOTS TO BE ACCUMULATED ON NEXT PLOT 07JU1
C         JPS( )               ARRAY CONTAINING THE MONITOR STA FOR        07JU1
C                                   PRINTING THE COMPUTED RESULTS          07JU1
C         JS                   INTERNAL BEAM STA FOR SPECIFIED CONDITIONS07JU1
C                                   IN TABLE 3                             07JU1
C         JSTA                 INTERNAL BEAM STA FOR PRINTING THE RESULTS07JU1
C         JT1                  INITIAL INTERNAL STA(TABLES 6 AND 7)        07JU1
C         JT2                  FINAL INTERNAL STA(TABLES 6 AND 7)          07JU1
C         J1                   INITIAL INTERNAL BEAM STA USED IN TABLE 8   07JU1
C         J2                   FINAL INTERNAL BEAM STA USED IN TABLE 8     07JU1
C         K                    INTERNAL TIME STA                           07JU1
C         KASE( )              CASE NUM OF SPECIFIED CONDITIONS,           07JU1
C                                   1 = DEFL, 2 = SLOPE, 3 = BOTH          07JU1
C         KCLOSE               SWITCH TO INDICATE THAT DEFLECTIONS ARE     07JU1
C                                   NOT CLOSED(IF = 0)                     07JU1
C         KCNT( )              COUNTER FOR CLOSURANCE OF DEFLECTIONS       07JU1
C         KEEP2 THRU KEEP9     IF=1, KEEP PRIOR DATA, TABLES 2 - 9         07JU1
C         KEY( )               ROUTING SWITCH FOR IDENTIFYING CASE NUM OF07JU1
C                                   SPECIFIED CONDITIONS OF DISPLACEMENTS07JU1
C         KEYP( )              SWITCH TO INDICATE THAT PLOT AXIS IS        07JU1
C                                   TIME(IF=1) OR BEAM(IF=2)               07JU1
C         KEYPT( ), KYST( )    TEMPORARY VALUE OF KEYP( ) $ KYS( ) FOR     07JU1
C                                   PLOT OF MOMENT ALONG THE BEAM AXIS     07JU1
C         KK                   COUNTER FOR THREE CONSECUTIVE TIME STA      07JU1
C         KMAX                 COUNTER FOR NUM OF STAS EXCEEDING MAX       07JU1
C                                   ALLOWABLE DEFLECTION                   07JU1
```

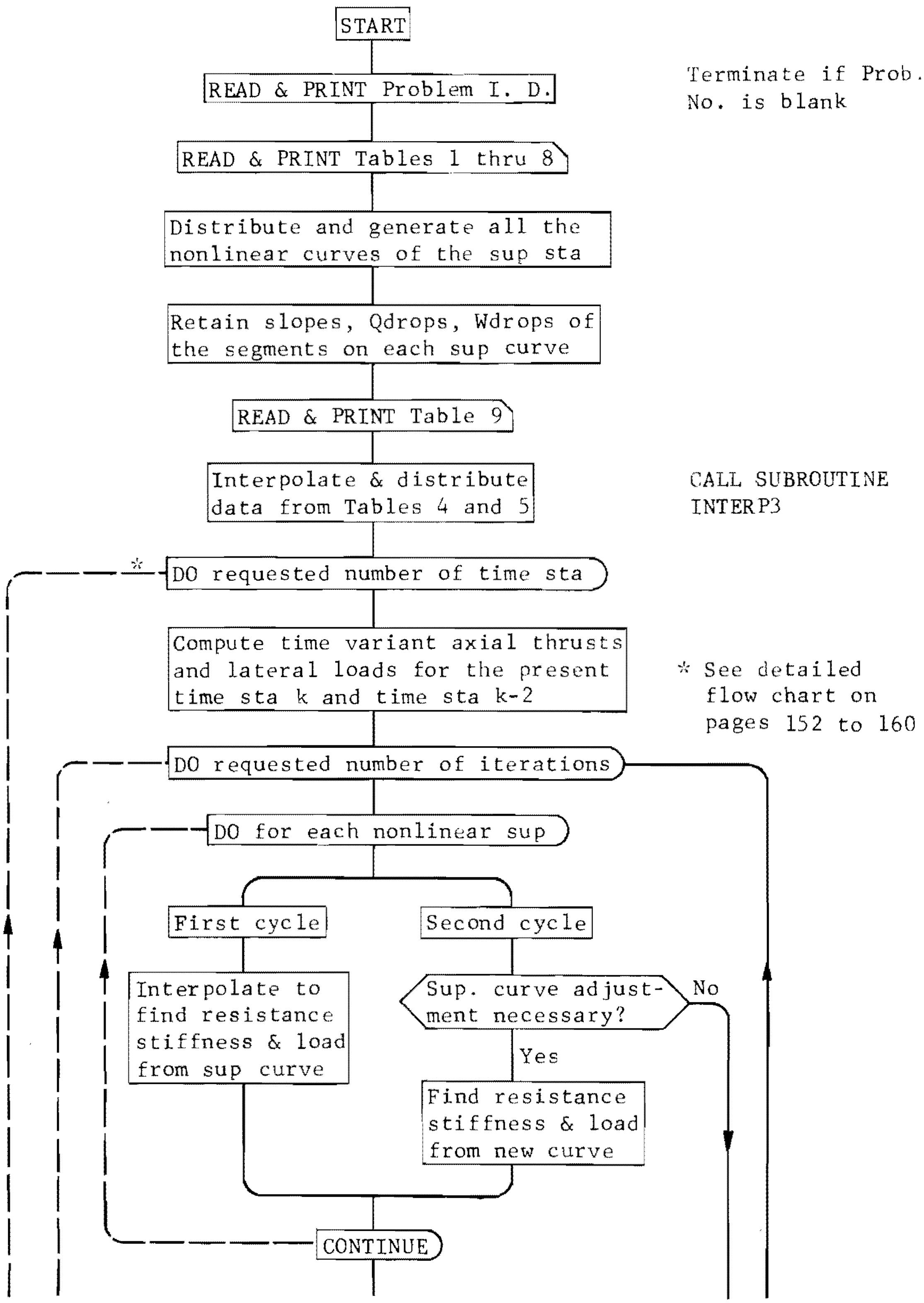
```
C         KMCNT( )                VALUE OF KCNT( )(FIRST ITERATION)         07JU1
C         KN1( )                  INITIAL INTERNAL TIME STA(TABLES 6 AND 7) 07JU1
C         KN2( )                  FINAL INTERNAL TIME STA(TABLES 6 AND 7)   07JU1
C         KOFFC( )                SWITCH TO INDICATE THAT DEFLECTIONS EXCEED07JU1
C                                      LIMITS OF SUPPORT CURVES             07JU1
C         KPC                     ROUTING COUNTER FOR COMPLETE PRINT-OUT    07JU1
C                                      OF RESULTS                           07JU1
C         KPI                     COMPLETE PRINTOUT OF THE RESULTS OF EVERY 07JU1
C                                      STA AT EVERY KPI TIME STA            07JU1
C         KPS4                    INTERNAL TIME STA OF KPI ( KPI+4 )        07JU1
C         KQ1( )                  INITIAL EXTERNAL TIME STA USED IN TABLE 7 07JU1
C         KQ2( )                  FINAL EXTERNAL TIME STA USED IN TABLE 7   07JU1
C         KR1                     PRIOR VALUE OF KR24( ), KR25( ), KR28( )  07JU1
C         KR24( ), KR25( ),       CONTINUE SWITCH FOR INPUT CONTINUING ON   07JU1
C         KR28( )                      NEXT CARD ( TABLES 4, 5, AND 8 )     07JU1
C         KS( )                   SAVED VALUE OF KSAV( ) FOR EACH PLOT FRAME07JU1
C         KSAV                    TEMPORARY VALUE OF KASE( )                07JU1
C         KSAV( )                 ARRAY CONTAINING EXTERNAL BEAM OR TIME STA07JU1
C                                      FOR THE TITLES OF PLOTS              07JU1
C         KSW4( ), KSW5( ),       ROUTING SWITCH IN TABLES 4, 5 AND 8       07JU1
C         KSW8( )                                                           07JU1
C         KSYM( )                 SYMMETRY OPTION USED IN TABLE 8           07JU1
C         KSYMJ(J)                SPECIFIED VALUE OF KSYM( ) AT EACH STA J  07JU1
C         KT1( )                  INITIAL EXTERNAL TIME STA USED IN TABLE 6 07JU1
C         KT2( )                  FINAL EXTERNAL TIME STA USED IN TABLE 6   07JU1
C         KYS( )                  SWITCH TO INDICATE THAT VERT PLOT AXIS IS 07JU1
C                                      DEFLECTION(IF=1) OR MOMENT(IF=2)     07JU1
C         LOP                     OPTIONAL LINE OR POINT PLOT SWITCH WHEN   07JU1
C                                      USING MICROFILM OR BALL-POINT PLOTS  07JU1
C         LSW                     SWITCH WHICH CAUSES THE AXIAL LOADS TO BE 07JU1
C                                      DISTRIBUTED TO HALF-STAS             07JU1
C         LSTA                    INDEX FOR EXTERNAL BEAM STA               07JU1
C         M                       NUM OF BEAM INCREMENTS                    07JU1
C         MAXI                    NUM OF POINTS FOR EACH PLOT FRAME         07JU1
C         MAXIT                   NUM OF ITERATIONS SPECIFIED (MAX = 50)    07JU1
C         MC                      NUM OF CHARACTERS IN PLOT TITLES          07JU1
C         MONI                    NUM OF MONITOR STATIONS FOR PRINTING THE  07JU1
C                                      ITERATION DATA(MAX = 5)              07JU1
C         MONS                    NUM OF MONITOR STATIONS FOR PRINTING RE-  07JU1
C                                      SULTS(MAX = 10)                      07JU1
C         MOP                          OPTIONAL PLOTTING METHOD SWITCH      07JU1
C                                      (-1=MICROFILM, 0 OR BLANK=PRINTER,   07JU1
C                                      +1=BALL-POINT)                       07JU1
C         MPC( )                  MULTIPLE PLOT SWITCH SAVED FOR EACH PLOT  07JU1
C         MPCT( )                 TEMPORARY VALUE OF MPC( ) FOR PLOTS OF    07JU1
C                                      MOMENTS ALONG THE BEAM AXIS          07JU1
C         MPS( )                  MULTIPLE PLOT SWITCH INPUT IN TABLE 9(IF =07JU1
C                                      1, PLOT IS SUPERIMPOSED WITH NEXT)   07JU1
C         MP1 THRU MP7            M PLUS ONE THRU M PLUS SEVEN              07JU1
C         MT                      NUM OF TIME INCREMENTS                    07JU1
C         MTP2                    MT PLUS TWO                               07JU1
C         MTP4                    MT PLUS FOUR                              07JU1
C         NA                      NUM OF PLOTS SUPERIMPOSED ON ONE FRAME    07JU1
C         NAC                     INDEX OF NUM OF PLOTS                     07JU1
C         NCD2 THRU NCD9          NUM OF CARDS INPUT IN TABLES 2 THRU 9 FOR 07JU1
C                                      THIS PROBLEM                         07JU1
C         NCT2 THRU NCT7+NCT9     TOTAL NUM OF CARDS IN THE PARTICULAR TABLE07JU1
C         NCV8                    TOTAL NUM OF CURVES IN TABLE 8            07JU1
C         NC14 THRU NC19          INITIAL INDEX VALUE FOR THE INPUT TO THE  07JU1
C                                      PARTICULAR TABLE                     07JU1
C         NERR                    NUM OF CARDS INPUT REPEATEDLY IN TABLE 9  07JU1
C         NIT                     INDEX USED IN THE ITERATION DO LOOP       07JU1
C         NITS                    ITERATION NUMBER AT WHICH THE LOAD ITERA- 07JU1
C                                      TION METHOD STARTS                   07JU1
C         NITT                    SAVED VALUE OF NIT FOR THE FIRST CYCLE OF 07JU1
C                                      ITERATIONS                           07JU1
C         NNC                     NUM OF SUPPORTING STAS WHICH HAVE NON-    07JU1
C                                      LINEAR RESISTANCE-DEFLECTION CURVES  07JU1
C         NOCI                    ROUTING SWITCH WHICH TELLS THE PROGRAM DO 07JU1
C                                      ONE MORE CYCLE OF LOAD ITERATIONS    07JU1
C                                      WHEN THE SOLUTION DOES NOT CLOSE     07JU1
C         NOS                     INDEX FOR COUNTING THE NUM OF SLOPES OF   07JU1
C                                      NONLINEAR CV                         07JU1
C         NOSJ(J)                 NUM OF SLOPES ON THE NONLINEAR RESISTANCE-07JU1
C                                      DEFLECTION CV AT A PARTICULAR STA J  07JU1
C         NPB                     INDEX FOR TOTAL NUM OF PLOTS              07JU1
C         NPBT                    INDEX FOR NUM OF PLOTS OF BENDING MOMENTS 07JU1
C                                      ALONG THE BEAM AXIS                  07JU1
C         NPCNT                   ROUTING COUNTER FOR THE NUM OF POINTS ON  07JU1
C                                      THE NONLINEAR RESISTANCE-DEFLECTION  07JU1
C                                      CV WHICH IS INCREASING ITS SPECIFIED 07JU1
C                                      VALUE OF DEFLECTION FROM NEG TO ZERO 07JU1
C                                      OR FROM NEG TO POSITIVE              07JU1
C         NPCT                    TEMP VALUE OF NUM OF POINTS ON SUP CV     07JU1
C         NPCTS(J)                TOTAL NUM OF POINTS ACTUALLY ON THE NON-  07JU1
C                                      LINEAR RESISTANCE-DEFLECTION CV AT A 07JU1
C                                      PARTICULAR STA J                     07JU1
C         NPCC( )                 NUM OF POINTS INPUT IN TABLE 8 TO DEFINE A07JU1
C                                      PARTICULAR NONLINEAR RESISTANCE-     07JU1
C                                      DEFLECTION CURVE                     07JU1
C         NPROB                   PROBLEM NUMBER(PROG STOPS IF = BLANK)     07JU1
C         NPS                     INDEX WHICH INDICATES THAT THE            07JU1
C                                      DEFLECTION AT A PARTICULAR STA IS    07JU1
C                                      WITHIN THE SEGMENT CONNECTED BETWEEN 07JU1
C                                      POINT NPS AND POINT (NPS-1) ON THE   07JU1
C                                      NONLINEAR SUP CV                     07JU1
C         NPT                     INDEX FOR NUM OF PLOTS ALONG TIME AXIS    07JU1
C         NPTTS(J)                NUM OF POINTS ON THE NONLINEAR RESISTANCE-07JU1
C                                      DEFLECTION CV AT A PARTICULAR STA J  07JU1
C         NPZERO                  ROUTING COUNTER WHICH DEFINES THE NUM OF  07JU1
C                                      SLOPES SPECIFIED ON THE PARTICULAR   07JU1
C                                      NONLINEAR RESISTANCE-DEFL CV         07JU1
C         NPIS                    ROUTING SWITCH TO INDICATE THAT THE       07JU1
C                                      DEFLECTION AT A PARTICULAR SUP STA IS07JU1
C                                      EQUAL TO THE VALUE OF THE FIRST      07JU1
C                                      POINT ON THE NONLINEAR SUP CV(IF =1) 07JU1
C         NS                      INDEX NUM FOR SPECIFIED CONDITIONS        07JU1
C         NUMOC(J)                NUM OF OSCILLATING CYCLES DURING THE      07JU1
```

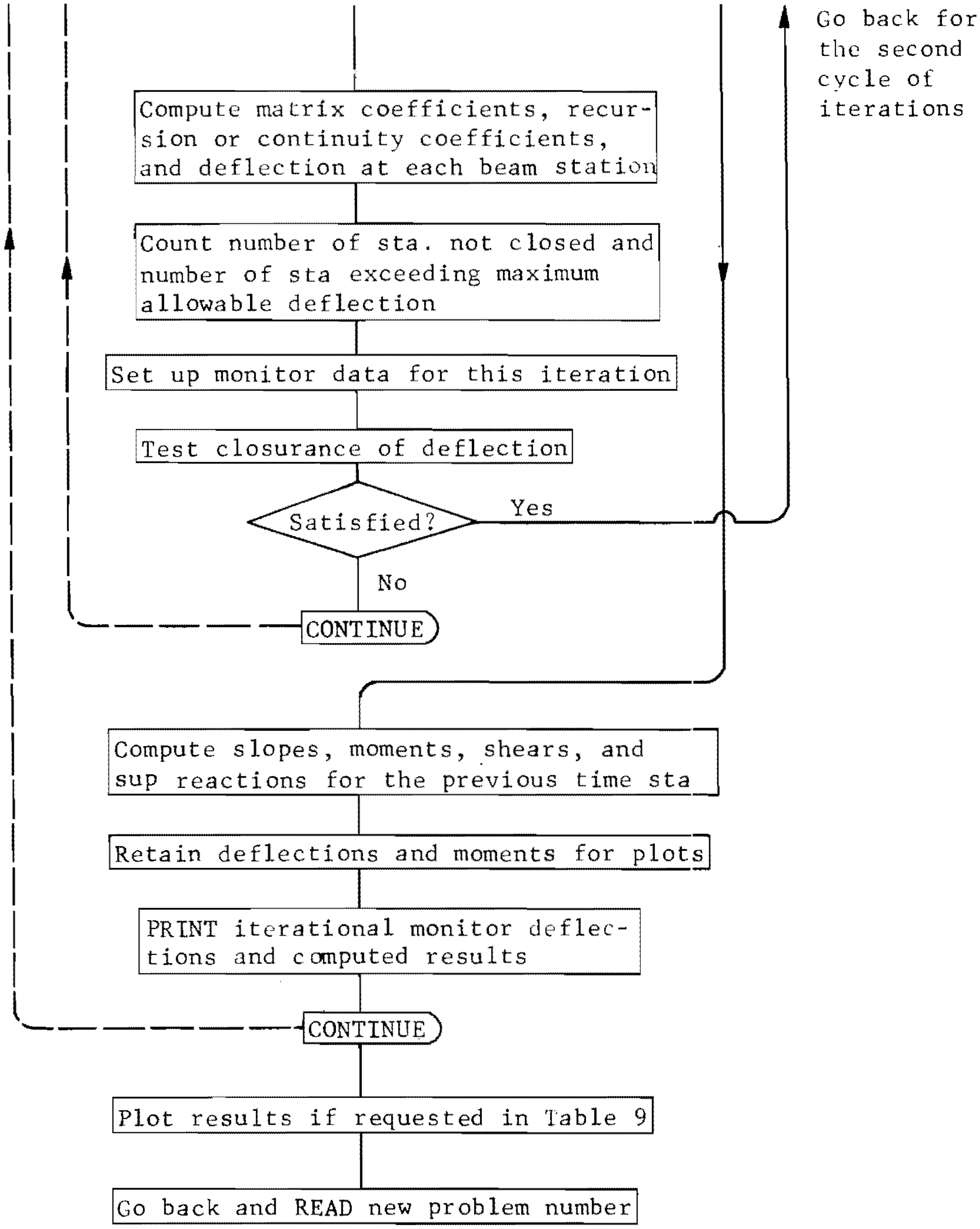
```
C                            ITERATION PROCESS OF THE DEFLECTION  07JU1
C                                 AT A PARTICULAR STA J                07JU1
C          PART              INTERPOLATION FRACTION                    07JU1
C          GDN2( ), Q(J)     TRANSVERSE STATIC LOAD (INPUT AND TOTAL)  07JU1
C          GDROP             PROJECTED VERTICAL VALUE OF EACH SEGMENT  07JU1
C                                 ON THE SUP CV                        07JU1
C          GI(J)             ITERATIVE LOAD DISTRIBUTED AT BEAM STA J  07JU1
C                                 FOR THE PRESENT TIME STA             07JU1
C          GIM1(J)           ITERATIVE LOAD DISTRIBUTED AT BEAM STA J  07JU1
C                                 FOR THE PREVIOUS TIME STA            07JU1
C          GIM2(J)           ITERATIVE LOAD DISTRIBUTED AT BEAM STA J  07JU1
C                                 TWO TIME STAS AGO                    07JU1
C          GMP( )            INPUT VALUE OF RESISTANCE-MULTIPLIER      07JU1
C          GNTOL( )          INPUT VALUE OF RESISTANCE-TOLERANCE       07JU1
C          GNTOLJ( )         DISTRIBUTED VALUE OF RESISTANCE-TOLERANCE 07JU1
C          GP                INPUT SUP CV RESISTANCE VALUES            07JU1
C          GPT               FINAL DISTRIBUTED RESISTANCE VALUES       07JU1
C          GPV               FINAL SUP CV RESISTANCE VALUES            07JU1
C          GPVT              TEMPORARY VALUES OF RESISTANCE OF THE     07JU1
C                                 POINTS ON SUP CV                     07JU1
C          GS(J)             [illegible] CORRECTION LOAD AT BEAM STA J FOR  07JU1
C                                 THE PREVIOUS TIME STA                07JU1
C          GT(J,1)           TOTAL VALUE OF TIME DEPENDENT LOAD        07JU1
C                                 DISTRIBUTED AT BEAM STA J            07JU1
C                                 FOR THE PRESENT TIME STA             07JU1
C          GT(J,2)           TOTAL VALUE OF THE TIME DEPENDENT LOAD    07JU1
C                                 TWO TIME STA AGO                     07JU1
C          GT1( ),GT2( ),GT3( )INPUT VALUES OF TIME DEPENDENT LOADS    07JU1
C                                 (TABLE 7)                            07JU1
C          REACT( )          NET REACTION ON THE BMCOL AT EACH BEAM STA07JU1
C          RHON2( ), RHO(J)  LUMPED MASS DENSITY (INPUT AND TOTAL)     07JU1
C          RN2( ), R(J)      ROTATIONAL RESTRAINT (INPUT AND TOTAL)    07JU1
C          SLOPE             SLOPE OF EACH SEGMENT ON THE SUP CV       07JU1
C          SN2( ), S(J)      LINEAR SPRING SUP STIFF (INPUT AND TOTAL) 07JU1
C          SS(J)             FINAL SPRING CONSTANT DISTRIBUTED AT BEAM 07JU1
C                                 STA J FOR THE PRESENT TIME STA       07JU1
C          SSKM1(J)          FINAL SPRING CONSTANT DISTRIBUTED AT BEAM 07JU1
C                                 STA J FOR THE PREVIOUS TIME STA      07JU1
C          SSKM2(J)          FINAL SPRING CONSTANT DISTRIBUTED AT BEAM 07JU1
C                                 STA J TWO TIME STAS AGO              07JU1
C          SYMB( )           SYMBOLS USED ON THE PRINTER PLOTS         07JU1
C          TDENOM            TIME INCREMENTS DENOMINATOR               07JU1
C          TESTB             = 4 LETTERS *BEAM* USED TO INDICATE THAT  07JU1
C                                 PLOT IS ALONG BEAM AXIS              07JU1
C          TESTD             = 4 LETTERS *DEFL* USED TO INDICATE THAT  07JU1
C                                 THE VERT AXIS IS DEFLECTION          07JU1
C          TESTM             = 4 LETTERS *MOMT* USED TO INDICATE THAT  07JU1
C                                 THE VERT AXIS IS MOMENT              07JU1
C          TESTT             = 4 LETTERS *TIME* USED TO INDICATE THAT  07JU1
C                                 PLOT IS ALONG TIME AXIS              07JU1
C          TINC              TIME INCREMENTS FOR INTERPOLATION IN      07JU1
C                                 TABLES 6 AND 7                       07JU1
C          TN2( ), T(J)      STATIC AXIAL TENSION OR COMPRESSION (INPUT07JU1
C                                 AND TOTAL)                           07JU1
C          TT(J,1)           TOTAL VALUE OF TIME DEPENDENT AXIAL       07JU1
C                                 THRUST FOR THE PRESENT TIME STA      07JU1
C          TT(J,2)           TOTAL VALUE OF TIME DEPENDENT AXIAL       07JU1
C                                 THRUST AT TWO TIME STA AGO           07JU1
C          TT1( ),TT2( ),TT3( )INPUT VALUES OF TIME DEPENDENT AXIAL    07JU1
C                                 THRUSTS (TABLE 6)                    07JU1
C          W(J,KK)           COMPUTED DEFLECTION AT BEAM STA J FOR THE 07JU1
C                                 PRESENT TIME STA                     07JU1
C          W(J,KK-1)         COMPUTED DEFLECTION AT BEAM STA J FOR THE 07JU1
C                                 PREVIOUS TIME STA                    07JU1
C          W(J,KK-2)         COMPUTED DEFLECTION AT BEAM STA J TWO     07JU1
C                                 TIME STAS AGO                        07JU1
C          WDROP             PROJECTED HORIZONTAL VALUE OF EACH SEGMENT07JU1
C                                 ON THE SUP CV                        07JU1
C          WM                ITERATION DATA STORED FOR THE FIRST CYCLE 07JU1
C                                 OF ITERATION                         07JU1
C          WMAX              SPECIFIED MAXIMUM ALLOWABLE DEFLECTION    07JU1
C          WMP( )            INPUT VALUE OF DEFLECTION-MULTIPLIER      07JU1
C          WNTOL( )          INPUT VALUE OF DEFLECTION-TOLERANCE       07JU1
C          WNTOLJ( )         DISTRIBUTED VALUE OF DEFLECTION-TOLERANCE 07JU1
C          WP                INPUT SUP CV DEFLECTION VALUES            07JU1
C          WPT               FINAL DISTRIBUTED DEFLECTION VALUES       07JU1
C          WPV               FINAL SUP CV DEFLECTION VALUES            07JU1
C          WPVT              TEMPORARY VALUES OF DEFLECTION OF THE     07JU1
C                                 POINTS ON SUP CV                     07JU1
C          WS(JS)            SPECIFIED VALUE OF DEFLECTION AT STA JS   07JU1
C          WU                ITERATION DATA STORED FOR THE SECOND CYCLE07JU1
C                                 OF ITERATION                         07J
C          WW( )             DEFLECTION AT PREVIOUS ITERATION          07JU1
C          WWW( )            DEFLECTION TWO ITERATIONS AGO             07JU1
C          XAXIS( )          NAME OF HORIZONTAL AXIS INPUT IN TABLE 9  07JU1
C          XF( )             STORED VALUES OF BEAM OR TIME STA NUM     07JU1
C                                 FOR THE PLOTS                        07JU1
C          XM( )             SCALE FOR THE HORIZ PLOT AXIS             07JU1
C          Y( ), YT( ), YP( )  STORED VALUES OF DEFLECTIONS OR MOMENTS 07JU1
C                                 FOR THE PLOTS                        07JU1
C          YA, AA            COEFF IN STIFFNESS MATRIX                 07JU1
C          YAXIS( )          NAME OF VERTICLE AXIS INPUT IN TABLE 9    07JU1
C          YB, BB            COEFF IN STIFFNESS MATRIX                 07JU1
C          YC, CC            COEFF IN STIFFNESS MATRIX                 07JU1
C          YD, DD            COEFF IN STIFFNESS MATRIX                 07JU1
C          YE, EE            COEFF IN STIFFNESS MATRIX                 07JU1
C          YF, FF            COEFF IN STIFFNESS MATRIX                 07JU1
C          YM( )             SCALE FOR THE VERT PLOT AXIS              07JU1
```

APPENDIX F

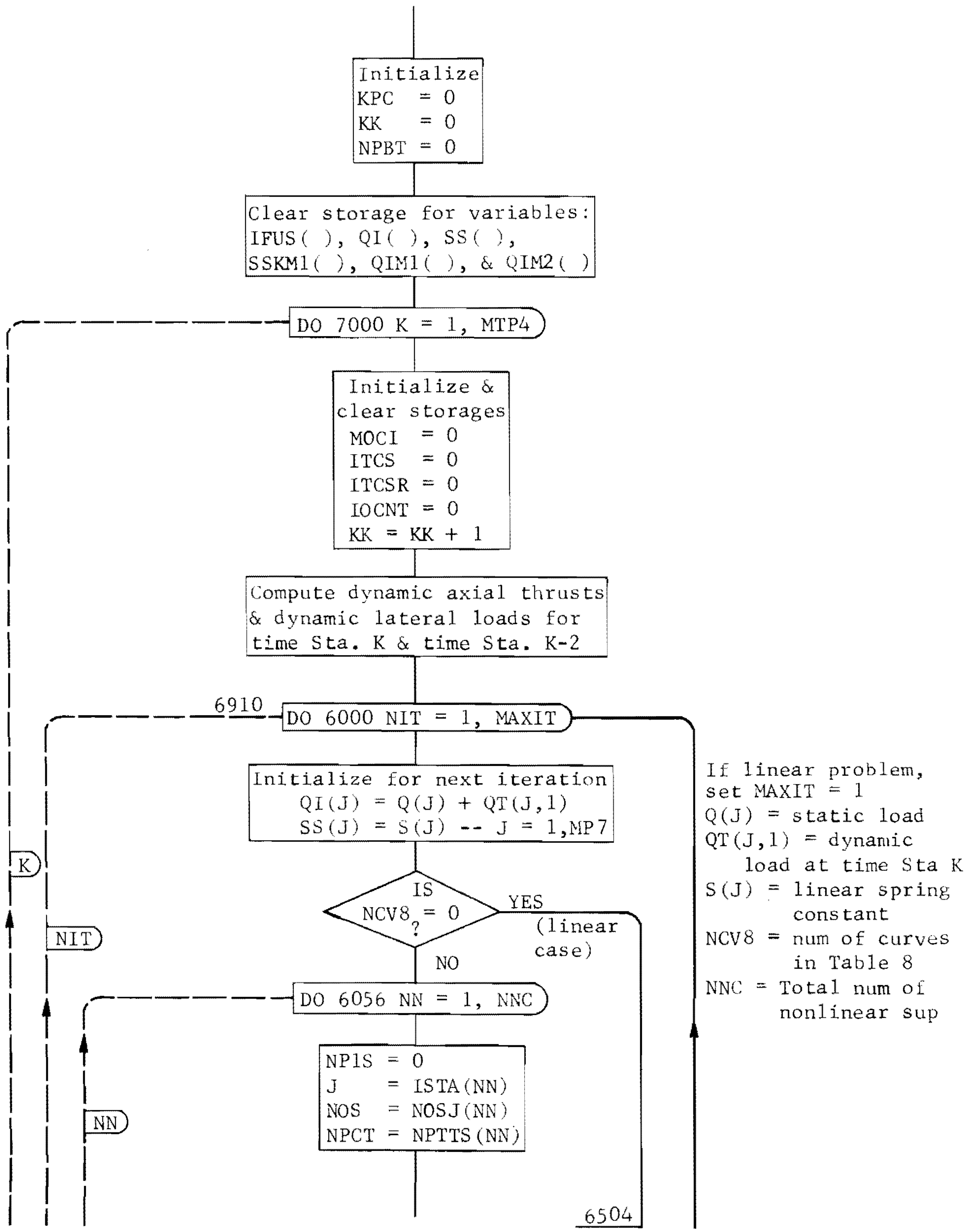
FLOW CHARTS AND LISTING OF DECK OF PROGRAM DBC5

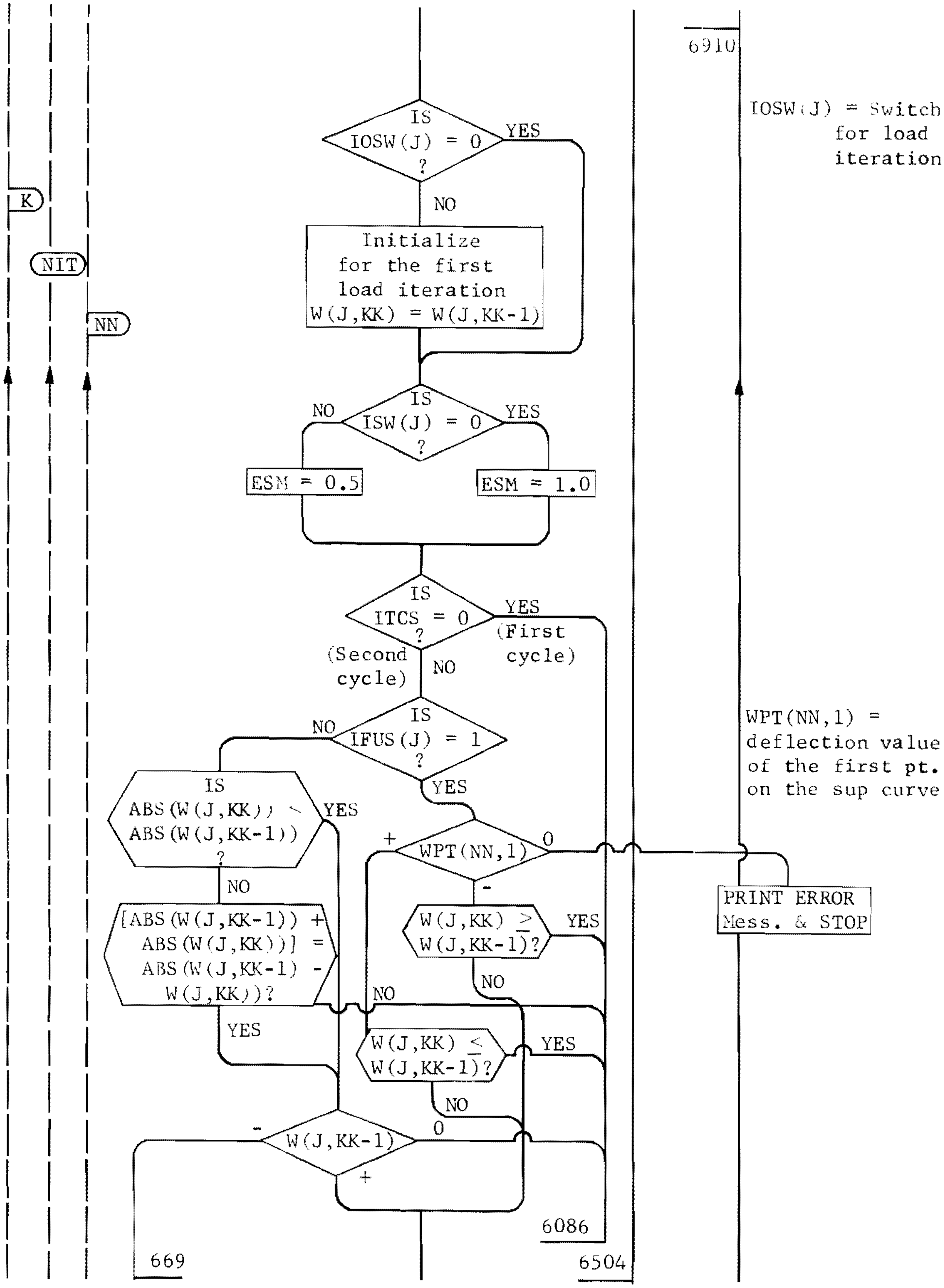
GENERAL FLOW CHART OF DBC5

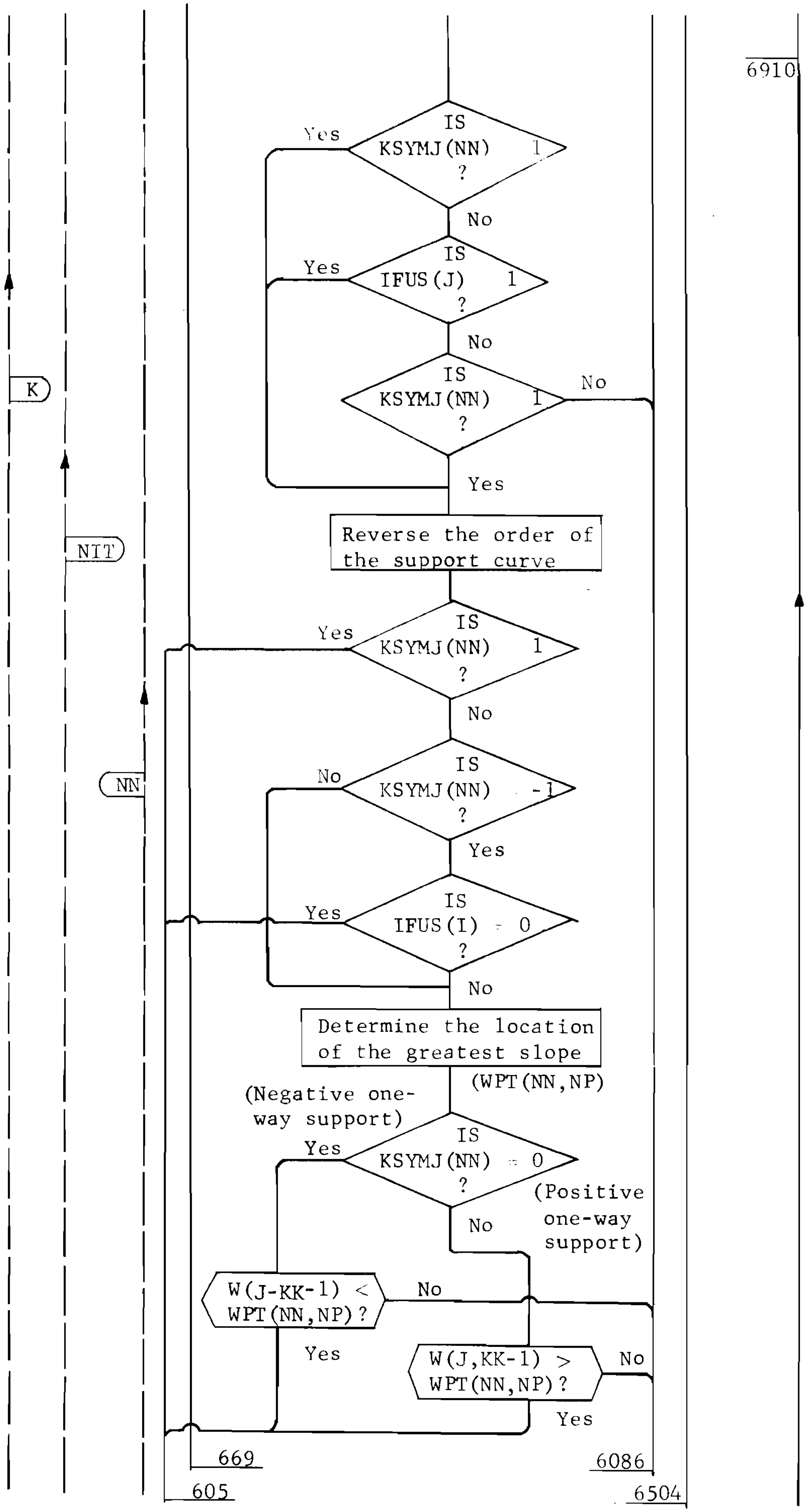


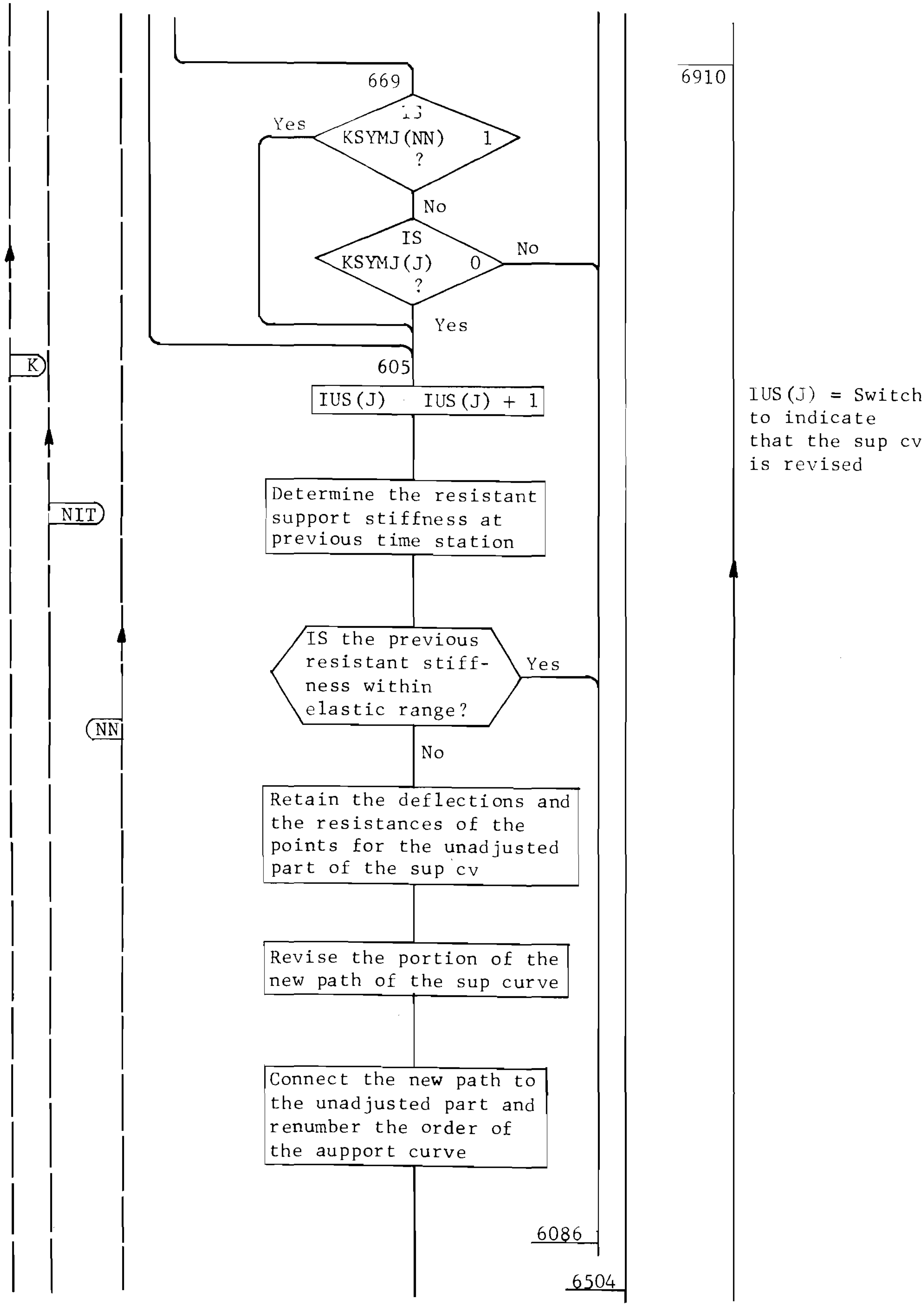

Go back for the second cycle of iterations
Compute matrix coefficients, recursion or continuity coefficients, and deflection at each beam station
Count number of sta. not closed and number of sta exceeding maximum allowable deflection
Set up monitor data for this iteration
Test closurance of deflection
Satisfied?
Yes
No
CONTINUE
Compute slopes, moments, shears, and sup reactions for the previous time sta
Retain deflections and moments for plots
PRINT iterational monitor deflections and computed results
CONTINUE
Plot results if requested in Table 9
Go back and READ new problem number

GENERAL FLOW CHART OF TIME DO LOOP

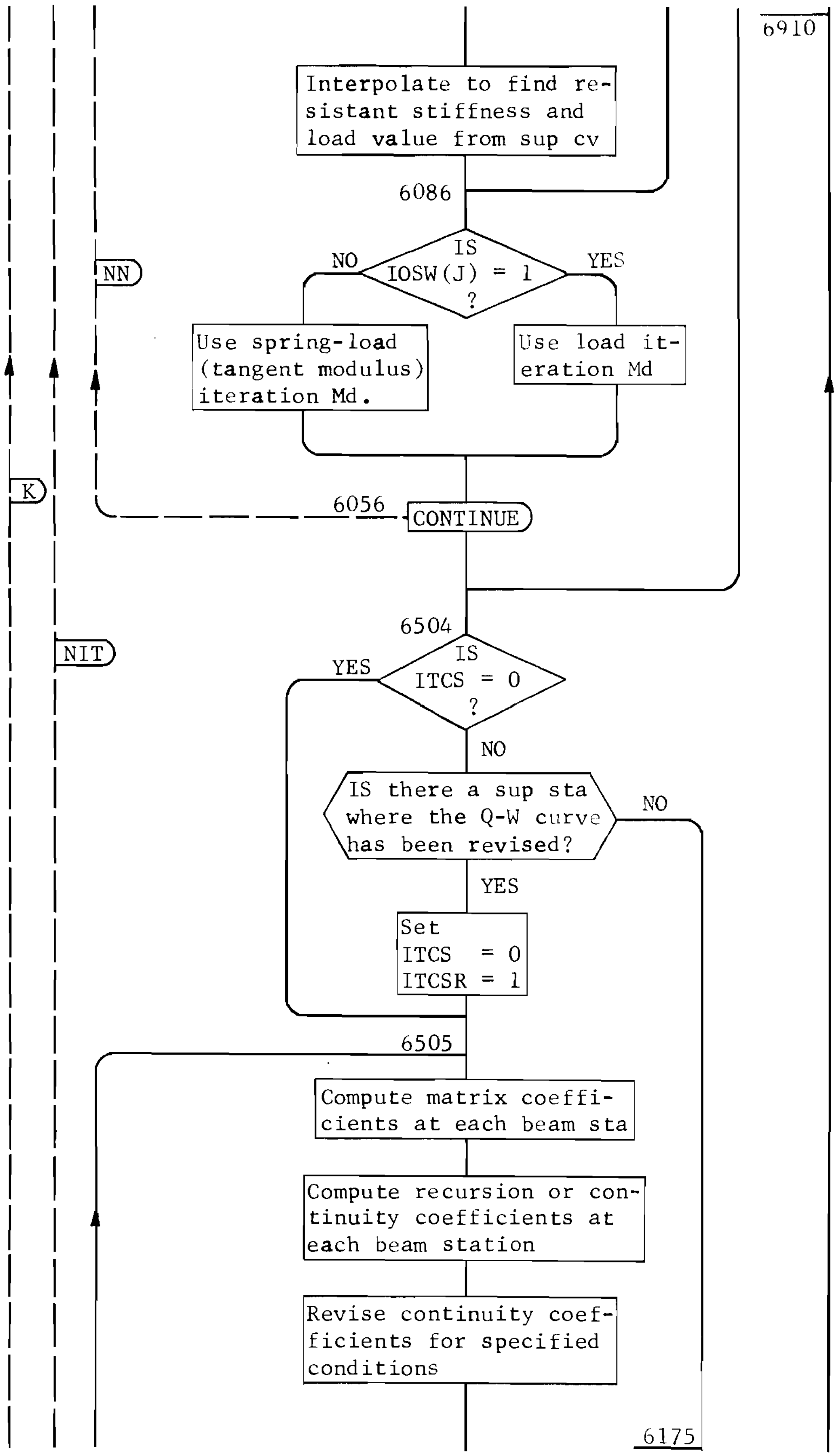


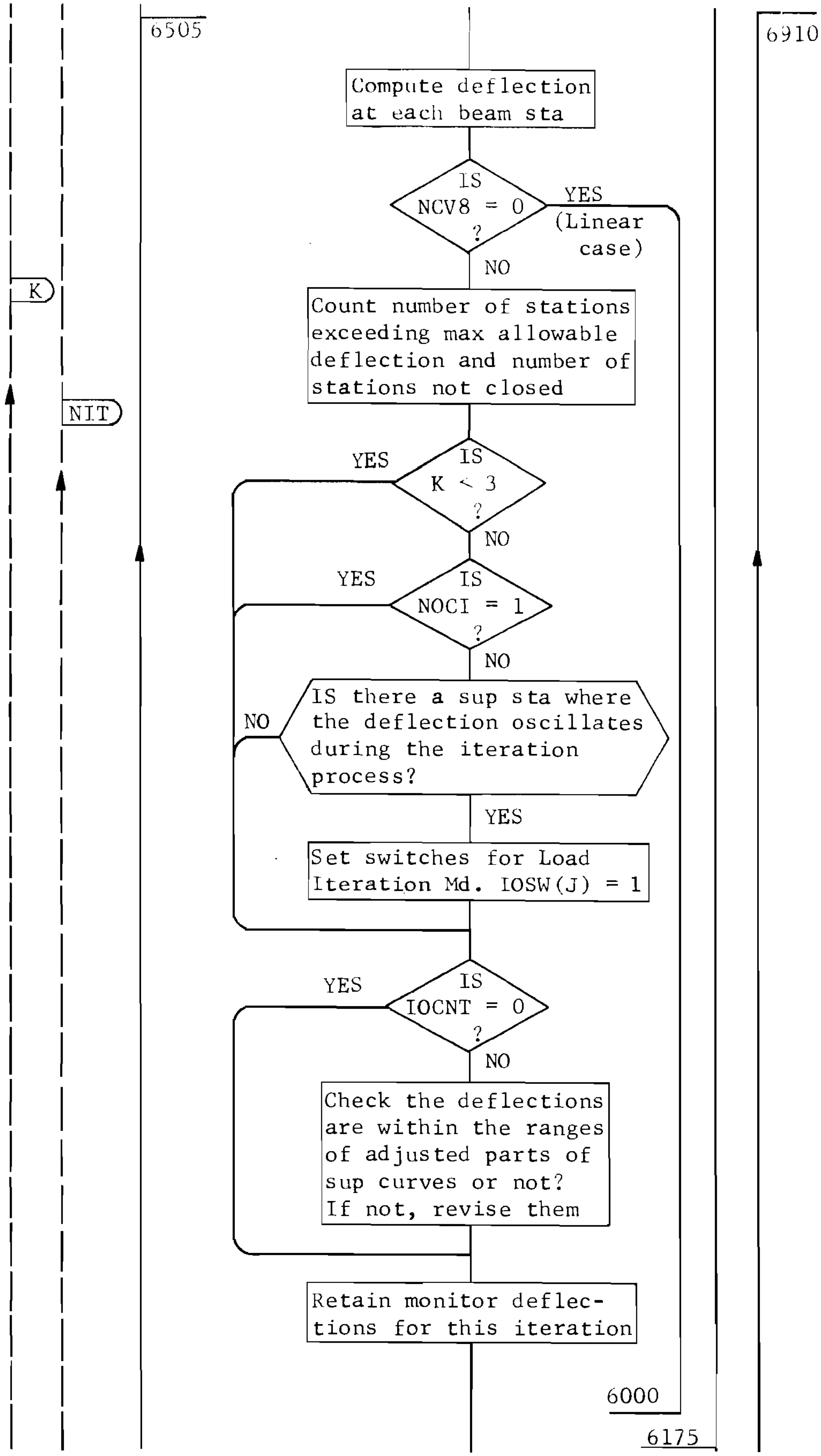

6910
IOSW(J) = Switch for load iteration
K
NIT
NN
IS IOSW(J) = 0 ?
YES
NO
Initialize for the first load iteration W(J,KK) = W(J,KK-1)
IS ISW(J) = 0 ?
NO
YES
ESM = 0.5
ESM = 1.0
IS ITCS = 0 ?
YES (First cycle)
(Second cycle)
NO
IS IFUS(J) = 1 ?
NO
YES
WPT(NN,1) = deflection value of the first pt. on the sup curve
IS ABS(W(J,KK)) < ABS(W(J,KK-1)) ?
YES
NO
WPT(NN,1)
+
0
-
PRINT ERROR Mess. & STOP
[ABS(W(J,KK-1)) + ABS(W(J,KK))] = ABS(W(J,KK-1) - W(J,KK))?
W(J,KK) ≥ W(J,KK-1)?
YES
NO
NO
YES
W(J,KK) ≤ W(J,KK-1)?
YES
NO
W(J,KK-1)
-
0
+
669
6086
6504

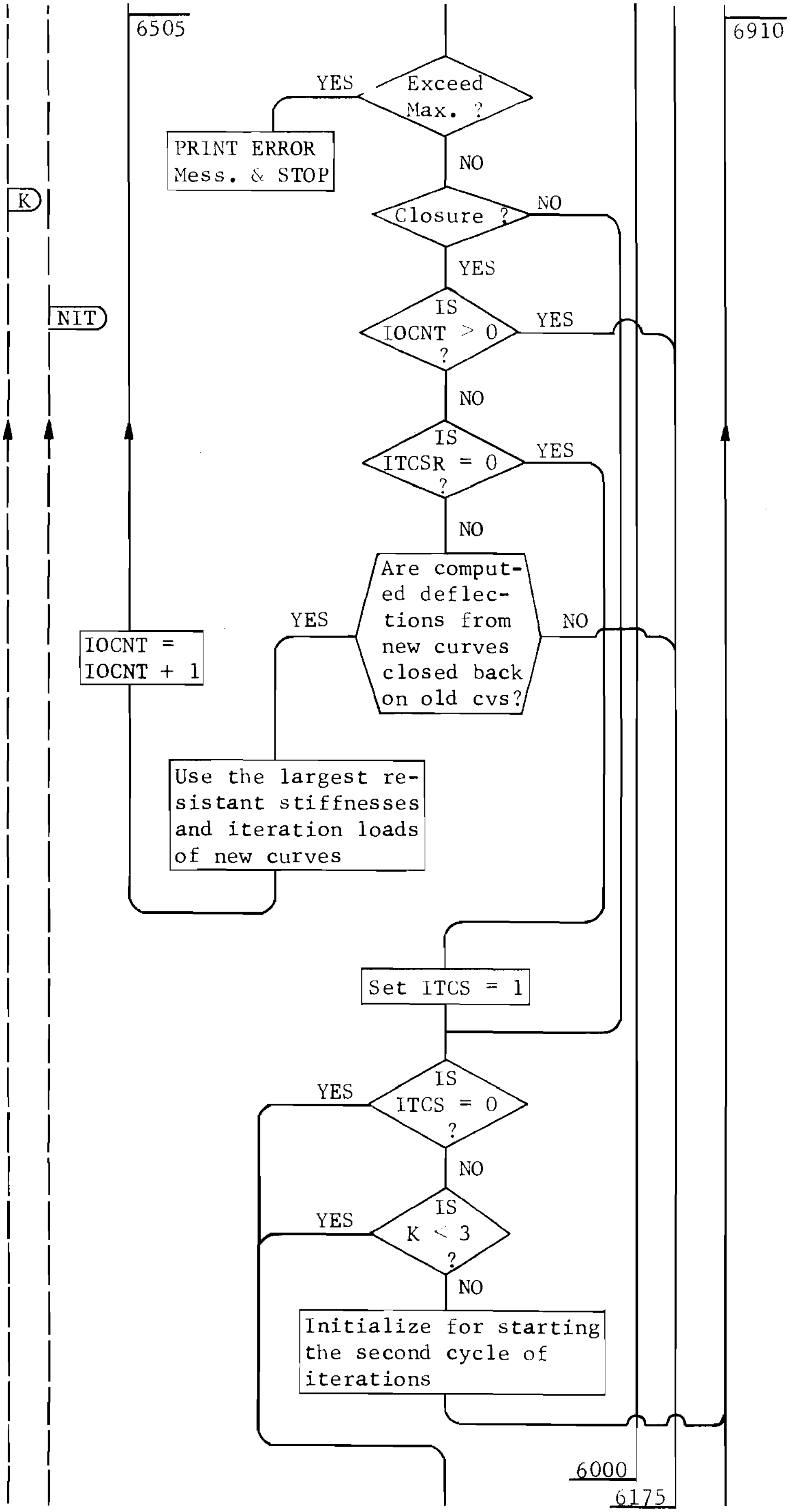

6910
IS KSYMJ(NN) 1 ?
Yes
No
IS IFUS(J) 1 ?
Yes
No
IS KSYMJ(NN) 1 ?
No
Yes
K
NIT
NN
Reverse the order of the support curve
IS KSYMJ(NN) 1 ?
Yes
No
IS KSYMJ(NN) -1 ?
No
Yes
IS IFUS(I) = 0 ?
Yes
No
Determine the location of the greatest slope
(WPT(NN,NP)
(Negative one-way support)
IS KSYMJ(NN) = 0 ?
Yes
No
(Positive one-way support)
W(J-KK-1) < WPT(NN,NP)?
No
Yes
W(J,KK-1) > WPT(NN,NP)?
No
Yes
669
605
6086
6504

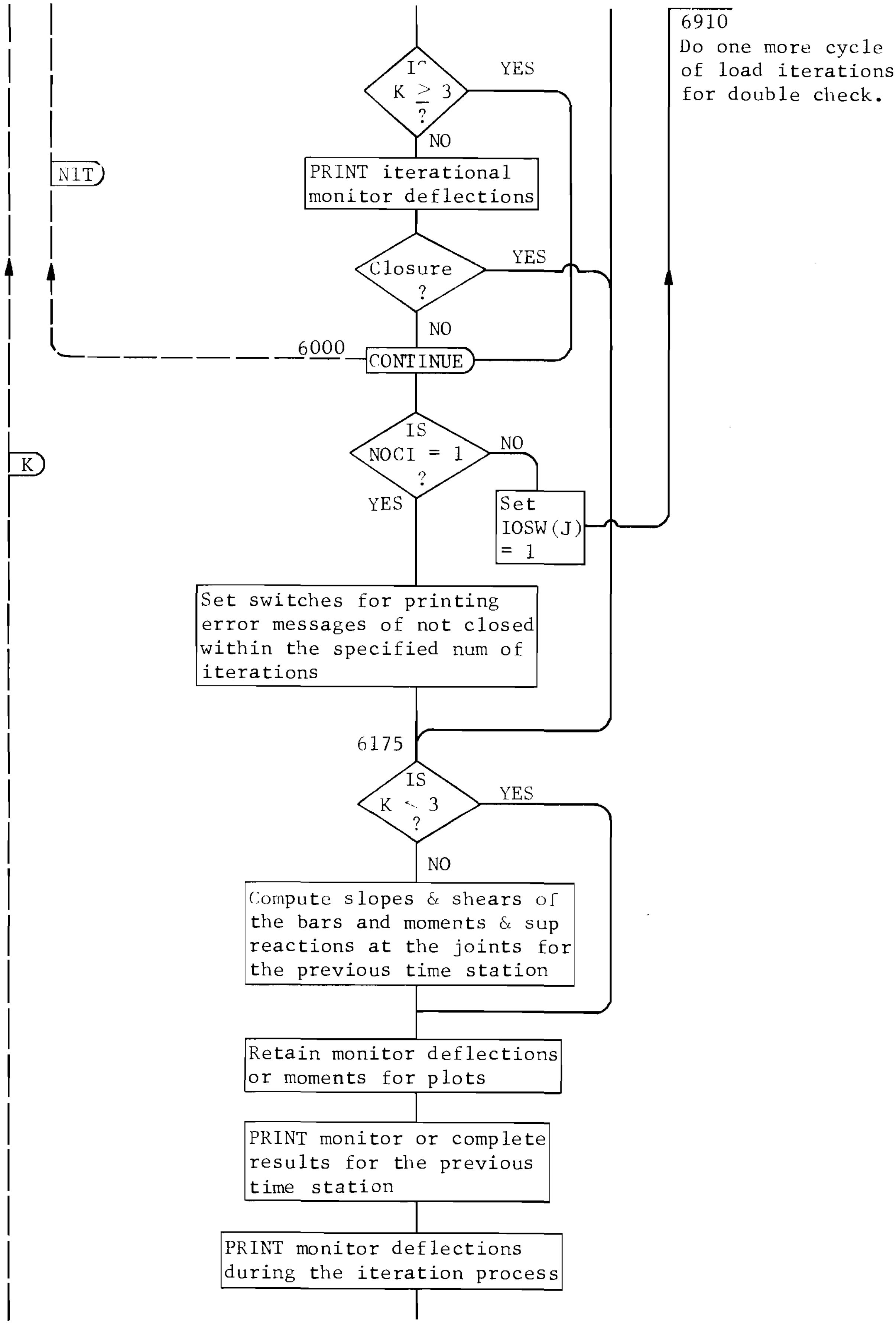


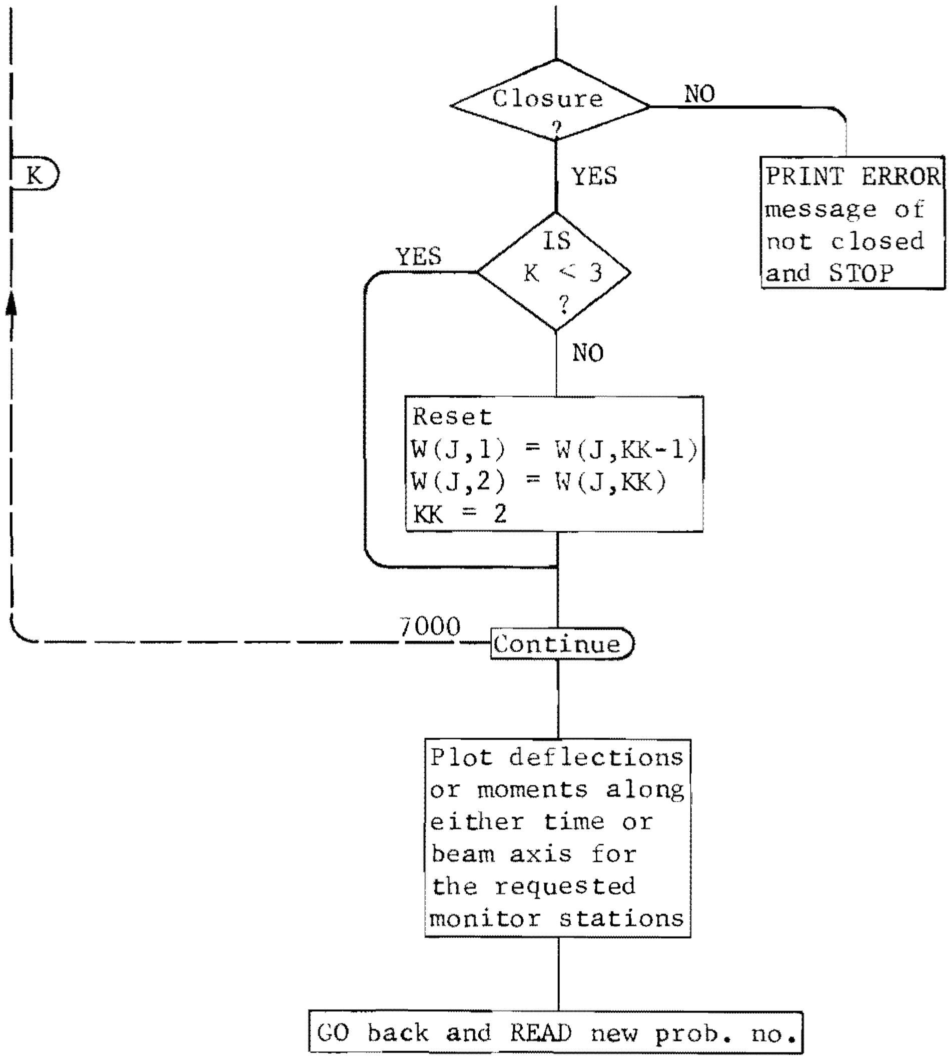
669
IS KSYMJ(NN) 1 ?
Yes
No
IS KSYMJ(J) 0 ?
No
Yes
605
K
IUS(J) IUS(J) + 1
Determine the resistant support stiffness at previous time station
NIT
IS the previous resistant stiffness within elastic range?
Yes
No
NN
Retain the deflections and the resistances of the points for the unadjusted part of the sup cv
Revise the portion of the new path of the sup curve
Connect the new path to the unadjusted part and renumber the order of the aupport curve
6086
6504
6910
IUS(J) = Switch to indicate that the sup cv is revised


6910
Interpolate to find resistant stiffness and load value from sup cv
6086
IS IOSW(J) = 1 ?
NO
YES
NN
Use spring-load (tangent modulus) iteration Md.
Use load iteration Md
K
6056
CONTINUE
6504
NIT
IS ITCS = 0 ?
YES
NO
IS there a sup sta where the Q-W curve has been revised?
NO
YES
Set ITCS = 0 ITCSR = 1
6505
Compute matrix coefficients at each beam sta
Compute recursion or continuity coefficients at each beam station
Revise continuity coefficients for specified conditions
6175


6505
6910
Compute deflection at each beam sta
IS NCV8 = 0 ?
YES (Linear case)
NO
K
Count number of stations exceeding max allowable deflection and number of stations not closed
NIT
YES
IS K < 3 ?
NO
YES
IS NOCI = 1 ?
NO
NO
IS there a sup sta where the deflection oscillates during the iteration process?
YES
Set switches for Load Iteration Md. IOSW(J) = 1
YES
IS IOCNT = 0 ?
NO
Check the deflections are within the ranges of adjusted parts of sup curves or not? If not, revise them
Retain monitor deflections for this iteration
6000
6175


6505
6910
Exceed Max. ?
YES
NO
PRINT ERROR Mess. & STOP
K
Closure ?
NO
YES
NIT
IS IOCNT > 0 ?
YES
NO
IS ITCSR = 0 ?
YES
NO
Are computed deflections from new curves closed back on old cvs?
YES
NO
IOCNT = IOCNT + 1
Use the largest resistant stiffnesses and iteration loads of new curves
Set ITCS = 1
IS ITCS = 0 ?
YES
NO
IS K < 3 ?
YES
NO
Initialize for starting the second cycle of iterations
6000
6175


6910
Do one more cycle of load iterations for double check.
IS K ≥ 3 ?
YES
NO
NIT
PRINT iterational monitor deflections
Closure ?
YES
NO
6000
CONTINUE
IS NOCI = 1 ?
NO
YES
K
Set IOSW(J) = 1
Set switches for printing error messages of not closed within the specified num of iterations
6175
IS K < 3 ?
YES
NO
Compute slopes & shears of the bars and moments & sup reactions at the joints for the previous time station
Retain monitor deflections or moments for plots
PRINT monitor or complete results for the previous time station
PRINT monitor deflections during the iteration process


Closure ?
NO
YES
PRINT ERROR message of not closed and STOP
K
YES
IS K < 3 ?
NO
Reset
W(J,1) = W(J,KK-1)
W(J,2) = W(J,KK)
KK = 2
7000
Continue
Plot deflections or moments along either time or beam axis for the requested monitor stations
GO back and READ new prob. no.

