NONLINEAR SOIL-STRUCTURE INTERACTION OF SKEW HIGHWAY BRIDGES

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ABSTRACT

This report is one in a series to result from the study, "An Investigation of the Effectiveness of Existing Bridge Design Methodology in Providing Adequate Structural Resistance to Seismic Disturbances", sponsored by the U. S. Department of Transportation. Federal Highway Administration. Descriptions are given of the analytical investigations of the seismic response of skew highway bridges where soil-structure interaction effects are important.

Four different mathematical model elements are incorporated into the three dimensional computer program which possesses the capability of performing linear or nonlinear time-history dynamic response analysis. Solid finite element modelling is used for the backfill soils and the abutment walls. The bridge deck, pier columns and pier caps are modelled using prismatic beam elements. A frictional element is used to model the discontinuous behavior at the interfaces of the backfill soils and abutments. Boundary elements provide foundation flexibility at the base of columns supported on either piles or spread footings. In the nonlinear mathematical model the effects of separation, impact and slippage at the interfaces between the abutment walls and the backfill soils are taken into consideration.

Computational efficiency is achieved through the use of mathematical techniques including matrix reduction procedures, iteration procedures and variable time steps.

A number of analytical solutions are carried out considering a skewed three-span bridge with backfill soils. Different mathematical models are used to study the parameters which may influence the seismic response of the bridge.

Finally, conclusions are deduced from the analytical results.

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TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

I. INTRODUCTION

Presented in this report is a study of the behavior of short, skew highway bridges interacting with their surrounding soils during strong motion earthquakes. The first part of the study defines a three-dimensional, nonlinear mathematical model for the complete bridge-soil system while the second part develops the associated computer program for carrying out time-history dynamic response analysis.

The mathematical model consists of (1) linear, elastic, three-dimensional solid finite elements representing backfill soils and abutment walls, (2) linear, elastic prismatic beam elements representing the bridge deck, pier columns, and pier caps, (3) nonlinear friction elements representing the discontinuous behavior of separation, impact, and slippage at the interfaces between backfills and abutment walls, and (4) discrete translational and rotational linear springs representing foundation flexibilities at the bases of supporting columns.

In developing the computer program for time-history dynamic response analysis, considerable effort has been spent in achieving computational efficiency. Special programming techniques including the use of matrix reduction procedures, iteration procedures, and variable time steps were used. The matrix reduction procedures reduce the number of coupled equations involved by constraining certain degrees of freedom without decreasing the number of nodal points in the system. The iteration procedures used in the nonlinear analysis express the stiffness matrix in the incremental equilibrium equation in terms of constant initial values placed on the left hand side of the equation and time dependent values associated with the nonlinearities which are placed on the right hand side of the equation to form an effective force vector. Total equilibrium is enforced at each time step in the numerical integration and variable time steps are used so that the "overshoot" errors never exceed a prescribed limit.

The stiffness properties of the four basic types of elements used in the mathematical model are described in Chapter II and the numerical techniques used in the dynamic response analyses are presented in Chapter III. Some numerical results are given in Chapter IV and certain conclusions are deduced in Chapter V. Finally, the computer program for carrying out time-history response analyses is listed in Appendix A.

II. BASIC ELEMENT STIFFNESSES

A. SOLID FINITE ELEMENT

The three-dimensional linear finite element used to model the abutment walls and backfill soils is the eight-node isoparametric hexahedron shown in Fig. 1 which contains incompatible deformation modes [27, 29]. The local and global coordinates of the element are related through a set of interpolation functions, namely,

$$X = \sum_{i=1}^{8} h_i \, x_i$$

$$Y = \sum_{i=1}^{8} h_i \, y_i \tag{1}$$

$$Z = \sum_{i=1}^{8} h_i \, z_i$$

where x_i, y_i, and z_i are the global coordinates of nodal point i and

$$\begin{aligned}
h_1 &= 1/8 \; (1 + \eta)(1 - \xi)(1 - \zeta) \\
h_2 &= 1/8 \; (1 + \eta)(1 + \xi)(1 - \zeta) \\
h_3 &= 1/8 \; (1 - \eta)(1 + \xi)(1 - \zeta) \\
h_4 &= 1/8 \; (1 - \eta)(1 - \xi)(1 - \zeta) \\
h_5 &= 1/8 \; (1 + \eta)(1 - \xi)(1 + \zeta) \\
h_6 &= 1/8 \; (1 + \eta)(1 + \xi)(1 + \zeta) \\
h_7 &= 1/8 \; (1 - \eta)(1 + \xi)(1 + \zeta) \\
h_8 &= 1/8 \; (1 - \eta)(1 - \xi)(1 + \zeta)
\end{aligned} \tag{2}$$

are the interpolation functions. The displacements within the element u_x, u_y, and u_z are related to the nodal displacements u_{xi}, u_{yi}, and u_{zi} (i = 1,2,...,8) through the equations

$$
\begin{aligned}
u_x &= \sum_{i=1}^{8} h_i\, u_{xi} + h_9\, \alpha_{x1} + h_{10}\, \alpha_{x2} + h_{11}\, \alpha_{x3} \\
u_y &= \sum_{i=1}^{8} h_i\, u_{yi} + h_9\, \alpha_{y1} + h_{10}\, \alpha_{y2} + h_{11}\, \alpha_{y3} \qquad (3) \\
u_z &= \sum_{i=1}^{8} h_i\, u_{zi} + h_9\, \alpha_{z1} + h_{10}\, \alpha_{z2} + h_{11}\, \alpha_{z3}
\end{aligned}
$$

where

$$
\begin{aligned}
h_9 &= (1 - \eta^2) \\
h_{10} &= (1 - \xi^2) \qquad (4) \\
h_{11} &= (1 - \zeta^2)
\end{aligned}
$$

The degrees of freedom corresponding to the last three terms in Eq. (3) are eliminated at the element level by static condensation; thus, the final dimensions of the element stiffness matrix are 24 x 24. Linear elastic isotropic material properties are specified for each element; however, these properties can vary from element to element.

B. FRICTIONAL ELEMENT

The frictional element representing separation, impact, and slippage at the interfaces of abutment walls and backfill soils uses relative displacements as the independent degrees-of-freedom to avoid numerical difficulties [11, 26]. Figure 2 shows the nodal displacements of the frictional element along with the corresponding displacements for its top-half element and its bottom-half element. The equations relating the displacements at nodal point k are

$$
\begin{aligned}
u_{xk}^{T} &= u_{xk}^{B} + \Delta u_{xk} \\
u_{yk}^{T} &= u_{yk}^{B} + \Delta u_{yk} \\
u_{zk}^{T} &= u_{zk}^{B} + \Delta u_{zk}
\end{aligned}
\tag{5}
$$

where superscripts T and B refer to the top- and bottom-half elements, respectively. Similar equations exist for nodal points i, j, and ℓ.

The degrees of freedom of the top-half element are obtained from the frictional element nodal displacements $\{\Delta u\}$ and the upper nodal displacements of the bottom-half element $\{u_u^B\}$ through a transformation matrix [A] as given by

$$
\{u^T\} = \begin{Bmatrix} u_u^T \\ u_\ell^T \end{Bmatrix} = \begin{bmatrix} \underline{I} & \underline{0} & \underline{0} \\ \underline{0} & \underline{I} & \underline{I} \end{bmatrix} \begin{Bmatrix} u_u^T \\ \Delta u \\ u_u^B \end{Bmatrix} \tag{6}
$$

or

$$
\{u^T\} = [A]\{u\} \tag{7}
$$

where $\underline{I}$ is a 12 x 12 unit matrix and $\underline{0}$ is a 12 x 12 null matrix. Subscripts u and ℓ refer to the upper 4 nodes and the lower 4 nodes of the element, respectively.

The procedure used in forming the stiffness matrix of the frictional element can be summarized as follows:

(1) Form the 24 x 24 top-half and bottom-half stiffness matrices in global coordinates by the standard procedure used for a solid element.

(2) Retain the bottom-half 24 x 24 element stiffness matrix but transform the top-half 24 x 24 element stiffness matrix into a 36 x 36 matrix using the relation

$$\underset{36 \times 36}{[K]} = \underset{36 \times 24}{[A]^T} \; \underset{24 \times 24}{[k]} \; \underset{24 \times 36}{[A]} \qquad (8)$$

(3) Form the 12 x 12 frictional element stiffness matrix in local coordinates and then transform to the global coordinates.

To form the frictional element stiffness matrix in local coordinates, the relative normal and tangential displacements Δu_n, Δu_s, and Δu_t as shown in Fig. 3 are assumed to vary linearly within the element, i.e.

$$\begin{aligned} \Delta u_n &= \sum_{i=1}^{4} h_i \; \Delta u_{ni} \\ \Delta u_s &= \sum_{i=1}^{4} h_i \; \Delta u_{si} \\ \Delta u_t &= \sum_{i=1}^{4} h_i \; \Delta u_{ti} \end{aligned} \qquad (9)$$

where

$$\begin{aligned} h_1 &= 1/4 \; (1 - \eta)(1 - \xi) \\ h_2 &= 1/4 \; (1 + \eta)(1 - \xi) \\ h_3 &= 1/4 \; (1 + \eta)(1 + \xi) \\ h_4 &= 1/4 \; (1 - \eta)(1 + \xi) \end{aligned} \qquad (10)$$

Assuming all strains are constant throughout the thickness W and neglecting the in-plane normal strains, the only remaining effective strain components are the normal strain ε_{nn} and the two in-plane shear strains ε_{ns} and ε_{nt} as given by

$$
\begin{aligned}
\varepsilon_{nn} &= \frac{1}{W}\,\Delta u_n \\
\varepsilon_{ns} &= \frac{1}{W}\,\Delta u_s \\
\varepsilon_{nt} &= \frac{1}{W}\,\Delta u_t
\end{aligned}
\tag{11}
$$

Making use of Eqs. (9)-(11), the strain-displacement relations for the element become

$$
\begin{Bmatrix} \varepsilon_{nn} \\ \varepsilon_{ns} \\ \varepsilon_{nt} \end{Bmatrix} = \frac{W}{4}
\begin{bmatrix}
h_1 & 0 & 0 & h_2 & 0 & 0 & h_3 & 0 & 0 & h_4 & 0 & 0 \\
0 & h_1 & 0 & 0 & h_2 & 0 & 0 & h_3 & 0 & 0 & h_4 & 0 \\
0 & 0 & h_1 & 0 & 0 & h_2 & 0 & 0 & h_3 & 0 & 0 & h_4
\end{bmatrix}
\begin{Bmatrix} \Delta u_{n1} \\ \Delta u_{s1} \\ \Delta u_{t1} \\ \Delta u_{n2} \\ \Delta u_{s2} \\ \Delta u_{t2} \\ \Delta u_{n3} \\ \Delta u_{s3} \\ \Delta u_{t3} \\ \Delta u_{n4} \\ \Delta u_{s4} \\ \Delta u_{t4} \end{Bmatrix}
\tag{12}
$$

or

$$\{\varepsilon\} = [B]\ \{\Delta u\} \tag{13}$$

The corresponding stress-strain relations are given by

$$\begin{Bmatrix} \sigma_{nn} \\ \sigma_{ns} \\ \sigma_{nt} \end{Bmatrix} = \begin{bmatrix} C_n & 0 & 0 \\ 0 & C_s & 0 \\ 0 & 0 & C_s \end{bmatrix} \begin{Bmatrix} \varepsilon_{nn} \\ \varepsilon_{ns} \\ \varepsilon_{nt} \end{Bmatrix} \tag{14}$$

or

$$\{\sigma\} = [C]\ \{\varepsilon\} \tag{15}$$

where C_n and C_s are the normal and shear stiffnesses, respectively.

The 12 x 12 stiffness matrix for the frictional element in local coordinates can now be evaluated using standard techniques [29], i.e.

$$\underline{K}_{nst} = \int_{Vol} \underline{B}^T\ \underline{C}\ \underline{B}\ dv \tag{16}$$

Transformation to the XYZ global coordinates is accomplished using the following relation through the coordinate transformation matrix T

$$\underline{K} = \underline{T}^T\ \underline{K}_{nst}\ \underline{T} \tag{17}$$

The nonlinear tangential stress-strain relation is assumed to be the elastic-perfectly plastic relation obtained from the Mohr-Coulomb yield criterion shown in Fig. 4, i.e.

$$C_s = G \text{ (shear modulus of frictional element)} \tag{18}$$

when

$$\tau < c + \sigma_{nn} \tan \phi \text{ (elastic)} \tag{19}$$

and

$$C_s = 0 \tag{20}$$

when

$$\tau = c + \sigma_{nn} \tan \phi \text{ (plastic)} \tag{21}$$

in which c and ϕ are the cohesion and angle of friction, respectively, and τ is either σ_{ns} or σ_{nt}.

The nonlinear normal stress-strain relation for the element is assumed to be bilinear as shown in Fig. 5 with C_n being assigned a very large value when contact is present at the interface of abutment and soil and a zero value when separation occurs.

C. BEAM ELEMENT

The prismatic beam element used to represent the bridge deck, pier columns, and pier caps, was assumed to be linear elastic. The deformations considered in the element were those caused by torsion, bending about the two principal axes of the cross-section, axial force, and the two-components of transverse shear. Thus, the 12 x 12 stiffness matrix for the element is of the standard form [21]

$$
\underset{12 \times 12}{[K]} = \begin{bmatrix}
\frac{EA}{\ell} & & & & & & & & & & & \\
0 & \frac{12EI_z}{\ell^3(1+\phi_y)} & & & & & & & \text{Symmetric} & & & \\
0 & 0 & \frac{12EI_y}{\ell^3(1+\phi_z)} & & & & & & & & & \\
0 & 0 & 0 & \frac{GJ}{\ell} & & & & & & & & \\
0 & 0 & \frac{-6EI_y}{\ell^2(1+\phi_z)} & 0 & \frac{(4+\phi_z)EI_y}{\ell(1+\phi_z)} & & & & & & & \\
0 & \frac{6EI_z}{\ell^2(1+\phi_y)} & 0 & 0 & 0 & \frac{(4+\phi_y)EI_z}{\ell(1+\phi_y)} & & & & & & \\
\frac{-EA}{\ell} & 0 & 0 & 0 & 0 & 0 & \frac{AE}{\ell} & & & & & \\
0 & \frac{-12EI_z}{\ell^3(1+\phi_y)} & 0 & 0 & 0 & \frac{-6EI_z}{\ell^2(1+\phi_y)} & 0 & \frac{12EI_z}{\ell^3(1+\phi_y)} & & & & \\
0 & 0 & \frac{-12EI_y}{\ell^3(1+\phi_z)} & 0 & \frac{6EI_y}{\ell^2(1+\phi_z)} & 0 & 0 & 0 & \frac{12EI_y}{\ell^3(1+\phi_z)} & & & \\
0 & 0 & 0 & \frac{-GJ}{\ell} & 0 & 0 & 0 & 0 & 0 & \frac{GJ}{\ell} & & \\
0 & 0 & \frac{-6EI_y}{\ell^2(1+\phi_z)} & 0 & \frac{(2-\phi_z)EI_y}{\ell(1+\phi_z)} & 0 & 0 & 0 & \frac{6EI_y}{\ell^2(1+\phi_z)} & 0 & \frac{(4+\phi_z)EI_y}{\ell(1+\phi_z)} & \\
0 & \frac{6EI_z}{\ell^2(1+\phi_y)} & 0 & 0 & 0 & \frac{(2-\phi_y)EI_z}{\ell(1+\phi_y)} & 0 & \frac{-6EI_z}{\ell^2(1+\phi_y)} & 0 & 0 & 0 & \frac{(4+\phi_y)EI_z}{\ell(1+\phi_y)}
\end{bmatrix} \tag{22}
$$

where ϕ_y and ϕ_z are shear deformation parameters given by

$$\phi_y = \frac{12EI_z}{G\,A_{sy}\,\ell^2} = 24\,(1+\nu)\,\frac{A}{A_{sy}}\left(\frac{\gamma_z}{\ell}\right)^2 \tag{23}$$

and

$$\phi_z = \frac{12EI_y}{G\,A_{sz}\,\ell^2} = 24\,(1+\nu)\,\frac{A}{A_{sz}}\left(\frac{\gamma_y}{\ell}\right)^2 \tag{24}$$

If (γ_z/ℓ) and (γ_y/ℓ), representing ratios of radius of gyration to element length, are small compared with unity as in the case of a slender member, both ϕ_y and ϕ_z can be taken equal to zero in Eq. (22).

D. BOUNDARY ELEMENT

The boundary element is used for modelling foundation flexibility at the base of columns supported on either piles or mat footings and soil flexibility at both horizontal and vertical boundaries of the backfill models, when necessary. The element consists of 3 translational and 3 rotational degrees of freedom as shown in Fig. 6. The individual stiffness in each degree of freedom can be approximated using either numerical or closed form solutions [4, 10, 20]. The 6 x 6 element stiffness matrix has diagonal terms only as given by

$$\underset{6 \times 6}{[k]} = \begin{bmatrix} k_x & & & & & \\ & k_y & & & & \\ & & k_z & & & \\ & & & k_\alpha & & \\ & & & & k_\beta & \\ & & & & & k_\gamma \end{bmatrix} \tag{25}$$

III. SOLUTION TECHNIQUES

This chapter discusses the formulation and solution of the dynamic equilibrium equations of motion for the complete soil-structure system. Included are discussions of the Guyan matrix reduction procedure, the step-by-step integration and iteration procedures used in solving the equations, the variable time step procedure for controlling overshooting errors, and finally the prescribed earthquake ground motions used in the study.