```
      PROGRAM DRCS ( INPUT, OUTPUT )
    1 FORMAT (     52H      PROGRAM DRCS - MASTER - JACK CHAN - MATLOCK -   04JA1
     1                          32HLECK1-REVISION DATE = 26 JUN 71 )  26JU1
      DIMENSION       AN1(22), AN2(14), A(207), B(207), C(207),          10OC0
     1                F(207), Q(207), S(207), T(207), R(207), CK(207),   10OC0
     2                KEY(207),IN13(20), KASE(20), WS(20), DWS(50),      10OC0
     3                IN14(100), IN24(100), KR24(100), FN2(100),         05SE0
     4                QDN2(100), SN2(100), TN2(100), RN2(100), CN2(100), 05SE0
     5                KSW4(100), IN15(100), IN25(100), KR25(100),        05SE0
     6                KSW5(100), QW(207), RHO(207), DI(207), DE(207),    10OC0
     7                RM(207), W(207,3), DR4(207), REACT(207), SW(207),  10OC0
     8                RHON2(100), DIN2(100), DEN2(100), JPS(10), SYMB(10) 05SE0
      DIMENSION       TT(207,2), QT(207,2), TT1(100),TT2(100),IQ1(100),  10OC0
     1                IQ2(100), KT1(100), KT2(100), KQ1(100), KQ2(100),  05SE0
     2                TT1(100), TT2(100), TT3(100), QT1(100), QT2(100),  05SE0
     3                QT3(100), XAXIS(10), IYSW(10), MPS(10), KSAV(10),  05SE0
     4                KEYP(10), Y(10,1002), MPO(10), IDX(10), KS(10),    05SE0
     5                YP( 5010), IX(1002) , XF(1004), ID(7), IS(10),ISS(2)17SE0
      DIMENSION       IN18(20), IN28(20), KR28(20), QMP(20), WMP(20),    04JA1
     2                KSYM(20), KSW8(20), QP(20,10), WP(20,10), QPV(20,20)04JA1
     3                , WPV(20,20), NPCTS(20), JIMS(5), QI(207), IUS(207),04JA1
     4                IOP(207), SS(207), WWW(207), KOEFC(50), YAXIS(10),  04JA1
     5                KCNT(50), WI(50,5), NUMOC(207), F(207), IOPS(20),   04JA1
     6                ITSW(207), KU(5,5), ISTA(100), KCLOSE(2),           15AP1
     7                WPVT(100,20), QPVT(100,20), NPLC(20), JDRVP(100,10),15FE1
     8                SLOPE(100,10), WDROP(100,10), KTS(10), NOSJ(100),   15FE1
     9                WPT(100,20), QPT(100,20), NPTTS(100), WNTOLJ(100),  15FE1
     A                QNTOLJ(100), WNTOL(20), QNTOL(20), KSYMJ(100),      15FE1
     B                KFCNT(50), IFUS(207), KSAVT(5), KEYPT(5), MPOT(5),  15FE1
     C                KYST(5), YT(5,203), SSKM1(207), YM(4), XM(4)        15FE1
      DIMENSION       SSKM2(207), QTM1(207), QIM2(207), QS(207)           21AP1
      DATA SYMB   / 1H8, 1H+, 1HX, 1H=, 1HO, 1H=, 1H$, 1H*, 1H/, 1HO /    11JE0
      COMMON/SPLOT/WIDTH,SMALL,BIG,SYMB                                   05SF0
      COMMON //OT/ LOP, MC, TROLL, MOP                                    17SE0
      INTEGER WIDTH                                                       05SE0
    4 FORMAT ( A5, A5 )                                                   26JU1
    5 FORMAT ( I5, I5 )                                                   17SF0
    6 FORMAT ( I5, A5 )                                                   17SF0
   10 FORMAT (      5H        , 80X, 10HI-----TRIM )                      27FE4 ID
   11 FORMAT (      5H1       , 80X, 10HI-----TRIM )                      27FE4 ID
   12 FORMAT (  16A5   )                                                  04MY3 ID
   13 FORMAT (             5X, 16A5 )                                     27FE4 ID
   14 FORMAT ( A5, 5X, 14A5 )                                             18FE5 ID
   15 FORMAT (///10H       PROB , /5X, A5, 5X, 14A5 )                     18FE5 ID
   16 FORMAT (///17H       PROB (CONTD), /5X, A5, 5X, 14A5 )              18FE5 ID
   20 FORMAT ( 16I5 )                                                     30DE0
   21 FORMAT ( 2( 5X, I5, F10.3 ), 5X, 6I5 )                              30DE0
   22 FORMAT ( 5X, I5, 10X, 10I5 )                                        05SF0
   23 FORMAT ( 5X, I5, 2F10.3, 10X, 5I5 )                                 30DE0
   31 FORMAT ( 2(5X, I5), 2F10.3, 5X, I5 )                                17SE0
   41 FORMAT ( 5X, 3I5, 6F10.3 )                                          23MR4
   51 FORMAT ( 5X, 3I5, 10X, 3F10.3 )                                     05SE0
   61 FORMAT ( 5X, 2( 2I5, 5X ), 3F10.3 )                                 05SF0
   81 FORMAT ( 5X, 3I5, 2E10.3, 2I5, 2E10.3 )                             24DE0
```

```
   82 FORMAT ( 30X, 10F5.0 )                                              24DE0
   91 FORMAT ( 2( 6X, A4), 2(5X, I5) )                                    10FE1
  100 FORMAT (///35H       TABLE 1 - PROGRAM-CONTROL DATA                 24JA4*
     1      / 43X, 30H                 TABLE NUMBER                       30DE0
     2      / 43X, 40H    2    3    4    5    6    7    8    9           30DE0
     3      //       41H       HOLD FROM PRECEDING PROBLEM (1=HOLD), 2X,  30DE0
     4                  8I5,                                              30DE0
     5      /        32H       NUM CARDS INPUT THIS PROBLEM, 10X, 8I5 )   30DE0
  200 FORMAT (///24H       TABLE 2 - CONSTANTS / )                        23MR4*
  201 FORMAT ( 32H              NUM OF BEAM INCREMENTS, 43X, I5,          05SE0
     1          / 32H              BEAM INCREMENT LENGTH , 39X, F10.3,    05SE0
     2          / 32H              NUM OF TIME INCREMENTS, 43X, I5,       05SE0
     3          / 32H              TIME INCREMENT LENGTH , 38X, F10.3,    05SE0
     4          / 35H              OPTIONAL PRINTING SWITCH  , 40X, I5,   05SF0
     5          / 41H              NUM OF MONITOR STA ( PRINTING ), 34X, I5, 30DE0
     6          / 40H              ITERATION SWITCH (0=LINEAR)   , 35X, I5, 30DE0
     7          / 42H              NUM OF MONITOR STA ( ITERATION ), 33X, I5, 30DE0
     A          / 54H              PLOTTING METHOD(-1=MIC.,0=PRINTER,1=PAPER) 25JA1
     B          ,21X, I5,                                                 25JA1
     B          / 36H              LINE OR POINTS PLOT OPTION, 39X, I5 )  30DE0
  202 FORMAT ( / 52H      -----COMPLETE PRINTING TIME INTERVAL AND MONITC25JA1
     1             28HR STATIONS FOR PRINTING-----,                       25JA1
     2          / 45H              TIME STA INTERVAL OF COMPLETE PRINT, 30X,I5,05SE0
     4          / 52H              MONITOR STATIONS(PRINTING)           , 04JA1
     5          / 54H                 1     2     3     4     5     6     7     8   04JA1
     6             6H9    10, /, 5X, 5HSTA J, 10I5 )                      04JA1
  203 FORMAT ( / 52H      -----ITERATION DATA FOR NONLINEAR SUP. CV.-----25JA1
     1          / 35H                  MAXIMUM ITERATION NUMBER , 40X, I5, 04JA1
     2          / 40H                  MAXIMUM ALLOWABLE DEFLECTION  , 30X, E10.304JA1
     3        , / 38H                  DEFLECTION CLOSURE TOLERANCE, 34X, E10.3, 04JA1
     4          / 10X, 27HMONITOR STATIONS(ITERATION),                    04JA1
     5          / 10X, 25H    1     2     3     4     5,                  04JA1
     6          /  5X, 5HSTA J, 5I5 )                                     04JA1
  300 FORMAT (///47H       TABLE 3 - SPECIFIED DEFLECTIONS AND SLOPES     20JA4*
     1 //     5X, 48H      STA        CASE        DEFLECTION        SLOPE  , 17SE0
     2           7X, 22HTOPS (IF=1,INITIAL  ,                             26JU1
     3        / 60X, 22H       IF=2,PERMANENT)  )                         26JU1
  311 FORMAT (       10X, I3, 7X, I2, 8X, E10.3, 9X, 4HNONE, 5X, I5 )     17SE0
  312 FORMAT (       10X, I3, 7X, I2, 11X, 4HNONE, 8X, E10.3, 5X, I5 )    17SE0
  313 FORMAT (       10X, I3, 7X, I2, 3X, 2(5X, E10.3), 5X, I5 )          17SE0
  400 FORMAT (///48H       TABLE 4  -  STIFFNESS AND FIXED-LOAD DATA      23OC4
     1 //        51H       FROM TO CONTD      F             QF          S 09FE5
     2           28H       T             R          CP / )                05SE0
  411 FORMAT (       5X, 2I4, I3, 1X, 6E11.3 )                            23MR4*
  412 FORMAT (       5X, I4, 4X, I3, 1X, 6E11.3 )                         23MR4*
  413 FORMAT (       9X, I4, I3, 1X, 6E11.3 )                             23MR4*
  500 FORMAT (///48H       TABLE 5 - MASS AND DAMPINGS DATA               05SE0
     1 //        45H       FROM TO CONTD     RHO            DI          DE  ,/)05SE0
  600 FORMAT (/// 42H       TABLE 6 - TIME DEPENDENT AXIAL THRUST         05SF0
     1       // 5X, 48H      BEAM STA          TIME STA                   05SE0
     2          ,5X, 48H     FROM  TO          FROM  TO             TT1   05SE0
     3              20H      TT2          TT3    / )                      05SF0
  610 FORMAT ( 10X, 2I4, 7X, 2I4, 10X, 3E11.3 )                           05SF0
  700 FORMAT (/// 4 H       TABLE 7 - TIME DEPENDENT LOADING              05SF0
```