A. EQUATIONS OF MOTION

The dynamic force equilibrium equations of motion associated with the nodes of the complete soil-structure system can be expressed in the form [7]

$$\underline{F}^{I} + \underline{F}^{D} + \underline{F}^{S} = \underline{R} \tag{26}$$

where $\underline{F}^{I}$ is the inertia force vector, $\underline{F}^{D}$ is the damping force vector, $\underline{F}^{S}$ is the internal resisting force vector caused by deformations in the system, and $\underline{R}$ is the external load vector. For linear elastic systems, the internal resisting force vector can be expressed in terms of the nodal displacement vector $\underline{u}$ through the relation

$$\underline{F}^{S} = \underline{K}\,\underline{u} \tag{27}$$

where $\underline{K}$ is the stiffness matrix of the structure. Likewise, the inertia and damping force vectors can be expressed in the form

$$\underline{F}^{I} = \underline{M}\,\ddot{\underline{u}} \tag{28}$$

$$\underline{F}^{D} = \underline{C}\,\dot{\underline{u}} \tag{29}$$

where $\underset{\sim}{M}$ and $\underset{\sim}{C}$ are the mass and damping matrices, respectively. For rigid base earthquake excitation, the external force vector has the form

$$\underset{\sim}{R} = - \ddot{u}_g \underset{\sim}{M} \left(g_x \begin{Bmatrix} 1 \\ 0 \\ 0 \\ \cdot \\ \cdot \\ \cdot \\ 1 \\ 0 \\ 0 \end{Bmatrix} + g_y \begin{Bmatrix} 0 \\ 1 \\ 0 \\ \cdot \\ \cdot \\ \cdot \\ 0 \\ 1 \\ 0 \end{Bmatrix} + g_z \begin{Bmatrix} 0 \\ 0 \\ 1 \\ \cdot \\ \cdot \\ \cdot \\ 0 \\ 0 \\ 1 \end{Bmatrix} \right) \tag{30}$$

where $\ddot{u}_g$ is the prescribed one-dimensional ground acceleration and g_x, g_y, and g_z are its direction cosines with respect to the x, y, and z axes, respectively.

For nonlinear systems, it is convenient to write the dynamic force equilibrium equations of motion in the incremental form [25]

$$\left(\underset{\sim}{F}_t^I + \Delta \underset{\sim}{F}_t^I\right) + \left(\underset{\sim}{F}_t^D + \Delta \underset{\sim}{F}_t^D\right) + \left(\underset{\sim}{F}_t^S + \Delta \underset{\sim}{F}_t^S\right) = \underset{\sim}{R}_{t+\Delta t} \tag{31}$$

where subscripts t and $t+\Delta t$ represent times at the beginning and end of a time increment of duration Δt, respectively. The incremental force vectors over the interval Δt become

$$\Delta \underset{\sim}{F}_t^I = \underset{\sim}{M}_t \; \Delta \ddot{\underset{\sim}{u}}_t \tag{32}$$

$$\Delta \underset{\sim}{F}_t^D = \underset{\sim}{C}_t \; \Delta \dot{\underset{\sim}{u}}_t \tag{33}$$

$$\Delta \underset{\sim}{F}_t^S = \underset{\sim}{K}_t \; \Delta \underset{\sim}{u}_t ; \tag{34}$$

thus, Eq. (31) can be written in the form

$$\underset{\sim}{M}_t \, \Delta\ddot{\underset{\sim}{u}}_t + \underset{\sim}{C}_t \, \Delta\dot{\underset{\sim}{u}}_t + \underset{\sim}{K}_t \, \Delta\underset{\sim}{u}_t = \underset{\sim}{R}_{t+\Delta t} - \left(\underset{\sim}{F}_t^I + \underset{\sim}{F}_t^D + \underset{\sim}{F}_t^S\right) \quad (35)$$

This equation can be solved by standard numerical procedures for $\Delta\underset{\sim}{u}_t$. Note that the subscript t associated with matrices $\underset{\sim}{M}_t$, $\underset{\sim}{C}_t$, and $\underset{\sim}{K}_t$ indicate that these physical properties vary with the time-dependent response; thus, the incremental form given by Eq. (35) is approximate unless complete equilibrium is achieved at the end of each time increment Δt. Normally, complete equilibrium is not achieved in which case the residual force vector

$$\Delta\underset{\sim}{P}_{t+\Delta t} = \underset{\sim}{R}_{t+\Delta t} - \left(\underset{\sim}{F}^I_{t+\Delta t} + \underset{\sim}{F}^D_{t+\Delta t} + \underset{\sim}{F}^S_{t+\Delta t}\right) \quad (36)$$

indicates the errors involved. To correct for these errors, the residual force vector can be evaluated at the end of each time increment Δt and then be added to the right hand side of Eq. (35) before proceeding on with the numerical iteration.

In the nonlinear analysis of this investigation, matrices $\underset{\sim}{M}_t$ and $\underset{\sim}{C}_t$ are considered constant in time, i.e. $\underset{\sim}{M}_t = \underset{\sim}{M}$ and $\underset{\sim}{C}_t = \underset{\sim}{C}$; however, matrix $\underset{\sim}{K}_t$ must be retained in its time dependent form requiring retriangularization at each time step [7]. It is convenient to express $\underset{\sim}{K}_t$ in terms of its initial tangent value $\underset{\sim}{K}$ and its incremental change $\Delta\underset{\sim}{K}_t$. The force vector associated with the nonlinear incremental changes can be placed on the right hand side of the equilibrium equation and be treated as an effective load vector; thus, Eq. (35) can be written in the form

$$\underset{\sim}{M} \, \Delta\ddot{\underset{\sim}{u}}_t + \underset{\sim}{C} \, \Delta\dot{\underset{\sim}{u}}_t + (\underset{\sim}{K} - \Delta\underset{\sim}{K}_t) \, \Delta\underset{\sim}{u}_t = \underset{\sim}{R}_{t+\Delta t} - \left(\underset{\sim}{F}_t^I + \underset{\sim}{F}_t^D + \underset{\sim}{F}_t^S\right) \quad (37)$$

or

$$\underline{M}\,\Delta\ddot{\underline{u}}_t + \underline{C}\,\Delta\dot{\underline{u}}_t + \underline{K}\,\Delta\underline{u}_t = \underline{R}_{t+\Delta t} - \left(\underline{F}_t^I + \underline{F}_t^D + \underline{F}_t^S\right) + \Delta\underline{K}_t\,\Delta\underline{u}_t \quad (38)$$

B. MASS MATRIX

In the present investigation, all masses are assumed concentrated at the nodal points which leads to a diagonal mass matrix of the form

$$\underline{M} = \text{diag} < M_1\ M_2\ \ldots\ M_n > \quad (39)$$

where M_i is the mass associated with the i^{th} degree of freedom and n is the total number of degrees of freedom in the system. No rotational moments of inertia are assigned to the lumped massed; therefore, the M_i's associated with rotational degrees of freedom equal zero.

C. STIFFNESS MATRIX

As pointed out previously, the complete stiffness matrix $\underline{K}_t$ at a particular time t can be expressed as the sum of the initial tangent stiffness matrix $\underline{K}$ and the incremental stiffness matrix $\Delta\underline{K}_t$, i.e.

$$\underline{K}_t = \underline{K} - \Delta\underline{K}_t \quad (40)$$

The individual element stiffnesses for each time interval are obtained by the procedures described in Chapter II. The initial tangent stiffness matrix $\underline{K}$ is assembled by the standard direct stiffness method [6]; however, the incremental stiffness matrix $\Delta\underline{K}_t$ must be treated differently. Since in the numerical examples carried out, the frictional element was the only nonlinear element in the system, the incremental stiffness matrix $\Delta\underline{K}_t$ for the entire soil-structure system contained relatively few nonzero elements. Thus, the effort involved in computing the term $\Delta \underline{K}_t \, \Delta \underline{u}_t$ in Eq. (38) is relatively small even though an iteration is involved for each time step Δt. This iteration starts by using the initial values $\Delta \underline{u}_{t-\Delta t}$ for $\Delta \underline{u}_t$ which are then changed through successive iterations towards their correct values $\Delta \underline{u}_t$. These iterative multiplications are carried out at the element level to reduce computational effort [11], i.e. one makes use of the relation

$$\Delta \underline{K}_t \, \Delta \underline{u} = \sum_{m=1}^{N} \Delta \underline{K}_t^m \, \Delta \underline{u} \qquad (41)$$

in which $\Delta \underline{K}_t^m$ is the incremental stiffness associated with the m^{th} frictional element and N is the total number of frictional elements. In this equation, subscript t has been dropped from $\Delta \underline{u}$ to reflect the changing values associated with the iteration process.

D. DAMPING MATRIX

Various methods have been used by investigators in evaluating the viscous damping matrix corresponding to matrix $\underline{C}$ in Eq. (38) [13]. Wilson and Penzien describe two methods for evaluating this matrix [28]. The first method relates the modal damping ratios to the coefficients in the Caughey series form for $\underline{C}$ [3]. If only the first two terms in this series are used, Rayleigh damping results, i.e. the damping matrix is a linear combination of the mass and stiffness matrices. The second method of Wilson and Penzien is a direct approach whereby the damping matrix is expressed in terms of a series of matrices each controlling damping in only one normal model. Clough describes another type of damping called "structural damping" which yields a damping force vector proportional to displacements but in phase with the velocities [7]. The above three types of damping will now be described in more detail.

1. Rayleigh Damping - Rayleigh damping is given by the first two terms of the Caughey series, i.e.

$$\underline{C} = \alpha \underline{M} + \beta \underline{K} \tag{42}$$

where α and β are scalar quantities having units consistent with the other units involved in this equation. By properly selecting these scalar values, the damping ratios in two normal modes can be controlled. It can be shown that these quantities are related to the damping ratios for modes i and j through the equations

$$\alpha = \frac{2\ \omega_i\ \omega_j\ (\xi_j\ \omega_i - \xi_i\ \omega_j)}{(\omega_i^2 - \omega_j^2)} \tag{43}$$

$$\beta = \frac{2\ (\xi_i\ \omega_i - \xi_j\ \omega_j)}{(\omega_i^2 - \omega_j^2)} \tag{44}$$

Further, it can be shown that if α and β satisfy these equations, the damping ratio in any other normal mode, say mode n, is given by

$$\xi_n = \frac{\alpha + \beta\ \omega_n^2}{2\ \omega_n} \tag{45}$$

In the present investigation, the numerical values of α and β were determined by specifying the damping ratios in the two most dominant modes of the initial elastic system. These values were then held constant throughout the time history of response including those periods of time when the system responded inelastically.

2. Direct Damping - By the direct method of Wilson and Penzien, the damping matrix controlling mode r only is given by

$$\underset{\sim}{C}_r = \beta_r \underset{\sim}{\theta}_r \underset{\sim}{\theta}_r^T \tag{46}$$

where the $\underset{\sim}{\theta}_r$ represents the mass normalized mode shape matrix given by

$$\underset{\sim}{\theta}_r = \underset{\sim}{M} \underset{\sim}{\phi}_r \tag{47}$$

where $\underset{\sim}{\phi}_r$ is the r^{th} mode shape vector. The scalar quantity β_r is obtained using the relation

$$\beta_r = \frac{2 \xi_r \omega_r}{M_r} \tag{48}$$

where ξ_r is the damping ratio of the r^{th} mode, ω_r is the frequency of the r^{th} mode, and M_r is the generalized mass of the r^{th} mode, i.e.

$$M_r = \underset{\sim}{\phi}_r^T \underset{\sim}{M} \underset{\sim}{\phi}_r \tag{49}$$

The total damping matrix is then given by a summation over all N modes; thus,

$$\underset{\sim}{C} = \sum_{r=1}^{N} \underset{\sim}{C}_r \tag{50}$$

(3) Structural Damping - For structural damping, the damping force vector is proportional to the elastic force vector $\underset{\sim}{F}_t^S$ as given by

$$\underset{\sim}{F}_t^D = b \; \hat{\underset{\sim}{F}}_t^S \tag{51}$$

where b is the proportionality factor and where the sign of each component in the vector is the same as the sign of the corresponding velocity component (the triangular "hat" symbol above vector $\underline{F}_t^S$ denotes this procedure in selecting the sign of each component). If damping is variable throughout the system, the proportionality factor b is replaced by a diagonal intensity matrix $\hat{\underline{B}}$; thus,

$$\underline{F}_t^D = \underline{B}\ \hat{\underline{F}}_t^S \tag{52}$$

$$\Delta\underline{F}_t^D = \underline{B}\ \Delta\hat{\underline{F}}_t^S = \underline{B}\ (\underline{K} - \Delta\underline{K}_t)\ \Delta\hat{\underline{u}}_t \tag{53}$$

where $\Delta\hat{\underline{u}}_t$ is the vector $\Delta\underline{u}_t$ with signs corresponding to the signs in the vector $\dot{\underline{u}}_t$.

E. GUYAN MATRIX REDUCTION

1. Linear Systems - To reduce computational effort the Guyan Matrix Reduction technique has been used effectively for linear systems [12, 14, 16, 17, 22]. By this technique, the independent degrees of freedom $\underline{u}$ in the system are separated into two sets $\underline{u}_o$ and $\underline{u}_a$ such that $\underline{u}_o$ can be eliminated before solving a reduced set of equations of motion. Consider first the static equilibrium equation

$$\underline{K}\ \underline{u} = \underline{R} \tag{54}$$

which may be written in the partitioned form

$$\begin{bmatrix} \underline{K}_{aa} & \underline{K}_{ao} \\ \underline{K}_{ao}^T & \underline{K}_{oo} \end{bmatrix} \begin{Bmatrix} \underline{u}_a \\ \underline{u}_o \end{Bmatrix} = \begin{Bmatrix} \underline{R}_a \\ \underline{R}_o \end{Bmatrix} \tag{55}$$

Solving for $\underline{u}_o$ in the second of Eqs. (55) and substituting back into the first gives the reduced static equilibrium equation

$$\underline{K}_{aa}^{R} \underline{u}_{a} = \underline{R}_{a}^{R} \tag{56}$$

where the reduced stiffness matrix $\underline{K}_{aa}^{R}$ and the reduced force vector are given by

$$\underline{K}_{aa}^{R} = \underline{K}_{aa} + \underline{K}_{ao} \underline{G}_{o} \tag{57}$$

and

$$\underline{R}_{a}^{R} = \underline{R}_{a} + \underline{G}_{o}^{T} \underline{R}_{o} , \tag{58}$$

respectively, and where the transformation stiffness matrix $\underline{G}_{o}$ is obtained by solving the equation

$$\underline{K}_{oo} \underline{G}_{o} = - \underline{K}_{ao}^{T} \tag{59}$$

Having solved for $\underline{u}_{a}$ in Eq. (56), $\underline{u}_{o}$ can then be obtained using the relation

$$\underline{u}_{o} = \underline{K}_{oo}^{-1} \underline{R}_{o} + \underline{G}_{o} \underline{u}_{a} \tag{60}$$

In the present analysis, the response quantities of main interest are the displacements of the column nodal points. Therefore, when using the Guyan Matrix Reduction method, it is advantageous to let the vector $\underline{u}_{o}$ contain the displacements of the nodal points within the backfills and the bridge deck and to place the displacements of the remaining nodal points within the columns in the vector $\underline{u}_{a}$.

In carrying out a linear dynamic analysis, the above matrix reduction procedure can also be used to reduce the inertia term $\underline{M}\,\ddot{\underline{u}}$ to the form $\underline{M}_{aa}^{R} \ddot{\underline{u}}_{a}$ in which case the reduced mass matrix is given by

$$\underline{M}_{aa}^{R} = \underline{M}_{aa} + \underline{M}_{ao} \underline{G}_{o} + \underline{G}_{o}^{T} \underline{M}_{ao}^{T} + \underline{G}_{o}^{T} \underline{M}_{oo} \underline{G}_{o} \tag{61}$$

When using a lumped mass system, the off-diagonal terms in matrix $\underset{\sim}{M}$ are all zero in which case Eq. (61) reduces to

$$\underset{\sim}{M}_{aa}^{R} = \underset{\sim}{M}_{aa} + \underset{\sim}{G}_{o}^{T} \underset{\sim}{M}_{oo} \underset{\sim}{G}_{o} \qquad (62)$$

2. Nonlinear Systems - For a general nonlinear system, the Guyan reduction procedure may be very inefficient due to the time dependency of stiffness matrix $\underset{\sim}{K}_t$ which could require using the reduction procedure each time step of the numerical integration. However, for the nonlinear system considered herein, the reduction procedure is still very efficient as in the case of the linear system for two reasons. First, the nonlinear system considered has relatively few nonlinear elements which are concentrated at the interfaces of abutments and backfills. Second, the procedure allows a shifting of the time dependent stiffness coefficients to the right hand side of the equation of motion so that the reduction procedure need only be applied once during the entire time of integration.

Following the same reasoning as in the case of the linear system, consider first the quasi-static equilibrium equation

$$\underset{\sim}{K}_t \underset{\sim}{u} = \underset{\sim}{R} \qquad (63)$$

which corresponds to Eq. (54) in the linear case. Making use of Eq. (40), this equation can be written in the form

$$[\underset{\sim}{K} - \Delta\underset{\sim}{K}_t] \underset{\sim}{u} = \underset{\sim}{R} \qquad (64)$$

Separating vector $\underset{\sim}{u}$ into two parts, namely $\underset{\sim}{u}_o$ and $\underset{\sim}{u}_a$, this equation becomes

$$\begin{bmatrix} \underline{K}_{aa} & \underline{K}_{ao} \\ \underline{K}_{ao}^T & \underline{K}_{oo} \end{bmatrix} \begin{Bmatrix} \underline{u}_a \\ \underline{u}_o \end{Bmatrix} - \begin{bmatrix} \Delta\underline{K}_t^R & \underline{0} \\ \underline{0} & \underline{0} \end{bmatrix} \begin{Bmatrix} \underline{u}_a \\ \underline{u}_o \end{Bmatrix} = \begin{Bmatrix} \underline{R}_a \\ \underline{R}_o \end{Bmatrix} \quad (65)$$

It is necessary, of course, that vector $\underline{u}_o$ which is to be eliminated not contain any components having time dependent stiffness coefficients consistent with the form of Eq. (65). Note that the nonlinear (or time dependent) reduced stiffness matrix $\Delta\underline{K}_t^R$ is the upper left submatrix in the coefficient matrix of the second term with the other three submatrices being zero matrices.

Solving for $\underline{u}_o$ in the second of Eqs. (65) and substituting back into the first gives the reduced static equilibrium equation

$$\underline{K}_{aa}^R \, \underline{u}_a = \underline{R}_a^R + \Delta\underline{K}_t^R \, \underline{u}_a \quad (66)$$

where the reduced stiffness matrix $\underline{K}_{aa}^R$ and the reduced force vector $\underline{R}_a^R$ are of the same forms given by Eqs. (57) and (58), respectively.

When carrying out a dynamic analysis, the reduction of the inertia term $\underline{M}\,\ddot{\underline{u}}$ to the reduced form $\underline{M}_{aa}^R\,\ddot{\underline{u}}_a$ is identical to that previously discussed for the linear system, i.e. Eqs. (61) and (62) are all applicable to the nonlinear case being considered.

Since the damping matrix is expressed in terms of the mass and stiffness matrices as shown by Eqs. 42, 46, and 53, the reduced mass and stiffness matrices can be used directly in defining the reduced damping matrix.

F. STEP-BY-STEP INTEGRATION PROCEDURES

After applying the Guyan reduction procedure as previously described, the resulting incremental reduced equations of motion are identical in form to those given by matrix Eq. (38), except that all quantities are of the reduced form. These equations can be solved numerically using various procedures [1, 19, 23]. The differences in these procedures relate to the analytical form of the variation in acceleration over the time interval Δt. In the investigation presented herein, two different forms have been used, namely, the constant acceleration method and the Wilson θ-method. These forms express the velocity and displacement vectors at time $t+\Delta t$ in terms of the velocity and displacement vector at time t and the acceleration vectors at times $t+\Delta t$ and $t+\theta\Delta t$ when using the constant acceleration and Wilson θ-methods, respectively. Since three forms of damping were used in the investigation, the step-by-step integration procedures will be developed for each case.

1. Constant-Acceleration Method - This form of acceleration over interval Δt leads to the relations

$$\dot{\underline{u}}_{t+\Delta t} = \dot{\underline{u}}_t + \frac{1}{2}\Delta t\,\ddot{\underline{u}}_t + \frac{1}{2}\Delta t\,\ddot{\underline{u}}_{t+\Delta t} \tag{67}$$

$$\underline{u}_{t+\Delta t} = \underline{u}_t + \Delta t\,\dot{\underline{u}}_t + \frac{1}{4}\Delta t^2\,\ddot{\underline{u}}_t + \frac{1}{4}\Delta t^2\,\ddot{\underline{u}}_{t+\Delta t} \tag{68}$$

Introducing incremental vectors as defined by

$$\Delta\ddot{\underline{u}}_t \equiv \ddot{\underline{u}}_{t+\Delta t} - \ddot{\underline{u}}_t \tag{69}$$

$$\Delta\dot{\underline{u}}_t \equiv \dot{\underline{u}}_{t+\Delta t} - \dot{\underline{u}}_t \tag{70}$$

$$\Delta\underline{u}_t \equiv \underline{u}_{t+\Delta t} - \underline{u}_t \tag{71}$$

and making use of Eqs. (67) and (68), one obtains

$$\Delta\ddot{\underline{u}}_t = \frac{4}{\Delta t^2}\,\Delta\underline{u}_t - \frac{4}{\Delta t}\,\dot{\underline{u}}_t - 2\,\ddot{\underline{u}}_t \tag{72}$$

$$\Delta\dot{\underline{u}}_t = \frac{2}{\Delta t}\,\Delta\underline{u}_t - 2\,\dot{\underline{u}}_t \tag{73}$$

Using these relations, Eq. (38) can be written in the form

$$\bar{\underline{K}}\,\Delta\underline{u}_t = \underline{p}_{t+\Delta t} + \Delta\underline{K}_t\,\Delta\underline{u}_t \tag{74}$$

where $\bar{\underline{K}}$ and $\underline{p}_{t+\Delta t}$ take on different forms depending upon the type of damping assumed as follows:

(a) Direct Damping

$$\bar{\underline{K}} = \frac{4}{\Delta t^2}\,\underline{M} + \frac{2}{\Delta t}\,\underline{C} + \underline{K} \tag{75}$$

$$\underline{p}_{t+\Delta t} = \underline{R}_{t+\Delta t} + \underline{M}\left(\frac{4}{\Delta t}\,\dot{\underline{u}}_t + \ddot{\underline{u}}_t\right) + \underline{C}\,\dot{\underline{u}}_t - \underline{K}\,\underline{u}_t + \sum_{i=\Delta t}^{t-\Delta t} \Delta\underline{K}_i\,\Delta\underline{u}_i \tag{76}$$

(b) Rayleigh Damping

$$\bar{\underline{K}} = \frac{4}{\Delta t^2}\,\underline{M} + \frac{2}{\Delta t}\,\underline{C} + \underline{K} \tag{77}$$

$$\underline{p}_{t+\Delta t} = \underline{R}_{t+\Delta t} + \underline{M}\left(\frac{4}{\Delta t}\,\dot{\underline{u}}_t + \ddot{\underline{u}}_t\right) + \underline{C}\,\dot{\underline{u}}_t - \underline{K}\,\underline{u}_t + \sum_{i=\Delta t}^{t-\Delta t} \Delta\underline{K}_i\,\Delta\underline{u}_i \tag{78}$$

$$\underline{C} = \alpha\,\underline{M} + \beta\,\underline{K} \tag{79}$$

(c) Structural Damping

$$\bar{\underline{K}} = \frac{4}{\Delta t^2}\,\underline{M} + \underline{K} \tag{80}$$

$$\underline{p}_{t+\Delta t} = \underline{R}_{t+\Delta t} + \underline{M}\left(\frac{4}{\Delta t}\dot{\underline{u}}_t + \ddot{\underline{u}}_t\right) - \underline{K}\,\underline{u}_t$$

$$+ \sum_{i=\Delta t}^{t-\Delta t} \Delta\underline{K}_i\,\Delta\underline{u}_i - \underline{B}\,\underline{K}\sum_{i=\Delta t}^{t-\Delta t}\Delta\hat{\underline{u}}_i + \sum_{i=\Delta t}^{t-\Delta t} B\,\Delta\underline{K}_i\,\Delta\hat{\underline{u}}_i$$

$$- \underline{B}\,\underline{K}\,\Delta\hat{\underline{u}}_t + \underline{B}\,\Delta\underline{K}_t\,\Delta\hat{\underline{u}}_t \qquad (81)$$

2. Wilson θ-Method - This form of acceleration which assumes a linear variation over the interval $\tau = \theta\,\Delta t$ (where $\theta \geq 1.0$), leads to the relations

$$\dot{\underline{u}}_{t+\tau} = \dot{\underline{u}}_t + \frac{\tau}{2}\,(\ddot{\underline{u}}_{t+\tau} + \ddot{\underline{u}}_t) \qquad (82)$$

$$\underline{u}_{t+\tau} = \underline{u}_t + \tau\,\dot{\underline{u}}_t + \frac{\tau^2}{6}\,(\ddot{\underline{u}}_{t+\tau} + 2\,\ddot{\underline{u}}_t)\ ; \qquad (83)$$

thus, one obtains

$$\ddot{\underline{u}}_{t+\tau} = \frac{6}{\tau^2}\,(\underline{u}_{t+\tau} - \underline{u}_t) - \frac{6}{\tau}\,\dot{\underline{u}}_t - 2\,\ddot{\underline{u}}_t \qquad (84)$$

$$\dot{\underline{u}}_{t+\tau} = \frac{3}{\tau}\,(\underline{u}_{t+\tau} - \underline{u}_t) - 2\,\dot{\underline{u}}_t - \frac{\tau}{2}\,\ddot{\underline{u}}_t \qquad (85)$$

Using these relations, Eq. (38) can again be written in the form

$$\bar{\underline{K}}\,\Delta\underline{u}_t = \underline{p}_{t+\Delta t} + \Delta\underline{K}_t\,\Delta\underline{u}_t \qquad (86)$$

where $\bar{\underline{K}}$ and $\underline{p}_{t+\Delta t}$ take on different forms as follows:

(a) Direct Damping

$$\bar{\underline{K}} = \frac{6}{\tau^2}\,\underline{M} + \frac{3}{\tau}\,\underline{C} + \underline{K} \qquad (87)$$

$$\mathbf{p}_{t+\Delta t} = \mathbf{R}_t + \theta\,(\mathbf{R}_{t+\Delta t} - \mathbf{R}_t) + \mathbf{M}\left(\frac{6}{\tau^2}\,\dot{\mathbf{u}}_t + 2\,\ddot{\mathbf{u}}_t\right)$$

$$+ \mathbf{C}\left(2\,\dot{\mathbf{u}}_t + \frac{\tau}{2}\,\ddot{u}_t\right) - \mathbf{K}\,\mathbf{u}_t + \sum_{i=\Delta t}^{t-\Delta t} \Delta\mathbf{K}_i\,\Delta\mathbf{u}_i \qquad (88)$$

(b) Rayleigh Damping

$$\bar{\mathbf{K}} = \frac{6}{\tau^2}\,\mathbf{M} + \frac{3}{\tau}\,\mathbf{C} + \mathbf{K} \qquad (89)$$

$$\mathbf{p}_{t+\Delta t} = \mathbf{R}_t + \theta\,(\mathbf{R}_{t+\Delta t} - \mathbf{R}_t) + \mathbf{M}\left(\frac{6}{\tau^2}\,\dot{\mathbf{u}}_t + 2\,\ddot{\mathbf{u}}_t\right)$$

$$+ \mathbf{C}\left(2\,\dot{\mathbf{u}}_t + \frac{\tau}{2}\,\ddot{\mathbf{u}}_t\right) - \mathbf{K}\,\mathbf{u}_t + \sum_{i=\Delta t}^{t-\Delta t} \Delta\mathbf{K}_i\,\Delta\mathbf{u}_i \qquad (90)$$

$$\mathbf{C} = \alpha\,\mathbf{M} + \beta\,\mathbf{K} \qquad (91)$$

(c) Structural Damping

$$\bar{\mathbf{K}} = \frac{6}{\tau^2}\,\mathbf{M} + \mathbf{K} \qquad (92)$$

$$\mathbf{p}_{t+\Delta t} = \mathbf{R}_t + \theta\,(\mathbf{R}_{t+\Delta t} - \mathbf{R}_t) + \mathbf{M}\left(\frac{6}{\tau}\,\dot{\mathbf{u}}_t + 2\,\ddot{\mathbf{u}}_t\right)$$

$$- \mathbf{K}\,\mathbf{u}_t + \sum_{i=\Delta t}^{t-\Delta t} \Delta\mathbf{K}_i\,\Delta\mathbf{u}_i - \mathbf{B}\,\mathbf{K} \sum_{i=\Delta t}^{t-\Delta t} \Delta\hat{\mathbf{u}}_i$$

$$+ \sum_{i=\Delta t}^{t-\Delta t} \mathbf{B}\,\Delta\mathbf{K}_i\,\Delta\hat{\mathbf{u}}_i - \mathbf{B}\,\mathbf{K}\,\Delta\hat{\mathbf{u}}_t + \mathbf{B}\,\Delta\mathbf{K}_t\,\Delta\hat{\mathbf{u}}_t \qquad (93)$$

G. ITERATION PROCEDURES

The dynamic equilibrium equations of motion, Eq. (38), can be solved by iteration for the unknown vector $\Delta\mathbf{u}_t$ which appears on both sides of the equation. Two different solution methods have been employed in the present investigation [2, 5, 9, 11, 18]. To explain these two procedures, express the incremental vector $\Delta \underline{u}_t$ as $\underline{x}^t$ which is to be approached iteratively through $\underline{x}_n^t$, n = 1,2,...,N. In the first procedure, the total values in $\underline{x}_n^t$ are determined for all iterative steps. In the second procedure, only the incremental values Δx_n^t of $\underline{x}^t$ are determined by successive iteration until sufficient convergence is reached. Convergence is based on two different criteria. One being the Euclidean norm of the difference in incremental displacement vectors obtained by consecutive iterations, i.e. $\underline{x}_{n+1}^t - \underline{x}_n^t$, and the second being the differences in successive values of x_i. Convergence is judged to be satisfactory when the differences in successive values of x_i drop to a certain pre-assigned tolerance level.

To explain further the first procedure mentioned above, consider $\underline{x}_n^t$ which is an approximation of $\underline{x}^t$. An improved value of $\underline{x}^t$ is obtained by solving for $\underline{x}_{n+1}^t$ using the equation

$$\underline{\bar{K}} \; \underline{x}_{n+1}^t = \underline{p} + \Delta \underline{K} \; \underline{x}_n^t \qquad n = 1,2,\ldots,N \tag{94}$$

To start this iteration, $\underline{x}_1^t$ is assumed to be the value finally reached for the previous time step, i.e. equal to $\underline{x}^{t-1}$. The second procedure makes use of the relations

$$\underline{\bar{K}} \; \underline{x}_o^t = \underline{p} + \Delta \underline{K} \; \underline{x}^{t-1} \tag{95}$$

$$\underline{\bar{K}} \; \Delta \underline{x}_n^t = \Delta \underline{K} \; \Delta \underline{x}_{n-1}^t \qquad n = 1,2,\ldots,N \tag{96}$$

$$\underline{x}_n^t = \sum_{i=1}^{n} \Delta \underline{x}_i^t + \underline{x}_o^t \tag{97}$$

$$\Delta \underline{x}_o^t = \underline{x}_o^t - \underline{x}^{t-1} \tag{98}$$

H. OVERSHOOT TOLERANCE AND VARIABLE TIME STEP

As explained previously in Chapter II and illustrated in Fig. 5, the normal stress-strain relation of the frictional element is a bilinear elastic function which is assigned a very large modulus in the compression region and zero modulus in the tension region. During transition from one region to the other, the regular numerical integration procedure permits an overshoot error to occur as shown in Fig. 7a. Experience shows that this error can accumulate over a number of cycles as shown in Fig. 7b; thus, becoming unacceptably large.

To reduce this error to an acceptable level, a variable time step interval can be used over the last regular interval which passes through the transition, i.e. the interval is changed to $\Delta t/n$, whenever it is found necessary to do so. Since the numerous frictional elements experience the transition at different instants of time during response, it is impractical from a computer usage point of view to apply the shorter interval every time a transition occurs. However, it is practical to use the shorter intervals provided they are used only when the overshoot error introduced by the regular interval exceeds a specified tolerance value. Thus, by properly specifying a tolerance value and the transition integration interval $\Delta t/n$, the overshoot errors can be controlled and the computer time will remain within practical limits.

The detailed procedure used in this investigation was as follows:

(1) First, specify overshoot tolerance limits of strain in the tension and compression regions as designated by zones 1 and 2 in Fig. 8.

(2) When the transition occurs from compression to tension, yielding without stress change is assumed to take place immediately after the strain at the end of a regular interval falls within either zone 1 or zone 2. Upon the return transition from tension to compression, the large modulus is introduced only at the end of a regular interval falling in the same zone in which the preceding compression to tension transition was allowed to take place. Figure 8 illustrates this procedure, once when the transitions in both directions take place in zone 2 and again when the transitions take place in zone 1.

(3) When the overshoot is so large that the strain either falls outside both zones or falls in an unacceptable zone as described in (2) above, the computation returns to the beginning of the regular time step and proceeds forward again using the smaller time step $\Delta t/n$. In the present investigation a value of 10 was used for n and found to always satisfy the acceptable overshoot error. After the integration proceeds over the regular transition interval Δt in n steps, the method returns back to using the regular interval Δt.

I. EARTHQUAKE INPUT

In the present investigation, the ground motion was prescribed in accordance with the acceleration time-history shown in Fig. 9. This artificial accelerogram was generated by A. K. Chopra, et al., to simulate the ground motions produced by the San Fernando earthquake at the site of the Olive View Hospital located about six miles southwest of the epicenter [8]. It has a peak acceleration of 0.5g and a uniform phase of high intensity shaking for 8 seconds.

The input motion was assumed to be in the longitudinal direction of the bridge for the present study. The computer program developed in the investigation does however permit multi-directional inputs in arbitrary directions with respect to the bridge axis.

IV. NUMERICAL EXAMPLES

A number of analytical solutions have been carried out to demonstrate the methods previously described. The bridge used for this purpose was a skewed structure similar to the North Connector Undercrossing located approximately 800 feet northerly of the Route 5-San Fernando Road Interchange in the city and county of Los Angeles. Three equal spans were assumed for the idealized bridge deck as shown in Fig. 10.

Five different mathematical models (A-E) were selected for this structure as shown in Fig. 11. These models differ only in the type of skew permitted and in the arrangement of abutments and backfills. Model A has no skew and the backfills extend laterally only over the width of the bridge deck. Model B is identical to Model A except the deck is skewed 37.5°. Model C has one abutment and its backfill similar to Model A while the other abutment and its backfill are similar to Model B. The elevation views of Models A, B, and C are identical as shown in Fig. 11d. The backfills in each case extend longitudinally a distance 1.5 times their depth H. All of these three models have identical abutment and columns which are assumed to be fixed at their bases. Model D is identical to Model B except that the backfill behind each abutment extends a distance 7H in the longitudinal direction and a distance 6H beyond the deck in the transverse direction. Each backfill in this case is modelled using 4 equal layers in depth with their finite elements having 3 different widths in the longitudinal direction as shown in Fig. 11f. Model E is identical to Model D except that the abutments and backfills are of depth 2H and the bases of the columns are provided with linear translational and rotational springs representing foundation flexibility. The backfill soils are modelled using three layers of depth H/3 and one layer of depth H as shown in Fig. 11g.