```
    1     //5X,   30H     BEAM STA        TIME STA                          05SE0
    2     / 5X,   48H     FROM  TO        FROM  TO                    QT1   05SE0
    3             20H     QT2         QT3     / )                           05SE0
800 FORMAT (/// 40H     TABLE 8 - NONLINEAR SUPPORT CURVES  //               24DE0
    1             51H      FROM  TO CONTD Q-MULTIPLIER W-MULTIPLIER PCIN24DE0
    2              34HTS SYM OPT W-TOLERANCE Q-TOLERANCE / )                 15FE1
811 FORMAT ( 5X, 3I5, 2E13.3, 2I7, 2E12.3 )                                   15FE1
812 FORMAT ( 5X, I5, 5X, I5, 2F13.3, 2I7, 2E12.3 )                            15FE1
813 FORMAT ( 10X, 2I5, 2E13.3, 2I7, 2E12.3 )                                  15FE1
814 FORMAT ( 10H      Q     , 10F7.0 )                                       24DE0
815 FORMAT ( 10H      W     , 10F7.0 )                                       24DE0
820 FORMAT ( // 35H      TABLE 10- CALCULATED RESULTS  /                     04JA1
    1             35H            J=BEAM AXIS, K=TIME AXIS  / )               05SE0
900 FORMAT ( /// 32H      TABLE 9 - PLOTTING SWITCHES                        30DE0
    1     //, 5X,48H HORIZONTAL VERTICAL BEAM OR TIME MULTIPLE PLOT ,       10FE1
    2      /, 5X,48H     AXIS       AXIS      STATION       SWITCH     ,    10FE1
    3              27H(IF=1,SUPERIMPOSE WITH NEXT ,/,                        26JU1
    4          53X,27H IF=0,PLOT ALL SAVED PLOTS)      )                     26JU1
901 FORMAT ( / 48H       STA J        DIST          DEFL        SLOPE        05SE0
    1             36H   MOM          SHEAR      SUP REACT      / )           05SE0
902 FORMAT ( // 31H       ***** STATIC RESULTS *****, // )                   30DE0
903 FORMAT ( / 25H                       *NONE*)                              05SE0
904 FORMAT (// 40H      TOO MUCH DATA FOR AVAILABLE STORAGE // )             05SE0
905 FORMAT (    46H            USING DATA FROM THE PREVIOUS PROBLEM )       05FE4*
907 FORMAT ( / 52H      ERROR STOP -- SLOPES AND DEFLECTIONS IMPROPERLY31DE4
    1            10H SPECIFIED  )                                            31DE4
908 FORMAT ( 9X, A4, 6X, A4, 5X, I5, 8X, I5 )                                10FE1
910 FORMAT (    43H            ADDITIONAL DATA FOR THIS PROBLEM  )           31DE4
911 FORMAT (55H      ***** PLOT OF DEFLECTION VS TIME FOR BEAM STATIONS05SE0
    1           ,4H OF,, 6H *****, // )                                      05SE0
912 FORMAT ( 10X, I2, 8H CURVE (, A1, 4H) = , I3 )                           05SE0
913 FORMAT (//,5X,16HPT.NC    *VALUE*,/)                                     05SE0
915 FORMAT ( // 32H      ***** DYNAMIC RESULTS *****, / )                    05SE0
916 FORMAT (/30X, 13HTIME STA K = , I5, / )                                  05SE0
917 FORMAT ( //40H      ERROR STOP -- STATIONS NOT IN ORDER  )              05SE0
919 FORMAT (55H      ***** PLOT OF BEND. MOM. VS TIME FOR BEAM STATIONS10FE1
    1           ,4H OF,, 6H *****, // )                                      05SE0
921 FORMAT ( 5X, I4, 2X, 2F12.3, 10X, E12.3, 10X, E12.3 )                    05SE0
922 FORMAT ( 34X, E12.3, 10X, E12.3 )                                        05SE0
923 FORMAT ( / 35X, 25HMONITOR              STATIONS, /, 20X, 3HJ =,         28DE0
    1             5( I5, 7X ) )                                              28DE0
924 FORMAT ( / 10X, 3HFOR, I3, 21H ITERATION, THERE ARE, I4,                 28DE0
    1            21H STATIONS NOT CLOSED  )                                  28DE0
925 FORMAT ( 20X, 5F12.3 )                                                   28DE0
929 FORMAT ( 54H       ***** PLOT OF DEFLECTIONS ALONG BEAM AXIS AT TIME05SE0
    1           ,13H STATIONS OF,,6H *****, // )                             05SE0
939 FORMAT ( 54H       ***** PLOT OF BEND.  MOM. ALONG BEAM AXIS AT TIME10FE1
    1           ,13H STATIONS OF,,6H *****, // )                             05SE0
960 FORMAT (/49X, 31H*****ERROR STOP IN TABLE 8*****, /,                     05SE0
    1              50H    *EITHER SPECIFYING ONE BEAM STA IN THE SAME CA05SE0
    2              38HRD OR BEAM STA NOT IN ASCENDING ORDER*, / )            05SE0
970 FORMAT ( 5X, 35H*PRINTING RESULTS IS NOT REQUESTED*, / )                  05SE0
971 FORMAT ( 5X, 29H*MICROFILM PLOT IS REQUESTED*, / )                        17SE0
972 FORMAT ( 5X, 50H*STANDARD 12 INCH BALLPOINT PAPER PLOT IS REQUESTE17SE0
    1              2HD*, / )                                                  17SE0
 973 FORMAT ( 5X, 27H*PRINTER PLOT IS REQUESTED*, / )                         17SE0
 980 FORMAT (///50H        UNDESIGNATED ERROR STOP                           05SE0
 990 FORMAT ( //5X, 44H****** TIME INCREMENTS SPECIFIED EXCEEDS LIMIT , 05SE0
    1             5H*****, // )                                              05SE0
9976 FORMAT ( 5X, 50HERROR INPUT IN TABLE 9, MORE THAN 5 CURVES TO BE P15FE1
    1             35HLOTTED IN ONE FRAME BY PRINTER PLOT  )                  15FE1
9977 FORMAT ( 10X, 49H* USED ADJUSTED LOAD-DEFL CURVE TO CALCULATE DEFL15FE1
    1             9HECTIONS *  )                                             15FE1
9978 FORMAT ( // 46H       NCV8 IS NOT ZERO WHEN ITSW SWITCH IS ZERO  )  29DE0
9979 FORMAT ( // 46H       ITSW SWITCH IS NOT ZERO WHEN NCV8 IS ZERO  )  29DE0
9981 FORMAT ( 54H      *****SUPPORT CURVE DATA IMPROPERLY SPECIFIED*****24DE0
    1      )                                                                 24DE0
9982 FORMAT ( // 5X, 45HMAXIMUM ITERATION NUMBER IMPROPERLY SPECIFIED )28DE0
9983 FORMAT ( // 46H       CALCULATED DISPLACEMENTS EXCEED ALLOWABLE         29DE0
    1             3H AT, I3, 24H STATIONS AT TIME STA = , I4 )               15FE1
9984 FORMAT ( // 46H       CALCULATED DISPLACEMENTS EXCEED LIMITS OF         28DE0
    1             35H SUPPORT CURVES DURING 1ST CYCLE OF , /                 15FE1
    2             18H      ITERATION NO., I3, 15H AT TIME STA = , I4 )       15FE1
9985 FORMAT ( // 46H       *********** ERROR OR DIAGNOSTIC ***********  )  29DE0
9986 FORMAT ( // 47H       SOLUTION DID NOT CLOSE IN SPECIFIED NUMBER        28DE0
    1             34H OF ITERATIONS FOR THE FIRST CYCLE  )                   15FE1
9987 FORMAT ( // 47H       SOLUTION DID NOT CLOSE IN SPECIFIED NUMBER        15FE1
    1             35H OF ITERATIONS FOR THE SECOND CYCLE  )                  15FE1
9988 FORMAT ( 5X, 50H*****ERROR STOP DUE TO THE SLOPES OF THE NONLINEAR21AP1
    1             ,10H CV AT STA, I5, 28H IS NOT IN PROPER ORDER***** ) 21AP1
9993 FORMAT ( 5X, 50H*****ERROR INPUT IN TABLE 8, STATION NO. IN ASCEND15FE1
    1             14HING ORDER*****  )                                       15FE1
9994 FORMAT ( // 46H       CALCULATED DISPLACEMENTS EXCEED LIMITS OF         28DE0
    1             35H SUPPORT CURVES DURING 2ND CYCLE OF , /                 15FE1
    2             18H      ITERATION NO., I3, 15H AT TIME STA = , I4 )       15FE1
9995 FORMAT ( // 39H       ***** ERROR IN TABLE 8 INPUT *****,/,            05SE0
    1          5X, I2,39H CARDS ARE SPECIFYING SAME BEAM STATION,I5,         05SE0
    2                  21H FOR ONE TIME STATION )                            05SE0
9996 FORMAT (// 39H       ***** ERROR IN TABLE 8 INPUT *****,/,             05SE0
    1          5X,I2,39H CARDS ARE SPECIFYING SAME TIME STATION,I5,          05SE0
    2                  25H FOR PLOT ALONG BEAM AXIS )                        05SE0
9998 FORMAT ( 5X, 27H*** ERROR IN MPS OPTION ***, //)                        05SE0
C-----START EXECUTION OF PROGRAM    SEE GENERAL FLOW DIAGRAM                 05SE0
            ITEST = 5H                                                       05SE0
            TESTT = 4HTIME                                                   05SE0
            TESTB = 4HBEAM                                                   05SE0
            TESTD = 4HDEFL                                                   10FE1
            TESTM = 4HMOMT                                                   10FE1
            WIDTH = 60                                                       05SE0
            SMALL = 0.0                                                      05SE0
            BIG = 0.0                                                        05SE0
            NCT3 = 0                                                         05SE0
            NCT4 = 0                                                         05SE0
            NCT5 = 0                                                         05SE0
            NCT6 = 0                                                         05SE0
            NCT7 = 0                                                         05SE0
            NCV8 = 0                                                         06JA1
            NCT9 = 0                                                         06JA1
```

```
      PRINT 10                                                          30DE0
      CALL TIC TOC (1)                                                  08MR8
C-----PROGRAM AND PROBLEM IDENTIFICATION                                04MY3 ID
      READ  12, ( AN1(N), N = 1, 32 )                                   18FE5 ID
 1010 READ  14,  NPROB, ( AN2(N), N = 1, 14 )                           28AG3 ID
         IF ( NPROB - ITEST ) 1020, 9999, 1020                          05SE0
 1020 PRINT 11                                                          26AG3 ID
      PRINT 1                                                           18FE5 ID
      PRINT 13, ( AN1(N), N = 1, 32 )                                   18FE5 ID
      PRINT 15, NPROB, ( AN2(N), N = 1, 14 )                            24AG3 ID
C-----INPUT TABLE 1                                                     10JE3
      READ 20, KEEP2, KEEP3, KEEP4, KEEP5, KEEP6, KEEP7, KEEP8, KEEP9,  30DE0
     1          NCD2, NCD3, NCD4, NCD5, NCD6, NCD7, NCD8, NCD9          30DE0
      PRINT 100, KEEP2, KEEP3, KEEP4, KEEP5, KEEP6, KEEP7, KEEP8, KEEP9,30DE0
     1            NCD2, NCD3, NCD4, NCD5, NCD6, NCD7, NCD8, NCD9        30DE0
C-----INPUT TABLE 2                                                     10JE3
      PRINT 200                                                         05SE0
         IF ( KEEP 2 ) 9980, 1210, 1220                                 05SE0
 1210 READ 21, M, H, MT, HT, IPS, MONS, ITSW, MONI, MOP, LOP            30DE0
C-----COMPUTE CONSTANTS AND INDEXES                                     10JE3
            HT2 = H + H                                                 11JA5
            HE2 = H * H                                                 30MY3
            HE3 = H * HE2                                               30MY3
            HTE2 = HT * HT                                              05SE0
            MP1 = M + 1                                                 05SE0
            MP3 = M + 3                                                 05SE0
            MP4 = M + 4                                                 30MY3
            MP5 = M + 5                                                 30MY3
            MP6 = M + 6                                                 10JE3
            MP7 = M + 7                                                 30MY3
            MTP2 = MT + 2                                               05SE0
            MTP4 = MT + 4                                               05SE0
            H3T2 = HE3 / HTE2                                           05SE0
            H3T1 = HE3 / HT                                             05SE0
         IF ( IPS ) 1225, 1235, 1235                                    30DE0
 1235    IF ( ITSW ) 1250, 1230, 1250                                   30DE0
 1250 PRINT 201, M, H, MT, HT, IPS, MONS, ITSW, MONI, MOP, LOP          30DE0
         GO TO 1245                                                     30DE0
 1220 PRINT 905                                                         30DE0
         IF ( IPS ) 1215, 1240, 1240                                    30DE0
 1240    IF ( ITSW ) 1255, 1230, 1255                                   30DE0
 1255 PRINT 201, M, H, MT, HT, IPS, MONS, ITSW, MONI, MOP, LOP          30DE0
         GO TO 1260                                                     30DE0
 1225 READ 22, KPT, ( JPS(I), I = 1, MONS )                             30DE0
            KPS4 = KPT + 4                                              30DE0
 1215 PRINT 201, M, H, MT, HT, IPS, MONS, ITSW, MONI, MOP, LOP          30DE0
      PRINT 202, KPT, ( JPS(I), I = 1, MONS )                           30DE0
         IF ( ITSW ) 1245, 1301, 1245                                   30DE0
 1245    IF ( KEEP2 .EQ. 1 ) GO TO 1260                                 30DE0
      READ 23, MAXIT, WMAX, WTOL, ( JIMS(I), I = 1, MONI )              30DE0
 1260 PRINT 203, MAXIT, WMAX, WTOL, ( JIMS(I), I = 1, MONI )            30DE0
         GO TO 1301                                                     30DE0
 1230 PRINT 201, M, H, MT, HT, IPS, MONS, ITSW, MONI, MOP, LOP          30DE0
C-----INPUT TABLE 3                                                     01JE5
```

```
 1301 PRINT 300                                                         11JA5
         DO 1303  J = 1, MP7                                            05SE0
            KEY(J) = 1                                                  03JE3
            IOP(J) = 2                                                  17SE0
            ISW(J) = 0                                                  15FE1
 1303    CONTINUE                                                       23FE5
         IF ( KEEP3 ) 9980, 1310, 1305                                  26MY5
 1305 PRINT 905                                                         26MY5
         GO TO 1326                                                     26MY5
 1310    IF ( NCD3 - 20 ) 1312, 1312, 1311                              25MY5
 1311 PRINT 904                                                         25MY5
         GO TO 9999                                                     05SE0
 1312       NCT3 = NCD3                                                 25MY5
         IF ( NCT3 - 1 ) 1326, 1320, 1320                               08MR8
 1320    DO 1325  N = 1, NCT3                                           26SE7
      READ 31, IN13(N), KASE(N), WS(N), DWS(N), IOPS(N)                 18NO4
 1325    CONTINUE                                                       02FE5
 1326    IF ( NCT3 ) 9980, 1327, 1328                                   25MY5
 1327 PRINT 903                                                         25MY5
         GO TO 1400                                                     25MY5
 1328    IF ( NCT3 - 2 ) 1355, 1329, 1329                               08MR8
 1329    DO 1350  JA = 2, NCT3                                          08MR8
            JM1 = JA - 1                                                31DE4
         DO 1345  N = JA, NCT3                                          02FE5
         IF ( IN13(JM1) - IN13(N) ) 1345, 1330, 1340                    02FE5
 1330 PRINT 907                                                         25MY5
         GO TO 9999                                                     05SE0
C-----ARRANGE THE CARDS IN ASCENDING ORDER OF STA NUMBER                01JE5
 1340       INSAV = IN13(JM1)                                           02FE5
            KSAV = KASE(JM1)                                            31DE4
            WSAV = WS(JM1)                                              31DE4
            DWSAV = DWS(JM1)                                            31DE4
            IOPSAV = IOPS(JM1)                                          17SE0
            IN13(JM1) = IN13(N)                                         31DE4
            KASE(JM1) = KASE(N)                                         31DE4
            WS(JM1) = WS(N)                                             31DE4
            DWS(JM1) = DWS(N)                                           31DE4
            IOPS(JM1) = IOPS(N)                                         17SE0
            IN13(N) = INSAV                                             31DE4
            KASE(N) = KSAV                                              31DE4
            WS(N) = WSAV                                                31DE4
            DWS(N) = DWSAV                                              31DE4
            IOPS(N) = IOPSAV                                            17SE0
 1345    CONTINUE                                                       02FE5
 1350    CONTINUE                                                       02FE5
 1355    DO 1380  N = 1, NCT3                                           23JA67
            JS = IN13(N) + 4                                            31DE4
         IF( KASE(N) - 2 ) 1360,1365,1370                               26SE7
 1360       KEY(JS)= 2                                                  25MY5
            IOP(JS) = IOPS(N)                                           17SE0
      PRINT 311, IN13(N), KASE(N), WS(N), IOPS(N)                       17SE0
         GO TO 1380                                                     02FE5
 1365    IF( KEY(JS-1) - 1 ) 9980, 1366, 1375                           02FE5
 1366    IF ( KEY(JS) - 1 ) 9980, 1367, 1375                            02FE5
```

```
1367 PRINT 312, IN13(N), KASE(N), DWS(N), IOPS(N)                        26MY5
               KEY(JS-1) = 3                                              02FE5
               KEY(JS+1) = 5                                              05JE3
               IOP(JS-1) = IOPS(N)                                        17SE0
               IOP(JS+1) = IOPS(N)                                        17SE0
          GO TO 1380                                                      02FE5
1370      IF( KEY(JS-1) - 1 ) 9980, 1371, 1375                            02FE5
1371      IF ( KEY(JS) - 1 ) 9980, 1372, 1375                             02FE5
1372 PRINT 313, IN13(N), KASE(N), WS(N), DWS(N), IOPS(N)                  17SE0
               KEY(JS-1) = 3                                              02FE5
               KEY(JS) = 4                                                05JE3
               KEY(JS+1) = 5                                              05JE3
               IOP(JS-1) = IOPS(N)                                        17SE0
               IOP(JS) = IOPS(N)                                          17SE0
               IOP(JS+1) = IOPS(N)                                        17SE0
          GO TO 1380                                                      02FE5
1375 PRINT 907                                                            02FE5
          GO TO 9999                                                      05SE0
1380      CONTINUE                                                        02FE5
C-----INPUT TABLE 4                                                       10JE3
1400 PRINT 400                                                            04JE3
          IF ( KEFP4 ) 9980, 1401, 1410                                   04JA5
1401           NC14 = 1                                                   26MR5
               NCT4 = NCD4                                                19OC4
           GO TO 1430                                                     04JA5
1410 PRINT 905                                                            04JA5
          IF( NCT4 - 1 ) 1426,1411,1411                                   26SE7
1411       DO 1425  N = 1, NCT4                                           26SE7
          IF( KSW4(N) - 2 ) 1413,1417,1421                                26SE7
1413 PRINT 411, IN14(N), IN24(N), KR24(N), FN2(N), QDN2(N), SN2(N),       04JA5
    1           TN2(N), RN2(N), CN2(N)                                    05SE0
           GO TO 1425                                                     04JA5
1417 PRINT 412, IN14(N), KR24(N), FN2(N), QDN2(N), SN2(N), TN2(N),        04JA5
    1           RN2(N), CN2(N)                                            05SE0
           GO TO 1425                                                     04JA5
1421 PRINT 413, IN24(N), KR24(N), FN2(N), QDN2(N), SN2(N), TN2(N),        04JA5
    1           RN2(N), CN2(N)                                            05SE0
1425       CONTINUE                                                       04JA5
1426      CONTINUE                                                        21SE66
     PRINT 910                                                            04JA5
               NC14 = NCT4 + 1                                            21OC4
               NCT4 = NCT4 + NCD4                                         19OC4
1430       IF ( NCT4 - 100 ) 1435, 1435, 1433                             04JA5
1433 PRINT 904                                                            04JA5
          GO TO 9999                                                      05SE0
1435       IF ( NCD4 ) 9980, 1437, 1440                                   04JA5
1437 PRINT 903                                                            04JA5
           GO TO 1500                                                     04JA5
1440           KR1 = 0                                                    04JA5
          IF( NCT4 - NC14 ) 1500,1445,1445                                26SE7
1445       DO 1470  N = NC14, NCT4                                        26SE7
     READ 41, IN14(N), IN24(N), KR24(N), FN2(N), QDN2(N), SN2(N),         19OC4
    1           TN2(N), RN2(N), CN2(N)                                    05SE0
               KSW4(N) = 1 + KR24(N) + 2 * KR1                            23OC4
               KR1 = KR24(N)                                              06NO4
          IF( KSW4(N) - 2 ) 1450,1455,1460                                26SE7
1450 PRINT 411, IN14(N), IN24(N), KR24(N), FN2(N), QDN2(N), SN2(N),       04JA5
    1           TN2(N), RN2(N), CN2(N)                                    05SE0
           GO TO 1470                                                     04JA5
1455 PRINT 412, IN14(N), KR24(N), FN2(N), QDN2(N), SN2(N), TN2(N),        04JA5
    1           RN2(N), CN2(N)                                            05SE0
           GO TO 1470                                                     04JA5
1460 PRINT 413, IN24(N), KR24(N), FN2(N), QDN2(N), SN2(N), TN2(N),        04JA5
    1           RN2(N), CN2(N)                                            05SE0
1470       CONTINUE                                                       04JA5
C-----INPUT TABLE 5                                                       05SE0
1500 PRINT 500                                                            05SE0
          IF ( KEFP5 ) 9980, 1501, 1510                                   05SE0
1501           NC15 = 1                                                   05SE0
               NCT5 = NCD5                                                05SE0
           GO TO 1530                                                     05SE0
1510 PRINT 905                                                            05SE0
          IF( NCT5 - 1 ) 1526, 1511, 1511                                 05SE0
1511       DO 1525  N = 1, NCT5                                           05SE0
          IF( KSW5(N) - 2 ) 1513, 1517, 1521                              05SE0
1513 PRINT 411, IN15(N), IN25(N), KR25(N), RHON2(N), DIN2(N), CEN2(N)     05SE0
          GO TO 1525                                                      05SE0
1517 PRINT 412, IN15(N), KR25(N), RHON2(N), DIN2(N), DEN2(N)              05SE0
          GO TO 1525                                                      05SE0
1521 PRINT 413, IN25(N), KR25(N), RHON2(N), DIN2(N), DEN2(N)              05SE0
1525      CONTINUE                                                        05SE0
1526      CONTINUE                                                        05SE0
     PRINT 910                                                            05SE0
               NC15 = NCT5 + 1                                            05SE0
               NCT5 = NCT5 + NCD5                                         05SE0
1530      IF ( NCT5 - 100 ) 1535, 1535, 1533                              05SE0
1533 PRINT 904                                                            05SE0
          GO TO 9999                                                      05SE0
1535      IF ( NCD5 ) 9980, 1537, 1540                                    05SE0
1537 PRINT 903                                                            05SE0
          GO TO 1600                                                      05SE0
1540           KR1 = 0                                                    05SE0
          IF ( NCT5 - NC15 ) 1600, 1545, 1545                             05SE0
1545      DO 1570  N = NC15, NCT5                                         05SE0
     READ 51, IN15(N), IN25(N), KR25(N), RHON2(N), DIN2(N), UEN2(N)       05SE0
               KSW5(N) = 1 + KR25(N) + 2 * KR1                            05SE0
               KR1 = KR25(N)                                              05SE0
          IF ( KSW5(N) - 2 ) 1550, 1555, 1560                             05SE0
1550 PRINT 411, IN15(N), IN25(N), KR25(N), RHON2(N), DIN2(N), DEN2(N)     05SE0
          GO TO 1570                                                      05SE0
1555 PRINT 412, IN15(N), KR25(N), RHON2(N), DIN2(N), DEN2(N)              05SE0
          GO TO 1570                                                      05SE0
1560 PRINT 413, IN25(N), KR25(N), RHON2(N), DIN2(N), DEN2(N)              05SE0
1570      CONTINUE                                                        05SE0
C-----INPUT TABLE 6                                                       05SE0
1600 PRINT 600                                                            05SE0
          IF ( KEFP6 ) 9980, 1601, 1610                                   05SE0
1601           NC16 = 1                                                   05SE0
```

```
             NCT6 = NCD6                                              055E0
         GO TO 1630                                                   055E0
 1610 PRINT 905                                                       055E0
         IF ( NCT6 - 1 ) 1626, 1611, 1611                             055E0
 1611    DO 1625  N = 1, NCT6                                         055E0
      PRINT 610, IT1(N), IT2(N), KT1(N), KT2(N), TT1(N), TT2(N), TT3(N) 055E0
 1625    CONTINUE                                                     055E0
 1626    CONTINUE                                                     055E0
      PRINT 910                                                       055E0
             NC16 = NCT6 + 1                                          055E0
             NCT6 = NCT6 + NCD6                                       055E0
 1630    IF ( NCT6 - 100 ) 1635, 1635, 1633                           055E0
 1633 PRINT 904                                                       055E0
         GO TO 9999                                                   055E0
 1635    IF ( NCD6 ) 9980, 1637, 1640                                 055E0
 1637 PRINT 903                                                       055E0
         GO TO 1700                                                   055E0
 1640    IF ( NCT6 - NC16 ) 1700, 1645, 1645                          055E0
 1645    DO 1670  N = NC16, NCT6                                      055E0
      READ 61, IT1(N), IT2(N), KT1(N), KT2(N), TT1(N), TT2(N), TT3(N) 055E0
      PRINT 610, IT1(N), IT2(N), KT1(N), KT2(N), TT1(N), TT2(N), TT3(N) 055E0
 1670    CONTINUE                                                     055E0
C-----INPUT TABLE 7                                                   055E0
 1700 PRINT 700                                                       055E0
         IF ( KEEP7 ) 9980, 1701, 1710                                055E0
 1701        NC17 = 1                                                 055E0
             NCT7 = NCD7                                              055E0
         GO TO 1730                                                   055E0
 1710 PRINT 905                                                       055E0
         IF ( NCT7 - 1 ) 1726, 1711, 1711                             055E0
 1711    DO 1725  N = 1, NCT7                                         055E0
      PRINT 610, IQ1(N), IQ2(N), KQ1(N), KQ2(N), QT1(N), QT2(N), QT3(N) 055E0
 1725    CONTINUE                                                     055E0
 1726    CONTINUE                                                     055E0
      PRINT 910                                                       055E0
             NC17 = NCT7 + 1                                          055E0
             NCT7 = NCT7 + NCD7                                       055E0
 1730    IF ( NCT7 - 100 ) 1735, 1735, 1733                           055E0
 1733 PRINT 904                                                       055E0
         GO TO 9999                                                   055E0
 1735    IF ( NCD7 ) 9980, 1737, 1740                                 055E0
 1737 PRINT 903                                                       055E0
         GO TO 1800                                                   055E0
 1740    IF ( NCT7 - NC17 ) 1800, 1745, 1745                          055E0
 1745    DO 1770  N = NC17, NCT7                                      055E0
      READ 61, IQ1(N), IQ2(N), KQ1(N), KQ2(N), QT1(N), QT2(N), QT3(N) 055E0
      PRINT 610, IQ1(N), IQ2(N), KQ1(N), KQ2(N), QT1(N), QT2(N), QT3(N) 055E0
 1770    CONTINUE                                                     055E0
C-----INPUT TABLE 8                                                   24DE0
 1800 PRINT 800                                                       24DE0
         IF ( KEEP8 ) 9980, 1801, 1810                                24DE0
 1801        NC18 = 1                                                 24DE0
             NCV8 = NCD8 / 3                                          24DE0
         GO TO 1830
 1810 PRINT 905                                                       24DE0
         IF ( NCV8 - 1 ) 1826, 1811, 1811                             24DE0
 1811    DO 1825  N = 1, NCV8                                         24DE0
         IF ( KSW8(N) - 2 ) 1813, 1817, 1821                          24DE0
 1813 PRINT 811, IN18(N),IN28(N), KR28(N), QMP(N), WMP(N), NPOC(N),   24DE0
     1            KSYM(N), WNTOL(N), QNTOL(N)                         24DE0
         GO TO 1824                                                   24DE0
 1817 PRINT 812, IN18(N), KR28(N), QMP(N), WMP(N), NPOC(N), KSYM(N),  24DE0
     1            WNTOL(N), QNTOL(N)                                  15FE1
         GO TO 1824                                                   24DE0
 1821 PRINT 813, IN28(N), KR28(N), QMP(N), WMP(N), NPOC(N), KSYM(N),  24DE0
     1            WNTOL(N), QNTOL(N)                                  15FE1
 1824        NPCT = NPOC(N)                                           24DE0
      PRINT 814, ( QP(N,NP), NP = 1, NPCT )                           24DE0
      PRINT 815, ( WP(N,NP), NP = 1, NPCT )                           24DE0
 1825    CONTINUE                                                     24DE0
 1826    CONTINUE                                                     24DE0
      PRINT 910                                                       24DE0
             NC18 = NCV8 + 1                                          24DE0
             NCV8 = NCV8 + NCD8 / 3                                   24DE0
 1830    IF ( NCV8 - 20 ) 1835, 1835, 1833                            24DE0
 1833 PRINT 904                                                       24DE0
         GO TO 9999                                                   24DE0
 1835    IF ( NCD8 ) 9980, 1837, 1840                                 24DE0
 1837 PRINT 903                                                       24DE0
         GO TO 1873                                                   15FE1
 1840        KR1 = 0                                                  24DE0
         IF ( NCV8 - NC18 ) 1873, 1845, 1845                          24DE0
 1845    DO 1870  N = NC18, NCV8                                      24DE0
      READ 81, IN18(N), IN28(N), KR28(N), QMP(N), WMP(N), NPOC(N),    24DE0
     1            KSYM(N), WNTOL(N), QNTOL(N)                         24DE0
             NPCT = NPOC(N)                                           24DE0
      READ 82, ( QP(N,NP), NP = 1, NPCT )                             24DE0
      READ 82, ( WP(N,NP), NP = 1, NPCT )                             24DE0
             KSW8(N) = 1 + KR28(N) + 2 * KR1                          24DE0
             KR1 = KR28(N)                                            24DE0
         IF ( KSW8(N) - 2 ) 1850, 1855, 1860                          24DE0
 1850 PRINT 811, IN18(N), IN28(N), KR28(N), QMP(N), WMP(N), NPOC(N),  24DE0
     1            KSYM(N), WNTOL(N), QNTOL(N)                         24DE0
         GO TO 1871                                                   24DE0
 1855 PRINT 812, IN18(N), KR28(N), QMP(N), WMP(N), NPOC(N), KSYM(N),  24DE0
     1            WNTOL(N), QNTOL(N)                                  15FE1
         GO TO 1871                                                   24DE0
 1860 PRINT 813, IN28(N), KR28(N), QMP(N), WMP(N), NPOC(N), KSYM(N),  24DE0
     1            WNTOL(N), QNTOL(N)                                  15FE1
 1871        NPCT = NPOC(N)                                           24DE0
      PRINT 814, ( QP(N,NP), NP = 1, NPCT )                           24DE0
      PRINT 815, ( WP(N,NP), NP = 1, NPCT )                           24DE0
 1870    CONTINUE                                                     24DE0
 1873    IF ( NCV8 .EQ. 0 ) GO TO 1900                                15FE1
C-----DISTRIBUTE SUPPORT CURVES                                       24DE0
         DO 1875  N = 1, NCV8                                         24DE0
             NPCT = NPOC(N)                                           24DE0
         DO 1880  NP = 1, NPCT                                        24DE0
```

```
              QPV(N,NP) = QP(N,NP) * WMP(N)                                     24DE0
              WPV(N,NP) = WP(N,NP) * WMP(N)                                     24DE0
 1880     CONTINUE                                                              24DE0
          IF ( NPCT - 1 ) 1885, 1890, 1895                                      24DE0
 1885 PRINT 9981                                                                24DE0
          GO TO 9999                                                            24DE0
C-----CHECK POINTS FOR PROPER ORDER                                             24DE0
 1895     DO 1896  NP = 2, NPCT                                                 24DE0
          IF ( WPV(N,NP) .LE. WPV(N,NP-1) ) GO TO 1885                          10FE1
          IF ( QPV(N,NP) .GT. QPV(N,NP-1) ) GO TO 1885                          10FE1
 1896     CONTINUE                                                              24DE0
          GO TO 1891                                                            24DE0
 1890     IF ( KSYM(N) .NE. 1 ) GO TO 1885                                      24DE0
 1891     IF ( KSYM(N) .NE. 1 ) GO TO 1892                                      24DE0
C-----APPLY SYMMETRY OPTION TO CONSTRUCT OTHER HALF OF SUPPORT CURVE           24DE0
              NP1 = NPOC(N) + 1                                                 24DE0
              NP2 = NPOC(N) * 2                                                 24DE0
          DO 1893  NP = NP1, NP2                                                24DE0
              NN = NP - NPCT                                                    24DE0
              QPV(N,NP) = QPV(N,NN)                                             24DE0
              WPV(N,NP) = WPV(N,NN)                                             24DE0
 1893     CONTINUE                                                              24DE0
          DO 1894  NP = 1, NPCT                                                 24DE0
              NN = NP2 + 1 - NP                                                 24DE0
              QPV(N,NP) = -QPV(N,NN)                                            24DE0
              WPV(N,NP) = -WPV(N,NN)                                            24DE0
 1894     CONTINUE                                                              24DE0
              NPCTS(N) = NP2                                                    24DE0
          GO TO 1875                                                            24DE0
 1892         NPCTS(N) = NPOC(N)                                                24DE0
 1875     CONTINUE                                                              24DE0
C-----GENERATE ALL THE SUPPORTING STA NONLINEAR CURVES                          15FE1
              NNC = 0                                                           15FE1
              KR1 = 0                                                           28DE0
          DO 6065  N = 1, NCVB                                                  28DE0
          IF ( KR1 .GT. 0 ) GO TO 6066                                          28DE0
              N1 = N                                                            28DE0
          IF ( KR2F(N) .EQ. 1 ) GO TO 6070                                      28DE0
 6066         J1 = IN18(N1) + 4                                                 28DE0
              J2 = IN28(N) + 4                                                  28DE0
              DENOM = J2 - J1                                                   28DE0
              JEND = J2                                                         28DE0
          IF ( DENOM .GT. 0 ) GO TO 6067                                        28DE0
          IF ( MP4 .GE. J1 ) GO TO 6068                                         28DE0
          GO TO 6075                                                            28DE0
 6067     IF ( MP4 .LE. J1 ) GO TO 6075                                         28DE0
          IF ( MP4 .GE. J2 ) GO TO 6069                                         28DE0
              JEND = MP4                                                        28DE0
          GO TO 6069                                                            28DE0
 6068         DENOM = 1.0                                                       28DE0
 6069     DO 6080  J = J1, JEND                                                 15FE1
          IF ( N1 .EQ. 1 ) GO TO 6082                                           15FE1
          IF ( KR1 .EQ. 0 ) GO TO 6082                                          26JU1
          IF ( KR28(N-2) .EQ. 0 ) GO TO 6082                                    26JU1
          IF ( ISTA(NNC) .NE. J ) GO TO 6082                                    26JU1
              ISW(J) = 0                                                        15FE1
          GO TO 6080                                                            15FE1
 6082         DIFF = J - J1                                                     15FE1
              PART = DIFF / DENOM                                               15FE1
              NNC = NNC + 1                                                     15FE1
          IF ( KSYM(N1) .NE. KSYM(N) ) GO TO 1885                               15FE1
          IF ( NPCTS(N1) .NE. NPCTS(N) ) GO TO 1885                             15FE1
          IF ( J .EQ. J1 .OR. J .EQ. JEND ) ISW(J) = 1                          15FE1
          IF ( J1 - JEND ) 683, 682, 681                                        15FE1
  681 PRINT 9993                                                                15FE1
          GO TO 9999                                                            15FE1
  682         ISW(J) = 0                                                        15FE1
  683         NPCT = NPCTS(N1)                                                  15FE1
          DO 6083  NP = 1, NPCT                                                 15FE1
          IF ( WPV(N1,NP) .NE. WPV(N,NP) ) GO TO 1885                           15FE1
              WPT(NNC,NP) = WPV(N1,NP)                                          15FE1
              QPT(NNC,NP) = QPV(N1,NP) + PART* ( QPV(N,NP) - QPV(N1,NP)15FE1
     1                       )                                                  15FE1
 6083     CONTINUE                                                              15FE1
          IF ( WNTOL(N1) .NE. WNTOL(N) ) GO TO 1885                             21AP1
              WNTOLJ(NNC) = WNTOL(N1)                                           21AP1
              QNTOLJ(NNC) = WNTOL(N1) + PART * ( QNTOL(N) - QNTOL(N1) )15FE1
              NPTTS(NNC) = NPCTS(N1)                                            15FE1
              ISTA(NNC) = J                                                     15FE1
              KSYMJ(NNC) = KSYM(N1)                                             15FE1
          IF ( ABS(WPT(NNC,1)) .NE. ABS(WPT(NNC,NPCT)) ) GO TO 1885             15FE1
 6080     CONTINUE                                                              15FE1
 6075     IF ( KR2B(N) .NE. 1 ) GO TO 6070                                      28DE0
              IN18(N) = IN2B(N)                                                 28DE0
              N1 = N                                                            28DE0
 6070     IF ( KR2B(N) .EQ. 1 ) GO TO 6095                                      28DE0
              KR1 = 0                                                           28DE0
          GO TO 6065                                                            28DE0
 6095         KR1 = 1                                                           28DE0
 6065     CONTINUE                                                              28DE0
          IF ( NNC .LE. 100 ) GO TO 1874                                        15FE1
      PRINT 904                                                                 15FE1
          GO TO 9999                                                            15FE1
C-----SAVE SLOPES, QDROPS, WDROPS FOR EACH CURVE                                15FE1
 1874     DO 1876  N = 1, NNC                                                   15FE1
              NPCT = NPTTS(N)                                                   15FE1
          IF ( NPCT - 2 ) 1885, 1877, 1878                                      15FE1
 1877     IF ( KSYMJ(N) .NE. 1 ) GO TO 1885                                     15FE1
 1878     IF ( KSYMJ(N) .NE. 1 ) GO TO 1879                                     15FE1
              NOS = NPCT / 2                                                    15FE1
          DO 1897  NP = 1, NOS                                                  15FE1
              NN = NOS - NP + 1                                                 15FE1
              QDROP(N,NP) = - ( QPT(N,NN+1) - QPT(N,NN) )                       15FE1
              WDROP(N,NP) = WPT(N,NN+1) - WPT(N,NN)                             15FE1
              SLOPE(N,NP) = QDROP(N,NP) / WDROP(N,NP)                           10FE1
          IF ( NP .EQ. 1 ) GO TO 1897                                           10FE1
              QDROP(N,NP) = QDROP(N,NP) * 2.0                                   10FE1
              WDROP(N,NP) = WDROP(N,NP) * 2.0                                   10FE1
```