Numerical results are presented for Models A-E in the subsequent sections of this chapter. Section A presents the results of linear analyses while Section B presents the results of nonlinear analyses. Computational efficiencies are demonstrated in Section C for one example case.

A. LINEAR ANALYSES

1. Duration of Input Acceleration - The computed longitudinal component of displacement at the top of the right bridge columns for the entire 15 seconds of input is shown in Fig. 12. A 3.775 second segment of this displacement time-history from about 5.7 to 9.4 seconds is shown again in Fig. 13a. If instead of using the entire 15 seconds of input only the input in this 3.775 second interval is used, the computed longitudinal component of displacement at the top of the right bridge column has the time-history shown in Fig. 13b. The displacement time histories in Figs 13a and 13b agree very well except in the beginning. This difference is, of course, due to the differences in the initial conditions imposed at the beginning of the 3.775 second segment. The point of this comparison is that the transient response caused by changes in initial conditions lasts only a very short time. Therefore, in the interest of saving of computer costs, it was decided that the methodology and computer program capabilities could be checked adequately using only the 3.775

second duration input. Therefore, all analytical results presented subsequently are computed using this input.

2. Effects of Skew on Bridge Response - The longitudinal displacement time-histories for the top of the right bridge column are shown for Models A, B, and C in Figs. 14a, 14b, and 14c, respectively. The dissimilarities in amplitudes and shapes noted in these wave forms are due to differences in amplitudes and phasing of the backfill forces on the two abutments.

Figures 15a and 15b show the time-histories of the transverse shear component in the left and right columns of Model B. The relatively low values of shear and the similarity in time-histories indicate that the dynamic backfill forces at the two abutments were nearly in-phase resulting in low torsional response of the bridge. Figures 16a and 16b show the time histories of the transverse shear component in the same two columns for Model C. The relatively large values of shear produced and the dissimilarities noted for the two columns in this case indicate that large torsional response developed due to the presence of skew at only one abutment. The backfill forces at the two abutments had large out-of-phase components.

Figures 17, 18, and 19 show time-histories of backfill force on the left and right abutment walls for Models A, B, and C, respectively. It is noted that the dynamic pressures on both walls for Models A and B are nearly in-phase, i.e. when the pressure is positive on one abutment, it is negative on the other, and vice versa. However, for Model C as shown in Fig. 19, these dynamic pressures on the two abutments differ considerably in amplitude and in their phasing. These results again provide evidence that unequal skews produce large torsional response.

To provide further comparisons of the results for Models A-C, maximum dynamic amplitudes of displacement, shear, and wall force are presented in Table 1. As indicated by the values in rows (1) and (2), the maximum amplitudes of longitudinal displacement and longitudinal shear in the right column are greatly reduced by the presence of skewed abutments. Rows (3) and (4) in this table, give maximum values of lateral shear in the left and right columns, respectively. Row (5) gives the ratio of maximum lateral shear to maximum longitudinal shear produced in the right column. The increase in this ratio with skewness indicates the corresponding increase in torsional response which induces a differential shear force between the two columns as shown at the top of Table 1. Half the difference in the shear forces of these two columns is the shear produced by torsional response. The maximum values of these torsional shears are 0.13 and 6.03 kips for Models B and C, respectively, as shown in row (6). Although the magnitude of maximum torsional shear is neglegible for Model B, it is large for Model C. The maximum amplitudes of the dynamic wall force are shown in rows (7) through (10). The ratios of maximum positive pressure on the left abutment to maximum negative pressure on the right abutment and maximum negative pressure on the left abutment to maximum positive pressure on the right abutment for both Models A and B are all equal to 1.0 which indicates the two wall pressures are in-phase with each other. Finally as indicated in row (11), the time history of the resultant of both backfill forces p(t) acts longitudinally along the axis of symmetry in the case of Model A but acts at angle $\theta(t)$ to the longitudinal axis in the case of Model B; causing no torsion in each case. However, in the case of Model C, the resultant force p(t) acting at an angle $\theta(t)$ has an eccentricity about the elastic center of the bridge. This is equivalent to its acting through the elastic center but with a torque $T(t)$ applied as shown in the table.

3. Effects of Foundation Flexibility - To study the effects of foundation flexibility on dynamic response, let us compare the results for Models D and E. The foundation flexibilities at the base of each column of Model E are modelled using 3 translational and 3 rotational springs with their spring constants established using elastic half-space theory. The flexibility at the base of each abutment wall is provided by finite element modelling of the soil below its base as shown in Fig. 11g.

The time-histories of longitudinal displacement at the top of the left column for Models D and E are shown in Figs. 20a and 20b. respectively. Noting the different displacement scales used, these two wave forms differ considerably in form and in their peak amplitudes.

To provide further comparative data, the maximum dynamic amplitudes of displacement and acceleration of the bridge deck, column shear forces, and backfill soil forces are listed in Table 2. Based on the ratios of corresponding responses for Models E and D given in rows (1) through (4) of the last column of this table, it is quite clear that the overall response of Model E having foundation flexibility is considerably greater than that for Model D. The ratios in rows (5) through (8) indicate however that the backfill soil forces for Model E are less than those of Model D. All of these ratios simply indicate that Model E has less constraint provided by its backfills than does Model D; thus, the bridge structural response is higher for Model E.

Rows (9) and (10) in Table 2 show ratios of maximum column shears to maximum total backfill force on one abutment wall. Comparing the magnitudes of these ratios confirms the above statement explaining the reason for higher overall structural response in the case of Model E.

B. NONLINEAR ANALYSIS

To study the effects of nonlinearities on seismic response, results obtained by linear and nonlinear analyses for Models A, B, and E in Fig. 10 are compared. Specifically, the effects of impact and separation between abutment wall and backfill soil are investigated and ratios of maximum response obtained by both methods of analysis are compared.

1. Effects of Impact - The most distinctive difference between the results obtained by linear and nonlinear analyses is the high acceleration produced at the point of impact in the nonlinear case. A typical acceleration time-history response for Model A is shown in Fig. 21. The high peaks of acceleration in this wave form are produced at moments of impact. While these acceleration peaks are high near the point of impact, the influence is very localized, i.e. the amplitudes of the peaks produced by impact decay rapidly with distance from the point of impact. Acceleration time-histories at the top of the left column as produced without and with impacts are shown in Figs. 22a and 22b for Model A. While the general features of the two wave forms are essentially the same, localized differences in the form of high frequency noise caused by impact are noted. This feature is better observed in Fig. 23 which shows an expanded-scale view of the first second of time-history shown in Fig. 22b.

2. Effects of Separation - A characteristic feature of allowing separation between wall and backfill soil to occur is that only positive pressure is permitted at the interface. Therefore, the backfill soils at the interfaces of both end abutments can have phase differences in their responses. Figures 24a and 24b show the time-histories of soil force on the left and right abutment walls, respectively, as determined by the nonlinear analysis for skewed Model B. Clearly there are significant out-of-phase components of response between the two abutments. Note that a small overshoot error is present during certain moments of the time-history. As previously pointed out, this overshoot error can be controlled by reducing the integration time-step and by introducing the variable time-step procedure.

The out-of-phase components of soil force on the end abutments produces a torsional response of the bridge structure. This effect is quite apparent when observing the unequal lateral shears produced in the two columns. This comparison can be made in Fig. 25 which shows the transverse shear time-histories for the two columns of Model B. While the frequency content of the two wave forms in this figure are similar, significant differences are present in the amplitudes. The maximum transverse shear produced in the left column is 16.81 kips while the maximum transverse shear in the right column is 18.95 kips. The maximum difference in the two shears is 3.72 kips.

3. Comparison of Amplitudes - For further comparison, maximum amplitudes of response obtained by linear and nonlinear analyses for Models A, B and E are shown in Table 3. The particular responses presented are longitudinal displacement and acceleration at the top of the left column and the shears in both principal directions of the

left column. In Models A and B, principal shears V_2 and V_3 are the lateral and longitudinal shears, respectively, as the column is oriented with one principal axis coinciding with the longitudinal axis of the bridge. In Model E, the column is placed so that one principal axis is oriented 52.5° from the longitudinal bridge axis.

The maximum amplitudes of dynamic response are listed for both linear and nonlinear response and for comparison purposes the ratios of linear to nonlinear response amplitudes are shown. From the results shown in Row 1 of Table 3, it is quite apparent that the displacements of Models A and B produced by nonlinear response are larger than the corresponding displacements produced by linear response. However, the reverse comparison is seen for Model E. From the results in Row 2 it is seen that the accelerations produced by the linear response are larger than the corresponding accelerations produced by nonlinear response. The differences in the amplitudes for both types of response are relatively small however. Row 3 shows a large difference in the transverse lateral shears produced in Model B. This large difference results from the torsional response produced in the nonlinear case. Row 4 shows only small differences in the longitudinal shears produced by the two types of response.

C. SEISMIC LOAD TRANSFER TO COLUMNS AND ABUTMENTS

It is of particular importance to know the division of the total longitudinal seismic deck force between the supporting columns and the abutments. To check this behavior characteristic, consider the unskewed Model A which experienced a maximum longitudinal deck acceleration of 1.09g as shown in Table 3. The tributary bridge weight for each column (center to center of spans of deck plus one-half of columns) in this case is 340 kips; thus, the estimated maximum column shear based on this tributary weight is 371 kips (340 x 1.09 = 371). Since the maximum calculated column shear as shown in Table 3 is only 47.6 kips, it is clear that most of the tributary seismic deck force (87%) is transferred to the foundation through the abutment walls. To further check this transfer characteristic, let us consider the total deck seismic force plus the seismic forces produced in the upper-half portions of both columns. The maximum combined seismic force in this case amounts to 1078 kips (989 x 1.09 = 1078) which occurs at about 2.1 seconds. The algebraic sum of the two abutment wall forces at this same instant of time is 855 kips (404 + 451 = 855; see Figs. 17a and 17b). Considering the bridge as a whole, this information indicates that about 79% of the maximum seismic force in the total deck is transferred to the foundation through the interaction of abutment walls with the backfills. Further, calculations show the maximum combined longitudinal shear in the two columns which occurs at the critical time of 2.1 seconds is approximately 94 kips. Therefore about 9% (94/1078) of the maximum seismic force is transferred to the foundation through the columns. The remaining 12% of the maximum seismic force is transferred to the foundation by shear in the abutment walls.

Making comparisons as shown above for the other bridge models gives similar results.

D. COMPUTATIONAL EFFICIENCY

Computational efficiency in the computer program is achieved through careful program arrangement and the use of three mathematical schemes, namely, the matrix reduction procedure, the iteration method, and variable time steps.

The increased efficiency through program arrangement is achieved using overlay programs which can reduce considerably the required core memory.

The increased efficiency through matrix reduction results from a decrease in the number of simultaneous equations involved and a decrease in bandwidths. If this scheme reduces the number of degrees of freedom from N to N^1 and the bandwidth from m to m^1, the ratio of computational effort required using matrix reduction to the effort required without matrix reduction is $N\ m^2/N^1 m^{1^2}$.

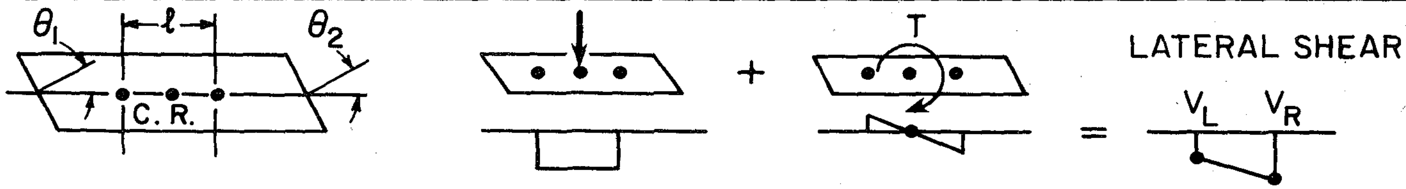
The iteration procedure used allows the normal multiple triangularization and backsubstitution of the nonlinear stiffness matrix at each time step to be substituted by only a single triangularization and backsubstitution. If the average number of iterations per time step is "i", then the ratio of computational effort required without using this scheme to the computation effort required using it is $N^1 m^{1^2}/N^1 m^1 i$ which equals m^1/i.

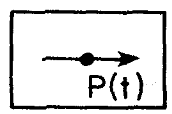
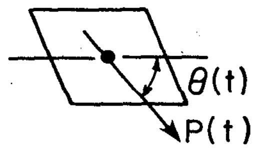
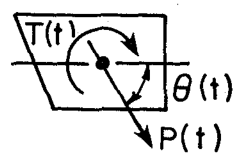
The increased efficiency using variable time steps is quite apparent; therefore, no further discussion of this procedure is needed.

To illustrate the savings in computational time which can be achieved by the above mentioned schemes consider Model E which has 402 degrees-of-freedom. Matrix reduction reduces this number to 140 and the bandwidth m which equals 93 can be reduced to 58. Therefore, the ratio of computational efforts mentioned above, i.e. $N\ m^2/N^1 m^{1^2}$ becomes $(402)(93)^2/(140)(58)^2$ or 7.4. Since the average number of iterations per time step in the nonlinear case equals 3, the computational effort ratio m^1/i becomes 58/3 or 19.3. Using the variable time step method, the total number of time steps required to produce a certain accuracy in this case was 4,040, including 8 subdivisions of 5 each to limit overshooting errors. By the standard equal interval procedure, 20,000 time steps would have been required to limit overshooting errors to the same level. Thus, the ratio of computational efforts as influenced by using (or not using) variable time steps is 20,000/4,040 which is approximately 5.

Thus, it is seen that for the above example nonlinear solution, the three above mentioned schemes lead to an overall ratio of computational efforts equal to (7.4)(19.3)(5) which approximately equals 720. Clearly, the methods used greatly increase computational efficiency. Without these special techniques the cost of solutions would be prohibitive. Even using these effective methods, the computer time for a single nonlinear solution was as great as 908 seconds using the CDC 7600 computer.

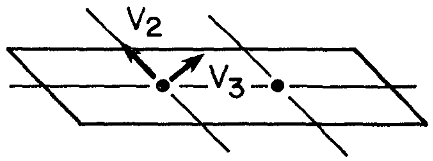
TABLE 1. EFFECTS OF SKEWNESS-MAXIMUM DYNAMIC AMPLITUDE

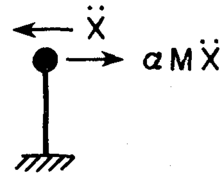


Model			A $\theta_1 = \theta_2 = 0$	B $\theta_1 = \theta_2 = 37.5°$	C $\theta_1 = 37.5°$ $\theta_2 = 0$
Long. Disp. @ Top of Rt. Col.		(1)	0.14	0.07	0.17
Long. Shear, Rt. Col.		(2)	47.37	23.70	5.64
Lateral Shear	Lt. Col.	(3)	0.	10.47	7.80
	Rt. Col.	(4)	0.	10.49	6.85
Ratio of Shear (4)/(2)		(5)	0.	0.44	1.22
Tors. Shear $T/\ell = \|V_L - V_R\|/2$		(6)	0.	0.13	6.03
Left Wall Force per ft	Tension	(7)	9.27	6.45	10.20
	Comp.	(8)	9.96	5.30	16.40
Rt. Wall Force per ft	Tension	(9)	9.96	5.30	11.20
	Comp.	(10)	9.27	6.45	12.30
Resulting Model		(11)			

Note: All displacements in inches; All forces in kips.

TABLE 2. EFFECTS OF FLEXIBILITY AT BASE

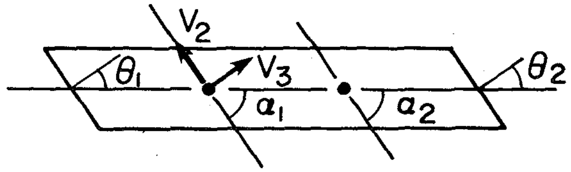
(a) 

(b) 

Maximum Response Values			Model D Fixed Base	Model E Flex. Base	Ratio E/D
Long. Disp. @ Top of Lt. Col.		(1)	0.087	0.178	2.05
Long. Accel. (g)		(2)	0.98	1.36	1.39
Shear @ Lt. Col.	V_2	(3)	31.35	55.70	1.78
	V_3	(4)	42.59	70.60	1.66
Lt. Wall Force per ft	Tension	(5)	11.06	9.98	0.91
	Comp.	(6)	13.31	8.95	0.67
Rt. Wall Force per ft	Tension	(7)	13.31	8.95	0.67
	Comp.	(8)	11.06	9.98	0.91
V_2/Wall Force,	$\frac{(3)}{(5) + (6)}$	(9)	1.29	2.95	2.29
V_3/Wall Force,	$\frac{(4)}{(5) + (6)}$	(10)	1.75	3.74	2.14

Note: All displacements in inches; All forces in kips.

TABLE 3. LINEAR Vs. NONLINEAR - MAXIMUM DYNAMIC RESPONSES



Model	A $\theta_1 = 0°$ $\theta_2 = 0°$ $\alpha_1 = 90.0$ $\alpha_2 = 90.0$			B $\theta_1 = 37.5°$ $\theta_2 = 37.5°$ $\alpha_1 = 90.0$ $\alpha_2 = 90.0$			E $\theta_1 = 37.5°$ $\theta_2 = 37.5°$ $\alpha_1 = 52.5$ $\alpha_2 = 52.5$		
Type of Analysis / Responses	Linear	Non-linear	Ratio Linear/Non-linear	Linear	Non-linear	Ratio Linear/Non-linear	Linear	Non-linear	Ratio Linear/Non-linear
Long. Disp. (1)	0.14	0.15	0.93	0.071	0.088	0.81	0.18	0.17	1.06
Long. Accel. (2)	1.09	1.05	1.04	0.80	0.75	1.07	1.36	1.31	1.04
Shear V_2 (3)				10.47	16.81	0.62	57.27	56.89	1.01
Shear V_3 (4)	47.6	51.5	0.91	29.96	28.63	1.04	70.60	68.01	1.01

Note: All displacements in inches; All accelerations in g's; All shears in kips.