```
1897      CONTINUE                                                     15FE1
               NOSJ(N) = NOS                                           15FE1
          GO TO 1886                                                   21AP1
1879           NPCNT = 0                                               10FE1
               NPCT1 = NPCT - 1                                        15FE1
          DO 1898  NP = 1, NPCT1                                       10FE1
          IF ( ABS(WPT(N,NP+1) - WPT(N,NP) ) .NE. ( ABS(WPT(N,NP+1)) + 10FE1
     1       ABS(WPT(N,NP)) ) ) GO TO 1898                             15FE1
               NPZERO = NP                                             10FE1
               NPCNT = NPCNT + 1                                       10FE1
1898      CONTINUE                                                     10FE1
          IF ( NPCNT .NE. 2 ) GO TO 1885                               15FE1
               NOS = NPZERO                                            10FE1
               NOS1 = NOS - 1                                          15FE1
          DO 1899  NP = 1, NOS1                                        15FE1
               QDROP(N,NP) = - ( QPT(N,NOS-NP+1) - QPT(N,NOS-NP) )     15FE1
               WDROP(N,NP) = WPT(N,NOS-NP+1) - WPT(N,NOS-NP)           15FE1
               SLOPE(N,NP) = QDROP(N,NP) / WDROP(N,NP)                 15FE1
1899      CONTINUE                                                     10FE1
               NOSJ(N) = NOS1                                          15FE1
          IF ( SLOPE(N,NOS1) .LE. 1.0E-06 ) GO TO 1864                 15FE1
               SLOPE(N,NOS) = 0.0                                      15FE1
               WDROP(N,NOS) = WPT(N,NOS+1) - WPT(N,NOS)                15FE1
               QDROP(N,NOS) = 0.0                                      15FE1
               NOSJ(N) = NOS                                           15FE1
          GO TO 1886                                                   21AP1
1864           WDROP(N,NOS1) = WPT(N,NOS+1) - WPT(N,NOS) + WDROP(N,NOS1)15FE1
C-----CHECK THE PROPER ORDER OF SLOPES FOR THIS NONLINEAR SUP CURVE    21AP1
1886           NOSN = NOSJ(N) - 1                                      21AP1
          DO 1887  NN = 1, NOSN                                        21AP1
          IF ( SLOPE(N,NN) .LE. 1.0E-06 ) GO TO 1887                   21AP1
          IF ( SLOPE(N,NN) .GT. SLOPE(N,NN+1) ) GO TO 1887             21AP1
               JJ = ISTA(N) - 4                                        21AP1
      PRINT 9988, JJ                                                   21AP1
          GO TO 9999                                                   21AP1
1887      CONTINUE                                                     21AP1
C-----REVERSE THE ORDER OF POINTS ON POSITIVE ONE-WAY SUPPORTS         26JU1
          IF ( KSYMJ(N) .NE. -1 ) GO TO 1876                           26JU1
          DO 1888  NP = 1, NPCT                                        26JU1
               NPR = NPCT - NP + 1                                     26JU1
               QRVT(N,NPR) = - QPT(N,NP)                               26JU1
               WRVT(N,NPR) = - WPT(N,NP)                               26JU1
1888      CONTINUE                                                     26JU1
          DO 1889  NP = 1, NPCT                                        26JU1
               QPT(N,NP) = QRVT(N,NP)                                  26JU1
               WPT(N,NP) = WRVT(N,NP)                                  26JU1
1889      CONTINUE                                                     26JU1
1876      CONTINUE                                                     15FE1
C-----INPUT TABLE 9                                                    30DE0
1900 PRINT 900                                                         30DE0
          IF ( KEEP9 ) 9980, 1901, 1910                                30DE0
1901           NC19 = 1                                                30DE0
               NCT9 = NCD9                                             30DE0
          GO TO 1930                                                   30DE0
```

```
1910 PRINT 905                                                         30DE0
          IF ( NCT9 - 1 ) 1926, 1911, 1911                             30DE0
1911      DO 1925  N = 1, NCT9                                         30DE0
     PRINT 908, XAXIS(N), YAXIS(N), IYSW(N), MPS(N)                    10FE1
1925      CONTINUE                                                     30DE0
1926      CONTINUE                                                     30DE0
     PRINT 910                                                         30DE0
               NC19 = NCT9 + 1                                         30DE0
               NCT9 = NCT9 + NCD9                                      30DE0
1930      IF ( NCT9 - 10 ) 1935, 1935, 1933                            05JA1
1933 PRINT 904                                                         30DE0
          GO TO 9999                                                   30DE0
1935      IF ( NCD9 ) 9980, 1937, 1940                                 30DE0
1937 PRINT 903                                                         30DE0
          GO TO 2000                                                   30DE0
1940      IF ( NCT9 - NC19 ) 2000, 1945, 1945                          30DE0
1945      DO 1970  N = NC19, NCT9                                      30DE0
     READ 91, XAXIS(N), YAXIS(N), IYSW(N), MPS(N)                      10FE1
     PRINT 908, XAXIS(N), YAXIS(N), IYSW(N), MPS(N)                    10FE1
1970      CONTINUE                                                     30DE0
C-----INTERPOLATE AND DISTRIBUTE VALUES FROM TABLE 4   AND TABLE 5     05SE0
2000           LSM = 0                                                 30DE0
     CALL INTERP3 ( MP7, NCT4, IN14, IN24, KR24, FN2, F, LSM, KSW4 )   10OC0
     CALL INTERP3 ( MP7, NCT4, IN14, IN24, KR24, QDN2, Q, LSM, KSW4 )  10OC0
     CALL INTERP3 ( MP7, NCT4, IN14, IN24, KR24, SN2, S, LSM, KSW4 )   10OC0
     CALL INTERP3 ( MP7, NCT4, IN14, IN24, KR24, RN2, R, LSM, KSW4 )   10OC0
     CALL INTERP3 ( MP7, NCT4, IN14, IN24, KR24, CN2, CP, LSM, KSW4 )  10OC0
     CALL INTERP3 ( MP7, NCT5, IN15, IN25, KR25, RHON2, RHO, LSM,KSW5 )10OC
     CALL INTERP3 ( MP7, NCT5, IN15, IN25, KR25, DIN2, DI, LSM, KSW5 ) 10OC0
     CALL INTERP3 ( MP7, NCT5, IN15, IN25, KR25, DEN2, DE, LSM, KSW5 ) 10OC0
               LSM = 1                                                 05SE0
     CALL INTERP3 ( MP7, NCT4, IN14, IN24, KR24, TN2, T, LSM, KSW4 )   10OC0
C-----START BEAM-COLUMN SOLUTION FOR EACH TIME STATION                 05SE0
     PRINT 11                                                          05SE0
     PRINT 1                                                           05SE0
     PRINT 13, ( AN1(N), N = 1, 32 )                                   05SE0
     PRINT 14, NPROB, ( AN2(N), N = 1, 14 )                            05SE0
     PRINT 820                                                         05SE0
               KPC = 0                                                 05SE0
               KK = 0                                                  05SE0
               NPRT = 0                                                15FE1
C-----INITIALIZING                                                     05SE0
          DO 6997  I = 1, MP7                                          30DE0
               IFUS(I) = 0                                             15FE1
               OI(I) = 0.0                                             25JA1
               SS(I) = 0.0                                             15FE1
               SSKM1(I) = 0.0                                          21AP1
               OIM1(I) = 0.0                                           21AP1
               OIM2(I) = 0.0                                           21AP1
6997      CONTINUE                                                     30DE0
          DO 7000  K = 1, MTP4                                         10FE1
               NOCI = 0                                                15AP1
               NITS = 1                                                06AP1
               IOCNT = 0                                               15FE1
```

```
            ITCS = 0                                                        25JA1
            ITCSP = 0                                                       25JA1
            KCLOSE(1) = 0                                                   06AP1
            KCLOSE(2) = 0                                                   06AP1
            KPC = KPC + 1                                                   05SE0
            KK = KK + 1                                                     05SE0
            KM1 = K - 1                                                     05SE0
            KM2 = K - 2                                                     10FE1
            KM3 = K - 3                                                     05SE0
            KM4 = K - 4                                                     05SE0
C-----INITIALIZING                                                          30DE0
      DO 6998  I = 1, MP7                                                   30DE0
      IF ( K .GT. 2 ) GO TO 6996                                            06AP1
            W(I,KK) = 0.0                                                   30DE0
            WW(I) = 0.0                                                     28DE0
            WWW(I) = 0.0                                                    13JA1
 6996 IF ( K .LE. 2 ) GO TO 6995                                            06AP1
            W(I,KK) = W(I,KK-1)                                             06AP1
            WW(I) = W(I,KK)                                                 06AP1
 6995       SSKM2(I) = SSKM1(I)                                             21AP1
            SSKM1(I) = SS(I)                                                15FE1
            QTM2(I) = QTM1(I)                                               21AP1
            QTM1(I) = QT(I)                                                 21AP1
            TOSW(I) = 0                                                     13JA1
            NUMOC(I) = 0                                                    13JA1
            IUS(I) = 0                                                      25JA1
      IF ( K .EQ. 1 ) GO TO 6998                                            21AP1
            QS(I) = QTM1(I) - Q(I) - QT(I+1)                                21AP1
 6998 CONTINUE                                                              30DE0
      IF ( 1004 - K ) 7002, 7003, 7003                                      15FE1
 7002 PRINT 990                                                             05SE0
      GO TO 9999                                                            05SE0
 7003 IF ( K .EQ. MTP4 ) GO TO 6175                                         10FE1
      DO 6999  KT = 1, 2                                                    06JA1
      DO 7001  J = 1, MP7                                                   10DC0
            TT(J,KT) = 0.0                                                  10DC0
            QT(J,KT) = 0.0                                                  10DC0
 7001 CONTINUE                                                              05SE0
C-----CALCULATE TIME VARIANT AXIAL THRUST FOR EACH BAR AT THIS TIME STA 05SE0
C-----K AND K-2 TIME STATION                                                05SE0
            K1 = K - ( KT - 1 ) * 2                                         10DC0
      DO 710  J = 3, MP5                                                    10DC0
      IF ( 1 .GT. NCT6 ) GO TO 711                                          05SE0
      DO 707  NC = 1, NCT6                                                  05SE0
            KN1 = KT1(NC) + 3                                               10DC0
            KN2 = KT2(NC) + 3                                               10DC0
            JT1 = IT1(NC) + 5                                               05SE0
            JT2 = IT2(NC) + 4                                               05SE0
      IF ( JT2 - JT1 ) 744, 745, 745                                        05SE0
  744 PRINT 960                                                             05SE0
      GO TO 9999                                                            05SE0
  745 IF ( KN2 .GE. KN1 ) GO TO 845                                         06AP1
    PRINT 917                                                               06AP1
      GO TO 9999                                                            06AP1
  845 IF ( K1 .LT. KN1 .OR. K1 .GT. KN2 ) GO TO 707                         06AP1
      IF ( K1 .EQ. KN1 .OR. K1 .EQ. KN2 ) GO TO 746                         16JA1
            FST = 1.0                                                       16JA1
      GO TO 748                                                             16JA1
  746       FST = 0.5                                                       16JA1
  748 IF ( J .LT. JT1 .OR. J .GT. JT2 ) GO TO 707                           05SE0
            TINC = K1 - KN1                                                 10DC0
      IF ( KN2 - KN1 ) 740, 741, 742                                        05SE0
  740 PRINT 917                                                             05SE0
      GO TO 9999                                                            05SE0
  741       TDENOM = 1.                                                     05SE0
            FST = 1.0                                                       16JA1
      GO TO 743                                                             05SE0
  742       TDENOM = KN2 - KN1                                              05SE0
  743       BINCT = J - JT1                                                 05SE0
            BINC = BINCT + 0.5                                              05SE0
            BDENOM = JT2 - JT1 + 1                                          05SE0
            TT(J,KT) = TT(J,KT) + ( TT1(NC) + ( TT2(NC) - TT1(NC) )  16JA1
     1                 * BINC / BDENOM + ( TT3(NC) - TT1(NC) ) * TINC16JA1
     2                 / TDENOM ) * FST                                     16JA1
  707 CONTINUE                                                              05SE0
C-----CALCULATE TIME VARIANT LATERAL LOADING FOR EACH STA AT THIS TIME STA5E0
C-----K AND K-2 TIME STA                                                    05SE0
  711 IF ( 1 .GT. NCT7 ) GO TO 710                                          10DC0
      DO 712  NC = 1, NCT7                                                  05SE0
            KN1 = KQ1(NC) + 3                                               10DC0
            KN2 = KQ2(NC) + 3                                               10DC0
            JT1 = IQ1(NC) + 4                                               05SE0
            JT2 = IQ2(NC) + 4                                               05SE0
      IF ( KN2 .GE. KN1 ) GO TO 846                                         06AP1
    PRINT 917                                                               06AP1
      GO TO 9999                                                            06AP1
  846 IF ( JT2 .GE. JT1 ) GO TO 847                                         06AP1
    PRINT 917                                                               06AP1
      GO TO 9999                                                            06AP1
  847 IF ( K1 .LT. KN1 .OR. K1 .GT. KN2 ) GO TO 712                         06AP1
      IF ( K1 .EQ. KN1 .OR. K1 .EQ. KN2 ) GO TO 758                         16JA1
            FST = 1.0                                                       16JA1
      GO TO 759                                                             16JA1
  758       FST = 0.5                                                       16JA1
  759 IF ( J .LT. JT1 .OR. J .GT. JT2 ) GO TO 712                           05SE0
      IF ( J .EQ. JT1 .OR. J .EQ. JT2 ) GO TO 760                           16JA1
            FSB = 1.0                                                       16JA1
      GO TO 761                                                             16JA1
  760       FSB = 0.5                                                       16JA1
  761       TINC = K1 - KN1                                                 10DC0
      IF ( KN2 - KN1 ) 750, 751, 752                                        05SE0
  750 PRINT 917                                                             05SE0
      GO TO 9999                                                            05SE0
  751       TDENOM = 1.0                                                    05SE0
            FST = 1.0                                                       16JA1
      GO TO 753                                                             05SE0
  752       TDENOM = KN2 - KN1                                              05SE0
  753       BINC = J - JT1                                                  05SE0
```

```
      IF ( JT2 - JT1 ) 754, 755, 756                                    05SE0
  754 PRINT 917                                                         05SE0
      GO TO 9999                                                        05SE0
  755      BDENOM = 1.0                                                 05SE0
           ESB = 1.0                                                    16JA1
      GO TO 757                                                         05SE0
  756      BDENOM = JT2 - JT1                                           05SE0
  757      QT(J,KT) = QT(J,KT) + ( QT1(NC) + ( QT2(NC) - QT1(NC) ) *16JA1
     1                 BINC , BDENOM + ( QT3(NC) - QT1(NC) ) * TINC  16JA1
     2                 / TDENOM ) * EST * ESB                           16JA1
  712 CONTINUE                                                          05SE0
  710 CONTINUE                                                          05SE0
 6999 CONTINUE                                                          10OC0
      IF ( ITSW ) 6900, 6905, 6900                                      28DE0
 6900 IF ( MAXIT .GT. 0 ) GO TO 6910                                    28DE0
   PRINT 9982                                                           28DE0
C-----ITSW = 0, LINEAR SPRINGS, SO SET MAXIT = 1                        28DE0
 6905      MAXIT = 1                                                    28DE0
 6910 DO 6000  NIT = 1, MAXIT                                           28DE0
           KOFFC(NIT) = 0                                               28DE0
C-----INITIALIZING FOR NEXT ITERATION                                   28DE0
      DO 6500  J = 1, MP7                                               28DE0
           QI(J) = Q(J) + QT(J,1)                                       21AP1
           SS(J) = S(J)                                                 28DE0
 6500 CONTINUE                                                          28DE0
      IF ( NCVB .EQ. 0 ) GO TO 6504                                     28DE0
      DO 6056  NN = 1, NNC                                              15FE1
           NP1S = 0                                                     10FE1
           J = ISTA(NN)                                                 15FE1
           NOS = NOSJ(NN)                                               15FE1
           NPCT = NPTTS(NN)                                             15FE1
      IF ( IOSW(J) .EQ. 0 ) GO TO 6557                                  06AP1
C-----INITIALIZING FOR THE FIRST LOAD ITERATION
      IF ( NIT .GT. NITS ) GO TO 6557                                   06AP1
           W(J,KK) = W(J,KK-1)                                          06AP1
 6557 IF ( ISW(J) .EQ. 0 ) GO TO 6057                                   06AP1
           ESM = 0.5                                                    15FE1
      GO TO 6085                                                        15FE1
 6057      ESM = 1.0                                                    15FE1
 6085 IF ( ITCS .EQ. 0 ) GO TO 6086                                     10FE1
      IF ( IFUS(J) .EQ. 1 ) GO TO 6081                                  15FE1
C-----TEST TO SEE IF NEEDS ADJUSTMENT OF THE Q-W CURVE FOR THE FIRST TIME5FE1
      IF ( ABS(W(J,KK)) .LT. ABS(W(J,KK-1)) ) GO TO 603                 10FE1
      IF ( ( ABS(W(J,KK-1)) + ABS(W(J,KK)) ) .EQ. ABS(W(J,KK-1) -    10FE1
     1           W(J,KK)) ) GO TO 603                                   10FE1
      GO TO 6086                                                        10FE1
 6081 IF ( WPT(NN,1) ) 601, 9991, 602                                   10FE1
C-----TEST TO SEE IF NEEDS ADJUSTMENT OF Q-W CURVE AFTER THE FIRST TIME 15FE1
  601 IF ( W(J,KK) .GE. W(J,KK-1) ) GO TO 6086                          10FE1
      GO TO 503                                                         15FE1
  602 IF ( W(J,KK) .LE. W(J,KK-1) ) GO TO 6086                          10FE1
      GO TO 503                                                         15FE1
  603 IF ( W(J,KK-1) ) 669, 6086, 503                                   26JU1
  503 IF ( KSYMJ(NN) .EQ. 1 ) GO TO 604                                 15FE1
      IF ( IFUS(J) .EQ. 1 ) GO TO 604                                   15AP1
      IF ( KSYMJ(NN) .EQ. -1 ) GO TO 604                                26JU1
      GO TO 6086                                                        15FE1
C-----REVERSE THE ORDER OF NONLINEAR SUPPORT CURVE                      10FE1
  604 DO 606  NP = 1, NPCT                                              10FE1
           NPR = NPCT - NP + 1                                          10FE1
           WPVT(NN,NP) = WPT(NN,NPR)                                    15FE1
           QPVT(NN,NP) = QPT(NN,NPR)                                    15FE1
  606 CONTINUE                                                          10FE1
      DO 506  NP = 1, NPCT                                              15FE1
           WPT(NN,NP) = WPVT(NN,NP)                                     15FE1
           QPT(NN,NP) = QPVT(NN,NP)                                     15FE1
  506 CONTINUE                                                          15FE1
      IF ( KSYMJ(NN) .EQ. 1 ) GO TO 605                                 15AP1
C-----CHECK TO SEE IF NEEDS ADJUSTMENT OF THE Q-W CV FOR ONE-WAY SUPPORT26JU1
      IF ( KSYMJ(NN) .NE. -1 ) GO TO 666                                26JU1
      IF ( IFUS(J) .EQ. 0 ) GO TO 605                                   26JU1
  666 DO 507  NP = 2, NPCT                                              26JU1
           STEMP = ABS ( ( QPT(NN,NP) - QPT(NN,NP-1) ) /                21AP1
     1                   ( WPT(NN,NP) - WPT(NN,NP-1) ) )                21AP1
      IF ( ABS(STEMP - SLOPE(NN,1)) .LE. 1.0E-06 ) GO TO 508            15AP1
  507 CONTINUE                                                          15AP1
   PRINT 980                                                            15AP1
      GO TO 9999                                                        15AP1
  508 IF ( WPT(NN,1) ) 509, 9991, 511                                   15AP1
  509      NP = NP - 1                                                  15AP1
  511 IF ( KSYMJ(NN) .EQ. 0 ) GO TO 667                                 26JU1
      IF ( W(J,KK-1) .LE. WPT(NN,NP) ) GO TO 6086                       26JU
      GO TO 605                                                         26JU1
  667 IF ( W(J,KK-1) .GE. WPT(NN,NP) ) GO TO 6086                       26JU1
      GO TO 605                                                         26JU1
  669 IF ( KSYMJ(NN) .EQ. 1 ) GO TO 605                                 26JU1
      IF ( KSYMJ(NN) .EQ. 0 ) GO TO 605                                 26JU1
      GO TO 6086                                                        26JU1
  605      IUS(J) = IUS(J) + 1                                          15FE1
      DO 607  NP = 2, NPCT                                              10FE1
      IF ( WPT(NN,1) ) 608, 9991, 609                                   10FE1
  608 IF ( W(J,KK-1) - WPT(NN,NP) ) 631, 613, 607                       10FE1
  609 IF ( W(J,KK-1) - WPT(NN,NP) ) 607, 613, 611                       10FE1
  607 CONTINUE                                                          10FE1
      GO TO 612                                                         10FE1
  631 IF ( W(J,KK-1) - WPT(NN,1) ) 612, 632, 614                        10FE1
  611 IF ( W(J,KK-1) - WPT(NN,1) ) 614, 632, 612                        10FE1
  612      KOFFC(NIT) = 1                                               10FE1
      GO TO 614                                                         10FE1
  613      NPS = NP + 1                                                 10FE1
      GO TO 615                                                         10FE1
  632      NP1S = 1                                                     10FE1
  614      NPS = NP                                                     10FE1
C-----TEST TO SEE W(J,KK-1) IS AT WHICH SLOPE(NN,NP)                    10FE1
  615      STEMP = ABS ( ( QPT(NN,NPS) - QPT(NN,NPS-1) ) /              21AP1
     1                   ( WPT(NN,NPS) - WPT(NN,NPS-1) ) )              21AP1
      IF ( STEMP .LE. 1.0E-06 ) GO TO 641                               10FE1
           QTEMP = STEMP * ABS(W(J,KK-1) - WPT(NN,NPS-1))               10FE1
```

```
      GO TO 642                                                         10FE1
641         QTEMP = ABS(W(J,KK-1) - WPT(NN,NPS-1))                      10FE1
642   DO 616  NSC = 1, NOS                                              06AP1
      IF ( STEMP - SLOPE(NN,NSC) ) 616, 617, 530                        06AP1
616   CONTINUE                                                          06AP1
      GO TO 617                                                         06AP1
530   IF ( NSC .EQ. 1 ) GO TO 617                                       06AP1
            SDHALF = ( SLOPE(NN,NSC-1) - SLOPE(NN,NSC) ) / 2.0          06AP1
            SPART = STEMP - SLOPE(NN,NSC)                               06AP1
      IF ( SPART .GT. SDHALF ) NSC = NSC - 1                            06AP1
617         QDROPL = QDROP(NN,NSC) - QTEMP                              10FE1
            NSC1 = NSC - 1                                              10FE1
      IF ( NSC1 .GT. 0 ) GO TO 520                                      15FE1
C-----NO NEED OF ADJUSTING THE Q-W CURVE, SINCE THE PREVIOUS DEFLECTION 21AP1
C-----IS WITHIN THE ELASTIC RANGE                                       21AP1
            IUS(J) = 0                                                  15FE1
      IF ( IFUS(J) .EQ. 1 ) GO TO 6086                                  15FE1
      IF ( WPT(NN,1) .LT. 0.0 ) GO TO 6086                              15FE1
C-----REVERSE THE ORDER OF POINTS OF Q-W CURVE BACK TO THE STARTED ORDER15FE1
      DO 510  NPA = 1, NPCT                                             15FE1
            NPR = NPCT - NPA + 1                                        15FE1
            WPVT(NN,NPA) = WPT(NN,NPR)                                  15FE1
            QPVT(NN,NPA) = QPT(NN,NPR)                                  15FE1
510   CONTINUE                                                          15FE1
      DO 515 NPA = 1, NPCT                                              15FE1
            WPT(NN,NPA) = WPVT(NN,NPA)                                  15FE1
            QPT(NN,NPA) = QPVT(NN,NPA)                                  15FE1
515   CONTINUE                                                          15FE1
      GO TO 6086                                                        15FE1
C-----SAVE WPT AND QPT FROM POINT 1 TO POINT NP-1 FOR THIS CURVE NN     21AP1
520         NPM1 = NP - 1                                               15FE1
      DO 618  NPVS = 1, NPM1                                            10FE1
            WPVT(NN,NPVS) = WPT(NN,NPVS)                                10FE1
            QPVT(NN,NPVS) = QPT(NN,NPVS)                                10FE1
618   CONTINUE                                                          10FE1
      IF ( NP1S .EQ. 0 ) GO TO 633                                      10FE1
            NP = NP - 1                                                 10FE1
      GO TO 634                                                         10FE1
C-----REGENERATE THE NONLINEAR SUPPORT CURVE FOR THIS CURVE NN          10FE1
633         WPVT(NN,NP) = W(J,KK-1)                                     10FE1
            QPVT(NN,NP) = ( WPT(NN,NPS) - W(J,KK-1) ) * STEMP +         10FE1
     1                            QPT(NN,NPS)                           10FE1
634   DO 619  NSCC = 1, NSC1                                            10FE1
            NST = NSCC + NP                                             10FE1
      IF ( WPT(NN,1) ) 620, 9991, 621                                   10FE1
620         WPVT(NN,NST) = WPVT(NN,NST-1) + WDROP(NN,NSCC)              10FE1
            QPVT(NN,NST) = QPVT(NN,NST-1) - QDROP(NN,NSCC)              10FE1
      GO TO 619                                                         10FE1
621         WPVT(NN,NST) = WPVT(NN,NST-1) - WDROP(NN,NSCC)              10FE1
            QPVT(NN,NST) = QPVT(NN,NST-1) + QDROP(NN,NSCC)              10FE1
619   CONTINUE                                                          10FE1
            NSL = NSC + NP                                              10FE1
      IF ( WPT(NN,1) ) 622, 9991, 623                                   10FE1
622   IF ( SLOPE(NN,NSC) .LE. 1.0E-06 ) GO TO 639                       10FE1
            WPVT(NN,NSL) = WPVT(NN,NSL-1) + QDROPL / SLOPE(NN,NSC)      10FE1
            QPVT(NN,NSL) = QPVT(NN,NSL-1) - QDROPL                      10FE1
      GO TO 624                                                         10FE1
639         WPVT(NN,NSL) = WPVT(NN,NSL-1) + WDROP(NN,NSC) -             15FE1
     1                        ABS(QDROPL)                               15FE1
            QPVT(NN,NSL) = QPVT(NN,NSL-1)                               10FE1
      GO TO 624                                                         10FE1
623   IF ( SLOPE(NN,NSC) .LE. 1.0E-06 ) GO TO 640                       10FE1
            WPVT(NN,NSL) = WPVT(NN,NSL-1) - QDROPL / SLOPE(NN,NSC)      10FE1
            QPVT(NN,NSL) = QPVT(NN,NSL-1) + QDROPL                      10FE1
      GO TO 624                                                         10FE1
640         WPVT(NN,NSL) = WPVT(NN,NSL-1) - WDROP(NN,NSC) +             15FE1
     1                        ABS(QDROPL)                               15FE1
            QPVT(NN,NSL) = QPVT(NN,NSL-1)                               10FE1
C-----SAVE THE REMAINNING WPT AND QPT IN WPVT AND QPVT ARRAYS           10FE1
624   DO 625  NPC = NP, NPCT                                            10FE1
      IF ( ABS(WPVT(NN,NSL) - WPT(NN,NPC)) .GT. WNTOLJ(NN) ) GO TO      15FE1
     1      625                                                         15FE1
      IF ( ABS(QPVT(NN,NSL) - QPT(NN,NPC)) .GT. QNTOLJ(NN) ) GO TO      15FE1
     1      625                                                         15FE1
      GO TO 626                                                         10FE1
625   CONTINUE                                                          10FE1
626         NPCTL = NPCT - NPC                                          10FE1
      IF ( NPCTL ) 9980, 627, 628                                       10FE1
628   DO 6628  NA = 1, NPCTL                                            10FE1
            WPVT(NN,NSL+NA) = WPT(NN,NPC+NA)                            10FE1
            QPVT(NN,NSL+NA) = QPT(NN,NPC+NA)                            10FE1
6628  CONTINUE                                                          10FE1
            NSL = NSL + NPCTL                                           10FE1
C-----SAVE THE NEW ADJUSTED Q-W CURVE IN WPT $ QPT ARRAYS              21AP1
627   DO 629  NP = 1, NSL                                               10FE1
            WPT(NN,NP) = WPVT(NN,NP)                                    10FE1
            QPT(NN,NP) = QPVT(NN,NP)                                    10FE1
629   CONTINUE                                                          10FE1
            NPTTS(NN) = NSL                                             10FE1
            IFUS(J) = 1                                                 15FE1
6086        NPCT = NPTTS(NN)                                            15FE1
C-----INTERPOLATE TO FIND RESISTANT STIFFNESS, AND LOAD VALUES FROM SUPPORT CV
      DO 6090  NP = 2, NPCT                                             10FE1
      IF ( WPT(NN,1) ) 6091, 9991, 6092                                 10FE1
6091  IF ( W(J,KK) - WPT(NN,NP) ) 6093, 6096, 6090                      10FE1
6092  IF ( W(J,KK) - WPT(NN,NP) ) 6090, 6096, 6097                      10FE1
6090  CONTINUE                                                          10FE1
            NP = NPTTS(NN)                                              10FE1
      GO TO 6098                                                        10FE1
6093  IF ( W(J,KK) - WPT(NN,1) ) 6098, 6111, 6110                       10FE1
6097  IF ( W(J,KK) - WPT(NN,1) ) 6110, 6111, 6098                       10FE1
6111  IF ( IOSW(J) .EQ. 1 ) GO TO 6196                                  06AP1
            NP = NP - 1                                                 06AP1
      GO TO 6096                                                        10FE1
6098        KOFFC(NIT) = 1                                              10FE1
      GO TO 6110                                                        15AP1
6096  IF ( IOSW(J) .EQ. 1 ) GO TO 6196                                  06AP1
C-----TANGENT MODULUS METHOD ( LOAD-SPRING ITERATION METHOD )           06AP1
```

```
          IF ( NP .LT. NPCT ) GO TO 6198                                21AP1
               SLOPE21 = 0.0                                            21AP1
               QI21 = 0.0                                               21AP1
          GO TO 6112                                                    21AP1
 6198          SLOPE21 = ABS ( ( QPT(NN,NP+1) - QPT(NN,NP) ) /          21AP1
     1                         ( WPT(NN,NP+1) - WPT(NN,NP) ) )          21AP1
          IF ( SLOPE21 .LE. 1.0E-06 ) SLOPE21 = 0.0                     21AP1
               QI21 = QPT(NN,NP) + SLOPE21 * WPT(NN,NP)                 10FE1
          IF ( NP .GT. 1 ) GO TO 6112                                   10FE1
               SLOPE21 = SLOPE21 * 2.0                                  10FE1
               QI21 = QI21 * 2.0                                        10FE1
               SLOPE22 = 0.0                                            10FE1
               QI22 = 0.0                                               10FE1
          GO TO 6113                                                    10FE1
 6112          SLOPE22 = ABS ( ( QPT(NN,NP) - QPT(NN,NP-1) ) /          21AP1
     1                         ( WPT(NN,NP) - WPT(NN,NP-1) ) )          21AP1
          IF ( SLOPE22 .LE. 1.0E-06 ) SLOPE22 = 0.0                     21AP1
               QI22 = QPT(NN,NP-1) + SLOPE22 * WPT(NN,NP-1)             10FE1
          IF ( NP .LT. NPCT ) GO TO 6113                                21AP1
               SLOPE22 = SLOPE22 * 2.0                                  21AP1
               QI22 = QI22 * 2.0                                        21AP1
 6113          SS(J) = SS(J) + 0.5 * ( SLOPE21 + SLOPE22 ) * ESM        15FE1
               QI(J) = QI(J) + 0.5 * ( QI21 + QI22 ) * ESM              15FE1
          GO TO 6056                                                    15FE1
 6110     IF ( IOSW(J) .EQ. 0 ) GO TO 6197                              06AP1
          GO TO 6196                                                    06AP1
C-----TANGENT MODULUS METHOD ( LOAD-SPRING ITERATION METHOD )           06AP1
 6197          SLOPE2 = ABS ( ( QPT(NN,NP) - QPT(NN,NP-1) ) /           21AP1
     1                        ( WPT(NN,NP) - WPT(NN,NP-1) ) )           21AP1
          IF ( SLOPE2 .LE. 1.0E-06 ) SLOPE2 = 0.0                       21AP1
               SS(J) = SS(J) + SLOPE2 * ESM                             15FE1
               QI(J) = QI(J) + ( QPT(NN,NP) + SLOPE2 * WPT(NN,NP) ) *   15FE1
     1                         ESM                                      15FE1
          GO TO 6056                                                    06AP1
C-----LOAD ITERATION METHOD                                             06AP1
 6196     DO 6296  NL = 2, NPCT                                         26JU1
               STEMP = ABS ( ( QPT(NN,NL) - QPT(NN,NL-1) ) /            26JU1
     1                       ( WPT(NN,NL) - WPT(NN,NL-1) ) )            26JU1
          IF ( ABS ( STEMP - SLOPE(NN,1) ) .LE. 1.0E-06 ) GO TO 6297    26JU1
 6296     CONTINUE                                                      26JU1
      PRINT 980                                                         26JU1
          GO TO 9999                                                    26JU1
 6297     IF ( KSYMJ(NN) .EQ. 1 ) GO TO 6298                            26JU1
C-----SET APPROXIMATE LINEAR SPRING CONSTANT FOR ONE-WAY SUP CV         26JU1
          IF ( ABS(QPT(NN,1)) .LE. 1.0E-12 ) GO TO 6310                 26JU1
               SI = ABS ( QPT(NN,NL-1) / WPT(NN,NL-1) )                 26JU1
          GO TO 6299                                                    26JU1
 6310          SI = ABS ( QPT(NN,NL) / WPT(NN,NL) )                     26JU1
          GO TO 6299                                                    26JU1
C-----SET APPROXIMATE LINEAR SPRING CONSTANT FOR SYMMETRIC SUP CV        26JU1
 6298          SI = SLOPE(NN,1)                                         26JU1
          IF ( IFUS(J) .EQ. 0 ) GO TO 6299                              26JU1
               SI = ABS ( ( QPT(NN,NL-1) - QPT(NN,NL+1) ) /             26JU1
     1                    ( WPT(NN,NL-1) - WPT(NN,NL+1) ) )             26JU1
```

```
 6299          SS(J) = SS(J) + SI * ESM                                 26JU1
               WC = - W(J,KK) + WPT(NN,NP)                              06AP1
               SI = ABS ( ( QPT(NN,NP) - QPT(NN,NP-1) ) /               21AP1
     1                    ( WPT(NN,NP) - WPT(NN,NP-1) ) )               21AP1
          IF ( SI .LE. 1.0E-06 ) SI = 0.0                               21AP1
               QC = QPT(NN,NP) + WC * SI                                06AP1
               QS = - W(J,KK) * SI                                      26JU1
               QI(J) = QI(J) + ( QC - QS ) * ESM                        06AP1
 6056     CONTINUE                                                      15FE1
 6504     IF ( ITCS .EQ. 0 ) GO TO 6505                                 25JA1
C-----TEST TO SEE IF THERE IS A STA OF SUPPORT UNLOADED                 25JA1
          DO 6506  J = 4, MP4                                           25JA1
          IF ( IUS(J) .EQ. 1 ) GO TO 6503                               15FE1
 6506     CONTINUE                                                      25JA1
          GO TO 6175                                                    25JA1
 6503          ITCS = 0                                                 15FE1
               ITCSP = 1                                                15FE1
 6505          NS = 1                                                   05SE0
               A(1) = 0                                                 05SE0
               A(2) = 0                                                 05SE0
               B(1) = 0                                                 05SE0
               B(2) = 0                                                 05SE0
               C(1) = 0                                                 05SE0
               C(2) = 0                                                 05SE0
          DO 6060 J = 3, MP5                                            05SE0
C-----COMPUTE MATRIX COEFFS AT EACH STA J FOR FIRST AND SECOND TIME STA 05SE0
               YA = F(J-1) - .25 * H * R(J-1)                           10OC0
               YB = -2.0 * ( F(J-1) + F(J) ) - HE2 * T(J)               100
               YC = F(J-1) + 4.0 * F(J) + F(J+1) + HE3 * SS(J) +        04JA1
     1              .25 * H * ( R(J-1) + R(J+1) ) + HE2 * ( T(J) +      05SE0
     2              T(J+1) )                                            05SE0
               YD = -2.0 * ( F(J) + F(J+1) ) - HE2 * T(J+1)             10OC0
               YE = F(J+1) - .25 * H * R(J+1)                           10OC0
               YF = HE3 * QI(J) - 0.5 * HE2 * ( CP(J-1) - CP(J+1) )     04JA1
          IF ( K - 3 ) 7004, 7005, 7005                                 05SE0
 7004          AA = YA                                                  10OC0
               BB = YB                                                  10OC0
               CC = YC                                                  10OC0
               DD = YD                                                  10OC0
               EE = YE                                                  10OC0
               FF = YF                                                  10OC0
          GO TO 7006                                                    10OC0
 7005          AA = YA + DI(J-1) / HT                                   10OC0
               BB = YB - 2.0 * ( DI(J-1) + DI(J) ) / HT - 0.5 * HE2 *   10OC0
     1              ( TT(J,2) + TT(J,1) )                               10OC0
               CC = YC + ( DI(J-1) + 4.0 * DI(J) + DI(J+1) ) / HT + 0.5 10OC0
     1              * HE2 * ( TT(J,2) + TT(J,1) + TT(J+1,2) + TT(J+1,1) 10OC0
     2              ) + 2.0 * H3T2 * RHO(J) + H3T1 * DE(J)              10OC0
     3              + 0.5 * HE3 * ( - SS(J) + SSKM2(J) )                21AP1
               DD = YD - 2.0 * ( DI(J) + DI(J+1) ) / HT - 0.5 * HE2 *   10OC0
     1              ( TT(J+1,2) + TT(J+1,1) )                           10OC0
               EE = YE + DI(J+1) / HT                                   10OC0
               FF = 2.0 * YF + 4.0 * H3T2 * RHO(J) * W(J,KK-1) + ( -AA +10OC0
     1              2.0 * DI(J-1) / HT ) * W(J-2,KK-2) + ( -BB - 4.0 * (10OC0
```

```
     2             DI(J-1) + DI(J) ) / HT ) * W(J-1,KK-2) + ( -CC + 2.0100C0
     3             * ( DI(J-1) + 4.0 * DI(J) + DI(J+1) ) / HT + 2.0 *  100C0
     4             H3T1 * DE(J) ) * W(J,KK-2) + ( -DD - 4.0 * ( DI(J) +100C0
     5             DI(J+1) ) / HT ) * W(J+1,KK-2) + ( -EE + 2.0 * DI(J+100C0
     6             1) / HT ) * W(J+2,KK-2) + HE3 * ( - QI(J) + QIM2(J))21AP1
C-----COMPUTE RECURSION OR CONTINUITY COEFFS AT EACH STA               05SE0
 7006          E = AA * B(J-2) + BB                                    05SE0
               DENOM = E * B(J-1) + AA * C(J-2) + CC                   05SE0
         IF ( DENOM ) 6010, 6005, 6010                                 05SE0
C-----NOTE IF DENOM IS ZERO, BEAM DOES NOT EXIST, D = 0 SETS DEFL = 0.  05SE0
 6005          D = 0.0                                                 05SE0
         GO TO 6015                                                    05SE0
 6010          D = - 1.0 / DENOM                                       05SE0
 6015          C(J) = D * EE                                           05SE0
               B(J) = D * ( E * C(J-1) + DD )                          05SE0
               A(J) = D * ( E * A(J-1) + AA * A(J-2) - FF )            05SE0
C-----CONTROL RESET ROUTINES FOR SPECIFIED CONDITIONS                  05SE0
               KEYJ = KEY(J)                                           05SE0
         IF ( K - 3 ) 6019, 6019, 6018                                 100C0
 6018    IF ( IOP(J) .NE. 1 ) GO TO 6019                               100C0
               NS = NS + 1                                             100C0
         GO TO 6060                                                    100C0
 6019    GO TO ( 6060, 6020, 6030, 6020, 6050 ), KEYJ                  05SE0
C-----RESET FOR SPECIFIED DEFLECTION                                   05SE0
 6020          C(J) = 0.0                                              05SE0
               B(J) = 0.0                                              05SE0
               A(J) = WS(NS)                                           05SE0
         IF ( KEYJ - 3 ) 6059, 6030, 6060                              05SE0
C-----RESET FOR SPECIFIED SLOPE AT NEXT STA                            05SE0
 6030          DTEMP = 0                                               05SE0
               CTEMP = C(J)                                            05SE0
               BTEMP = B(J)                                            05SE0
               ATEMP = A(J)                                            05SE0
               C(J) = 1.0                                              05SE0
               B(J) = 0.0                                              05SE0
               A(J) = - HT2 * DWS(NS)                                  05SE0
         GO TO 6040                                                    05SE0
C-----RESET FOR SPECIFIED SLOPE AT PRECEDING STATION                   05SE0
 6050          DREV = 1.0 / ( 1.0 - ( BTEMP * B(J-1) + CTEMP * 1.0 ) * 05SE0
     1                D / DTEMP )                                      05SE0
               CREV = DREV * C(J)                                      05SE0
               BREV = DREV * ( B(J) + ( BTEMP * C(J-1) ) * D / DTEMP ) 05SE0
               AREV = DREV * ( A(J) + ( HT2 * DWS(NS) + ATEMP + BTEMP  05SE0
     1                * A(J-1) ) * D / DTEMP )                         05SE0
               C(J) = CREV                                             05SE0
               B(J) = BREV                                             05SE0
               A(J) = AREV                                             05SE0
 6059          NS = NS+1                                               05SE0
 6060    CONTINUE                                                      05SE0
C-----COMPUTE DEFLECTIONS                                              05SE0
         DO 6100  J = 3, MP5                                           05SE0
               L = M + 8 - J                                           05SE0
               WWW(L) = WW(L)                                          13JA1
               WW(L) = W(L,KK)                                         30DE0
               W(L,KK) = A(L) + B(L) * W(L+1,KK) + C(L) * W(L+2,KK)    05SE0
 6100    CONTINUE                                                      05SE0
               W(2,KK) = 2.0 * W(3,KK) - W(4,KK)                       05SE0
               W(MP6,KK) = 2.0 * W(MP5,KK) - W(MP4,KK)                 05SE0
C-----COUNT NUMBER OF STATIONS EXCEEDING MAXIMUM ALLOWABLE DEFLECTIONS  28DE0
C----- AND NUMBER OF STATIONS NOT CLOSED                               28DE0
               KCNT(NIT) = 0                                           15FE1
               KMAX = 0                                                28DE0
         IF ( NCVP .EQ. 0 ) GO TO 6000                                 28DE0
         DO 6150  J = 4, MP4                                           28DE0
         IF ( WMAX - ABS(W(J,KK)) ) 6155, 6160, 6160                   28DE0
 6155          KMAX = KMAX + 1                                         28DE0
 6160    IF ( IOCNT .GT. 0 ) GO TO 6150                                15FE1
         IF ( ABS(W(J,KK) - WW(J) ) - WTOL ) 6150, 6150, 6165          15FE1
 6165          KCNT(NIT) = KCNT(NIT) + 1                               05JA1
 6150    CONTINUE                                                      28DE0
         IF ( K .LT. 3 ) GO TO 6541                                    21AP1
         IF ( NOCI .EQ. 1 ) GO TO 6541                                 21AP1
C-----TEST TO SEE IF THERE IS A SUP STA WHERE THE DEFLECTION IS OSCILLATING
C-----DURING THE ITERATION PROCESS                                     21AP1
         DO 6540  NN = 1, NNC                                          06AP1
               J = ISTA(NN)                                            06AP1
         IF ( ABS(W(J,KK) - WWW(J) ) .GT. 1.0E-08 ) GO TO 6540         21AP1
         IF ( ABS(W(J,KK)) .LE. WTOL ) GO TO 6540                      21AP1
         IF ( ABS(W(J,KK) - WW(J)) .LE. WTOL ) GO TO 6540              21AP1
               NUMOC(J) = NUMOC(J) + 1                                 21AP1
         IF ( NUMOC(J) - 2 ) 6540, 6164, 6164                          06AP1
 6164          NITS = NIT + 1                                          21AP1
 6540    CONTINUE                                                      06AP1
         IF ( NITS .LT. 2 ) GO TO 6541                                 21AP1
C-----SETTING SWITCH IOSW(J) FOR LOAD ITERATION METHOD NEXT ITERATION   21AP1
         DO 6542  NN = 1, NNC                                          21AP1
               J = ISTA(NN)                                            21AP1
               IOSW(J) = 1                                             21AP1
               NUMOC(J) = 0                                            21AP1
 6542    CONTINUE                                                      21AP1
 6541    IF ( IOCNT .EQ. 0 ) GO TO 6151                                15FE1
C-----TEST TO SEE IF THE DEFLECTIONS COMPUTED FROM THE INITIAL SPRINGS $21AP1
C-----ITERATION LOADS ARE WITHIN THE ADJUSTED RANGE OF THE Q-W CURVE    21AP1
         DO 6152  N = 1, NNC                                           15FE1
               J = ISTA(N)                                             15FE1
         IF ( IFUS(J) .EQ. 0 ) GO TO 6152                              15FE1
         IF ( KSYMJ(N) .EQ. 1 ) GO TO 6149                             15FE1
         IF ( KSYMJ(N) .EQ. 0 ) GO TO 6249                             26JU1
         IF ( W(J,KK-1) .LE. 0.0 ) GO TO 6152                          26JU1
         GO TO 6149                                                    26JU1
 6249    IF ( W(J,KK-1) .GE. 0.0 ) GO TO 6152                          26JU1
 6149    IF ( WPT(N,1) ) 6153, 9991, 6154                              15FE1
 6153    IF ( W(J,KK) .GT. W(J,KK-1) ) GO TO 6152                      15FE1
               W(J,KK) = W(J,KK-1) + 1.0E-06                           15FE1
         GO TO 6152                                                    15FE1
 6154    IF ( W(J,KK) .LT. W(J,KK-1) ) GO TO 6152                      15FE1
               W(J,KK) = W(J,KK-1) - 1.0E-06                           15FE1
 6152    CONTINUE                                                      15FE1
```

```
 6151      IF ( MONI .EQ. 0 ) GO TO 6174                                  15FE1
C-----SET UP MONITOR DATA                                                  25JA1
           IF ( ITCSR .EQ. 1 ) GO TO 6178                                  10FE1
                KMCNT(NITT) = KCNT(NIT)                                    15FE1
           DO 6170  N = 1, MONI                                            28DE0
                JM = JIMS(N) + 4                                           28DE0
                WM(NIT,N) = W(JM,KK)                                       28DE0
 6170      CONTINUE                                                        28DE0
           GO TO 6174                                                      10FE1
 6178      DO 6179  N = 1, MONI                                            10FE1
                JM = JIMS(N) + 4                                           10FE1
                WM(NIT,N) = W(JM,KK)                                       10FE1
 6179      CONTINUE                                                        10FE1
C-----TEST CLOSURANCE                                                      28DE0
 6174      IF ( KMAX .NE. 0 ) GO TO 8500                                   28DE0
           IF ( KOFFC(NITT) .EQ. 0 ) GO TO 6274                            15FE1
           IF ( ITCSR .EQ. 0 ) PRINT 9984, NIT, KM3                        15FE1
           IF ( ITCSR .EQ. 1 ) PRINT 9994, NIT, KM3                        15FE1
      PRINT 9985                                                           15AP1
           GO TO 9999                                                      15AP1
 6274      IF ( KCNT(NIT) .NE. 0 ) GO TO 6173                              25JA1
           IF ( IOCNT .GT. 0 ) GO TO 6175                                  15FE1
           IF ( ITCSR .EQ. 0 ) GO TO 6230                                  15FE1
C-----TEST TO SEE IF THE DEFLECTIONS COMPUTED FROM THE NEW ADJ. Q-W CV  21AP1
C-----ARE CLOSED BACK ON THE OLD CV OR NOT, IF YES, USING THE GREATEST   26JU1
C-----STIFFNESS $ ITERATION LOAD OF THE NEW Q-W CV AND RECOMPUTE THE DEF26JU1
           DO 6235  N = 1, NNC                                             15FE1
                J = ISTA(N)                                                15FE1
           IF ( IUS(J) .EQ. 0 ) GO TO 6235                                 15FE1
                NPCT = NPTTS(N)                                            15FE1
           IF ( ISW(J) .EQ. 0 ) GO TO 6236                                 15FE1
                ESM = 0.5                                                  15FE1
           GO TO 6237                                                      15FE1
 6236           ESM = 1.0                                                  15FE1
 6237      IF ( WPT(N,1) ) 6240, 9991, 6244                                15FE1
 6240      IF ( KSYMJ(N) .EQ. 1 ) GO TO 6241                               26JU1
           IF ( KSYMJ(N) .EQ. 0 ) GO TO 6241                               26JU1
           GO TO 6235                                                      26JU1
 6241      IF ( W(J,KK) .GE. W(J,KK-1) ) GO TO 6235                        26JU1
           DO 6250  NP = 1, NPCT                                           15FE1
           IF ( W(J,KK-1) .EQ. WPT(N,NP) ) GO TO 6260                      15FE1
 6250      CONTINUE                                                        15FE1
           GO TO 6235                                                      15FE1
 6244      IF ( KSYMJ(N) .EQ. 1 ) GO TO 6245                               15FE1
           IF ( KSYMJ(N) .EQ. -1 ) GO TO 6245                              26JU1
           GO TO 6235                                                      15FE1
 6245      IF ( W(J,KK) .LE. W(J,KK-1) ) GO TO 6235                        15FE1
           DO 6255  NP = 1, NPCT                                           15FE1
           IF ( W(J,KK-1) .EQ. WPT(N,NP) ) GO TO 6260                      15FE1
 6255      CONTINUE                                                        15FE1
           GO TO 6235                                                      15FE1
 6260           SS(J) = SS(J) + SLOPE(N,1) * ESM                           21AP1
                QI(J) = QI(J) + QT(J,1) + ESM * ( QPT(N,NP) - SLOPE(N,1)   21AP1
     1                                            * WPT(N,NP) )            21AP1
```

```
                IOCNT = IOCNT + 1                                          15FE1
 6235      CONTINUE                                                        15FE1
           IF ( IOCNT .EQ. 0 ) GO TO 6175                                  15FE1
           GO TO 6505                                                      15FE1
 6230           ITCS = 1                                                   15FE1
 6173      IF ( ITCS .EQ. 0 ) GO TO 6176                                   25JA1
           IF ( K .LT. 3 ) GO TO 6176                                      15FE1
C-----INITIALIZING FOR STARTING THE SECOND CYCLE OF ITERATIONS             21AP1
           DO 6177  N = 1, NNC                                             15AP1
                J = ISTA(N)                                                15AP1
                IOSW(J) = 0                                                15AP1
                NUMOC(J) = 0                                               15FE1
 6177      CONTINUE                                                        25JA1
                NITT = NIT                                                 10FE1
                NITS = 1                                                   21AP1
                NOCI = 0                                                   15AP1
           GO TO 6910                                                      10FE1
 6176      IF ( K .GE. 3 ) GO TO 6000                                      28DE0
           IF ( MONI .EQ. 0 ) GO TO 5998                                   21AP1
           IF ( NIT .GE. 2 ) GO TO 5999                                    15FE1
      PRINT 916, KM3                                                       28DE0
      PRINT 923, ( JIMS(N), N = 1, MONI )                                  28DE0
 5999 PRINT 924, NIT, KCNT(NIT)                                            28DE0
      PRINT 925, ( WM(NIT,N), N = 1, MONI )                                28DE0
 5998      IF ( KCNT(NIT) .EQ. 0 ) GO TO 6175                              15FE1
 6000      CONTINUE                                                        28DE0
           IF ( K .LT. 3 ) GO TO 6599                                      21AP1
           IF ( NOCI .EQ. 1 ) GO TO 6599                                   14AP1
           IF ( NCVS .EQ. 0 )          GO TO  6599                         13NO2
C-----SINCE TANGENT MODULUS METHOD DID NOT CLOSE, GO BACK USE LOAD IT. MD.AP1
                NOCI = 1                                                   15AP1
                NITS = 1                                                   15AP1
           DO 6604  N = 1, NNC                                             15AP1
                J = ISTA(N)                                                15AP1
                IOSW(J) = 1                                                15AP1
                NUMOC(J) = 0                                               15AP1
 6604      CONTINUE                                                        15AP1
           GO TO 6910                                                      15AP1
 6599      IF ( ITCSR .EQ. 1 ) GO TO 6594                                  15AP1
                NITT = NIT                                                 06AP1
 6594      IF ( ITSW ) 6595, 6590, 6595                                    06AP1
 6595      IF ( NCVS .NE. 0 ) GO TO 6600                                   29DE0
      PRINT 9979                                                           29DE0
           GO TO 9999                                                      29DE0
 6590      IF ( NCVS .EQ. 0 ) GO TO 6175                                   29DE0
      PRINT 9978                                                           29DE0
           GO TO 9999                                                      29DE0
C-----SET SWITCHES FOR PRINTING THE ERROR MESSAGE OF NOT CLOSED WITHIN    21AP1
C-----THE SPECIFIED NUMBER OF ITERATIONS                                   21AP1
 6600      IF ( ITCSR .EQ. 0 ) KCLOSE(1) = 1                               06AP1
           IF ( ITCSR .EQ. 1 ) KCLOSE(2) = 1                               06AP1
C-----CALCULATE SLOPES,SHEARS OF THE BARS AND MOMENTS,SUP.REACTIONS AT    15FE1
C-----THE JOINTS FOR THE PREVIOUS TIME STA                                 15FE1
 6175      IF ( K .LT. 3 ) GO TO 8101                                      15FE1
           DO 8000  J = 3, MP5                                             05SE0
```

```
              DW(J) = ( -W(J-1,KK-1) + W(J,KK-1) ) / H                   05SE0
              BM(J) = F(J) * ( W(J-1,KK-1) - 2.0 * W(J,KK-1) +           05SE0
     1                   W(J+1,KK-1) ) / HE2                             05SE0
         IF ( K - 3 ) 8000, 8000, 8006                                   21AP1
 8006         BM(J) = BM(J) + DI(J) * ( - W(J-1,KK-2) + 2.0 * W(J,KK-2)21AP1
     1                   - W(J+1,KK-2) + W(J-1,KK) - 2.0 * W(J,KK) +     21AP1
     2                   W(J+1,KK) ) / ( HE2 * 2.0 * HT )                21AP1
 8000    CONTINUE                                                        05SE0
              BM(2) = 0.0                                                05SE0
              BM(MP6) = 0.0                                              05SE0
         DO 8100  J = 3, MP5                                             05SE0
         IF ( K - 3 ) 8105, 8105, 8106                                   05SE0
 8105         DBM(J) = ( -BM(J-1) + BM(J) ) / H - T(J) * ( -W(J-1,KK-1))05SE0
     1                   + W(J,KK-1) ) / H                               05SE0
         GO TO 8107                                                      05SE0
 8106         DBM(J) = ( -BM(J-1) + BM(J) ) / H - ( 0.5 * ( TT(J+1) +  100C0
     1                  TT(J,2) ) + T(J) ) * ( -W(J-1,KK-1)              100C0
     2                   + W(J,KK-1) ) / H - DI(J-1) * (-W(J-2,KK-2) +   100C0
     3                   2.0 * W(J-1,KK-2) - W(J,KK-2) + W(J-2,KK) - 2.0 100C0
     4                   * W(J-1,KK) + W(J,KK) ) / ( HE3 * HT * 2.0 )    100C0
     5                   + DI(J) * ( -W(J-1,KK-2) + 2.0 * W(J,KK-2) - W( 100C0
     6                   J+1,KK-2) + W(J-1,KK) - 2.0 * W(J,KK) + W(J+1,KK100C0
     7                   ) ) / ( HE3 * HT * 2.0 )                        100C0
 8107         KEYJ = KEY(J)                                              05SE0
         IF ( K .EQ. 3 ) GO TO 8108                                      21AP1
         IF ( IOP(J) .NE. 1 ) GO TO 8108                                 21AP1
         GO TO 8140                                                      21AP1
 8108    GO TO ( 8140, 8120, 8140, 8120, 8140 ), KEYJ                    21AP1
 8120         REAC      = ( BM(J-1) - 2.0 * BM(J) + BM(J+1) ) / H        05SE0
     1                    - Q(J)  + ( CP(J-1) - CP(J+1) ) / ( 2.0 * H ) 04JA1
     2                    - ( R(J-1) * W(J-2,KK-1) - R(J-1) * W(J,KK-1)  05SE0
     3                    - R(J+1) * W(J,KK-1) + R(J+1) * W(J+2,KK-1) )  05SE0
     4                    / ( 4.0 * HE2 ) - ( T(J) * W(J-1,KK-1) - T(J)  05SE0
     5                    * W(J,KK-1) - T(J+1) * W(J,KK-1) + T(J+1) *    05SE0
     6                    W(J+1,KK-1) ) / H                              05SE0
         IF ( K - 3 ) 8121, 8121, 8122                                   05SE0
 8121         REACT(J) = REAC                                            05SE0
         GO TO 8100                                                      05SE0
 8122         REACT(J) = REAC - ( QT(J,1) + QT(J,2) ) * 0.5 * RHO(J) *   100C0
     1                    ( W(J,KK-2) - 2.0 * W(J,KK-1) + W(J,KK) ) /    100C0
     2                    HTE2 + DE(J) * ( -W(J,KK-2) + W(J,KK) ) / ( 2.100C0
     3                    * HT) + ( DI(J-1) * ( -W(J-2,KK-2) + 2.0 *     100C0
     4                    W(J-1,KK-2) - W(J,KK-2) + W(J-2,KK) - 2.0 *    100C0
     5                    W(J-1,KK) + W(J,KK) ) - 2.0 * DI(J) * (        100C0
     6                    -W(J-1,KK-2) + 2.0 * W(J,KK-2) - W(J+1,KK-2) +100C0
     7                    W(J-1,KK) - 2.0 * W(J,KK) + W(J+1,KK) ) +      100C0
     8                    DI(J+1) * ( -W(J,KK-2) + 2.0 * W(J+1,KK-2) -   100C0
     9                    W(J+2,KK-2) + W(J,KK) - 2.0 * W(J+1,KK) +      100C0
     A                    W(J+2,KK) ) ) / ( HE3 * HT * 2.0 )             100C0
              REACT(J) = REACT(J) - ( 0.5 * ( TT(J,1) + TT(J,2) ) *      100C0
     1                    W(J-1,KK-1) - 0.5 * ( TT(J,1) + TT(J,2) ) *    100C0
     2                    W(J,KK-1) - 0.5 * ( TT(J+1,1) + TT(J+1,2) ) * 100C0
     3                    W(J,KK-1) + 0.5 * ( TT(J+1,1) + TT(J+1,2) ) * 100C0
     4                    W(J+1,KK-1) ) / H                              100C0
         GO TO 8100                                                      05SE0
 8140         REACT(J) = - SSKM1(J) * W(J,KK-1) + QS(J)                  21AP1
 8100    CONTINUE                                                        05SE0
C-----SAVE DEFLECTIONS FOR PLOTS ALONG THE TIME AXIS                      15FE1
 8101         NPT = 0                                                    28DE0
         DO 6180  J = 4, MP4                                             29DE0
              NERR = 0                                                   15FE1
              LSTA = J - 4                                               29DE0
         IF ( NCT9 ) 9980, 6180, 6185                                    29DE0
 6185    IF ( K - 2 ) 8317, 6190, 6190                                   06AP1
 6190    DO 6195  NC9 = 1, NCT9                                          29DE0
         IF ( XAXIS(NC9) .NE. TESTT ) GO TO 6195                         29DE0
         IF ( YAXIS(NC9) .NE. TESTD ) GO TO 6195                         15FE1
         IF ( IYSW(NC9) .NE. LSTA ) GO TO 6195                           29DE0
              NPT = NPT + 1                                              29DE0
              KSAV(NPT) = LSTA                                           29DE0
              KEYP(NPT) = 1                                              29DE0
              MPC(NPT) = MPS(NC9)                                        29DE0
              KYS(NPT) = 1                                               10FE1
         IF ( K .EQ. MTP4 ) GO TO 6195                                   15FE1
              Y(NPT,KM1) = W(J,KK)                                       10FE1
              NERR = NERR + 1                                            10FE1
 6195    CONTINUE                                                        29DE0
         IF ( NERR .LE. 1 ) GO TO 6180                                   15FE1
      PRINT 9995, NERR, LSTA                                             29DE0
         GO TO 9999                                                      29DE0
 6180    CONTINUE                                                        29DE0
C-----SAVE MOMENTS FOR PLOTS ALONG THE TIME AXIS                          15FE1
         DO 6280  J = 4, MP4                                             15FE1
              NERR = 0                                                   15FE1
              LSTA = J - 4                                               15FE1
         IF ( NCT9 ) 9980, 6280, 6285                                    15FE1
 6285    DO 6290  NC9 = 1, NCT9                                          15FE1
         IF ( XAXIS(NC9) .NE. TESTT ) GO TO 6290                         15FE1
         IF ( YAXIS(NC9) .NE. TESTM ) GO TO 6290                         15FE1
         IF ( IYSW(NC9) .NE. LSTA ) GO TO 6290                           15FE1
              NPT = NPT + 1                                              15FE1
              KSAV(NPT) = LSTA                                           15FE1
              KEYP(NPT) = 1                                              15FE1
              MPC(NPT) = MPS(NC9)                                        15FE1
              KYS(NPT) = 2                                               10FE1
         IF ( K .LT. 3 ) GO TO 6290                                      15FE1
              Y(NPT,KM2) = BM(J)                                         10FE1
              NERR = NERR + 1                                            15FE1
 6290    CONTINUE                                                        15FE1
         IF ( NERR .LE. 1 ) GO TO 6280                                   15FE1
      PRINT 9995, NERR, LSTA                                             15FE1
         GO TO 9999                                                      15FE1
 6280    CONTINUE                                                        15FE1
C-----SAVE DEFLECTIONS FOR PLOTS ALONG THE BEAM AXIS                      15FE1
         IF ( NCT9 ) 9980, 6200, 6205                                    29DE0
 6205    IF ( K - 3 ) 6200, 6210, 6215                                   29DE0
 6210         NPB = NPT                                                  29DE0
 6215         NERR = 0                                                   29DE0
```

```
      DO 6220  NC9 = 1, NCT9                                        29DE0
      IF ( XAXIS(NC9) .NE. TESTR ) GO TO 6220                       29DE0
      IF ( YAXIS(NC9) .NE. TESTD ) GO TO 6220                       10FE1
      IF ( IYSW(NC9) .NE. KM3 ) GO TO 6220                          15FE1
           NPB = NPB + 1                                            15FE1
           KSAV(NPB) = KM3                                          29DE0
           KEYP(NPB) = 2                                            29DE0
           MPO(NPB) = MPS(NC9)                                      29DE0
           KYS(NPB) = 1                                             10FE1
      DO 6225  NPP = 1, MP3                                         29DE0
           NPP2 = NPP + 2                                           29DE0
           Y(NPB, NPP) = W(NPP2, KK)                                15FE1
6225  CONTINUE                                                      29DE0
           NERR = NERR + 1                                          29DE0
6220  CONTINUE                                                      29DE0
      IF ( NERR .LE. 1 ) GO TO 6295                                 15FE1
   PRINT 9996, NERR, KM3                                            29DE0
      GO TO 9999                                                    15FE1
C-----SAVE MOMENTS ALONG THE BEAM AXIS FOR PLOTS                    15FE1
6295       NERR = 0                                                 15FE1
      DO 6300  NC9 = 1, NCT9                                        15FE1
      IF ( XAXIS(NC9) .NE. TESTR ) GO TO 6300                       15FE1
      IF ( YAXIS(NC9) .NE. TESTM ) GO TO 6300                       15FE1
      IF ( IYSW(NC9) .NE. KM4 ) GO TO 6300                          15FE1
           NPBT = NPBT + 1                                          15FE1
           KSAVT(NPBT) = KM4                                        15FE1
           KEYPT(NPBT) = 2                                          15FE1
           MPOT(NPBT) = MPS(NC9)                                    15FE1
           KYST(NPBT) = 2                                           15FE1
      DO 6305  NPP = 1, MP3                                         15FE1
           NPP1 = NPP + 2                                           15FE1
           YT(NPBT,NPP) = BM(NPP1)                                  15FE1
6305  CONTINUE                                                      15FE1
           NERR = NERR + 1                                          15FE1
6300  CONTINUE                                                      15FE1
      IF ( NERR .LE. 1 ) GO TO 6200                                 15FE1
   PRINT 9996, NERR, KM4                                            15FE1
      GO TO 9999                                                    15FE1
6200  IF ( K .LT. 3 ) GO TO 8317                                    06AP1
      IF ( IPS ) 8102, 8325, 8102                                   15FE1
C-----PRINT RESULTS                                                 05SE0
8102  IF ( K .GT. 3 ) GO TO 8200                                    29DE0
   PRINT 902                                                        29DE0
      GO TO 8205                                                    05SE0
8200  IF ( K .GT. 4 ) GO TO 8201                                    05SE0
   PRINT 915                                                        05SE0
8201 PRINT 916, KM4                                                 05SE0
8205 PRINT 901                                                      05SE0
      IF ( IPS ) 8300, 8325, 8320                                   29DE0
8300  IF ( K .LE. 4 ) GO TO 8320                                    05SE0
      IF ( KPC .EQ. KPS4 ) GO TO 8320                               05SE0
      IF ( MONS .EQ. 0 ) GO TO 8325                                 06AP1
C-----PRINT MONITOR STATIONS RESULTS                                05SE0
      DO 8340  J = 1, MONS                                          05SE0
           JSTA = JPS(J) + 4                                        05SE0
           Z1 = JPS(J)                                              05SE0
           X = Z1 * H                                               05SE0
   PRINT 922, DW(JSTA), DBM(JSTA)                                   05SE0
   PRINT 921, JPS(J), X, W(JSTA,KK-1), BM(JSTA), REACT(JSTA)        05SE0
8340  CONTINUE                                                      05SE0
      GO TO 8325                                                    29DE0
C-----PRINT COMPLETE RESULTS                                        05SE0
8320       JSTA = -1                                                05SE0
           Z1 = JSTA                                                05SE0
           X = Z1 * H                                               05SE0
   PRINT 921, JSTA, X, W(3,KK-1), BM(3), REACT(3)                   05SE0
      DO 8210  J = 4,MP5                                            05SE0
           JSTA = J - 4                                             05SE0
           Z1 = JSTA                                                05SE0
           X = Z1 * H                                               05SE0
   PRINT 922, DW(J), DBM(J)                                         05SE0
   PRINT 921, JSTA, X, W(J,KK-1), BM(J), REACT(J)                   05SE0
8210  CONTINUE                                                      05SE0
           KPC = 6                                                  05SE0
8325  IF ( ITSW ) 8326, 8315, 8326                                  29DE0
8326  IF ( K .EQ. MTP4 ) GO TO 8315                                 06JA1
      IF ( MONI .EQ. 0 ) GO TO 8317                                 25JA1
C-----PRINT ITERATION MONITOR DATA                                  06JA1
   PRINT 916, KM3                                                   06JA1
   PRINT 923, ( JIMS(N), N = 1, MONI )                              06JA1
      DO 8316  NI = 1, NITT                                         10FE1
   PRINT 924, NI, KMCNT(NI)                                         15F'
   PRINT 925, ( WM(NI,N), N = 1, MONI )                             29DE0
8316  CONTINUE                                                      29DE0
      IF ( ITCSR .EQ. 0 ) GO TO 8317                                10FE1
   PRINT 9977                                                       10FE1
      DO 8330  NI = 1, NIT                                          10FE1
   PRINT 924, NI, KCNT(NI)                                          10FE1
   PRINT 925, ( WU(NI,N), N = 1, MONI )                             10FE1
8330  CONTINUE                                                      10FE1
8317  IF ( KCLOSE(1) .EQ. 0 .AND. KCLOSE(2) .EQ. 0 ) GO TO 8318     06AP1
      IF ( KCLOSE(1) .EQ. 1 ) PRINT 9986                            06AP1
      IF ( KCLOSE(2) .EQ. 1 ) PRINT 9987                            06AP1
   PRINT 9985                                                       15AP1
      GO TO 9999                                                    15AP1
8318  IF ( K .LT. 3 ) GO TO 7000                                    06AP1
C-----RESET W(J,1) = W(J,KK-1) AND W(J,2) = W(J,KK) AND KK = 2      05SE0
8315  DO 8215  J = 1, MP7                                           10OC0
           W(J,1) = W(J,KK-1)                                       05SE0
           W(J,2) = W(J,KK)                                         05SE0
8215  CONTINUE                                                      05SE0
           KK = 2                                                   05SE0
7000  CONTINUE                                                      05SE0
C-----PLOTTING CURVES                                               05SE0
      IF ( NPBT .EQ. 0 ) GO TO 8500                                 15FE1
      DO 8600  N = 1, NPBT                                          15FE1
           KSAV(NPB+N) = KSAVT(N)                                   15FE1
           KEYP(NPB+N) = KEYPT(N)                                   15FE1
```

```
            MPO(NPB+N) = MPOT(N)                                15FE1
            KYS(NPB+N) = KYST(N)                                15FE1
        DO 8605  NN = 1, MP3                                    15FE1
            Y(NPB+N,NN) = YT(N,NN)                              15FE1
8605    CONTINUE                                                15FE1
8600    CONTINUE                                                15FE1
            NPB = NPB + NPBT                                    15FE1
8500    IF ( KMAX .EQ. 0 ) GO TO 8501                           29DE0
     PRINT 9983, KMAX, KM3                                      15FE1
     PRINT 9985                                                 29DE0
        GO TO 9999                                              29DE0
8501    IF ( IPS ) 8502, 8503, 8502                             15FE1
8503 PRINT 970                                                  15FE1
8502    IF ( NCT9 ) 9980, 1010, 7050                            05SE0
7050    IF ( MOP ) 8312, 8314, 8313                             17SE0
8312 PRINT 971                                                  17SE0
        GO TO 7040                                              17SE0
8314 PRINT 973                                                  17SE0
        GO TO 7040                                              17SE0
8313 PRINT 972                                                  17SE0
7040        YM(1) = 0.0                                         15FE1
            YM(2) = 0.0                                         15FE1
            NAC = 0                                             05SE0
            NA = 1                                              05SE0
            IQS = 0                                             05SE0
        DO 7065  NP = 1, NPB                                    05SE0
            NAC = NAC + 1                                       05SE0
        IF ( NAC .EQ. 1 ) JN1 = 0                               25JA1
        IF ( KEYP(NP) .EQ. 1 ) GO TO 7051                       17SE0
        IF ( KEYP(NP) .EQ. 2 ) IDX(NAC) = MP3                   05SE0
            KPS = 2 + KYS(NP)                                   10FE1
            KS(NAC) = KSAV(NP)                                  05SE0
        GO TO 7052                                              05SE0
7051        IDX(NAC) = MTP2                                     05SE0
            KS(NAC) = KSAV(NP)                                  05SE0
            KPS = KYS(NP)                                       10FE1
7052        MAXI = IDX(NAC)                                     05SE0
        IF ( MOP ) 7250, 7255, 7250                             15FE1
7250    IF ( NP .NE. NA ) GO TO 7255                            15FE1
C-----SAVE TIME OR BEAM STAS FOR TITLES ON THE PLOT             15FE1
7158        IA = NA - NP + 1                                    17SE0
            IS(IA) = KSAV(NA)                                   17SE0
        IF ( MPO(NA) .EQ. 0 ) GO TO 7159                        17SE0
            NA = NA + 1                                         17SE0
        GO TO 7158                                              17SE0
7159        NA = NA + 1                                         17SE0
            ISS(1) = NPRCB                                      26JU1
        IF ( KEYP(NP) .EQ. 1 ) GO TO 7059                       17SE0
            ID(2) = 10HTIME STA =                               17SE0
        IF ( KPS .EQ. 3 ) ISS(2) = 5H DVB                       26JU1
        IF ( KPS .EQ. 4 ) ISS(2) = 5H MVB                       26JU1
            ENCODE ( 10, 4, ID(1) ) ISS                         26JU1
        GO TO 7079                                              17SE0
7059        ID(2) = 10HBEAM STA =                               17SE0
```