V. CONCLUSIONS

Based on the studies contained herein for short bridges, conclusions can be deduced as follows:

(1) The total seismic load of the bridge deck is transmitted to the foundation primarily through the abutments with the columns carrying only a small percentage.

(2) Backfill soil forces on the two end abutments remain essentially in-phase under linear conditions but can develop significant out-of-phase components under nonlinear conditions.

(3) Skewness of a bridge tends to reduce maximum longitudinal response but it causes coupled lateral response to develop.

(4) Unequally skewed end abutments can cause both lateral and large torsional responses to develop.

(5) Foundation flexibilities at the bases of columns and abutments have significant influence on overall bridge response.

(6) Impacts at the interfaces of abutment walls and the bridge deck cause very large local transient accelerations but they have little effect on the average deck acceleration.

(7) Separations which occur between abutments and backfill soils cause significant out-of-phase components to develop in the backfill forces.

(8) The three-dimensional, nonlinear seismic response, including soil-structure interaction, can be treated analytically in a fairly efficient manner.

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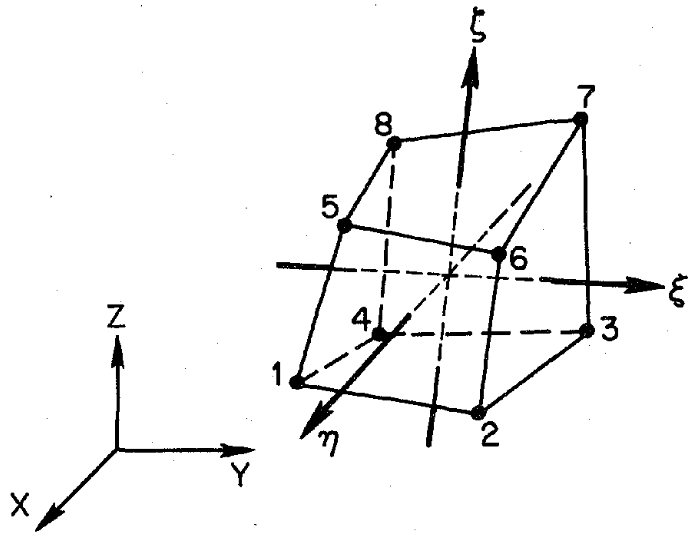
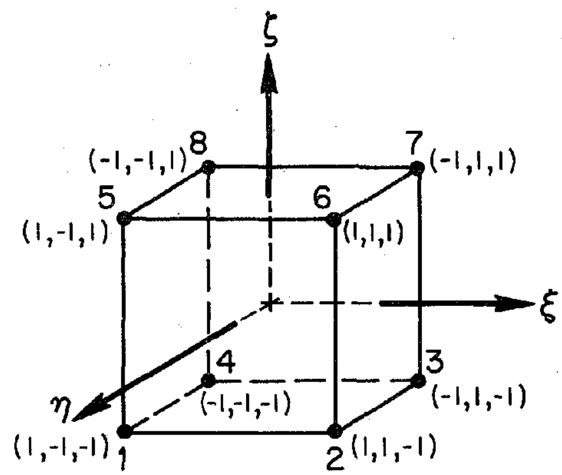