```
        IF ( KPS .EQ. 1 ) ISS(2) = 5H DVT                       26JU1
        IF ( KPS .EQ. 2 ) ISS(2) = 5H MVT                       26JU1
            ENCODE ( 10, 4, ID(1) ) ISS                         26JU1
7079        IAD2 = IA / 2                                       17SE0
            II = 2 * IAD2                                       17SE0
        IF ( IA .EQ. II ) GO TO 7078                            17SE0
            IA = IA + 1                                         17SE0
            IQS = 1                                             17SE0
            IS(IA) = 5H                                         17SE0
7078        IA2 = IA / 2                                        15FE1
        DO 7076  N = 1, IA2                                     17SE0
            NP2 = N + 2                                         17SE0
            NN = 2 * N - 1                                      17SE0
            ISS(1) = IS(NN)                                     17SE0
            ISS(2) = IS(NN+1)                                   17SE0
        IF ( N .NE. IA2 ) GO TO 7077                            17SE0
        IF ( IQS .EQ. 1 ) GO TO 7081                            17SE0
7077        ENCODE ( 10, 5, ID(NP2) ) ISS                       17SE0
        GO TO 7076                                              17SE0
7081        ENCODE ( 10, 6, ID(NP2) ) ISS                       17SE0
7076    CONTINUE                                                17SE0
            IQS = 0                                             17SE0
            MC = ( IA2 + 2 ) * 10                               17SE0
C-----SAVE THE VERTICAL VALUES OF THE ACCUMULATED PLOTS IN AN ONE-DIMENSIONAL
C-----ARRAY OF YP                                               21AP1
7255    DO 7060  NI = 1, MAXI                                   15FE1
            YP(JN1+NI) = Y(NP,NI)                               05SE0
7060    CONTINUE                                                05SE0
        IF ( MPO(NP) .EQ. 1 ) GO TO 7090                        05SE0
        IF ( MPO(NP) .NE. 0 ) GO TO 9990                        05SE0
        IF ( MOP ) 7053, 7054, 7053                             17SE0
C-----SET SCALE FOR THIS FRAME OF ACCUMULATED PLOTS BY MICROFILM OR BALL-POINT
C-----PAPER PLOTTING METHOD                                     21AP1
7053        NPP = NAC * MAXI                                    15FE1
        DO 7260  N = 1, NPP                                     15FE1
        IF ( YM(1) .GT. YP(N) ) YM(1) = YP(N)                   15FE1
        IF ( YM(2) .LT. YP(N) ) YM(2) = YP(N)                   15FE1
7260    CONTINUE                                                15FE1
            XM(1) = -1.                                         15FE1
            XM(2) = MAXI - 2                                    15FE1
            IROLL = 1                                           15FE1
            LOPT = LOP                                          15FE1
            LOP = -1                                            15FE1
     CALL ZOT 1 ( XM, YM, 2, ID )                               15FE1
            LOP = LOPT                                          15FE1
        DO 7058  J = 1, MAXI                                    17SE0
            XF(J) = J - 2                                       05SE0
7058    CONTINUE                                                05SE0
            XF(MAXI+1) = XM(3)                                  15FE1
            XF(MAXI+2) = XM(4)                                  15FE1
C-----PLOT THIS FRAME OF ACCUMULATED PLOTS BY MICROFILM OR BALL-POINT PAPER
C-----PLOTTING METHOD                                           21AP1
        DO 7265  N = 1, NAC                                     15FE1
            NN = ( N - 1 ) * MAXI                               15FE1
```

```
          DO 7270  NI = 1, MAXT                                              15FE1
                YP(NI) = YP(NN+NI)                                           15FE1
 7270     CONTINUE                                                           15FE1
                YM(1) = YP(MAXI+1)                                           15FE1
                YM(2) = YP(MAXI+2)                                           15FE1
                YP(MAXI+1) = YM(3)                                           15FE1
                YP(MAXI+2) = YM(4)                                           15FE1
                IROLL = MPO(NP - NAC + N)                                    15FE1
          IF ( NP .NE. NPB ) GO TO 7275                                      15FE1
          IF ( N .EQ. NAC ) IROLL = -1                                       15FE1
 7275 CALL ZOT 1 ( XF, YP, MAXI, ID )                                        15FE1
                YP(MAXI+1) = YM(1)                                           15FE1
                YP(MAXI+2) = YM(2)                                           15FE1
 7265     CONTINUE                                                           15FE1
                YM(1) = 0.0                                                  15FE1
                YM(2) = 0.0                                                  15FE1
                NAC = 0                                                      15FE1
          GO TO 7065                                                         17SE0
C-----PLOT THIS FRAME OF ACCUMULATED PLOTS BY PRINTER PLOTTING METHOD        21AP1
 7054     DO 7080  J = 1, MAXI                                               15FE1
                IX(J) = J - 2                                                05SE0
 7080     CONTINUE                                                           05SE0
      PRINT 11                                                               05SE0
      PRINT 1                                                                05SE0
      PRINT 13, ( AN1(N), N = 1, 32 )                                        05SE0
      PRINT 16, NPROB, ( AN2(N), N = 1, 14 )                                 05SE0
          IF ( KPS .EQ. 1 ) PRINT 911                                        05SE0
          IF ( KPS .EQ. 2 ) PRINT 919                                        05SE0
          IF ( KPS .EQ. 3 ) PRINT 929                                        10FE1
          IF ( KPS .EQ. 4 ) PRINT 939                                        10FE1
          IF ( NAC .LE. 5 ) GO TO 7084                                       15FE1
      PRINT 9976                                                             15FE1
          GO TO 9999                                                         15FE1
 7084     DO 7085  KI = 1, NAC                                               05SE0
      PRINT 912, KI, SYMB(KI), KS(KI)                                        05SE0
 7085     CONTINUE                                                           05SE0
      PRINT 913                                                              05SE0
      CALL SPLOT 9 ( NAC, YP, IDX, IX )                                      05SE0
                NAC = 0                                                      05SE0
          GO TO 7065                                                         05SE0
 7090           JN1 = JN1 + IDX(NAC)                                         05SE0
 7065     CONTINUE                                                           05SE0
      PRINT 11                                                               15FE1
      PRINT 16, NPROB, ( AN2(N), N = 1, 14 )                                 15FE1
      CALL TIC TOC (4)                                                       05SE0
          GO TO 1010                                                         05SE0
 9990 PRINT 9998                                                             05SE0
          GO TO 9999                                                         05SE0
 9991 PRINT 9981                                                             15FE1
          GO TO 9999                                                         10FE1
 9980 PRINT 980                                                              05SE0
 9999     CONTINUE                                                           05SE0
C         END OF DRC5                                                        05JA1
      END                                                                    05SE0
```

```
      SUBROUTINE INTERP3 ( MP7, NCT, JN1, JN2, KR2, ZN, Z, LSM, KSW )      05SF0
      DIMENSION JN1(100), JN2(100), KR2(100), ZN(100), Z(207), KSW(100)   10FE6
  905 FORMAT ( //40H      ERROR STOP -- STATIONS NOT IN ORDER )            14MY5
  908 FORMAT ( //43H      UNDESIGNATED ERROR STOP IN SUBROUTINE  )         14MY5
  909 FORMAT ( //46H      ERROR -- NON-ZERO DATA BEYOND END OF BEAM  )     14MY5
         DO 1603  J = 1, MP7                                                05SF0
            Z(J) = 0.0                                                      26MR5
 1603    CONTINUE                                                           26MR5
            ASM = LSM                                                       12AP5
            ASM = ASM / 2.                                                  09AP5
            M = MP7 - 7                                                     05SF0
            KR1 = 0                                                         12JA5
         IF( NCT - 1 ) 1674,1604,1604                                       28SE7
 1604    DO 1675  NC = 1, NCT                                               26SE7
         IF ( KR1 ) 1698, 1605, 1607                                        10FE6
 1605       NC1 = NC                                                        12JA5
            JV = JN1(NC1) + LSM                                             12AP5
         IF ( KR2(NC) ) 1698, 1607, 1670                                    10FE6
 1607    IF ( JN2(NC) - M ) 1609, 1609, 1611                                24FE6
 1609       JS2 = JN2(NC)                                                   10FE6
            ZNS = ZN(NC)                                                    21FE6
         GO TO 1619                                                         10FE6
 1611       JS2 = M                                                         10FE6
            ZNS = ZN(NC1) + ( ZN(NC) - ZN(NC1) ) * ( JS2 - JV + LSM )10MR6
    1                  / ( JN2(NC) - JV + LSM )                             10MR6
            KASS = KSW(NC)                                                  21SE66
         GO TO  ( 1613, 1615, 1617, 1617 ), KASS                            21SE66
 1613    IF ( JN1(NC) - M ) 1619, 1619, 1670                                10FE6
 1615    IF ( JN1(NC1) - M ) 1619, 1619, 1670                               10FE6
 1617    IF ( KSW(NC1) - 2 ) 1618, 1615, 1618                               09MR6
 1618    IF ( JN2(NC1) - M ) 1619, 1619, 1670                               09MR6
 1619       J1 = JV + 4                                                     10FE6
            J2 = JS2 + 4                                                    10FE6
            DENOM = J2 - J1 + LSM                                           12AP5
            JINCR = 1                                                       12JA5
            ESM = 1.0                                                       12JA5
            ISW = 1                                                         12JA5
         IF ( DENOM ) 1695, 1620, 1630                                      12JA5
 1620       DENOM = 1.0                                                     12JA5
            ISW = 0                                                         12JA5
         IF ( J2 - J1 ) 1651, 1630, 1630                                    08MR8
 1630    DO 1650  J = J1, J2, JINCR                                         12JA5
            F = J                                                           09AP5
            F1 = J1                                                         09AP5
            DIFF = F - F1 + ASM                                             09AP5
            PART = DIFF / DENOM                                             12JA5
            Z(J) = Z(J) + ( ZN(NC1) + PART * ( ZNS - ZN(NC1) )) * ESM10FE6
 1650    CONTINUE                                                           12JA5
 1651    IF ( LSM ) 1698, 1652, 1660                                        08MR8
 1652    IF ( ISW ) 1698, 1660, 1655                                        09AP5
 1655       JINCR = J2 - J1                                                 12JA5
            ESM = -0.5                                                      12JA5
            ISW = 0                                                         12JA5
         GO TO 1630                                                         12JA5
 1660    IF ( KR2(NC) ) 1698, 1670, 1665                                    12JA5
 1665       JV = JN2(NC) + LSM                                              12AP5
 1670       KR1 = KR2(NC)                                                   12JA5
            NC1 = NC                                                        12JA5
 1675    CONTINUE                                                           12JA5
 1674    CONTINUE                                                           21SE66
            MP5 = MP7 - 2                                                   05SF0
            MP6 = MP7 - 1                                                   05SF0
C-----TEST FOR DATA ERRONEOUSLY STORED BEYOND ENDS OF REAL BEAM             08MR8
            ZCK = Z(1) + Z(2) + Z(3) + Z(MP5) + Z(MP6) + Z(MP7)             05SF0
         IF ( ZCK ) 1699, 1676, 1699                                        14MY5
 1676 RETURN                                                                14MY5
 1695 PRINT 905                                                             14MY5
         GO TO 1799                                                         05JA67
 1698 PRINT 908                                                             14MY5
         GO TO 1799                                                         05JA67
 1699 PRINT 909                                                             14MY5
 1799    CONTINUE                                                           05JA67
      END                                                                   12JA5
```

```
      SUAROUTINE TIC TOC (J)                                             24DC66
C----- TIC TOC (1) = COMPILE TIME                                         08MR8
C       TIC TOC (2) = ELAPSED CPU TIME                                    08MRA
C       TIC TOC (3) = TIME FOR THIS PROALEM                               08MRA
C       TIC TOC (4) = TIME FOR THIS PROALEM AND ELAPSED CPU TIME          08MR8
   10 FORMAT(///30X19HELAPSED CPU TIME = I5,8H MINUTESF9.3,8H SECONDS )  25SF66
   11 FORMAT(///30X15HCOMPILE TIME = ,I5,8H MINUTES,F9.3,8H SECONDS   )  25SF66
   12 FORMAT(///30X24HTIME FOR THIS PROBLEM = ,I5,8H MINUTES,F9.3,       25SF66
     1        8H SECONDS   )                                             25SE66
              I = J - 2                                                  24DC66
          IF( I-1 ) 40,30,30                                             25SF66
   30         FI4 = F                                                    25SF66
   40 CALL SECOND (F)                                                    25SF66
              II1 = F                                                    25SF66
              I1 = II1 / 60                                              25SF66
              FI2 =  F - I1*60                                           25SF66
          IF( I ) 50,70,60                                               25SE66
   50 PRINT 11, I1,FI2                                                   25SF66
          GO TO 990                                                      25SE66
   60         FI3 = F - FI4                                              25SE66
              I2 = FI3 / 60                                              25SE66
              FI3 = FI3 - I2*60                                          25SE66
      PRINT 12, I2, FI3                                                  25SF66
          IF( I-1 ) 990,990,70                                           25SF66
   70 PRINT 10, I1,FI2                                                   25SF66
  990 CONTINUE                                                           25SE66
      RETURN                                                             25SF66
      END                                                                25SE66
```

```
      SUBROUTINE SPLOT 9 ( NPLT, X, IDX, IX )                           11JE0
C * * * * THE LATEST REVISION DATA FOR THIS ROUTINE IS  -  -  11 JUN 70 REVISED
      COMMON / SPLOT / WIDTH, SMALL, BIG, SYMB                          11JE0
      DIMENSION  IDX(1), X(1), IX(1), SPACE(62), SYMB(10)               11JE0
      INTEGER WIDTH                                                     04JE0
      DATA SPACE / 62*1H / , SYMA / 1HI / , BLANK / 1H  /               11JE0
C******** THIS ROUTINE SUPERIMPOSES UP TO 10 PLOTS PER FRAME            04JE0
C         THE FIRST PLOT SHOULD BE THE LONGEST (MOST POINTS)            05JE0
C         THE PAPER SHOULD BE POSITIONED PROPERLY AND ALL               10OC9
C         HEADINGS PRINTED BEFORE CALLING.                              10OC9
C  ****   INPUT -NPLT, THE NUMBER OF PLOTS FOR THIS FRAME               04JE0
C                 IDX, ARRAY CONTAINING LENGTH OF THE RESPECTIVE PLOTS  04JE0
C                      IDX(1) = NUMBER OF POINTS IN FIRST PLOT, ETC.    04JE0
C                   X, STARTING ADDRESS OF THE FIRST PLOT               04JE0
C                      - NOTE - THE PLOTS MUST BE STORED CONTIGOUSLY    04JE0
C                  IX, INDEPENDENT VARIABLE ( INDEXING )                11JE0
C               WIDTH, WIDTH OF PLOT( LESS THAN 63 )                    14OC9
C               SMALL, LOWER LIMIT OF VALUES TO BE CONSIDERED           11JE0
C                 BIG, UPPER LIMIT OF VALUES TO BE CONSIDERED           11JE0
C  ****   OUTPUT-   NO ACTUAL VALUES ARE RETURNED TO THE                10OC9
C                   CALLING ROUTINE - THE VALUES ARE PRINTED            10OC9
C                   AND PLOTTED VERTICALLY.                             10OC9
C         THE VALUES PRINTED ARE THOSE OF THE FIRST PLOT.               05JE0
C         IF WIDTH IS GREATER THAN 0 THE X-AXIS (....) IS PLOTTED       04JE0
C         WITH THE APPROPRIATE ADJUSTMENTS IN SCALE MADE, IF NECCESARY  04JE0
C         IF WIDTH IS LESS THAN 0 THE X-AXIS IS NOT PLOTTED AND THE     04JE0
C         ROUTINE FUNCTIONS JUST LIKE SPLOT 1                           04JE0
C  ****   FRANK L ENDRES  -  PAX 1892   ****                            11JE0
   12 FORMAT ( 4X,I4,3X E10.3,2X 62A1 )                                 11JE0
            NENO = 0                                                    04JE0
            MMAX = 0                                                    04JE0
            IMSK = 1                                                    11JE0
         DO 30  I = 1, NPLT                                             04JE0
         IF ( MMAX.LT.IDX(I) )     MMAX = IDX(I)                        04JE0
            NENU = NEND + IDX(I)                                        04JE0
   30    CONTINUE                                                       04JE0
         IF ( NEND.LE.0 )          GO TO  990                           11NO9
            IWIDE = WIDTH                                               04JE0
            IAX = 0                                                     04JE0
         IF ( IWIDE.LT.0  )        IAX = 1                              04JE0
         IF ( IWIDE.LT.0  )        IWIDE = -IWIDE                       04JE0
            IOTA = IWIDE / 2                                            11JE0
            OMEGA = X(1)                                                10OC9
            THETA = X(1)                                                10OC9
         IF ( NEND.EQ.1 )          GO TO  55                            11NO9
         DO 50  I = 2, NEND                                             10OC9
         IF ( OMEGA.LT.X(I) )      OMEGA = X(I)                         10OC9
         IF ( THETA.GT.X(I) )      THETA = X(I)                         10OC9
   50    CONTINUE                                                       11JE0
         IF ( SMALL.GE.BIG )       GO TO  53                            10JE0
         IF ( OMEGA.GT.BIG )       OMEGA = BIG                          08JE0
         IF ( THETA.LT.SMALL )     THETA = SMALL                        08JE0
   53    IF ( IAX.EQ.1 )           GO TO  55                            11JE0
         IF ( THETA.GT.0. )        THETA = 0.                           04JE0
         IF ( OMEGA.LT.0. )        OMEGA = 0.                           04JE0
   55    IF ( OMEGA.EQ.THETA )     GO TO  60                            11NO9
            SIGMA = ( IWIDE - 1  ) / ( OMEGA - THETA )                  04JE0
         IF ( IAX.EQ.1 .OR. NEND.EQ.1 )     GO TO  60                   11JE0
            BETA = 1. - SIGMA * THETA                                   11JE0
            IOTA = BETA                                                 04JE0
         IF ( (BETA - IOTA) .GE. .5 )       IOTA = IOTA + 1             04JE0
            ISKX = IOTA                                                 11JE0
            IMSK = ISKX                                                 11JE0
   60    DO 100  I = 1, MMAX                                            11JE0
         IF ( OMEGA.NE.THETA )     GO TO  65                            11JE0
            IMSK = IOTA                                                 11JE0
            SPACE(IOTA) = SYMB(5)                                       11JE0
         GO TO  88                                                      11JE0
   65       IIXX = 0                                                    11JE0
         IF ( IAX.EQ.1 )      GO TO  70                                 11JE0
            SPACE(ISKX) = SYMA                                          11JE0
   70    DO 85  NP = 1, NPLT                                            04JE0
         IF ( NP.GT.1 )            IIXX = IDX(NP-1) + IIXX              04JE0
         IF ( I.GT.IDX(NP) )       GO TO 85                             04JE0
         IF ( X(I+IIXX).LT.THETA )      GO TO  85                       11JE0
         IF ( X(I+IIXX).GT.OMEGA )      GO TO  85                       11JE0
            BETA = SIGMA * ( X(I+IIXX) - THETA ) + 1.                   04JE0
            IOTA = BETA                                                 10OC9
         IF ( (BETA - IOTA).GE.0.5 )   IOTA = IOTA + 1                  10OC9
         IF ( IOTA.GT.IMSK )       IMSK = IOTA                          11JE0
            SPACE(IOTA) = SYMB(NP)                                      11JE0
   85    CONTINUE                                                       04JE0
   88 PRINT 12, IX(I), X(I), ( SPACE(L), L=1,IMSK )                     11JE0
         DO 90  J = 1, 62                                               11JE0
   90       SPACE(J) = BLANK                                            11JE0
  100    CONTINUE                                                       10OC9
  990 RETURN                                                            10OC9
C     END SPLOT 9                                                       10JE0
      END
```

```
      SUBROUTINE ZOT 1  ( XF, YF, NP, ID )                              11JF0
C * * * * THE LATEST REVISION DATA FOR THIS ROUTINE IS  -  -  11 JUN 70 REVISED
      COMMON / ZOT /  LOP, MC, IROLL, MOP                               11JF0
      DIMENSION  XF(1), YF(1), ID(1)                                    09JF0
      DATA INC, IQ, X, Y, XL, YL, XO, YO / 1,12,0.,0.,9.,8.,0.,90. /    09JF0
      DATA IT1, IT2 / -1,.0 /                                           09JF0
C           XF    -  ARRAY CONTAINING THE X - COORDINATES               09JF0
C           YF    -  ARRAY CONTAINING THE Y - COORDINATES               09JF0
C           NP    -  NUMBER OF POINTS TO BE PLOTTED                     09JF0
C           LOP   -  LINE OR POINT PLOT OPTION                          09JF0
C                    =  0 , LINE PLOT                                   09JF0
C                    = -J , POINT PLOT AT EVERY J-TH POINT              09JF0
C                    = +J , LINE PLOT WITH A POINT PLOT AT EVERY J-TH PT. 09JF0
C           ID    -  VARIABLE OR ARRAY CONTAINING TITLE OF PLOT         09JF0
C           MC    -  NUMBER OF CHARACTERS IN TITLE ( 0 IF NO TITLE )    09JF0
C           IROLL -  OPTION TO MOVE TO A NEW FRAME - AFTER THIS PLOT    09JF0
C                    = 1 , SAME FRAME                                   09JF0
C                    EQUAL TO 0 , NEW FRAME                             09JF0
C                    LESS THAN 0 , TERMINATE                            09JF0
C           MOP      MICROFILM OR PAPER PLOT OPTION                     09JF0
C                    = 1 , PAPER PLOTS                                  09JF0
C                    = -1 , MICROFILM                                   09JF0
C   ****    FRANK L ENDRES  -  PAX 1892    ****                         09JF0
                NC = MC                                                 09JF0
                IT1 = IT1 + 1                                           09JF0
            IF ( IT1.NE.0 )      GO TO  20                              09JF0
            IF ( MOP.EQ.1 )      CALL AGNPLT                            09JF0
            IF ( MOP.EQ. -1 )    CALL AGNPLT ( ALFILMPL )               09JF0
   20       IF (  NC.NE.0 )      GO TO  50                              09JF0
                NC = 10                                                 09JF0
                ID = 10H                                                09JF0
   50       CONTINUE                                                    09JF0
C - - - - POSITION ORIGIN                                               09JF0
            IF ( IT2.EQ.0)       CALL PLT (1.0, 1.5, -3)                09JF0
            IF ( IT2.EQ.1 )      GO TO  100                             09JF0
C - - - - SCALE X - AXIS                                                09JF0
      CALL SCALE   ( XF, XL, NP, INC )                                  09JF0
C - - - - SCALE Y - AXIS                                                09JF0
      CALL SCALE   ( YF, YL, NP, INC )                                  09JF0
C - - - - SET UP X-AXIS                                                 09JF0
                YM = - YF(NP+1) / YF(NP+2)                              09JF0
      CALL AXIS    ( X, YM+1H , -1, XL, XO, XF(NP+1), XF(NP+2) )        09JF0
C - - - - SET UP Y-AXIS                                                 09JF0
                XM = - XF(NP+1) / XF(NP+2)                              09JF0
      CALL AXIS    ( XM, Y, 1H , 1, YL, YO, YF(NP+1), YF(NP+2) )        09JF0
C - - - - PRINT TITLE                                                   09JF0
      CALL SYMBOL ( .1, -.5, .14, ID, XO, NC )                          09JF0
C - - - - PLOT THE FUNCTION                                             09JF0
  100 CALL LINE    ( XF, YF, NP, 1, LOP, IQ )                           09JF0
            IF ( IT2.EQ.1 )      IT2 = 0                                09JF0
            IF ( IROLL.EQ.0 )    CALL PLT ( .0, .0, 999 )               09JF0
            IF ( IROLL.LT.0 )    CALL ENDPLT                            09JF0
            IF ( IROLL.GT.0 )    IT2 = 1                                09JF0
            IF ( IROLL.LT.0 )    IT1 = -1                               11JF0
      RETURN                                                            09JF0
      END                                                               09JF0
```

APPENDIX G

LISTING OF DATA FOR EXAMPLE PROBLEMS

```
       EXAMPLE PROBLEMS FOR DBCS PROGRAM        BY JACK CHAN APRIL 1971
       DYNAMIC BEAM-COLUMN PROGRAM USING 5-1-5 IMPLICIT OPERATOR
 1     INELASTICALLY SUPPORTED MASS UNDER FREE VIBRATION
 0   0    0    0    0    0    0    0    2    0    1    1    0    3    3    1
     1 1.000E+00        800 6.283E-03         0         -1    0    1    1
    50 1.000E+01 1.000E-06
     1    1    0              1.000E+02
     1    1    0              1.000E+00
     1    1         0    0        -5.000E+01-5.000E+01-5.000E+01
     1    1         0  800        -1.000E+02-1.000E+02-1.000E+02
     1    1       800  800        -5.000E+01-5.000E+01-5.000E+01
     1    1    0-1.000E+00 1.000E+01    5    1 1.000E-02 1.000E+00
                              20   36   60  120  120
                               2    4    8   20  100
   TIME      DEFL          1         0
 1A    FREE VIBRATION OF MASS BY SPECIFYING INITIAL DISPLACEMENTS
 0   0    0    0    0    0    0    0    2    1    0    1    0    0    3    1
     1 1.000E+00        800 6.283E-03         0         -1    0    1    1
    50 1.000E+01 1.000E-06
     1         1 3.000E+00                    1
     1    1    0              1.000E+00
     1    1    0-1.000E+00 1.000E-01    5    1 1.000E-02 1.000E+00
                              20   36   60  120  120
                               2    4    8   20  100
   TIME      DEFL          1         0
2-1    LATERAL VIBRATION OF A SIMPLY SUPPORTED BEAM WITH AXIAL COMPRESSION F.
 0   0    0    0    0    0    0    0    1   11    1    1    0    0    0    2
    10 1.200E+01        200 3.752E-04         0         0         1    1
     0         1 0.000E+00                    2
     1         1-1.221E+00                    1
     2         1-2.324E+00                    1
     3         1-3.197E+00                    1
     4         1-3.758E+00                    1
     5         1-3.952E+00                    1
     6         1-3.758E+00                    1
     7         1-3.197E+00                    1
     8         1-2.324E+00                    1
     9         1-1.221E+00                    1
    10         1 0.000E+00                    2
     0   10    0 1.080E+09                     -3.700E+05
     0   10    0              1.085E-01
   TIME      DEFL          5         0
   TIME      MOMT          5         0
2-2    LATERAL VIBRATION OF A BEAM ON ELASTIC FOUNDATION
 0   0    0    1    0    0    0    1    1   11    1    0    0    0    0    0
    10 1.200E+01        200 1.540E-04         0         0         1    1
     0         1 0.                           2
     1         1-2.062E+00                    1
     2         1-3.923E+00                    1
     3         1-5.398E+00                    1
     4         1-6.345E+00                    1
     5         1-6.672E+00                    1
     6         1-6.345E+00                    1
     7         1-5.398E+00                    1
     8         1-3.923E+00                    1
     9         1-2.062E+00                    1
    10         1 0.                           2
     0   10    0 1.080E+09              1.200E+06
 3     THREE-SPAN BEAM, AN AASHO STANDARD 2-D TRUCK MOVING WITH 60 MPH
 0   0    0    0    0    0    0    0    1    2    4    2    0   75    0    2
    40 6.000E+01         80 5.666E-02         0         0         -1    1
     0         1 0.000E+00                    2
    40         1 0.000E+00                    2
     0   40    0 4.500E+11
    10   30    0 4.500E+11
    10   10    0                        2.000E+05
    30   30    0                        2.000E+05
     0   40    0              5.944E+00
    10   30    0             -2.982E+00
     1    1         1    1       -3.146E+03-3.146E+03-3.146E+03
     2    2         2    2       -3.133E+03-3.133E+03-3.133E+03
     3    3         3    3       -3.019E+03-3.019E+03-3.019E+03
     0    1         3    3       -7.441E+03-7.441E+03-7.441E+03
     4    4         4    4       -2.808E+03-2.808E+03-2.808E+03
     1    2         4    4       -7.445E+03-7.445E+03-7.445E+03
     5    5         5    5       -3.022E+03-3.022E+03-3.022E+03
     2    3         5    5       -7.487E+03-7.487E+03-7.487E+03
     6    6         6    6       -3.030E+03-3.030E+03-3.030E+03
     3    4         6    6       -7.391E+03-7.391E+03-7.391E+03
     7    7         7    7       -2.917E+03-2.917E+03-2.917E+03
     4    5         7    7       -7.491E+03-7.491E+03-7.491E+03
     8    8         8    8       -3.234E+03-3.234E+03-3.234E+03
     5    6         8    8       -6.407E+03-6.407E+03-6.407E+03
     9    9         9    9       -3.047E+03-3.047E+03-3.047E+03
     6    7         9    9       -7.009E+03-7.009E+03-7.009E+03
    10   10        10   10       -3.056E+03-3.056E+03-3.056E+03
     7    8        10   10       -6.860E+03-6.860E+03-6.860E+03
    11   11        11   11       -3.171E+03-3.171E+03-3.171E+03
     8    9        11   11       -7.686E+03-7.686E+03-7.686E+03
    12   12        12   12       -3.160E+03-3.160E+03-3.160E+03
     9   10        12   12       -7.828E+03-7.828E+03-7.828E+03
    13   13        13   13       -4.144E+03-4.144E+03-4.144E+03
    10   11        13   13       -7.537E+03-7.537E+03-7.537E+03
    14   14        14   14       -2.844E+03-2.844E+03-2.844E+03
    11   12        14   14       -7.424E+03-7.424E+03-7.424E+03
    15   15        15   15       -2.324E+03-2.324E+03-2.324E+03
    12   13        15   15       -7.894E+03-7.894E+03-7.894E+03
    16   16        16   16       -2.969E+03-2.969E+03-2.969E+03
    13   14        16   16       -7.728E+03-7.728E+03-7.728E+03
    17   17        17   17       -2.672E+03-2.672E+03-2.672E+03
    14   15        17   17       -7.100E+03-7.100E+03-7.100E+03
    18   18        18   18       -3.054E+03-3.054E+03-3.054E+03
    15   16        18   18       -6.214E+03-6.214E+03-6.214E+03
    19   19        19   19       -2.945E+03-2.945E+03-2.945E+03
    16   17        19   19       -7.148E+03-7.148E+03-7.148E+03
    20   20        20   20       -3.273E+03-3.273E+03-3.273E+03
    17   18        20   20       -8.766E+03-8.766E+03-8.766E+03
    21   21        21   21       -3.386E+03-3.386E+03-3.386E+03
```

```
   18   19         21   21     -6.886E+03-6.886E+03-6.886E+03
   22   22         22   22     -2.773E+03-2.773E+03-2.773E+03
   19   20         22   22     -7.577E+03-7.577E+03-7.577E+03
   23   23         23   23     -3.704E+03-3.704E+03-3.704E+03
   20   21         23   23     -7.963E+03-7.963E+03-7.963E+03
   24   24         24   24     -3.201E+03-3.201E+03-3.201E+03
   21   22         24   24     -7.420E+03-7.420E+03-7.420E+03
   25   25         25   25     -3.473E+03-3.473E+03-3.473E+03
   22   23         25   25     -7.020E+03-7.020E+03-7.020E+03
   26   26         26   26     -2.670E+03-2.670E+03-2.670E+03
   23   24         26   26     -7.784E+03-7.784E+03-7.784E+03
   27   27         27   27     -2.679E+03-2.679E+03-2.679E+03
   24   25         27   27     -8.077E+03-8.077E+03-8.077E+03
   28   28         28   28     -3.270E+03-3.270E+03-3.270E+03
   25   26         28   28     -6.656E+03-6.656E+03-6.656E+03
   29   29         29   29     -2.403E+03-2.403E+03-2.403E+03
   26   27         29   29     -7.212E+03-7.212E+03-7.212E+03
   30   30         30   30     -3.065E+03-3.065E+03-3.065E+03
   27   28         30   30     -7.139E+03-7.139E+03-7.139E+03
   31   31         31   31     -3.285E+03-3.285E+03-3.285E+03
   28   29         31   31     -7.871E+03-7.871E+03-7.871E+03
   32   32         32   32     -2.686E+03-2.686E+03-2.686E+03
   29   30         32   32     -6.243E+03-6.243E+03-6.243E+03
   33   33         33   33     -3.797E+03-3.797E+03-3.797E+03
   30   31         33   33     -6.441E+03-6.441E+03-6.441E+03
   34   34         34   34     -3.103E+03-3.103E+03-3.103E+03
   31   32         34   34     -7.887E+03-7.887E+03-7.887E+03
   35   35         35   35     -3.449E+03-3.449E+03-3.449E+03
   32   33         35   35     -7.637E+03-7.637E+03-7.637E+03
   36   36         36   36     -3.449E+03-3.449E+03-3.449E+03
   33   34         36   36     -8.331E+03-8.331E+03-8.331E+03
   37   37         37   37     -3.449E+03-3.449E+03-3.449E+03
   34   35         37   37     -9.171E+03-9.171E+03-9.171E+03
   38   38         38   38     -3.449E+03-3.449E+03-3.449E+03
   35   36         38   38     -9.171E+03-9.171E+03-9.171E+03
   39   39         39   39     -3.449E+03-3.449E+03-3.449E+03
   36   37         39   39     -9.171E+03-9.171E+03-9.171E+03
   37   38         40   40     -9.171E+03-9.171E+03-9.171E+03
   38   39         41   41     -9.171E+03-9.171E+03-9.171E+03
   39   40         42   42     -9.171E+03-9.171E+03-9.171E+03
 TIME      DEFL          20        0
 TIME      MOMT          20        0
4-1     SIMPLY SUPPORTED STEEL ROD - AXIAL PULSE BASE TIME = 0.10 SEC
 0    0    0    0    0    0    0    0    1    0    3    1   20    0    0    2
     41 3.750E+00          40 5.000E-03         0         0         1    1
    0   41    0 3.280E+05-3.950E-01
    0    0    0                         1.000E+20
   40   40    0                         1.000E+20
    0   41    0               1.023E-03 2.000E+01
    0   41          0    1        0.0        0.0      -6.000E+01
    0   41          1    2     -6.000E+01-6.000E+01-9.500E+01
    0   41          2    3     -9.500E+01-9.500E+01-1.200E+02
    0   41          3    4     -1.200E+02-1.200E+02-1.350E+02
    0   41          4    5     -1.350E+02-1.350E+02-1.500E+02
    0   41          5    6     -1.500E+02-1.500E+02-1.650E+02
    0   41          6    7     -1.650E+02-1.650E+02-1.700E+02
    0   41          7    8     -1.700E+02-1.700E+02-1.750E+02
    0   41          8    9     -1.750E+02-1.750E+02-1.680E+02
    0   41          9   10     -1.680E+02-1.680E+02-1.320E+02
    0   41         10   11     -1.320E+02-1.320E+02-1.080E+02
    0   41         11   12     -1.080E+02-1.080E+02-7.500E+01
    0   41         12   13     -7.500E+01-7.500E+01-5.300E+01
    0   41         13   14     -5.300E+01-5.300E+01-3.000E+01
    0   41         14   15     -3.000E+01-3.000E+01-2.000E+01
    0   41         15   16     -2.000E+01-2.000E+01-1.000E+01
    0   41         16   17     -1.000E+01-1.000E+01-5.000E+00
    0   41         17   18     -5.000E+00-5.000E+00-2.000E+00
    0   41         18   19     -2.000E+00-2.000E+00-1.000E+00
    0   41         19   20     -1.000E+00-1.000E+00-0.0
 TIME      DEFL          20        0
 TIME      MOMT          20        0
4-2     SIMPLY SUPPORTED STEEL ROD - AXIAL PULSE BASE TIME = 0.026 SEC
 0    0    0    0    0    0    0    0    1    0    3    1   26    0    0    2
     41 3.750E+00         300 1.000E-03         0         0         1    1
    0   41    0 3.280E+05-3.950E-01
    0    0    0                         1.000E+20
   40   40    0                         1.000E+20
    0   41    0               1.023E-03 2.000E+01
    0   41          0    1        0.0        0.0      -6.500E+01
    0   41          1    2     -6.500E+01-6.500E+01-1.180E+02
    0   41          2    3     -1.180E+02-1.180E+02-1.750E+02
    0   41          3    4     -1.750E+02-1.750E+02-2.700E+02
    0   41          4    5     -2.700E+02-2.700E+02-3.200E+02
    0   41          5    6     -3.200E+02-3.200E+02-3.950E+02
    0   41          6    7     -3.950E+02-3.950E+02-4.700E+02
    0   41          7    8     -4.700E+02-4.700E+02-5.200E+02
    0   41          8    9     -5.200E+02-5.200E+02-5.600E+02
    0   41          9   10     -5.600E+02-5.600E+02-5.850E+02
    0   41         10   11     -5.850E+02-5.850E+02-6.200E+02
    0   41         11   12     -6.200E+02-6.200E+02-6.350E+02
    0   41         12   13     -6.350E+02-6.350E+02-6.100E+02
    0   41         13   14     -6.100E+02-6.100E+02-5.600E+02
    0   41         14   15     -5.600E+02-5.600E+02-5.200E+02
    0   41         15   16     -5.200E+02-5.200E+02-4.700E+02
    0   41         16   17     -4.700E+02-4.700E+02-4.200E+02
    0   41         17   18     -4.200E+02-4.200E+02-3.700E+02
    0   41         18   19     -3.700E+02-3.700E+02-3.100E+02
    0   41         19   20     -3.100E+02-3.100E+02-2.500E+02
    0   41         20   21     -2.500E+02-2.500E+02-2.000E+02
    0   41         21   22     -2.000E+02-2.000E+02-1.350E+02
    0   41         22   23     -1.350E+02-1.350E+02-9.500E+01
    0   41         23   24     -9.500E+01-9.500E+01-4.000E+01
    0   41         24   25     -4.000E+01-4.000E+01-1.000E+01
    0   41         25   26     -1.000E+01-1.000E+01 0.0
 TIME      DEFL          20        0
 TIME      MOMT          20        0
4-3     SIMPLY SUPPORTED STEEL ROD - AXIAL PULSE BASE TIME = 0.026 SEC
 0    0    1    1    0    0    0    1    1    0    0    0   12    0    0    0
```

```
     41 3.750E+00         400 5.000E-04        0           0           1   -1
      0   41          0    1     0.0      0.0       -4.750E+02
      0   41          1    2    -4.750E+02-4.750E+02-6.000E+02
      0   41          2    3    -6.000E+02-6.000E+02-8.500E+02
      0   41          3    4    -8.500E+02-8.500E+02-8.250E+02
      0   41          4    5    -8.250E+02-8.250E+02-7.500E+02
      0   41          5    6    -7.500E+02-7.500E+02-6.250E+02
      0   41          6    7    -6.250E+02-6.250E+02-5.150E+02
      0   41          7    8    -5.150E+02-5.150E+02-3.850E+02
      0   41          8    9    -3.850E+02-3.850E+02-2.750E+02
      0   41          9   10    -2.750E+02-2.750E+02-1.600E+02
      0   41         10   11    -1.600E+02-1.600E+02-7.000E+01
      0   41         11   12    -7.000E+01-7.000E+01 0.0
5     PARTIALLY EMBEDDED STEEL PIPE LOADED BY WAVE FORCES
0     0    0    0    0    0    0    0    2    0    7    2    0   32   12   10
     31 4.800E+01         400 1.000E-02        0          -1    0    1    1
     50 2.000E+01 1.000E-06
      1    1    0                          3.000E+07           2.100E+10
     31   31    0                          1.000E+20
      0   31    0 2.877E+11
      1         1          -2.000E+04
         11     0          -1.000E+04
      1         1                                    -1.220E+04
         31     0                                    -4.924E+04
      1   31    0             3.210E+00 1.918E+06
      0    0    0             3.210E+01
      1   11          1   10    -3.090E+02 0.        -3.090E+03
      1   11         10   20    -3.090E+03 0.        -6.180E+03
      1   11         20   30    -6.180E+03 0.        -8.968E+03
      1   11         30   40    -8.968E+03 0.        -1.118E+04
      1   11         40   50    -1.118E+04 0.        -1.260E+04
      1   11         50   60    -1.260E+04 0.        -1.309E+04
      1   11         60   70    -1.309E+04 0.        -1.260E+04
      1   11         70   80    -1.260E+04 0.        -1.118E+04
      1   11         80   90    -1.118E+04 0.        -8.968E+03
      1   11         90  100    -8.968E+03 0.        -6.180E+03
      1   11        100  110    -6.180E+03 0.        -3.090E+03
      1   11        110  119    -3.090E+03 0.        -3.090E+02
      1   11        121  130     2.788E+02 0.         2.788E+03
      1   11        130  140     2.788E+03 0.         5.000E+03
      1   11        140  150     5.000E+03 0.         6.421E+03
      1   11        150  160     6.421E+03 0.         6.910E+03
      1   11        160  170     6.910E+03 0.         6.421E+03
      1   11        170  180     6.421E+03 0.         5.000E+03
      1   11        180  190     5.000E+03 0.         2.788E+03
      1   11        190  199     2.788E+03 0.         2.788E+02
      1   11        201  210    -2.212E+02 0.        -2.212E+03
      1   11        210  220    -2.212E+03 0.        -3.633E+03
      1   11        220  230    -3.633E+03 0.        -4.122E+03
      1   11        230  240    -4.122E+03 0.        -3.633E+03
      1   11        240  250    -3.633E+03 0.        -2.212E+03
      1   11        250  259    -2.212E+03 0.        -2.212E+02
      1   11        261  270     1.421E+02 0.         1.421E+03
      1   11        270  280     1.421E+03 0.         1.910E+03
      1  -11        280  290     1.910E+03 0.         1.421E+03
      1   11        290  299     1.421E+03 0.         1.421E+02
      1   11        301  310    -4.890E+01 0.        -4.890E+02
      1   11        310  319    -4.890E+02 0.        -4.890E+01
     11            1-1.000E+00 1.000E-03   10     1 1.000E-04 1.000E+00
                               1070 1932 2465 3022 3380 3735 4240 4750 5800 5800
                                 34  202  418  769 1072 1444 2119 2963 542620000
          13       1-1.000E+00 1.000E-03   10     1 1.000E-04 1.000E+00
                               2650 4700 6100 7490 8365 92401050011750143801438
                                 34  202  418  769 1072 1444 2119 2963 542620000
          16       1-1.000E+00 1.000E-03   10     1 1.000E-04 1.000E+00
                               70201184015696195222172223652253402630528235282
                                 34  202  418  769 1072 1444 2119 2963 542620000
          31       0-1.000E+00 1.000E-03   10     1 1.000E-04 1.000E+00
                               70201184015696195222172223652253402630528235282
                                 34  202  418  769 1072 1444 2119 2963 542620000
   TIME       DEFL         10          1
   TIME       DEFL         21          0
   TIME       MOMT         10          1
   TIME       MOMT         21          0
   BEAM       DEFL         60          1
   BEAM       DEFL        160          0
   BEAM       DEFL        230          1
   BEAM       DEFL        280          0
   BEAM       MOMT         60          1
   BEAM       MOMT        320          0
6     THREE-SPAN BEAM WITH ONE-WAY AND SYMMETRIC NONLINEAR SUP LOADED BY T.P
0     0    0    0    0    0    0    0    3    2    2    1    0    5    9   10
     30 4.800E+01          40 4.000E-02           -1    4   -1    4    0
      4               8   15   16   17
     50 4.000E+00 1.000E-06                  8   15   16   17
      0         1 0.                              2
     30         1 0.                              2
      0    0    0                                           3.000E+10
      0   30    0 2.400E+10                          -1.000E+05
      0   30    0              5.184E-01
     17   17          0    4     0.0       0.0       -1.000E+04
     17   17          4    8    -1.000E+04-1.000E+04 1.000E+03
     17   17          8   12     1.000E+03 1.000E+03-1.000E+04
     17   17         12   16    -1.000E+04-1.000E+04 1.000E+03
     17   17         16   20     1.000E+03 1.000E+03-1.000E+04
      8    8       0-1.000E+03 1.000E-01    7        1.000E-02 1.000E+00
                                -40  -40  -39  -35  -20    0    0
                                -40  -30  -20  -10   -5    0   40
     15            1-1.000E+02 1.000E-01    4     1 1.000E-04 1.000E+00
                                  0    0    0    0
                                  3   10   20   40
          17       0-1.000E+02 1.000E-01    4     1 1.000E-04 1.000E+00
                                 30   86  136  136
                                  3   10   20   40
   TIME       DEFL          8          1
   TIME       DEFL         17          0
   TIME       MOMT          8          1
   TIME       MOMT         17          0
```

```
   BEAM      DEFL        4        1
   BEAM      DEFL        8        1
   BEAM      DEFL       20        0
   BEAM      MOMT       12        1
   BEAM      MOMT       16        1
   BEAM      MOMT       30        0
7     PARTIALLY EMBEDDED PILE EXCITED BY EARTHQUAKE INDUCED FORCES(1/10 G)
0    0    0    0    0    0    0    0    3    0    1    2    0   19    6   10
    50 1.200E+01       160 5.000E-03         -1    5   -1    0    1    1
    10             10   20   30   40   50
    50 1.000E+01 1.000E-06
     0   50    0 1.090E+10                       -1.000E+04
     0   40    0           5.184E-01
    41   50    0           2.592E+00
     0   40         1    1      1.223E+01 1.223E+01 1.223E+01
     0   40         2    2      2.417E+01 2.417E+01 2.417E+01
     0   40         3    3      3.550E+01 3.550E+01 3.550E+01
     0   40         4    4      4.597E+01 4.597E+01 4.597E+01
     0   40         5    5      5.530E+01 5.530E+01 5.530E+01
     0   40         6    6      6.327E+01 6.327E+01 6.327E+01
     0   40         7    7      6.968E+01 6.968E+01 6.968E+01
     0   40         8    8      7.437E+01 7.437E+01 7.437E+01
     0   40         9    9      7.724E+01 7.724E+01 7.724E+01
     0   40        10   10      7.820E+01 7.820E+01 7.820E+01
     0   40        11   11      7.724E+01 7.724E+01 7.724E+01
     0   40        12   12      7.437E+01 7.437E+01 7.437E+01
     0   40        13   13      6.968E+01 6.968E+01 6.968E+01
     0   40        14   14      6.327E+01 6.327E+01 6.327E+01
     0   40        15   15      5.530E+01 5.530E+01 5.530E+01
     0   40        16   16      4.597E+01 4.597E+01 4.597E+01
     0   40        17   17      3.550E+01 3.550E+01 3.550E+01
     0   40        18   18      2.417E+01 2.417E+01 2.417E+01
     0   40        19   19      1.223E+01 1.223E+01 1.223E+01
     0   40    0 1.000E+00-1.000E-02    4    0 1.000E-03 1.000E+00
                         100  100    0    0
                        1000    5    0-1000
     0   40    0 1.000E+00-1.000E-02    4   -1 1.000E-03 1.000E+00
                         100  100    0    0
                        1000    5    0-1000
   TIME      DEFL       10        1
   TIME      DEFL       30        0
   TIME      DEFL       40        1
   TIME      DEFL       50        0
   BEAM      DEFL       10        1
   BEAM      DEFL       20        0
   BEAM      DEFL       50        1
   BEAM      DEFL      150        0
   BEAM      MOMT       30        1
   BEAM      MOMT      100        0
```

APPENDIX H

PARTIAL SAMPLE COMPUTER OUTPUT FOR EXAMPLE PROBLEMS

```
PROGRAM DBC5 - MASTER - JACK CHAN - MATLOCK -  DECK1-REVISION DATE = 26 JUN 71
          EXAMPLE PROBLEMS FOR DBC5 PROGRAM        BY JACK CHAN APRIL 1971
          DYNAMIC BEAM-COLUMN PROGRAM USING 5-1-5 IMPLICIT OPERATOR


PROB
   1      ONE MASS SUPPORTED BY A NONLINEAR SPRING UNDER FREE VIBRATION


TABLE 1 - PROGRAM-CONTROL DATA
                                                              TABLE NUMBER
                                                2     3     4     5     6     7     8     9

HOLD FROM PRECEDING PROBLEM (1=HOLD)            0     0     0     0     0     0     0     0
NUM CARDS INPUT THIS PROBLEM                    2     0     1     1     0     3     3     1


TABLE 2 - CONSTANTS

     NUM OF BEAM INCREMENTS                                                  1
     BEAM INCREMENT LENGTH                                           1.000E+00
     NUM OF TIME INCREMENTS                                                800
     TIME INCREMENT LENGTH                                           6.283E-03
     OPTIONAL PRINTING SWITCH                                                0
     NUM OF MONITOR STA ( PRINTING )                                        -0
     ITERATION SWITCH (0=LINEAR)                                            -1
     NUM OF MONITOR STA ( ITERATION )                                        0
     PLOTTING METHOD(-1=MIC.,0=PRINTER,1=PAPER)                              1
     LINE OR POINTS PLOT OPTION                                              1

-----ITERATION DATA FOR NONLINEAR SUP. CV.-----
     MAXIMUM ITERATION NUMBER                                               50
     MAXIMUM ALLOWABLE DEFLECTION                                    1.000E+01
     DEFLECTION CLOSURE TOLERANCE                                    1.000E-06
     MONITOR STATIONS(ITERATION)
         1    2    3    4    5
STA J   -0


TABLE 3 - SPECIFIED DEFLECTIONS AND SLOPES

     STA      CASE       DEFLECTION        SLOPE        IOPS (IF=1,INITIAL  ,
                                                              IF=2,PERMANENT)

              *NONE*


TABLE 4  -  STIFFNESS AND FIXED-LOAD DATA

FROM TO CONTD      F          QF          S          T          R          CP

  1   1  0  -0.          1.000E+02 -0.        -0.        -0.        -0.


TABLE 5 - MASS AND DAMPINGS DATA

FROM TO CONTD     RHO         DI          DE

  1   1  0   1.000E+00 -0.          -0.


TABLE 6 - TIME DEPENDENT AXIAL THRUST

     BEAM STA         TIME STA
     FROM  TO         FROM  TO                TT1         TT2         TT3


              *NONE*


TABLE 7 - TIME DEPENDENT LOADING

     BEAM STA         TIME STA
     FROM  TO         FROM  TO                QT1         QT2         QT3

        1   1            0    0         -5.000E+01 -5.000E+01 -5.000E+01
        1   1            0  800         -1.000E+02 -1.000E+02 -1.000E+02
        1   1          800  800         -5.000E+01 -5.000E+01 -5.000E+01


TABLE 8 - NONLINEAR SUPPORT CURVES

 FROM  TO CONTD Q-MULTIPLIER W-MULTIPLIER POINTS SYM OPT W-TOLERANCE Q-TOLERANCE

   1    1    0   -1.000E+00   1.000E-01      5       1   1.000E-02   1.000E+00
Q          20      36      60     120     120
W           2       4       8      20     100


TABLE 9 - PLOTTING SWITCHES

 HORIZONTAL VERTICAL BEAM OR TIME MULTIPLE PLOT
    AXIS      AXIS      STATION      SWITCH     (IF=1,SUPERIMPOSE WITH NEXT
                                                 IF=0,PLOT ALL SAVED PLOTS)
    TIME      DEFL         1            0
```

```
PROGRAM DBC5 - MASTER - JACK CHAN - MATLOCK -  DECK1-REVISION DATE = 26 JUN 71
          EXAMPLE PROBLEMS FOR DBC5 PROGRAM        BY JACK CHAN APRIL 1971
          DYNAMIC BEAM-COLUMN PROGRAM USING 5-1-5 IMPLICIT OPERATOR


PROB (CONTD)
    1     ONE MASS SUPPORTED BY A NONLINEAR SPRING UNDER FREE VIBRATION


TABLE 10- CALCULATED RESULTS
     J=BEAM AXIS, K=TIME AXIS

*PRINTING RESULTS IS NOT REQUESTED*

*STANDARD 12 INCH BALLPOINT PAPER PLOT IS REQUESTED*
```

```
PROB (CONTD)
    1     ONE MASS SUPPORTED BY A NONLINEAR SPRING UNDER FREE VIBRATION


                    TIME FOR THIS PROBLEM =     0 MINUTES    6.841 SECONDS


                    ELAPSED CPU TIME =     0 MINUTES   31.086 SECONDS
```

PROGRAM DBC5 - MASTER - JACK CHAN - MATLOCK - DECK1-REVISION DATE = 26 JUN 71
EXAMPLE PROBLEMS FOR PROGRAM DBC5 BY JACK CHAN JUNE 1971
DYNAMIC BEAM-COLUMN PROGRAM (5-1-5 IMPLICIT OPERATOR)

PROB
6 THREE-SPAN BEAM WITH ONE-WAY AND SYMMETRIC NONLINEAR SUP LOADED BY T.P

TABLE 1 - PROGRAM-CONTROL DATA

	TABLE NUMBER 2	3	4	5	6	7	8	9
HOLD FROM PRECEDING PROBLEM (1=HOLD)	0	0	0	0	0	0	0	0
NUM CARDS INPUT THIS PROBLEM	3	2	2	1	0	5	9	10

TABLE 2 - CONSTANTS

NUM OF BEAM INCREMENTS	30
BEAM INCREMENT LENGTH	4.800E+01
NUM OF TIME INCREMENTS	40
TIME INCREMENT LENGTH	4.000E-02
OPTIONAL PRINTING SWITCH	-1
NUM OF MONITOR STA (PRINTING)	4
ITERATION SWITCH (0=LINEAR)	-1
NUM OF MONITOR STA (ITERATION)	4
PLOTTING METHOD(-1=MIC.,0=PRINTED,1=PAPER)	0
LINE OR POINTS PLOT OPTION	-0

-----COMPLETE PRINTING TIME INTERVAL AND MONITOR STATIONS FOR PRINTING-----

TIME STA INTERVAL OF COMPLETE PRINT 4

MONITOR STATIONS(PRINTING)

	1	2	3	4	5	6	7	8	9	10
STA J	8	15	16	17						

-----ITERATION DATA FOR NONLINEAR SUP. CV.------

MAXIMUM ITERATION NUMBER	50
MAXIMUM ALLOWABLE DEFLECTION	4.000E+00
DEFLECTION CLOSURE TOLERANCE	1.000E-06

MONITOR STATIONS(ITERATION)

	1	2	3	4	5
STA J	8	15	16	17	

TABLE 3 - SPECIFIED DEFLECTIONS AND SLOPES

STA	CASE	DEFLECTION	SLOPE	IOPS (IF=1,INITIAL , IF=2,PERMANENT)
0	1	0.	NONE	2
30	1	0.	NONE	2

TABLE 4 - STIFFNESS AND FIXED-LOAD DATA

FROM	TO	CONTD	F	QF	S	T	R	CP
0	0	0	-0.	-0.	-0.	-0.	3.000E+10	-0.
0	30	0	2.400E+10	-0.	-0.	-1.000E+05	-0.	-0.

TABLE 5 - MASS AND DAMPINGS DATA

FROM	TO	CONTD	RHO	DI	DE
0	30	0	5.184E-01	-0.	-0.

TABLE 6 - TIME DEPENDENT AXIAL THRUST

BEAM STA FROM	TO	TIME STA FROM	TO	TT1	TT2	TT3

NONE

TABLE 7 - TIME DEPENDENT LOADING

BEAM STA FROM	TO	TIME STA FROM	TO	QT1	QT2	QT3
17	17	0	4	0.	0.	-1.000E+04
17	17	4	8	-1.000E+04	-1.000E+04	1.000E+03
17	17	8	12	1.000E+03	1.000E+03	-1.000E+04
17	17	12	16	-1.000E+04	-1.000E+04	1.000E+03
17	17	16	20	1.000E+03	1.000E+03	-1.000E+04

TABLE 8 - NONLINEAR SUPPORT CURVES

	FROM	TO	CONTD	Q-MULTIPLIER	W-MULTIPLIER	POINTS	SYM OPT	W-TOLERANCE	Q-TOLERANCE
	8	8	0	-1.000E+03	1.000E-01	7	-0	1.000E-02	1.000E+00
Q		-40	-40	-39	-35	-20	0	0	
W		-40	-30	-20	-10	-5	0	40	
	15		1	-1.000E+02	1.000E-01	4	1	1.000E-04	1.000E+00
Q		0	0	0	0				
W		3	10	20	40				
		17	0	-1.000E+02	1.000E-01	4	1	1.000E-04	1.000E+00
Q		30	66	136	136				
W		3	10	20	40				

TABLE 9 - PLOTTING SWITCHES

HORIZONTAL AXIS	VERTICAL AXIS	BEAM OR TIME STATION	MULTIPLE PLOT SWITCH	(IF=1,SUPERIMPOSE WITH NEXT IF=0,PLOT ALL SAVED PLOTS)
TIME	DEFL	8	1	
TIME	DEFL	17	0	
TIME	MOMT	8	1	
TIME	MOMT	17	0	

BEAM	DEFL	4	1
BEAM	DEFL	8	1
BEAM	DEFL	20	0
BEAM	MOMT	12	1
BEAM	MOMT	16	1
BEAM	MOMT	30	0

PROGRAM DBC5 - MASTER - JACK CHAN - MATLOCK - DECK1-REVISION DATE = 26 JUN 71
EXAMPLE PROBLEMS FOR PROGRAM DBC5 BY JACK CHAN JUNE 1971
DYNAMIC BEAM-COLUMN PROGRAM (5-1-5 IMPLICIT OPERATOR)

PROB (CONTD)
6 THREE-SPAN BEAM WITH ONE-WAY AND SYMMETRIC NONLINEAR SUP LOADED BY T.P

TABLE 10- CALCULATED RESULTS
J=BEAM AXIS, K=TIME AXIS

```
                    TIME STA K =     -2

                         MONITOR            STATIONS
           J =     8          15          16          17

 FOR  1 ITERATION, THERE ARE   0 STATIONS NOT CLOSED
           -1.313E-16  -1.125E-15  -1.236E-15  -1.317E-15
                    TIME STA K =     -1

                         MONITOR            STATIONS
           J =     8          15          16          17

 FOR  1 ITERATION, THERE ARE   0 STATIONS NOT CLOSED
           -1.313E-16  -1.125E-15  -1.236E-15  -1.317E-15
```

***** STATIC RESULTS *****

STA J	DIST	DEFL	SLOPE	MOM	SHEAR	SUP REACT
-1	-4.800E+01	5.001E-18		0.		0.
			-1.642E-19		1.123E-12	
0	0.	0.		5.390E-11		-1.189E-12
			1.114E-19		-6.651E-14	
1	4.800E+01	5.346E-18		5.017E-11		0.
			2.117E-19		-1.189E-12	
2	9.600E+01	1.551E-17		-7.936E-12		0.
			1.058E-19		-1.189E-12	
3	1.440E+02	2.491E-17		-6.596E-11		0.
			6.392E-20		-1.189E-12	
4	1.920E+02	2.798E-17		-1.234E-10		0.
			-1.928E-19		-1.189E-12	
5	2.400E+02	1.920E-17		-1.796E-10		0.
			-5.419E-19		-1.189E-12	
6	2.880E+02	-6.810E-18		-2.341E-10		0.
			-1.010E-18		-1.189E-12	
7	3.360E+02	-5.529E-17		-2.863E-10		0.
			-1.593E-18		-1.189E-12	
8	3.840E+02	-1.313E-16		-3.358E-10		2.625E-12
			-2.254E-18		1.436E-12	
9	4.320E+02	-2.395E-16		-2.560E-10		0.
			-2.766E-18		1.436E-12	

10	4.800E+02	-3.722E-16		-1.738E-10		0.
			-3.114E-18		1.436E-12	
11	5.280E+02	-5.217E-16		-8.998E-11		0.
			-3.294E-18		1.436E-12	
12	5.760E+02	-6.798E-16		-5.247E-12		0.
			-3.304E-18		1.436E-12	
13	6.240E+02	-8.384E-16		7.953E-11		0.
			-3.145E-18		1.436E-12	
14	6.720E+02	-9.894E-16		1.636E-10		0.
			-2.818E-18		1.436E-12	
15	7.200E+02	-1.125E-15		2.460E-10		0.
			-2.326E-18		1.436E-12	
16	7.680E+02	-1.236E-15		3.261E-10		-1.094E-12
			-1.674E-18		3.417E-13	
17	8.160E+02	-1.317E-15		3.505E-10		-3.924E-13
			-9.730E-19		-3.507E-13	
18	8.640E+02	-1.363E-15		3.384E-10		0.
			-2.963E-19		-3.507E-13	
19	9.120E+02	-1.378E-15		3.229E-10		0.
			3.496E-19		-3.507E-13	
20	9.600E+02	-1.361E-15		3.044E-10		0.
			9.584E-19		-3.507E-13	
21	1.008E+03	-1.315E-15		2.830E-10		0.
			1.524E-18		-3.507E-13	
22	1.056E+03	-1.242E-15		2.588E-10		0.
			2.042E-18		-3.507E-13	
23	1.104E+03	-1.144E-15		2.322E-10		0.
			2.507E-18		-3.507E-13	
24	1.152E+03	-1.023E-15		2.033E-10		0.
			2.913E-18		-3.507E-13	
25	1.200E+03	-8.835E-16		1.725E-10		0.
			3.258E-18		-3.507E-13	
26	1.248E+03	-7.271E-16		1.401E-10		0.
			3.538E-18		-3.507E-13	
27	1.296E+03	-5.573E-16		1.062E-10		0.
			3.751E-18		-3.507E-13	
28	1.344E+03	-3.772E-16		7.139E-11		0.
			3.894E-18		-3.507E-13	
29	1.392E+03	-1.903E-16		3.587E-11		0.
			3.965E-18		-3.507E-13	
30	1.440E+03	0.		0.		3.507E-13
			3.965E-18		0.	
31	1.488E+03	1.903E-16		0.		0.

TIME STA K = 0

MONITOR STATIONS

J = 8 15 16 17

FOR 1 ITERATION, THERE ARE 0 STATIONS NOT CLOSED

-6.601E-17 -1.104E-15 -1.223E-15 -1.310E-15

***** DYNAMIC RESULTS *****

TIME STA K = 0

STA J	DIST	DEFL	SLOPE	MOM	SHEAR	SUP REACT
-1	-4.800E+01	7.329E-18		0.		0.
			-1.527E-19		1.645E-12	
0	0.	0.		7.898E-11		-1.397E-12
			1.632E-19		2.488E-13	
1	4.800E+01	7.835E-18		9.014E-11		0.
			3.435E-19		-1.398E-12	
2	9.600E+01	2.432E-17		2.137E-11		0.
			3.862E-19		-1.404E-12	
3	1.440E+02	4.286E-17		-4.787E-11		0.
			2.905E-19		-1.416E-12	
4	1.920E+02	5.681E-17		-1.172E-10		0.
			5.606E-20		-1.434E-12	
5	2.400E+02	5.950E-17		-1.863E-10		0.
			-3.166E-19		-1.460E-12	
6	2.880E+02	4.430E-17		-2.549E-10		0.
			-8.264E-19		-1.494E-12	
7	3.360E+02	4.631E-18		-3.226E-10		0.
			-1.472E-18		-1.532E-12	
8	3.840E+02	-6.601E-17		-3.891E-10		2.640E-12
			-2.250E-18		1.718E-12	
9	4.320E+02	-1.740E-16		-2.958E-10		0.
			-2.842E-18		1.676E-12	
10	4.800E+02	-3.104E-16		-2.018E-10		0.
			-3.245E-18		1.636E-12	
11	5.280E+02	-4.662E-16		-1.077E-10		0.
			-3.460E-18		1.600E-12	
12	5.760E+02	-6.323E-16		-1.426E-11		0.
			-3.489E-18		1.569E-12	
13	6.240E+02	-7.997E-16		7.779E-11		0.
			-3.333E-18		1.544E-12	
14	6.720E+02	-9.597E-16		1.679E-10		0.
			-2.998E-18		1.525E-12	
15	7.200E+02	-1.104E-15		2.555E-10		0.
			-2.487E-18		1.511E-12	
16	7.680E+02	-1.223E-15		3.399E-10		-1.161E-12
			-1.807E-18		3.414E-13	
17	8.160E+02	-1.310E-15		3.650E-10		-7.274E-13
			-1.077E-18		-3.906E-13	
18	8.640E+02	-1.361E-15		3.514E-10		0.
			-3.739E-19		-3.919E-13	
19	9.120E+02	-1.379E-15		3.344E-10		0.
			2.949E-19		-3.908E-13	
20	9.600E+02	-1.365E-15		3.142E-10		0.
			9.233E-19		-3.880E-13	
21	1.008E+03	-1.321E-15		2.912E-10		0.
			1.506E-18		-3.841E-13	
22	1.056E+03	-1.249E-15		2.655E-10		0.
			2.037E-18		-3.796E-13	
23	1.104E+03	-1.151E-15		2.375E-10		0.
			2.512E-18		-3.749E-13	
24	1.152E+03	-1.030E-15		2.075E-10		0.
			2.927E-18		-3.705E-13	
25	1.200E+03	-8.898E-16		1.756E-10		0.
			3.278E-18		-3.664E-13	
26	1.248E+03	-7.324E-16		1.423E-10		0.
			3.563E-18		-3.629E-13	
27	1.296E+03	-5.614E-16		1.078E-10		0.
			3.778E-18		-3.602E-13	
28	1.344E+03	-3.801E-16		7.237E-11		0.
			3.923E-18		-3.584E-13	
29	1.392E+03	-1.918E-16		3.634E-11		0.
			3.996E-18		-3.574E-13	

30	1.440E+03	0.		-4.109E-24		3.574E-13
			3.096E-18		8.560E-26	
31	1.488E+03	1.918E-16		0.		0.

TIME STA K = 1

MONITOR STATIONS
J = 8 15 16 17

FOR 1 ITERATION, THERE ARE 29 STATIONS NOT CLOSED
- -6.665E-03 -1.190E-01 -1.347E-01 -1.462E-01

FOR 2 ITERATION, THERE ARE 0 STATIONS NOT CLOSED
-6.665E-03 -1.190E-01 -1.347E-01 -1.462E-01

TIME STA K = 1

STA J	DIST	DEFL	SLOPE	MOM	SHEAR	SUP REACT
			-1.375E-04		-1.382E+02	
8	3.840E+02	-6.665E-03		-3.578E+04		2.666E+02
			-3.778E-04		2.847E+02	
15	7.200E+02	-1.190E-01		2.514E+04		0.
			-3.275E-04		3.618E+02	
16	7.680E+02	-1.347E-01		4.408E+04		6.735E+02
			-2.394E-04		1.123E+03	
17	8.160E+02	-1.462E-01		9.912E+04		7.309E+02

TIME STA K = 2

MONITOR STATIONS
J = 8 15 16 17

FOR 1 ITERATION, THERE ARE 29 STATIONS NOT CLOSED
-1.690E-02 -3.120E-01 -3.537E-01 -3.880E-01

FOR 2 ITERATION, THERE ARE 29 STATIONS NOT CLOSED
-1.613E-02 -2.998E-01 -3.404E-01 -3.744E-01

FOR 3 ITERATION, THERE ARE 0 STATIONS NOT CLOSED
-1.613E-02 -2.998E-01 -3.404E-01 -3.744E-01

TIME STA K = 2

STA J	DIST	DEFL	SLOPE	MOM	SHEAR	SUP REACT
			-3.644E-04		-3.629E+02	
8	3.840E+02	-1.613E-02		-9.538E+04		6.452E+02
			-9.351E-04		4.050E+02	
15	7.200E+02	-2.998E-01		4.396E+04		0.
			-8.472E-04		4.451E+02	
16	7.680E+02	-3.404E-01		6.939E+04		1.662E+03
			-7.084E-04		2.323E+03	
17	8.160E+02	-3.744E-01		1.843E+05		1.798E+03

TIME STA K = 3

MONITOR STATIONS
J = 8 15 16 17

FOR 1 ITERATION, THERE ARE 29 STATIONS NOT CLOSED
-2.991E-02 -5.667E-01 -6.468E-01 -7.180E-01

FOR 2 ITERATION, THERE ARE 0 STATIONS NOT CLOSED
-2.991E-02 -5.667E-01 -6.468E-01 -7.180E-01

TIME STA K = 3

STA J	DIST	DEFL	SLOPE	MOM	SHEAR	SUP REACT
			-6.041E-04		-6.800E+02	
8	3.840E+02	-2.991E-02		-1.812E+05		1.196E+03
			-1.788E-03		5.185E+02	
15	7.200E+02	-5.667E-01		5.998E+04		0.
			-1.669E-03		4.972E+02	
16	7.680E+02	-6.468E-01		9.186E+04		2.887E+03
			-1.485E-03		3.618E+03	
17	8.160E+02	-7.180E-01		2.727E+05		3.172E+03

TIME STA K = 4

MONITOR STATIONS
J = 8 15 16 17

FOR 1 ITERATION, THERE ARE 29 STATIONS NOT CLOSED
-4.673E-02 -8.891E-01 -1.019E+00 -1.137E+00

FOR 2 ITERATION, THERE ARE 29 STATIONS NOT CLOSED
-4.336E-02 -8.359E-01 -9.416E-01 -1.078E+00

FOR 3 ITERATION, THERE ARE 29 STATIONS NOT CLOSED
-4.576E-02 -8.684E-01 -9.957E-01 -1.111E+00

FOR 4 ITERATION, THERE ARE 0 STATIONS NOT CLOSED
-4.576E-02 -8.684E-01 -9.957E-01 -1.111E+00

TIME STA K = 4

STA J	DIST	DEFL	SLOPE	MOM	SHEAR	SUP REACT
-1	-4.800E+01	5.388E-03		0.		0.
			-1.122E-04		1.210E+03	
0	0.	0.		5.806E+04		-1.028E+03
			1.200E-04		1.811E+02	
1	4.800E+01	5.759E-03		6.617E+04		0.
			2.623E-04		-1.028E+03	
2	9.600E+01	1.787E-02		1.561E+04		0.
			2.836E-04		-1.027E+03	
3	1.440E+02	3.148E-02		-3.505E+04		0.
			2.135E-04		-1.025E+03	
4	1.920E+02	4.173E-02		-8.529E+04		0.
			4.288E-05		-1.023E+03	
5	2.400E+02	4.379E-02		-1.346E+05		0.
			-2.263E-04		-1.020E+03	
6	2.880E+02	3.293E-02		-1.824E+05		0.
			-5.912E-04		-1.017E+03	

```
 7     3.360E+02   4.549E-03                 -2.294E+05                0.
                              -1.048E-03                -1.016E+03
 8     3.840E+02  -4.576E-02                 -2.722E+05                1.830E+03
                              -1.592E-03                 8.142E+02
 9     4.320E+02  -1.222E-01                 -2.254E+05                0.
                              -2.043E-03                 8.105E+02
10     4.800E+02  -2.203E-01                 -1.767E+05                0.
                              -2.397E-03                 8.032E+02
11     5.280E+02  -3.353E-01                 -1.267E+05                0.
                              -2.650E-03                 7.923E+02
12     5.760E+02  -4.625E-01                 -7.592E+04                0.
                              -2.802E-03                 7.786E+02
13     6.240E+02  -5.970E-01                 -2.510E+04                0.
                              -2.852E-03                 7.628E+02
14     6.720E+02  -7.339E-01                  2.521E+04                0.
                              -2.802E-03                 7.459E+02
15     7.200E+02  -8.684E-01                  7.446E+04                0.
                              -2.653E-03                 7.283E+02
16     7.680E+02  -9.957E-01                  1.222E+05                4.283E+03
                              -2.408E-03                 4.823E+03
17     8.160E+02  -1.111E+00                  3.652E+05                4.578E+03
                              -1.678E-03                -2.547E+02
18     8.640E+02  -1.192E+00                  3.610E+05                0.
                              -9.560E-04                -2.793E+02
19     9.120E+02  -1.238E+00                  3.522E+05                0.
                              -2.516E-04                -3.073E+02
20     9.600E+02  -1.250E+00                  3.387E+05                0.
                               4.257E-04                -3.375E+02
21     1.008E+03  -1.229E+00                  3.204E+05                0.
                               1.067E-03                -3.684E+02
22     1.056E+03  -1.178E+00                  2.976E+05                0.
                               1.662E-03                -3.982E+02
23     1.104E+03  -1.098E+00                  2.705E+05                0.
                               2.203E-03                -4.258E+02
24     1.152E+03  -9.927E-01                  2.395E+05                0.
                               2.682E-03                -4.500E+02
25     1.200E+03  -8.640E-01                  2.050E+05                0.
                               3.092E-03                -4.704E+02
26     1.248E+03  -7.155E-01                  1.676E+05                0.
                               3.427E-03                -4.865E+02
27     1.296E+03  -5.510E-01                  1.278E+05                0.
                               3.683E-03                -4.984E+02
28     1.344E+03  -3.743E-01                  8.621E+04                0.
                               3.855E-03                -5.062E+02
29     1.392E+03  -1.892E-01                  4.341E+04                0.
                               3.942E-03                -5.101E+02
30     1.440E+03   0.                         0.                       5.101E+02
                               3.942E-03                 0.
31     1.488E+03   1.892E-01                  0.                       0.
```

TIME STA K = 5

```
                      MONITOR            STATIONS
         J =    8         15              16            17

FOR  1 ITERATION, THERE ARE  29 STATIONS NOT CLOSED
          -4.600E-02  -8.578E-01  -9.930E-01  -1.125E+00

FOR  2 ITERATION, THERE ARE   0 STATIONS NOT CLOSED
          -4.600E-02  -8.578E-01  -9.930E-01  -1.125E+00
* USED ADJUSTED LOAD-DEFL CURVE TO CALCULATE DEFLECTIONS *
```