a) GLOBAL COORDINATES



b) LOCAL COORDINATES

Fig. 1 Three dimensional coordinate systems

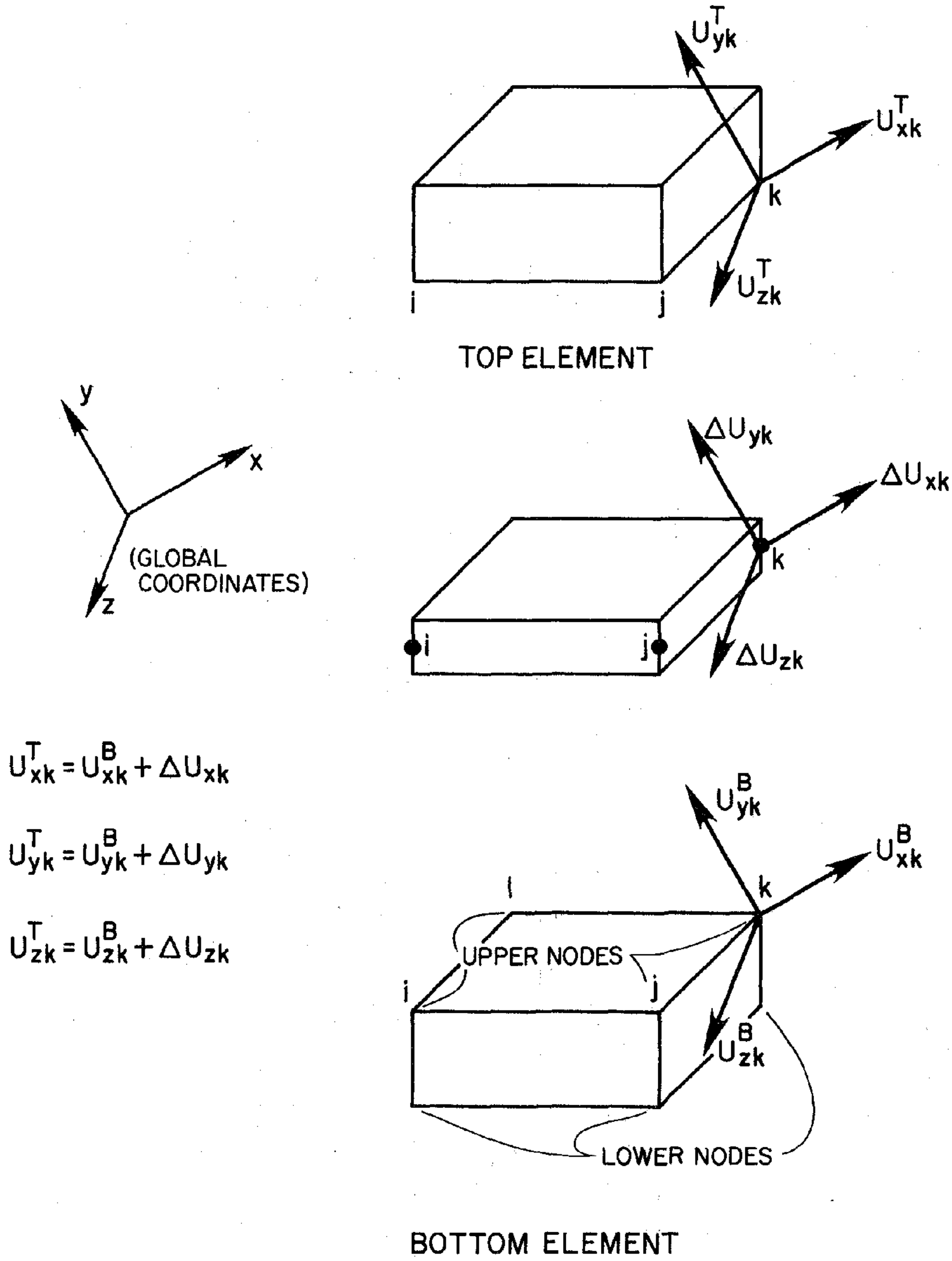


Fig. 2 Frictional element

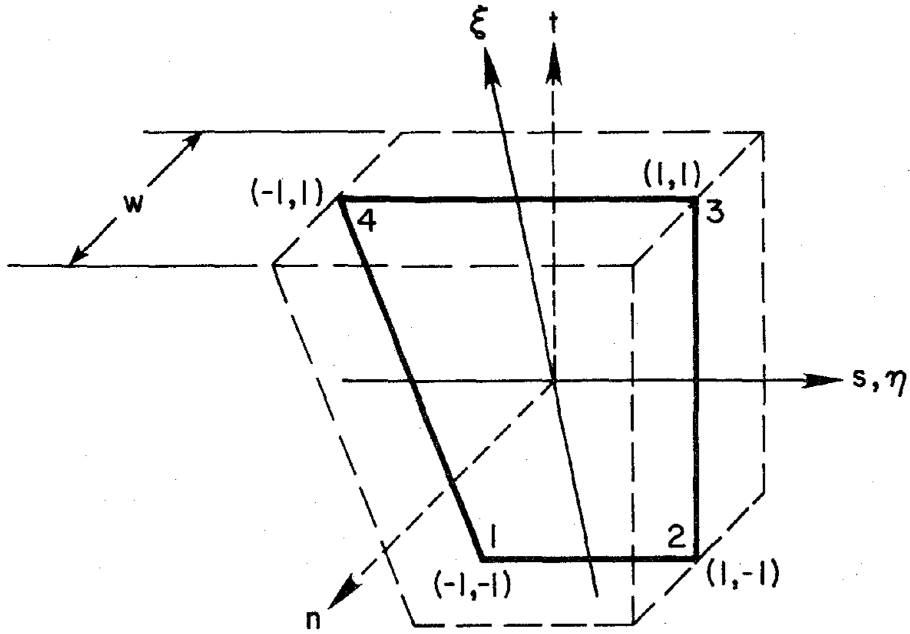


Fig. 3 Frictional element in local coordinates

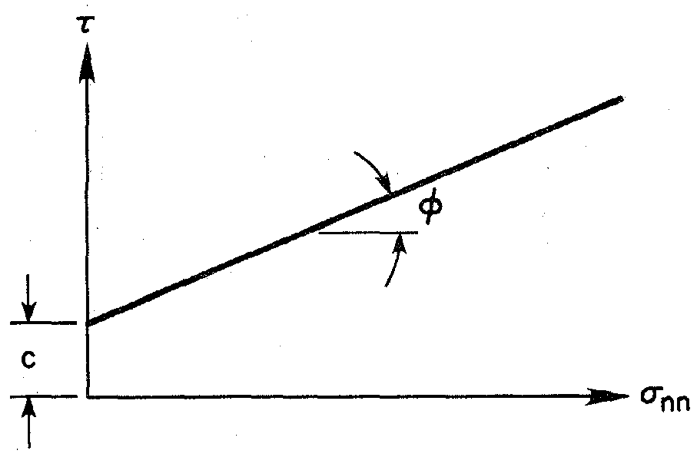


Fig. 4 Mohr-Coulomb yield criterion

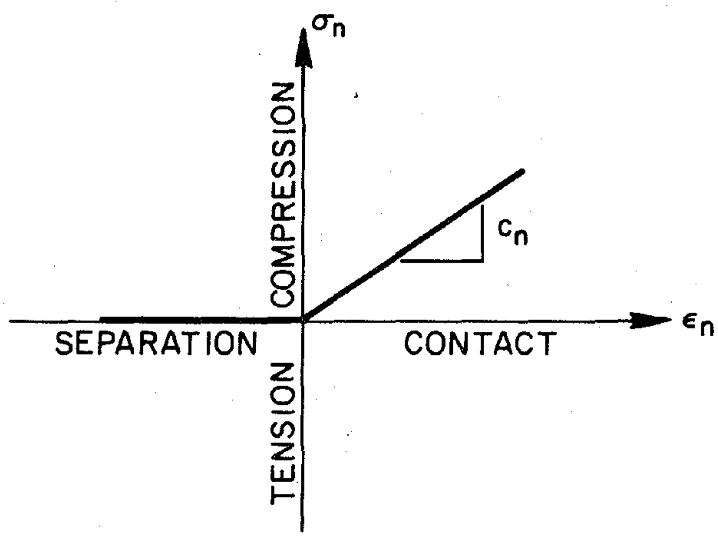


Fig. 5 Normal stress-strain relation for frictional element

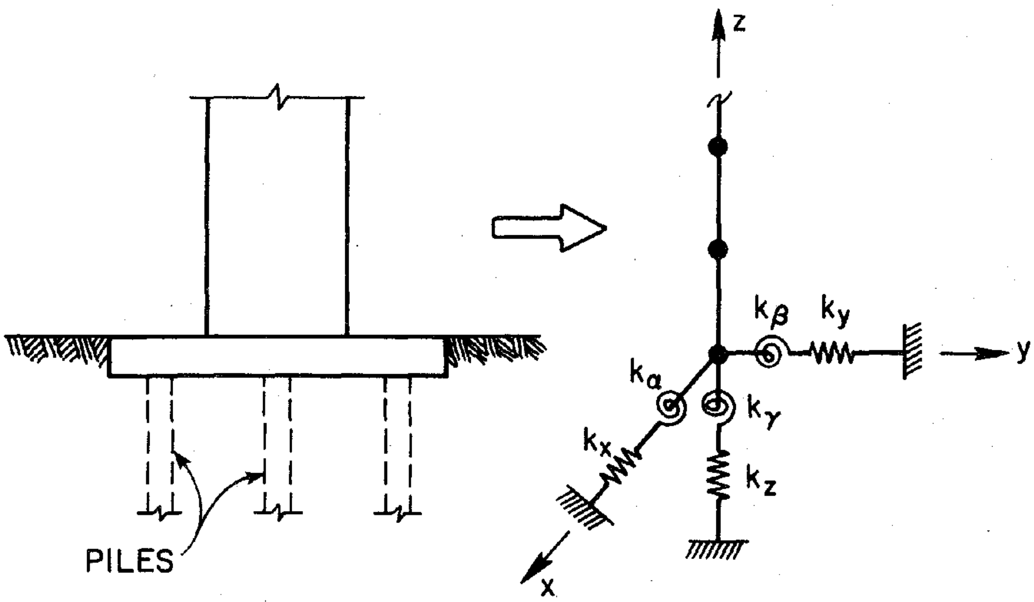


Fig. 6 Column foundation and boundary element

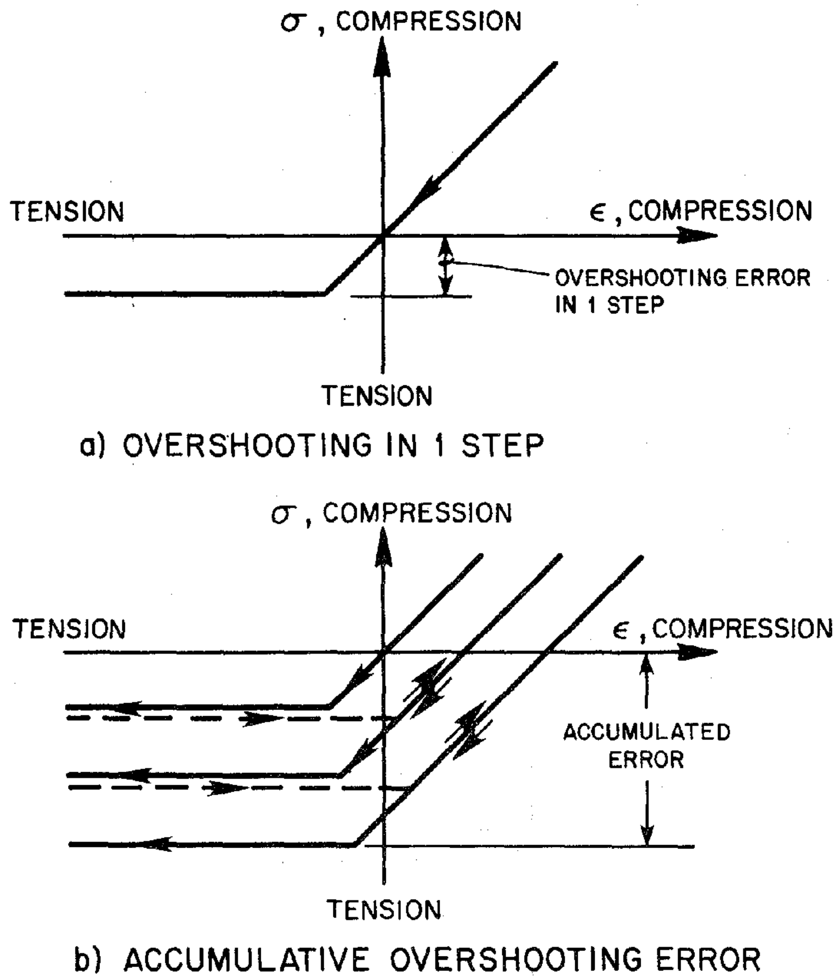


Fig. 7 Overshooting errors

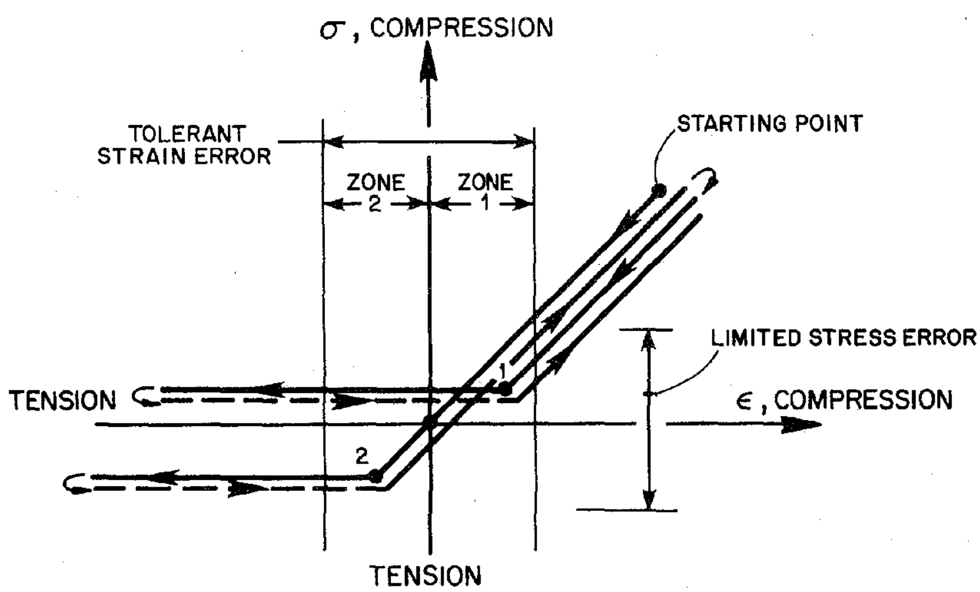


Fig. 8 Limiting overshooting errors

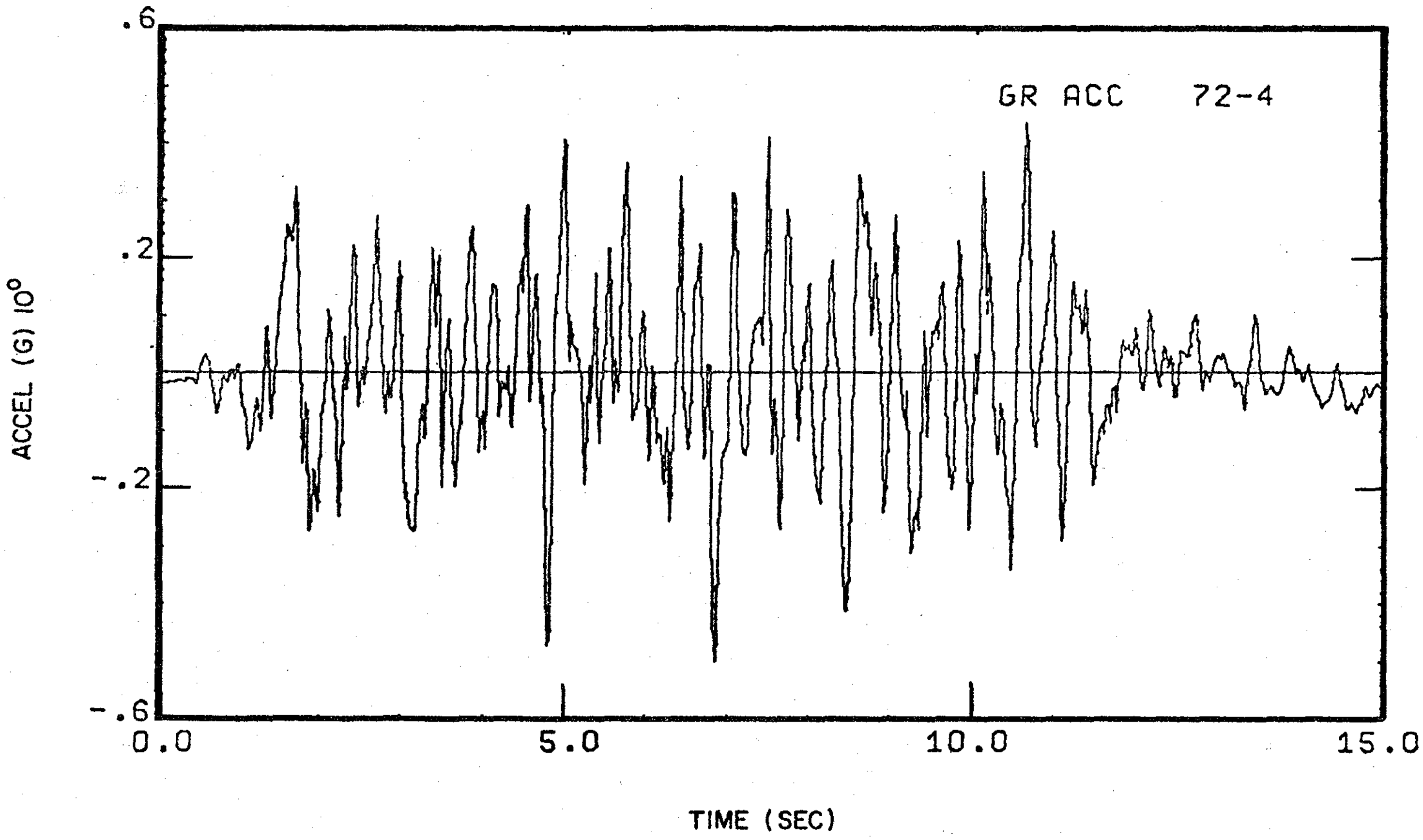


Fig. 9 Simulated ground acceleration record of the San Fernando Earthquake at the Olive View Hospital site

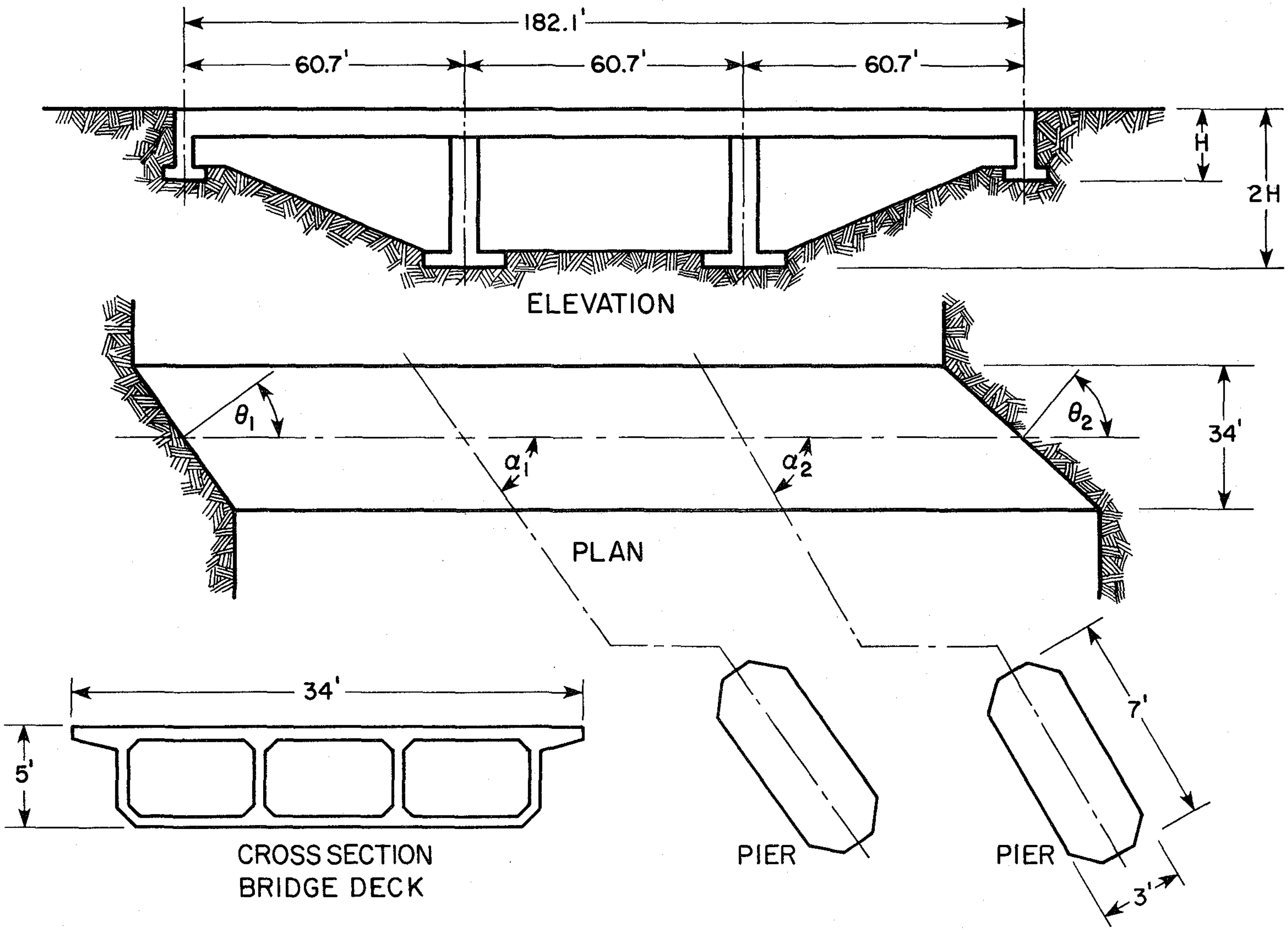


Fig. 10 General plan of model bridge

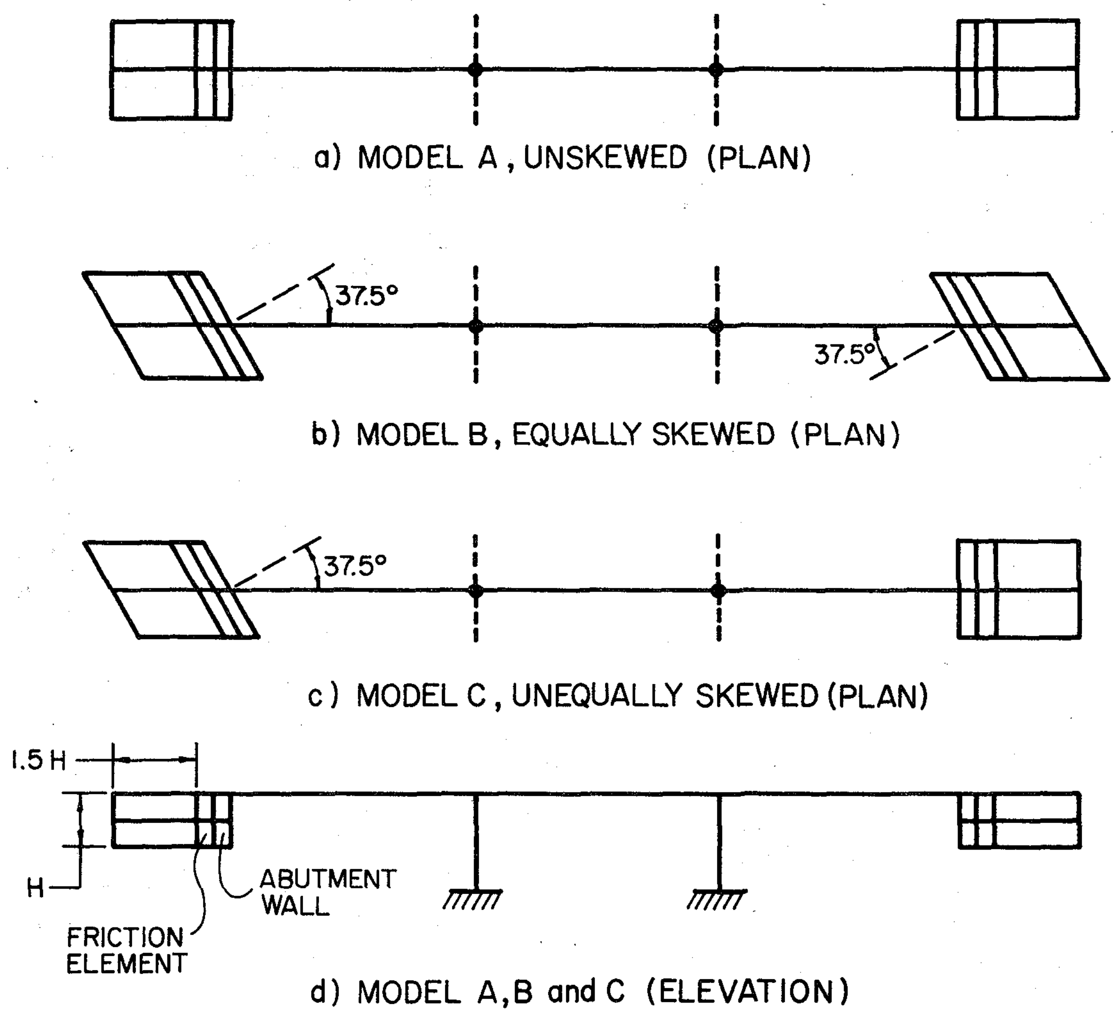
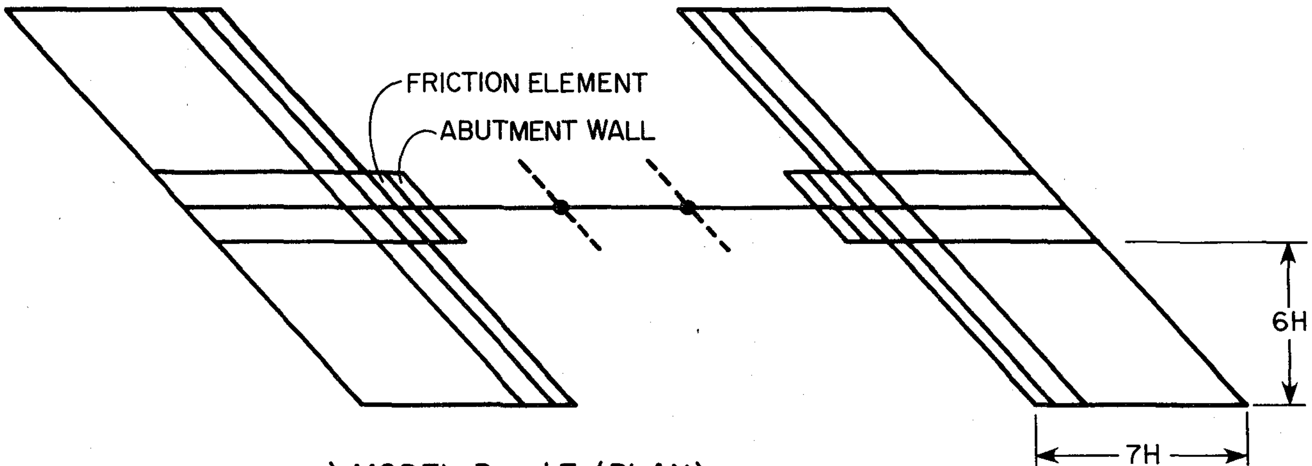
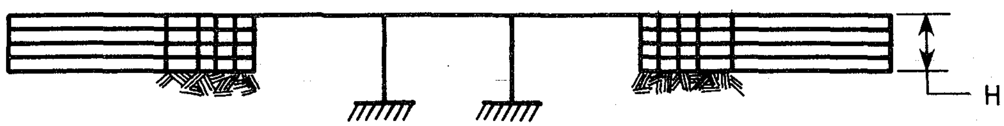


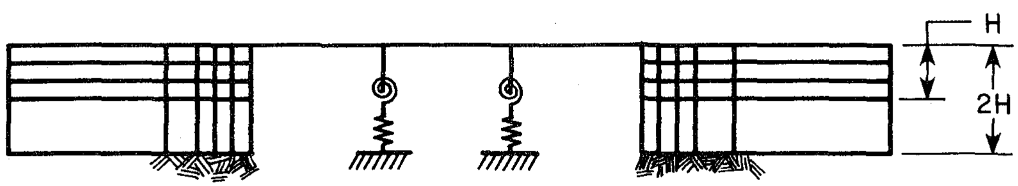
Fig. 11 Mathematical models



e) MODEL D and E (PLAN)



f) MODEL D, FIXED COLUMN, WALL BASE (ELEVATION)



g) MODEL E, FLEXIBLE COLUMN, WALL BASE (ELEVATION)

Fig. 11 (cont.) Mathematical models

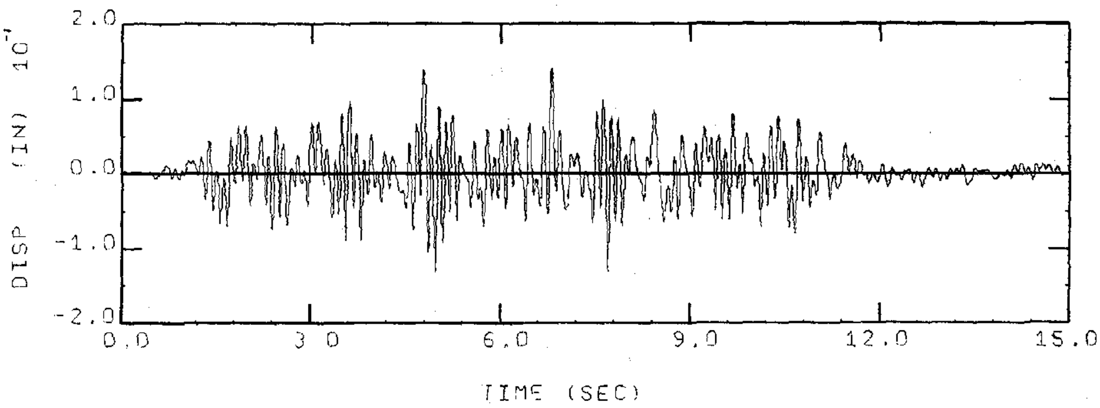
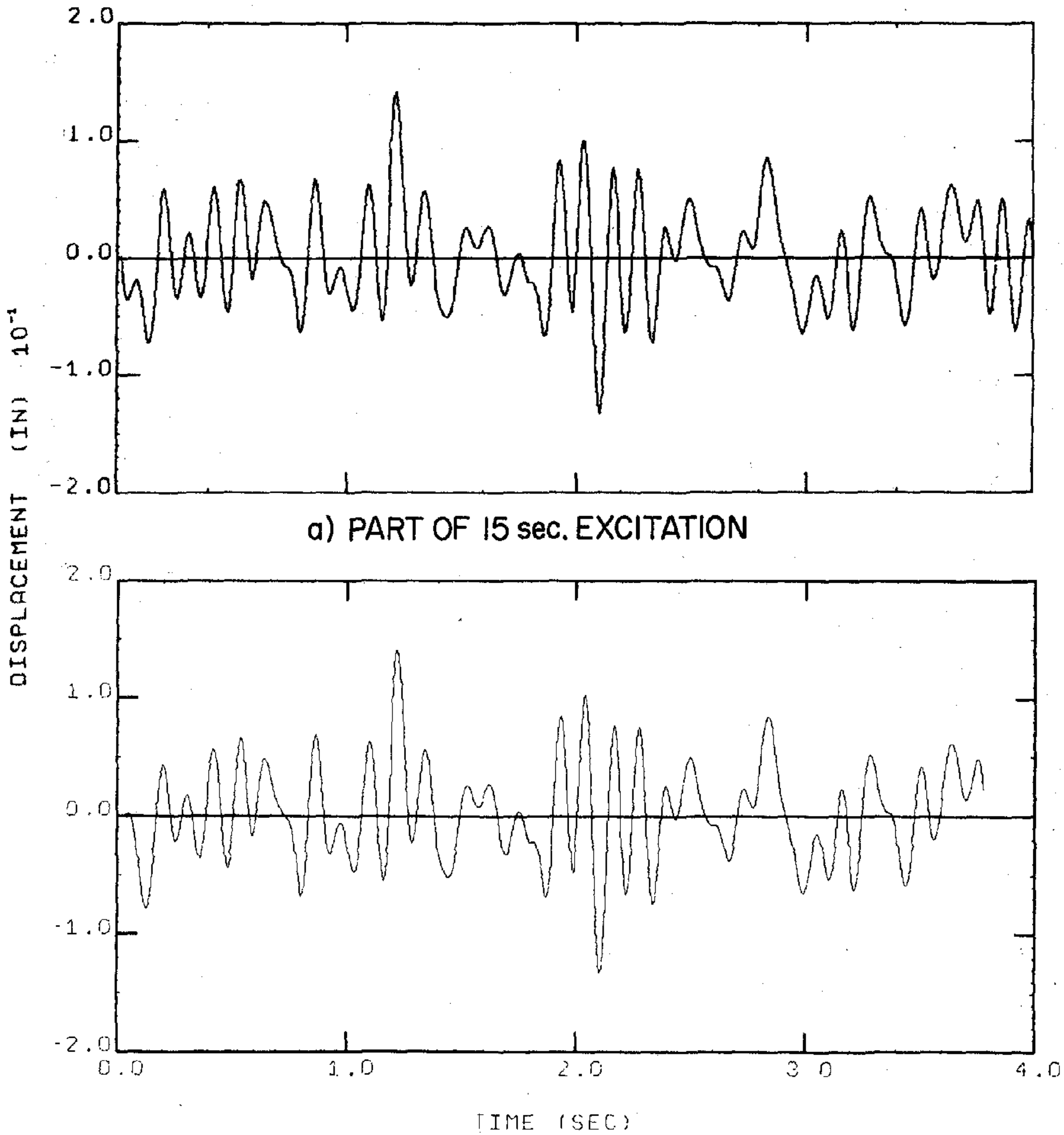
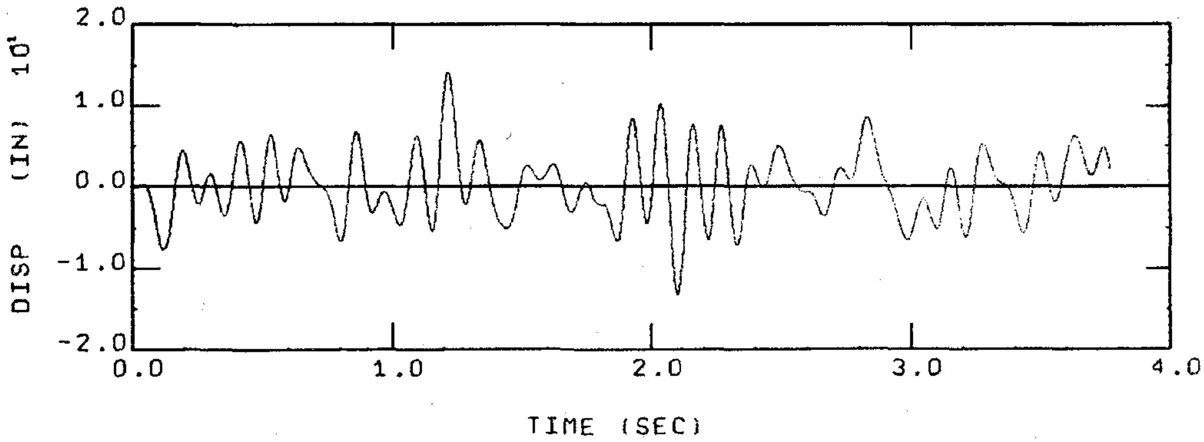


Fig. 12 Longitudinal acceleration at top of right column

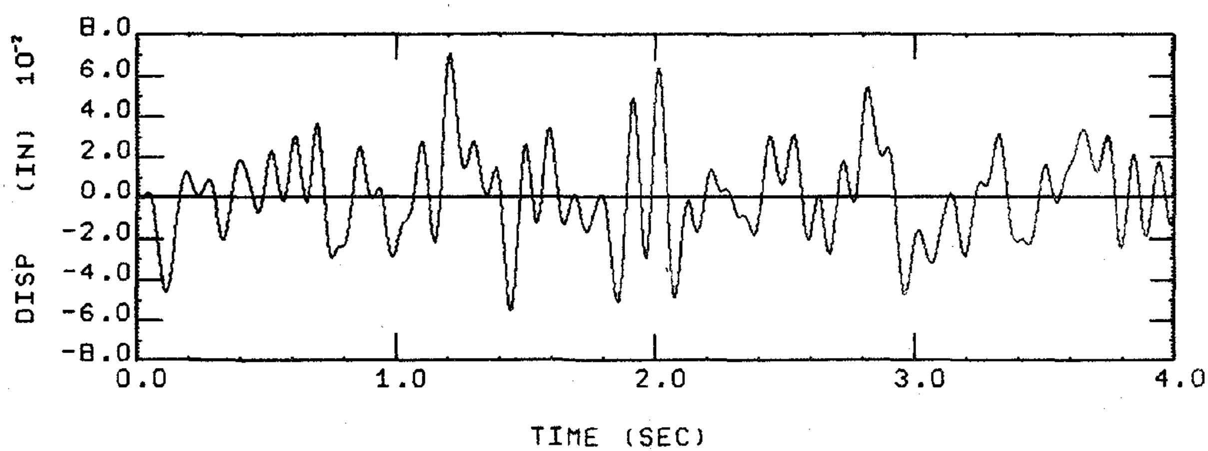


b) 3.775 sec. EXCITATION

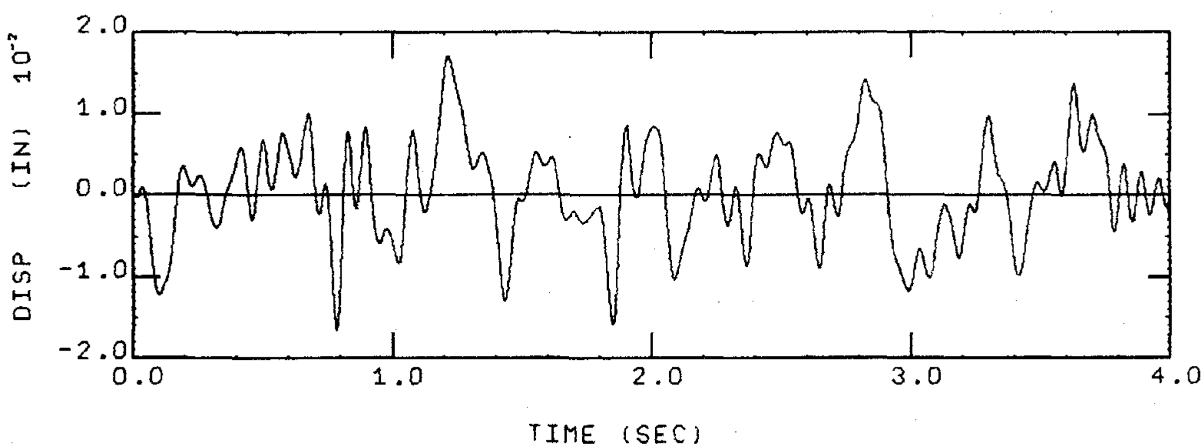
Fig. 13 Longitudinal acceleration at top of right column