```
FOR  1 ITERATION, THERE ARE  29 STATIONS NOT CLOSED
          -4.678E-02  -8.684E-01  -1.004E+00  -1.135E+00

FOR  2 ITERATION, THERE ARE  29 STATIONS NOT CLOSED
          -4.470E-02  -8.402E-01  -9.745E-01  -1.106E+00

FOR  3 ITERATION, THERE ARE  29 STATIONS NOT CLOSED
          -4.678E-02  -8.684E-01  -1.004E+00  -1.135E+00

FOR  4 ITERATION, THERE ARE  29 STATIONS NOT CLOSED
          -4.470E-02  -8.402E-01  -9.745E-01  -1.106E+00

FOR  5 ITERATION, THERE ARE  29 STATIONS NOT CLOSED
          -4.738E-02  -8.853E-01  -1.024E+00  -1.158E+00

FOR  6 ITERATION, THERE ARE  29 STATIONS NOT CLOSED
          -4.785E-02  -8.938E-01  -1.033E+00  -1.167E+00

FOR  7 ITERATION, THERE ARE  29 STATIONS NOT CLOSED
          -4.798E-02  -8.961E-01  -1.036E+00  -1.170E+00

FOR  8 ITERATION, THERE ARE  29 STATIONS NOT CLOSED
          -4.801E-02  -8.966E-01  -1.036E+00  -1.171E+00

FOR  9 ITERATION, THERE ARE  27 STATIONS NOT CLOSED
          -4.802E-02  -8.968E-01  -1.036E+00  -1.171E+00

FOR 10 ITERATION, THERE ARE  26 STATIONS NOT CLOSED
          -4.802E-02  -8.968E-01  -1.036E+00  -1.171E+00

FOR 11 ITERATION, THERE ARE  20 STATIONS NOT CLOSED
          -4.802E-02  -8.968E-01  -1.036E+00  -1.171E+00

FOR 12 ITERATION, THERE ARE  15 STATIONS NOT CLOSED
          -4.802E-02  -8.968E-01  -1.036E+00  -1.171E+00

FOR 13 ITERATION, THERE ARE   0 STATIONS NOT CLOSED
          -3.474E-02  -7.216E-01  -8.534E-01  -9.930E-01
```

TIME STA K = 5

```
STA J     DIST        DEFL        SLOPE        MOM        SHEAR     SUP REACT

                                -8.204E-04              -7.733E+02
  8     3.840E+02  -3.474E-02              -2.115E+05               1.390E+03
                                -2.613E-03              -2.778E+02
 15     7.200E+02  -7.216E-01              -6.705E+04               0.
                                -2.747E-03              -5.472E+02
 16     7.680E+02  -8.534E-01              -8.012E+04               7.175E+03
                                -2.907E-03               5.529E+03
 17     8.160E+02  -9.930E-01               1.992E+05               3.838E+03
```

TIME STA K = 6

```
                      MONITOR            STATIONS
         J =    8         15              16            17

FOR  1 ITERATION, THERE ARE  29 STATIONS NOT CLOSED
          -1.698E-02  -5.000E-01  -5.987E-01  -7.008E-01
```

24	1.152E+03	4.348E-01		-2.178E+05		0.
			-6.932E-04		1.790E+02	
25	1.200E+03	4.015E-01		-2.058E+05		0.
			-1.105E-03		4.004E+02	
26	1.248E+03	3.485E-01		-1.813E+05		0.
			-1.467E-03		5.885E+02	
27	1.296E+03	2.781E-01		-1.460E+05		0.
			-1.760E-03		7.361E+02	
28	1.344E+03	1.936E-01		-1.022E+05		0.
			-1.964E-03		8.376E+02	
29	1.392E+03	9.932E-02		-5.262E+04		0.
			-2.069E-03		8.892E+02	
30	1.440E+03	0.		-4.626E-09		-8.892E+02
			-2.069E-03		9.637E-11	
31	1.488E+03	-9.932E-02		0.		0.

TIME STA K = 9

MONITOR STATIONS
J = 8 15 16 17

FOR 1 ITERATION, THERE ARE 29 STATIONS NOT CLOSED
-1.559E-02 5.584E-02 1.039E-01 1.656E-01

FOR 2 ITERATION, THERE ARE 0 STATIONS NOT CLOSED
-1.559E-02 5.584E-02 1.039E-01 1.656E-01

* USED ADJUSTED LOAD-DEFL CURVE TO CALCULATE DEFLECTIONS *

FOR 1 ITERATION, THERE ARE 29 STATIONS NOT CLOSED
-1.430E-02 7.719E-02 1.272E-01 1.896E-01

FOR 2 ITERATION, THERE ARE 29 STATIONS NOT CLOSED
-1.479E-02 6.642E-02 1.150E-01 1.764E-01

FOR 3 ITERATION, THERE ARE 29 STATIONS NOT CLOSED
-1.430E-02 7.719E-02 1.272E-01 1.896E-01

FOR 4 ITERATION, THERE ARE 29 STATIONS NOT CLOSED
-1.479E-02 6.642E-02 1.150E-01 1.764E-01

FOR 5 ITERATION, THERE ARE 29 STATIONS NOT CLOSED
-1.490E-02 6.719E-02 1.162E-01 1.783E-01

FOR 6 ITERATION, THERE ARE 28 STATIONS NOT CLOSED
-1.485E-02 6.798E-02 1.171E-01 1.792E-01

FOR 7 ITERATION, THERE ARE 26 STATIONS NOT CLOSED
-1.485E-02 6.791E-02 1.170E-01 1.791E-01

FOR 8 ITERATION, THERE ARE 15 STATIONS NOT CLOSED
-1.485E-02 6.791E-02 1.170E-01 1.791E-01

FOR 9 ITERATION, THERE ARE 0 STATIONS NOT CLOSED
-1.485E-02 6.791E-02 1.170E-01 1.791E-01

TIME STA K = 9

STA J	DIST	DEFL	SLOPE	MOM	SHEAR	SUP REACT
			-7.660E-05		-6.310E+00	
8	3.840E+02	-1.485E-02		-5.331E+03		5.940E+02
			7.712E-04		3.071E+02	
15	7.200E+02	6.791E-02		1.259E+05		0.
			1.023E-03		3.004E+02	
16	7.680E+02	1.170E-01		1.354E+05		-7.505E+02
			1.294E-03		5.907E+02	
17	8.160E+02	1.791E-01		1.574E+05		-1.007E+03

TIME STA K = 10

MONITOR STATIONS
J = 8 15 16 17

FOR 1 ITERATION, THERE ARE 29 STATIONS NOT CLOSED
-1.738E-02 -1.844E-01 -1.970E-01 -2.008E-01

FOR 2 ITERATION, THERE ARE 0 STATIONS NOT CLOSED
-1.738E-02 -1.844E-01 -1.970E-01 -2.008E-01

TIME STA K = 10

STA J	DIST	DEFL	SLOPE	MOM	SHEAR	SUP REACT
			-2.732E-04		-2.799E+02	
8	3.840E+02	-1.738E-02		-6.771E+04		6.952E+02
			-3.977E-04		3.847E+02	
15	7.200E+02	-1.844E-01		6.785E+04		0.
			-2.620E-04		4.580E+02	
16	7.680E+02	-1.970E-01		9.109E+04		8.195E+02
			-7.681E-05		1.945E+03	
17	8.160E+02	-2.008E-01		1.848E+05		8.928E+02

TIME STA K = 11

MONITOR STATIONS
J = 8 15 16 17

FOR 1 ITERATION, THERE ARE 29 STATIONS NOT CLOSED
-2.115E-02 -6.451E-01 -7.590E-01 -8.668E-01

FOR 2 ITERATION, THERE ARE 29 STATIONS NOT CLOSED
-2.036E-02 -6.332E-01 -7.464E-01 -8.540E-01

FOR 3 ITERATION, THERE ARE 0 STATIONS NOT CLOSED
-2.036E-02 -6.332E-01 -7.464E-01 -8.540E-01

TIME STA K = 11

STA J	DIST	DEFL	SLOPE	MOM	SHEAR	SUP REACT
			-6.527E-04		-7.132E+02	
8	3.840E+02	-2.036E-02		-1.828E+05		8.144E+02
			-2.369E-03		6.882E+02	
15	7.200E+02	-6.332E-01		6.249E+03		0.
			-2.357E-03		8.223E+02	
16	7.680E+02	-7.464E-01		5.703E+04		3.285E+03
			-2.243E-03		3.448E+03	
17	8.160E+02	-8.540E-01		2.333E+05		3.716E+03

			-1.691E-03		1.016E+03	
20	9.600E+02	-1.719E+00		4.891E+05		0.
			-7.330E-04		7.210E+02	
21	1.008E+03	-1.753E+00		5.271E+05		0.
			3.512E-04		4.002E+02	
22	1.056E+03	-1.736E+00		5.446E+05		0.
			1.440E-03		6.144E+01	
23	1.104E+03	-1.667E+00		5.407E+05		0.
			2.522E-03		-2.845E+02	
24	1.152E+03	-1.546E+00		5.149E+05		0.
			3.552E-03		-6.237E+02	
25	1.200E+03	-1.375E+00		4.679E+05		0.
			4.487E-03		-9.405E+02	
26	1.248E+03	-1.160E+00		4.012E+05		0.
			5.290E-03		-1.219E+03	
27	1.296E+03	-9.061E-01		3.173E+05		0.
			5.925E-03		-1.443E+03	
28	1.344E+03	-6.217E-01		2.197E+05		0.
			6.364E-03		-1.600E+03	
29	1.392E+03	-3.162E-01		1.123E+05		0.
			6.589E-03		-1.681E+03	
30	1.440E+03	0.		-9.252E-09		1.681E+03
			6.589E-03		1.927E-10	
31	1.498E+03	3.162E-01		0.		0.

TIME STA K = 13

MONITOR STATIONS
J = 8 15 16 17

FOR 1 ITERATION, THERE ARE 29 STATIONS NOT CLOSED
-5.080E-02 -9.677E-01 -1.130E+00 -1.296E+00

FOR 2 ITERATION, THERE ARE 0 STATIONS NOT CLOSED
-5.080E-02 -9.677E-01 -1.130E+00 -1.296E+00
* USED ADJUSTED LOAD-DEFL CURVE TO CALCULATE DEFLECTIONS *

FOR 1 ITERATION, THERE ARE 29 STATIONS NOT CLOSED
-5.499E-02 -1.037E+00 -1.205E+00 -1.374E+00

FOR 2 ITERATION, THERE ARE 29 STATIONS NOT CLOSED
-5.080E-02 -9.677E-01 -1.130E+00 -1.296E+00

FOR 3 ITERATION, THERE ARE 29 STATIONS NOT CLOSED
-5.499E-02 -1.037E+00 -1.205E+00 -1.374E+00

FOR 4 ITERATION, THERE ARE 29 STATIONS NOT CLOSED
-5.395E-02 -1.026E+00 -1.186E+00 -1.354E+00

FOR 5 ITERATION, THERE ARE 29 STATIONS NOT CLOSED
-5.403E-02 -1.021E+00 -1.188E+00 -1.356E+00

FOR 6 ITERATION, THERE ARE 28 STATIONS NOT CLOSED
-5.404E-02 -1.021E+00 -1.188E+00 -1.356E+00

FOR 7 ITERATION, THERE ARE 17 STATIONS NOT CLOSED
-5.404E-02 -1.021E+00 -1.188E+00 -1.356E+00

FOR 8 ITERATION, THERE ARE 0 STATIONS NOT CLOSED
-3.996E-02 -8.339E-01 -9.919E-01 -1.165E+00

TIME STA K = 13

STA J	DIST	DEFL	SLOPE	MOM	SHEAR	SUP REACT
			-9.567E-04		-8.592E+02	
8	3.840E+02	-3.996E-02		-2.433E+05		1.598E+03
			-3.058E-03		-7.246E+02	
15	7.200E+02	-8.339E-01		-1.163E+05		0.
			-3.290E-03		-1.198E+03	
16	7.680E+02	-9.919E-01		-1.581E+05		7.744E+03
			-3.607E-03		6.156E+03	
17	8.160E+02	-1.165E+00		1.547E+05		4.359E+03

TIME STA K = 14

MONITOR STATIONS
J = 8 15 16 17

FOR 1 ITERATION, THERE ARE 29 STATIONS NOT CLOSED
-3.344E-02 -5.676E-01 -6.521E-01 -7.297E-01

FOR 2 ITERATION, THERE ARE 29 STATIONS NOT CLOSED
-3.422E-02 -5.840E-01 -6.706E-01 -7.497E-01

FOR 3 ITERATION, THERE ARE 0 STATIONS NOT CLOSED
-3.422E-02 -5.840E-01 -6.706E-01 -7.497E-01

TIME STA K = 14

STA J	DIST	DEFL	SLOPE	MOM	SHEAR	SUP REACT
			-7.036E-04		-7.239E+02	
8	3.840E+02	-3.422E-02		-1.828E+05		1.369E+03
			-1.888E-03		4.914E+02	
15	7.200E+02	-5.840E-01		4.225E+04		0.
			-1.804E-03		5.635E+02	
16	7.680E+02	-6.706E-01		7.796E+04		2.210E+03
			-1.648E-03		2.838E+03	
17	8.160E+02	-7.497E-01		2.221E+05		2.159E+03

TIME STA K = 15

MONITOR STATIONS
J = 8 15 16 17

FOR 1 ITERATION, THERE ARE 29 STATIONS NOT CLOSED
-1.099E-02 -1.445E-01 -1.385E-01 -1.102E-01

FOR 2 ITERATION, THERE ARE 29 STATIONS NOT CLOSED
-1.095E-02 -1.439E-01 -1.378E-01 -1.096E-01

FOR 3 ITERATION, THERE ARE 0 STATIONS NOT CLOSED
-1.095E-02 -1.439E-01 -1.378E-01 -1.096E-01

TIME STA K = 15

STA J DIST DEFL SLOPE MOM SHEAR SUP REACT

```
                                    -2.074E-04              -2.756E+02
 8      3.840E+02   -1.095E-02                 -5.922E+04              4.378E+02
                                    -1.861E-04              1.235E+03
15      7.200E+02   -1.439E-01                  1.558E+05              0.
                                     1.256E-04              1.585E+03
16      7.680E+02   -1.378E-01                  2.313E+05             -1.435E+01
                                     5.882E-04             -4.396E+02
17      8.160E+02   -1.096E-01                  2.074E+05             -4.011E+02

                         TIME STA K =    16

                                 MONITOR          STATIONS
                 J =     8          15               16             17

FOR  1 ITERATION, THERE ARE  29 STATIONS NOT CLOSED
              5.534E-04   1.760E-01   2.399E-01   3.191E-01

FOR  2 ITERATION, THERE ARE  29 STATIONS NOT CLOSED
             -2.174E-02   1.686E-01   2.351E-01   3.164E-01

FOR  3 ITERATION, THERE ARE  29 STATIONS NOT CLOSED
              5.534E-04   1.760E-01   2.399E-01   3.191E-01

FOR  4 ITERATION, THERE ARE  29 STATIONS NOT CLOSED
             -2.174E-02   1.686E-01   2.351E-01   3.164E-01

FOR  5 ITERATION, THERE ARE  29 STATIONS NOT CLOSED
              7.264E-04   1.790E-01   2.432E-01   3.224E-01

FOR  6 ITERATION, THERE ARE  29 STATIONS NOT CLOSED
              2.095E-03   1.923E-01   2.575E-01   3.372E-01

FOR  7 ITERATION, THERE ARE  29 STATIONS NOT CLOSED
              3.214E-03   1.931E-01   2.583E-01   3.379E-01

FOR  8 ITERATION, THERE ARE  29 STATIONS NOT CLOSED
              4.107E-03   1.934E-01   2.585E-01   3.380E-01

FOR  9 ITERATION, THERE ARE  29 STATIONS NOT CLOSED
              4.819E-03   1.937E-01   2.587E-01   3.381E-01

FOR 10 ITERATION, THERE ARE  29 STATIONS NOT CLOSED
              5.387E-03   1.938E-01   2.588E-01   3.382E-01

FOR 11 ITERATION, THERE ARE  29 STATIONS NOT CLOSED
              5.839E-03   1.940E-01   2.589E-01   3.382E-01

FOR 12 ITERATION, THERE ARE  29 STATIONS NOT CLOSED
              6.200E-03   1.941E-01   2.590E-01   3.383E-01

FOR 13 ITERATION, THERE ARE  29 STATIONS NOT CLOSED
              6.487E-03   1.942E-01   2.590E-01   3.383E-01

FOR 14 ITERATION, THERE ARE  29 STATIONS NOT CLOSED
              6.716E-03   1.943E-01   2.591E-01   3.383E-01

FOR 15 ITERATION, THERE ARE  29 STATIONS NOT CLOSED
              6.898E-03   1.944E-01   2.591E-01   3.384E-01

FOR 16 ITERATION, THERE ARE  29 STATIONS NOT CLOSED
              7.044E-03   1.944E-01   2.592E-01   3.384E-01

FOR 17 ITERATION, THERE ARE  29 STATIONS NOT CLOSED
              7.160E-03   1.944E-01   2.592E-01   3.384E-01

FOR 18 ITERATION, THERE ARE  28 STATIONS NOT CLOSED
              7.252E-03   1.945E-01   2.592E-01   3.384E-01

FOR 19 ITERATION, THERE ARE  28 STATIONS NOT CLOSED
              7.326E-03   1.945E-01   2.592E-01   3.384E-01

FOR 20 ITERATION, THERE ARE  28 STATIONS NOT CLOSED
              7.385E-03   1.945E-01   2.592E-01   3.384E-01

FOR 21 ITERATION, THERE ARE  27 STATIONS NOT CLOSED
              7.432E-03   1.945E-01   2.592E-01   3.384E-01

FOR 22 ITERATION, THERE ARE  27 STATIONS NOT CLOSED
              7.469E-03   1.946E-01   2.593E-01   3.384E-01

FOR 23 ITERATION, THERE ARE  27 STATIONS NOT CLOSED
              7.499E-03   1.946E-01   2.593E-01   3.384E-01

FOR 24 ITERATION, THERE ARE  25 STATIONS NOT CLOSED
              7.522E-03   1.946E-01   2.593E-01   3.384E-01

FOR 25 ITERATION, THERE ARE  23 STATIONS NOT CLOSED
              7.541E-03   1.946E-01   2.593E-01   3.384E-01

FOR 26 ITERATION, THERE ARE  22 STATIONS NOT CLOSED
              7.556E-03   1.946E-01   2.593E-01   3.384E-01

FOR 27 ITERATION, THERE ARE  20 STATIONS NOT CLOSED
              7.568E-03   1.946E-01   2.593E-01   3.384E-01

FOR 28 ITERATION, THERE ARE  16 STATIONS NOT CLOSED
              7.578E-03   1.946E-01   2.593E-01   3.384E-01

FOR 29 ITERATION, THERE ARE  15 STATIONS NOT CLOSED
              7.585E-03   1.946E-01   2.593E-01   3.385E-01

FOR 30 ITERATION, THERE ARE  14 STATIONS NOT CLOSED
              7.592E-03   1.946E-01   2.593E-01   3.385E-01

FOR 31 ITERATION, THERE ARE  14 STATIONS NOT CLOSED
              7.596E-03   1.946E-01   2.593E-01   3.385E-01

FOR 32 ITERATION, THERE ARE  13 STATIONS NOT CLOSED
              7.600E-03   1.946E-01   2.593E-01   3.385E-01

FOR 33 ITERATION, THERE ARE  12 STATIONS NOT CLOSED
              7.603E-03   1.946E-01   2.593E-01   3.385E-01

FOR 34 ITERATION, THERE ARE  11 STATIONS NOT CLOSED
              7.606E-03   1.946E-01   2.593E-01   3.385E-01

FOR 35 ITERATION, THERE ARE   9 STATIONS NOT CLOSED
              7.608E-03   1.946E-01   2.593E-01   3.385E-01

FOR 36 ITERATION, THERE ARE   7 STATIONS NOT CLOSED
              7.609E-03   1.946E-01   2.593E-01   3.385E-01
```

FOR 37 ITERATION, THERE ARE 5 STATIONS NOT CLOSED
7.611E-03 1.946E-01 2.593E-01 3.385E-01

FOR 38 ITERATION, THERE ARE 0 STATIONS NOT CLOSED
7.612E-03 1.946E-01 2.593E-01 3.385E-01

TIME STA K = 16

STA J	DIST	DEFL	SLOPE	MOM	SHEAR	SUP REACT
-1	-4.800E+01	-5.278E-04		0.		0.
			1.100E-05		-1.185E+02	
0	0.	0.		-5.688E+03		1.111E+02
			-1.175E-05		-7.430E+00	
1	4.800E+01	-5.642E-04		-5.988E+03		0.
			-2.373E-05		1.100E+02	
2	9.600E+01	-1.703E-03		-5.926E+02		0.
			-2.492E-05		1.075E+02	
3	1.440E+02	-2.899E-03		4.699E+03		0.
			-1.554E-05		1.047E+02	
4	1.920E+02	-3.645E-03		9.789E+03		0.
			4.041E-06		1.039E+02	
5	2.400E+02	-3.451E-03		1.476E+04		0.
			3.356E-05		1.084E+02	
6	2.880E+02	-1.840E-03		1.980E+04		0.
			7.316E-05		1.218E+02	
7	3.360E+02	1.671E-03		2.530E+04		0.
			1.238E-04		1.474E+02	
8	3.840E+02	7.612E-03		3.178E+04		0.
			1.873E-04		1.874E+02	
9	4.320E+02	1.660E-02		3.988E+04		0.
			2.671E-04		2.433E+02	
10	4.800E+02	2.942E-02		5.027E+04		0.
			3.676E-04		3.104E+02	
11	5.280E+02	4.707E-02		6.341E+04		0.
			4.944E-04		3.794E+02	
12	5.760E+02	7.080E-02		7.924E+04		0.
			6.529E-04		4.382E+02	
13	6.240E+02	1.021E-01		9.715E+04		0.
			8.472E-04		4.763E+02	
14	6.720E+02	1.428E-01		1.159E+05		0.
			1.079E-03		4.887E+02	
15	7.200E+02	1.946E-01		1.342E+05		0.
			1.348E-03		4.825E+02	
16	7.680E+02	2.593E-01		1.509E+05		-1.603E+03
			1.649E-03		-1.422E+03	
17	8.160E+02	3.385E-01		7.474E+04		-2.193E+03
			1.799E-03		-1.793E+03	
18	8.640E+02	4.248E-01		-1.994E+04		0.
			1.759E-03		-1.651E+03	
19	9.120E+02	5.092E-01		-1.076E+05		0.
			1.644E-03		-1.429E+03	
20	9.600E+02	5.833E-01		-1.836E+05		0.
			1.176E-03		-1.140E+03	
21	1.008E+03	6.398E-01		-2.440E+05		0.
			6.885E-04		-8.047E+02	
22	1.056E+03	6.728E-01		-2.859E+05		0.
			1.166E-04		-4.450E+02	
23	1.104E+03	6.784E-01		-3.079E+05		0.
			-4.991E-04		-8.370E+01	
24	1.152E+03	6.545E-01		-3.095E+05		0.
			-1.118E-03		2.592E+02	
25	1.200E+03	6.008E-01		-2.917E+05		0.
			-1.701E-03		5.670E+02	
26	1.248E+03	5.192E-01		-2.563E+05		0.
			-2.214E-03		8.266E+02	
27	1.296E+03	4.129E-01		-2.060E+05		0.
			-2.626E-03		1.029E+03	
28	1.344E+03	2.868E-01		-1.440E+05		0.
			-2.914E-03		1.166E+03	
29	1.392E+03	1.470E-01		-7.404E+04		0.
			-3.062E-03		1.236E+03	
30	1.440E+03	0.		-4.626E-09		-1.236E+03
			-3.062E-03		9.637E-11	
31	1.488E+03	-1.470E-01		0.		0.

TIME STA K = 17

MONITOR STATIONS
J = 8 15 16 17

FOR 1 ITERATION, THERE ARE 29 STATIONS NOT CLOSED
-1.726E-02 3.952E-02 6.717E-02 1.005E-01

FOR 2 ITERATION, THERE ARE 29 STATIONS NOT CLOSED
-6.020E-03 4.335E-02 6.968E-02 1.019E-01

FOR 3 ITERATION, THERE ARE 0 STATIONS NOT CLOSED
-6.020E-03 4.335E-02 6.968E-02 1.019E-01
* USED ADJUSTED LOAD-DEFL CURVE TO CALCULATE DEFLECTIONS *

FOR 1 ITERATION, THERE ARE 29 STATIONS NOT CLOSED
-3.977E-03 7.709E-02 1.064E-01 1.398E-01

FOR 2 ITERATION, THERE ARE 0 STATIONS NOT CLOSED
-3.977E-03 7.709E-02 1.064E-01 1.398E-01

TIME STA K = 17

STA J	DIST	DEFL	SLOPE	MOM	SHEAR	SUP REACT
			3.654E-06		1.015E+02	
8	3.840E+02	-3.977E-03		1.222E+04		1.591E+02
			5.147E-04		-1.584E+01	
15	7.200E+02	7.709E-02		4.810E+04		0.
			6.110E-04		-7.083E+01	
16	7.680E+02	1.064E-01		4.177E+04		-8.385E+02
			6.945E-04		1.579E+03	
17	8.160E+02	1.398E-01		1.143E+05		-1.200E+03

TIME STA K = 18

MONITOR STATIONS
J = 8 15 16 17

FOR 1 ITERATION, THERE ARE 29 STATIONS NOT CLOSED
-3.739E-02 -3.899E-01 -4.511E-01 -5.068E-01

FOR 2 ITERATION, THERE ARE 29 STATIONS NOT CLOSED
-3.483E-02 -3.654E-01 -4.248E-01 -4.802E-01

```
15      7.200E+02   1.489E-01                 -6.300E+03                    0.
                               3.843E-04                   8.961E+02
16      7.680E+02   1.673E-01                  3.487E+04               -1.235E+03
                               4.541E-04                   4.983E+02
17      8.160E+02   1.891E-01                  5.660E+04               -1.596E+03
                         TIME STA K =    23

                            MONITOR             STATIONS
              J =     8            15             16             17

   FOR  1 ITERATION, THERE ARE  29 STATIONS NOT CLOSED
                  1.290E-02   3.648E-01   4.548E-01   5.723E-01

   FOR  2 ITERATION, THERE ARE  29 STATIONS NOT CLOSED
                  8.561E-03   3.633E-01   4.539E-01   5.718E-01

   FOR  3 ITERATION, THERE ARE   0 STATIONS NOT CLOSED
                  8.561E-03   3.633E-01   4.539E-01   5.718E-01

                         TIME STA K =    23

STA J      DIST        DEFL        SLOPE        MOM        SHEAR    SUP REACT

                                 4.439E-04               1.771E+02
  8     3.840E+02   8.561E-03               1.018E+05               0.
                                 1.517E-03               1.620E+03
 15     7.200E+02   3.633E-01               1.844E+05               0.
                                 1.886E-03               2.294E+03
 16     7.680E+02   4.539E-01               2.855E+05            -2.381E+03
                                 2.457E-03              -2.063E+03
 17     8.160E+02   5.718E-01               1.747E+05            -3.127E+03
                         TIME STA K =    24

                            MONITOR             STATIONS
              J =     8            15             16             17

   FOR  1 ITERATION, THERE ARE  29 STATIONS NOT CLOSED
                 -1.015E-04   1.150E-01   1.943E-01   2.981E-01

   FOR  2 ITERATION, THERE ARE  29 STATIONS NOT CLOSED
                  1.965E-03   1.157E-01   1.948E-01   2.983E-01

   FOR  3 ITERATION, THERE ARE  29 STATIONS NOT CLOSED
                 -1.015E-04   1.150E-01   1.943E-01   2.981E-01

   FOR  4 ITERATION, THERE ARE  29 STATIONS NOT CLOSED
                  1.965E-03   1.157E-01   1.948E-01   2.983E-01

   FOR  5 ITERATION, THERE ARE  29 STATIONS NOT CLOSED
                  9.429E-03   1.286E-01   2.078E-01   3.111E-01

   FOR  6 ITERATION, THERE ARE  29 STATIONS NOT CLOSED
                  9.571E-03   1.188E-01   1.982E-01   3.011E-01

   FOR  7 ITERATION, THERE ARE  29 STATIONS NOT CLOSED
                  9.664E-03   1.195E-01   1.979E-01   3.008E-01

   FOR  8 ITERATION, THERE ARE  29 STATIONS NOT CLOSED
                  9.737E-03   1.195E-01   1.979E-01   3.008E-01

   FOR  9 ITERATION, THERE ARE  28 STATIONS NOT CLOSED
                  9.795E-03   1.196E-01   1.979E-01   3.008E-01

   FOR 10 ITERATION, THERE ARE  27 STATIONS NOT CLOSED
                  9.841E-03   1.196E-01   1.979E-01   3.008E-01

   FOR 11 ITERATION, THERE ARE  27 STATIONS NOT CLOSED
                  9.878E-03   1.196E-01   1.979E-01   3.008E-01

   FOR 12 ITERATION, THERE ARE  27 STATIONS NOT CLOSED
                  9.907E-03   1.196E-01   1.979E-01   3.008E-01

   FOR 13 ITERATION, THERE ARE  25 STATIONS NOT CLOSED
                  9.931E-03   1.196E-01   1.979E-01   3.008E-01

   FOR 14 ITERATION, THERE ARE  24 STATIONS NOT CLOSED
                  9.949E-03   1.196E-01   1.979E-01   3.008E-01

   FOR 15 ITERATION, THERE ARE  22 STATIONS NOT CLOSED
                  9.964E-03   1.196E-01   1.979E-01   3.008E-01

   FOR 16 ITERATION, THERE ARE  20 STATIONS NOT CLOSED
                  9.976E-03   1.196E-01   1.979E-01   3.008E-01

   FOR 17 ITERATION, THERE ARE  16 STATIONS NOT CLOSED
                  9.986E-03   1.196E-01   1.979E-01   3.008E-01

   FOR 18 ITERATION, THERE ARE  15 STATIONS NOT CLOSED
                  9.993E-03   1.196E-01   1.979E-01   3.008E-01

   FOR 19 ITERATION, THERE ARE  14 STATIONS NOT CLOSED
                  9.999E-03   1.196E-01   1.979E-01   3.008E-01

   FOR 20 ITERATION, THERE ARE  14 STATIONS NOT CLOSED
                  1.000E-02   1.196E-01   1.979E-01   3.008E-01

   FOR 21 ITERATION, THERE ARE  13 STATIONS NOT CLOSED
                  1.001E-02   1.196E-01   1.979E-01   3.008E-01

   FOR 22 ITERATION, THERE ARE  12 STATIONS NOT CLOSED
                  1.001E-02   1.196E-01   1.979E-01   3.008E-01

   FOR 23 ITERATION, THERE ARE  11 STATIONS NOT CLOSED
                  1.001E-02   1.196E-01   1.979E-01   3.008E-01

   FOR 24 ITERATION, THERE ARE   9 STATIONS NOT CLOSED
                  1.002E-02   1.196E-01   1.979E-01   3.008E-01

   FOR 25 ITERATION, THERE ARE   7 STATIONS NOT CLOSED
                  1.002E-02   1.196E-01   1.979E-01   3.008E-01

   FOR 26 ITERATION, THERE ARE   5 STATIONS NOT CLOSED
                  1.002E-02   1.196E-01   1.979E-01   3.008E-01

   FOR 27 ITERATION, THERE ARE   0 STATIONS NOT CLOSED
                  1.002E-02   1.196E-01   1.979E-01   3.008E-01
 * USED ADJUSTED LOAD-DEFL CURVE TO CALCULATE DEFLECTIONS *

   FOR  1 ITERATION, THERE ARE  29 STATIONS NOT CLOSED
```

3.095E-03 1.473E-01 2.293E-01 3.340E-01

FOR 2 ITERATION, THERE ARE 0 STATIONS NOT CLOSED
3.095E-03 1.473E-01 2.293E-01 3.340E-01

TIME STA K = 24

STA J	DIST	DEFL	SLOPE	MOM	SHEAR	SUP REACT
-1	-4.800E+01	1.448E-04		0.		0.
			-3.016E-06		3.250E+01	
0	0.	0.		1.560E+03		-6.333E-01
			3.224E-06		3.187E+01	
1	4.800E+01	1.548E-04		3.074E+03		0.
			9.373E-06		-4.694E+00	
2	9.600E+01	6.047E-04		2.804E+03		0.
			1.498E-05		-1.629E+01	
3	1.440E+02	1.324E-03		1.951E+03		0.
			1.888E-05		-3.464E+01	
4	1.920E+02	2.230E-03		1.970E+02		0.
			1.928E-05		-5.540E+01	
5	2.400E+02	3.155E-03		-2.555E+03		0.
			1.417E-05		-7.178E+01	
6	2.880E+02	3.836E-03		-6.068E+03		0.
			2.031E-06		-7.628E+01	
7	3.360E+02	3.933E-03		-9.739E+03		0.
			-1.745E-05		-6.268E+01	
8	3.840E+02	3.095E-03		-1.266E+04		0.
			-4.278E-05		6.572E+02	
9	4.320E+02	1.042E-03		1.909E+04		0.
			-4.599E-06		7.112E+02	
10	4.800E+02	8.215E-04		5.325E+04		0.
			1.019E-04		7.724E+02	
11	5.280E+02	5.713E-03		8.983E+04		0.
			2.916E-04		8.199E+02	
12	5.760E+02	1.923E-02		1.278E+05		0.
			5.372E-04		8.283E+02	
13	6.240E+02	4.501E-02		1.650E+05		0.
			8.673E-04		7.739E+02	
14	6.720E+02	8.664E-02		1.980E+05		0.
			1.263E-03		6.447E+02	
15	7.200E+02	1.473E-01		2.229E+05		0.
			1.709E-03		4.533E+02	
16	7.680E+02	2.293E-01		2.364E+05		-1.258E+03
			2.182E-03		-1.280E+03	
17	8.160E+02	3.340E-01		1.645E+05		-1.938E+03
			2.511E-03		-2.494E+03	
18	8.640E+02	4.546E-01		3.274E+04		0.
			2.576E-03		-2.454E+03	
19	9.120E+02	5.782E-01		-9.762E+04		0.
			2.382E-03		-2.250E+03	
20	9.600E+02	6.925E-01		-2.169E+05		0.
			1.948E-03		-1.898E+03	
21	1.008E+03	7.860E-01		-3.173E+05		0.
			1.313E-03		-1.430E+03	
22	1.056E+03	8.491E-01		-3.922E+05		0.
			5.288E-04		-8.868E+02	
23	1.104E+03	8.745E-01		-4.373E+05		0.
			-3.459E-04		-3.123E+02	
24	1.152E+03	8.579E-01		-4.507E+05		0.
			-1.247E-03		2.534E+02	
25	1.200E+03	7.980E-01		-4.325E+05		0.
			-2.112E-03		7.750E+02	
26	1.248E+03	6.966E-01		-3.852E+05		0.
			-2.883E-03		1.224E+03	
27	1.296E+03	5.582E-01		-3.126E+05		0.
			-3.508E-03		1.579E+03	
28	1.344E+03	3.899E-01		-2.200E+05		0.
			-3.948E-03		1.823E+03	
29	1.392E+03	2.004E-01		-1.135E+05		0.
			-4.175E-03		1.948E+03	
30	1.440E+03	0.		-1.850E-08		-1.948E+03
			-4.175E-03		3.855E-10	
31	1.488E+03	-2.004E-01		0.		0.

TIME STA K = 25

MONITOR STATIONS
J = 8 15 16 17

FOR 1 ITERATION, THERE ARE 29 STATIONS NOT CLOSED
-7.518E-02 -2.391E-01 -2.430E-01 -2.520E-01

FOR 2 ITERATION, THERE ARE 29 STATIONS NOT CLOSED
-2.837E-02 -1.996E-01 -2.058E-01 -2.187E-01

FOR 3 ITERATION, THERE ARE 0 STATIONS NOT CLOSED
-2.837E-02 -1.986E-01 -2.058E-01 -2.187E-01

TIME STA K = 25

STA J	DIST	DEFL	SLOPE	MOM	SHEAR	SUP REACT
			-4.695E-04		-4.693E+01	
8	3.840E+02	-2.837E-02		-8.175E+04		1.135E+03
			-1.784E-04		-9.609E+02	
15	7.200E+02	-1.986E-01		1.406E+04		0.
			-1.502E-04		-1.551E+03	
16	7.680E+02	-2.058E-01		-5.965E+04		8.575E+02
			-2.695E-04		1.419E+03	
17	8.160E+02	-2.187E-01		9.746E+03		6.354E+02

TIME STA K = 26

MONITOR STATIONS
J = 8 15 16 17

FOR 1 ITERATION, THERE ARE 29 STATIONS NOT CLOSED
-3.069E-02 -3.255E-01 -4.270E-01 -5.527E-01

FOR 2 ITERATION, THERE ARE 0 STATIONS NOT CLOSED
-3.069E-02 -3.255E-01 -4.270E-01 -5.527E-01

TIME STA K = 26

STA J	DIST	DEFL	SLOPE	MOM	SHEAR	SUP REACT
			-2.731E-04		-8.745E+01	
8	3.840E+02	-3.069E-02		-3.985E+04		1.228E+03

THE AUTHORS

Jack Hsiao-Chieh Chan was a Research Engineer Assistant with the Center for Highway Research, The University of Texas at Austin. His experience includes work as a teaching assistant in Taiwan and work as a highway engineer with Howard, Needle, Tammon, and Bergendoff, Consulting Engineers, Kansas City, Missouri. His research interest is primarily in the area of discrete-element analysis in structural dynamics.

Hudson Matlock is a Professor of Civil Engineering at The University of Texas at Austin. He has a broad base of experience, including research at the Center for Highway Research and as a consultant for other organizations such as the Alaska Department of Highways, Shell Development Company, Humble Oil and Refining Company, Penrod Drilling Company, and Esso Production Research Company. He is the author of over 50 technical papers and 25 research reports and received the 1967 ASCE J. James R. Croes Medal. His primary areas of interest in research include (1) soil-structure interaction, (2) experimental mechanics, and (3) development of computer methods for simulation of civil engineering problems.