a) MODEL A , UNSKEWED

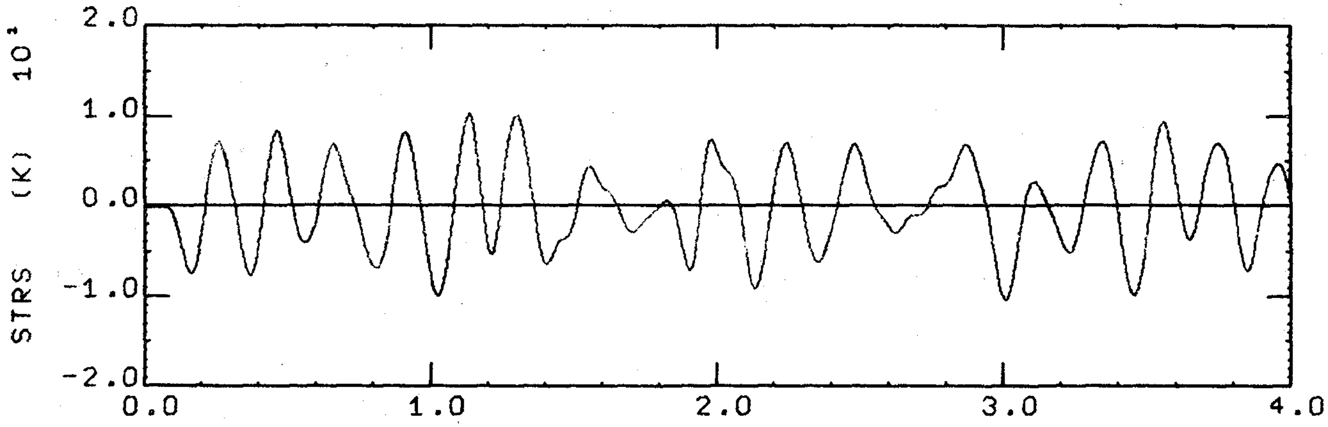


b) MODEL B, EQUALLY SKEWED

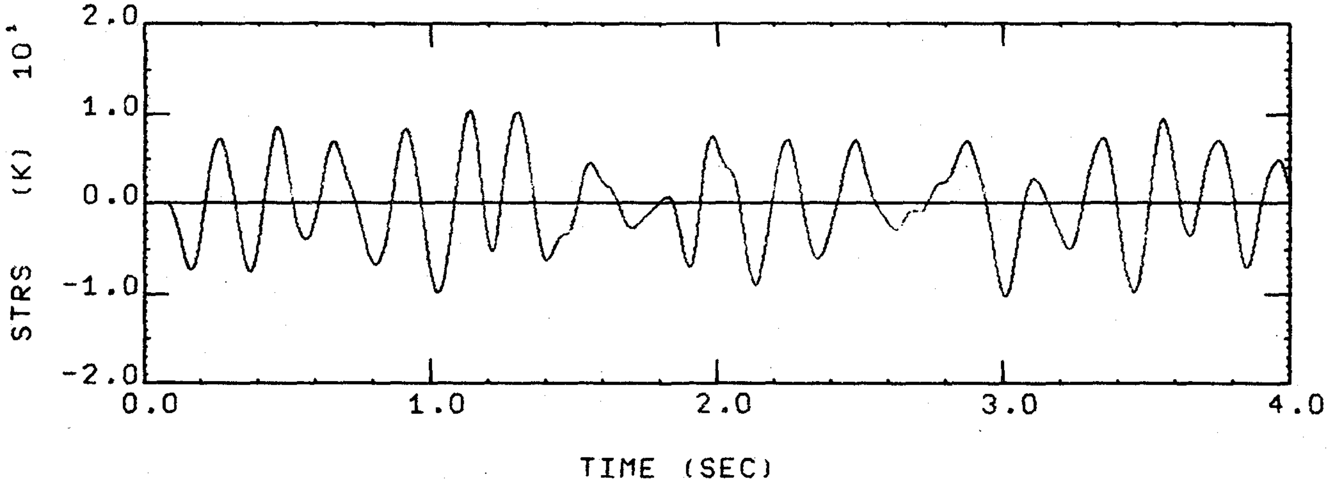


c) MODEL C, UNEQUALLY SKEWED

Fig. 14 Longitudinal displacement at top of right column

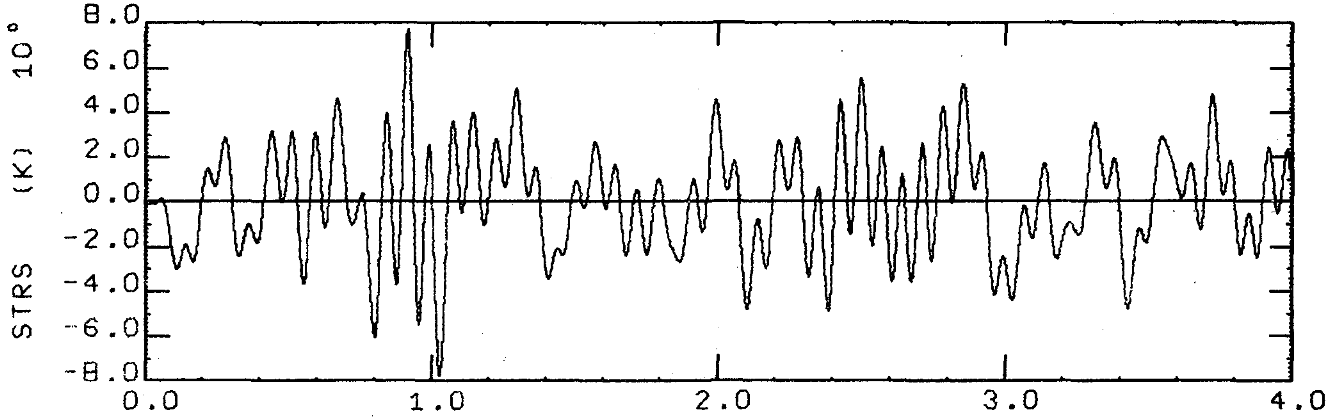


a) LEFT COLUMN

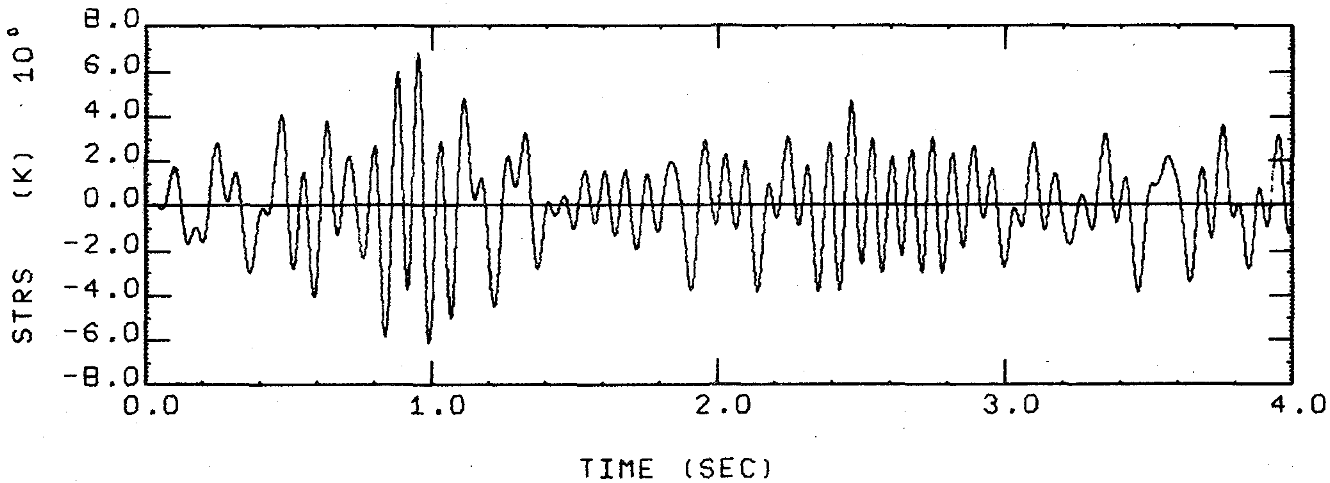


b) RIGHT COLUMN

Fig. 15 Lateral shear - equally skewed - Model B

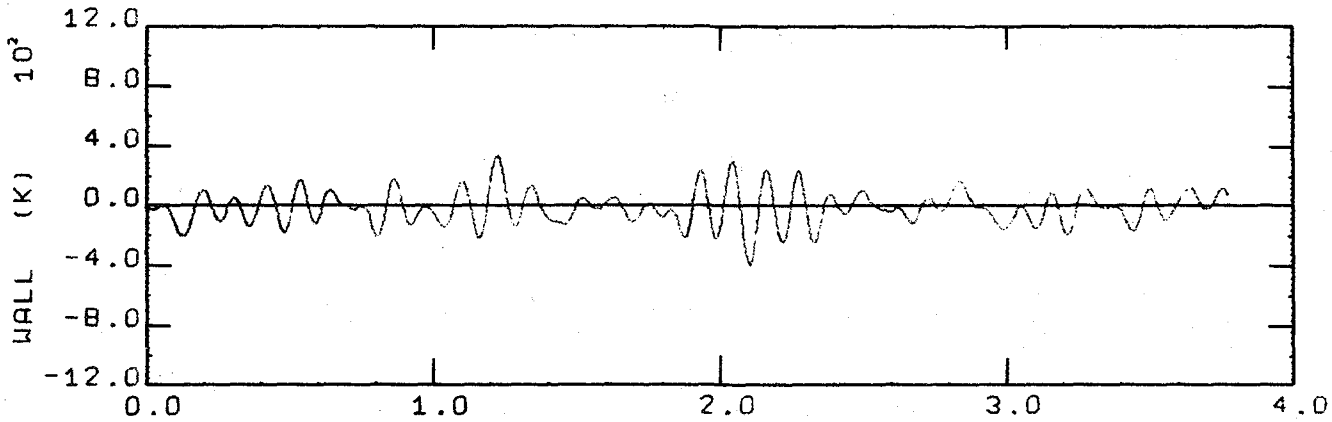


a) LEFT COLUMN

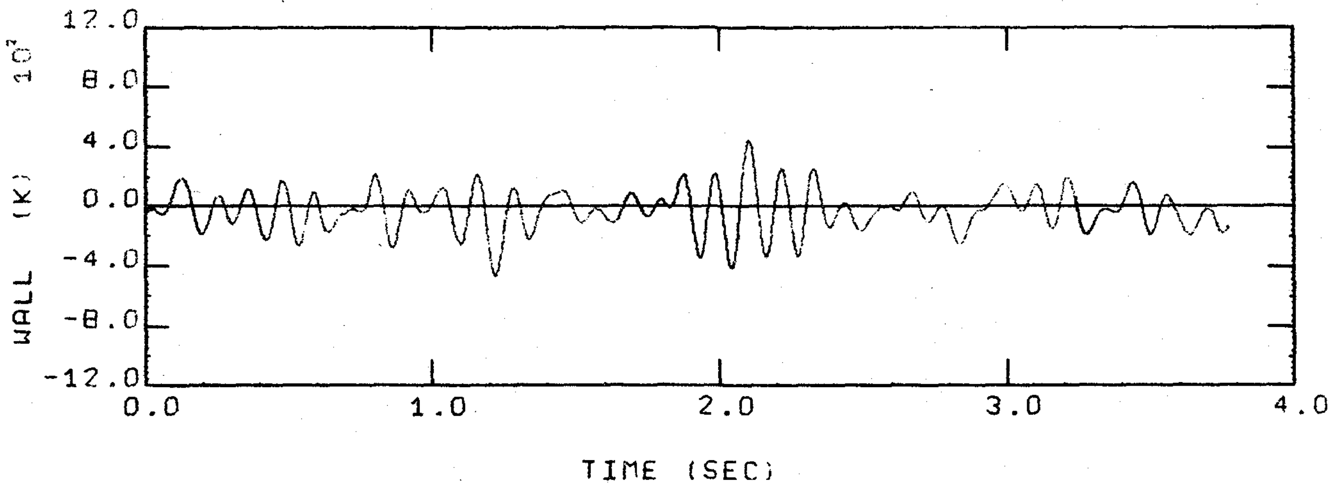


b) RIGHT COLUMN

Fig. 16 Lateral shear - unequally skewed - Model C

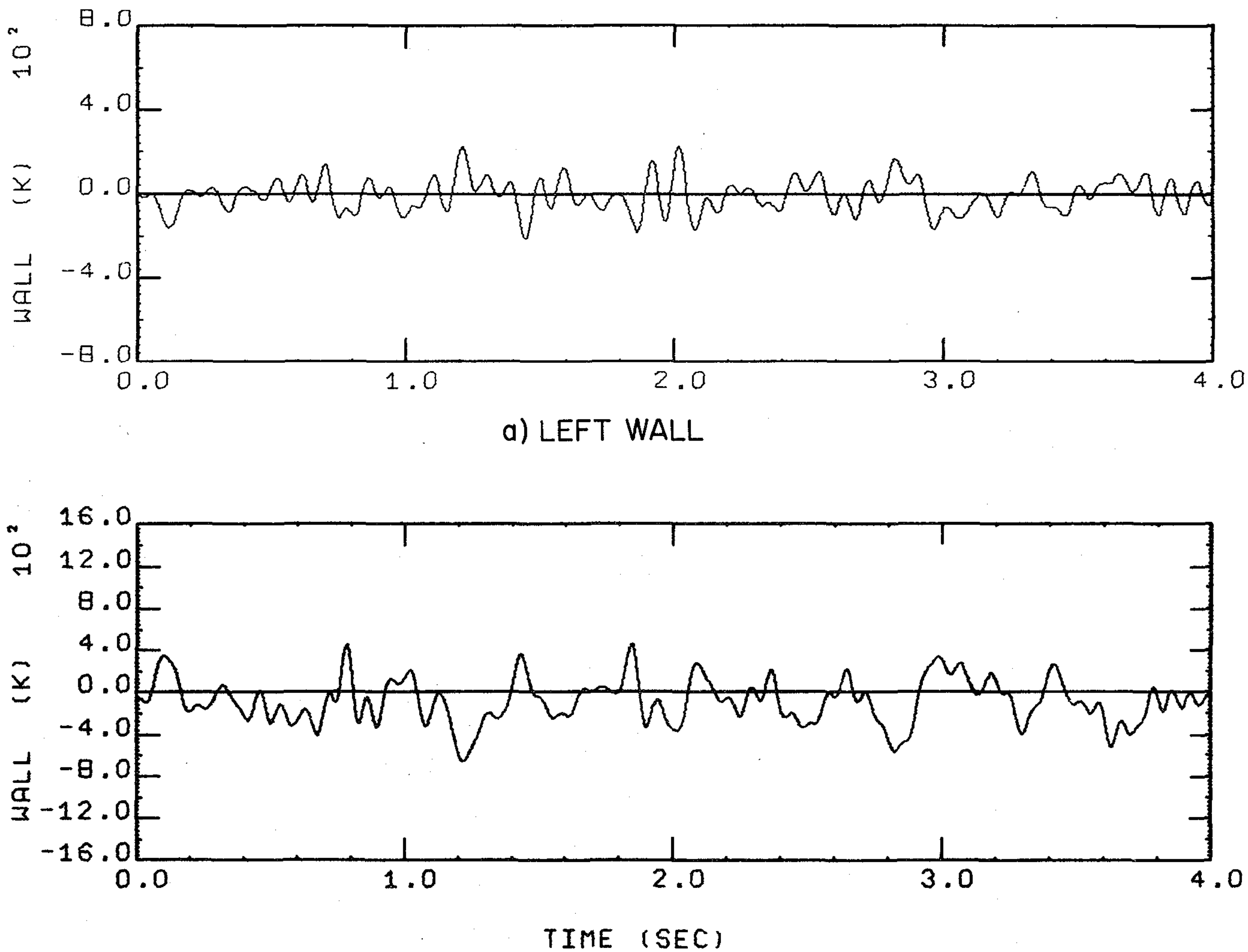


a) LEFT WALL



b) RIGHT WALL

Fig. 17 Wall pressure - unskewed - Model A



b) RIGHT WALL

Fig. 18 Wall pressure - equally skewed - Model A

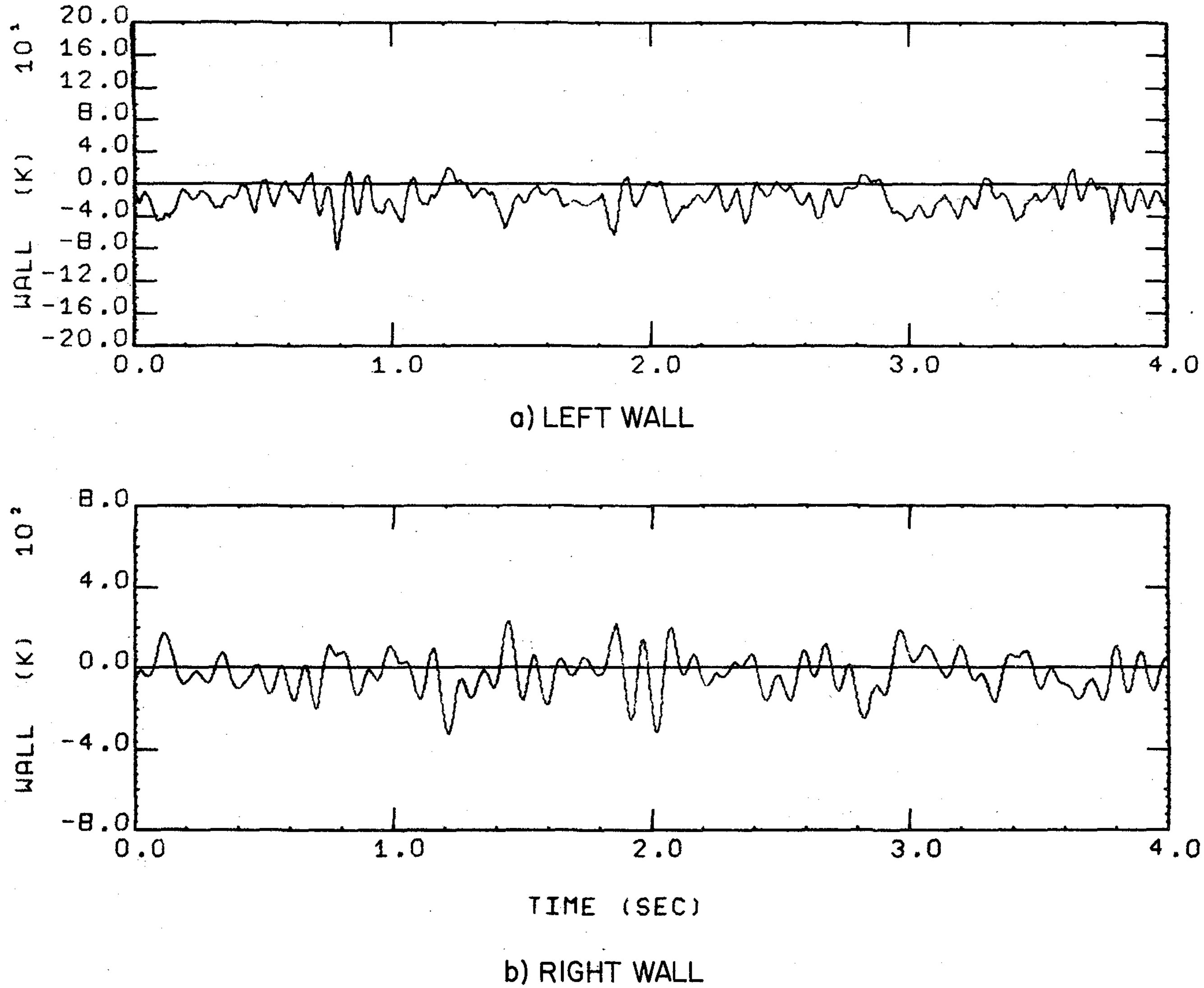


Fig. 19 Wall pressure - unequally skewed - Model C

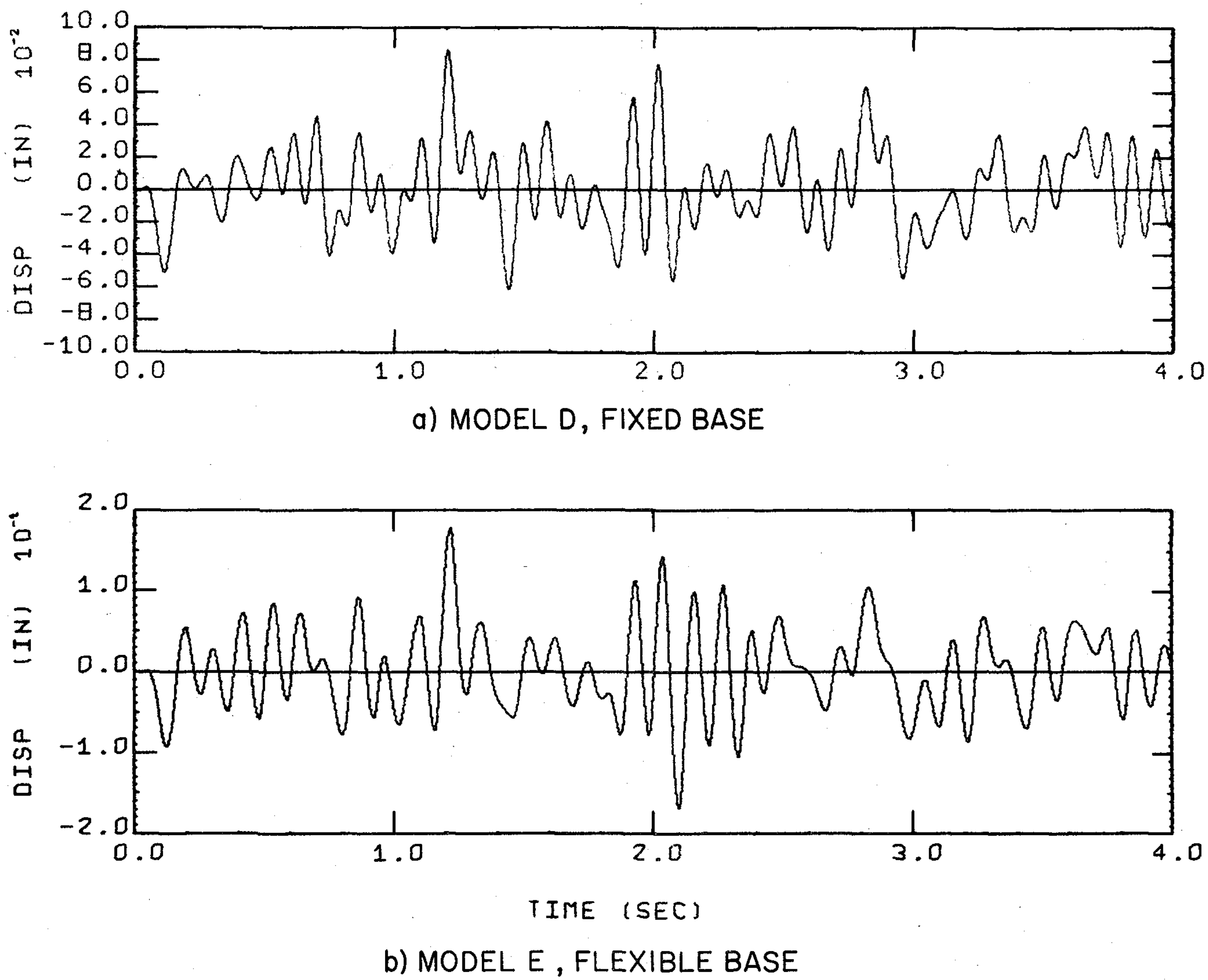


Fig. 20 Longitudinal displacement at top of left column - Model D and E

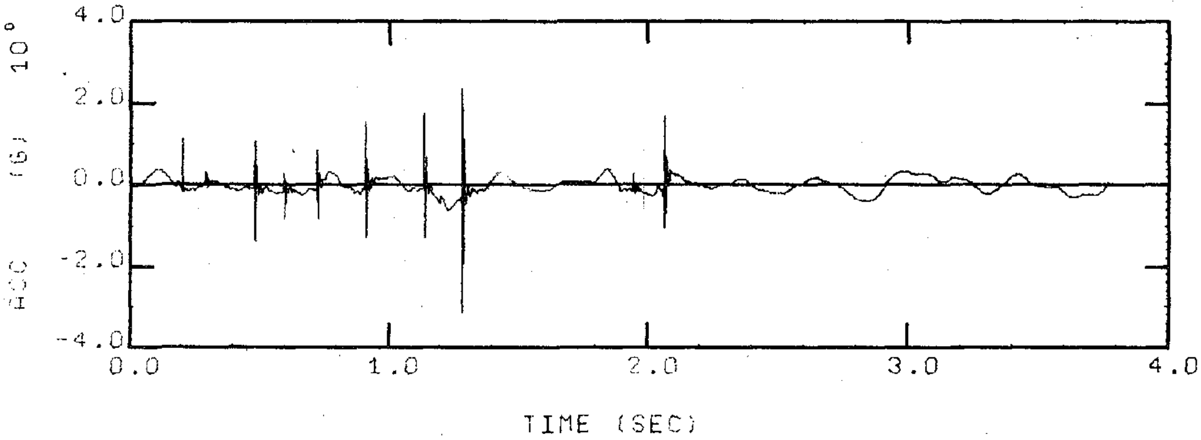
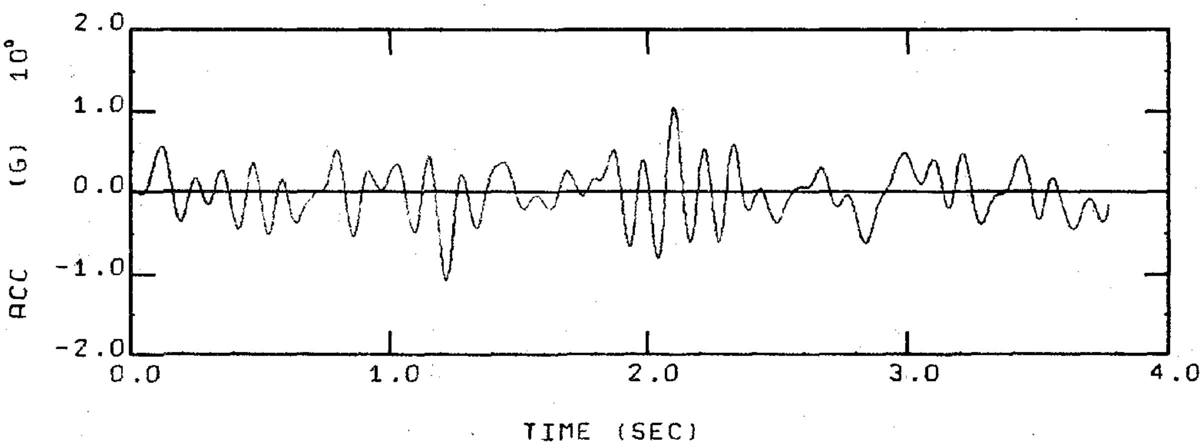
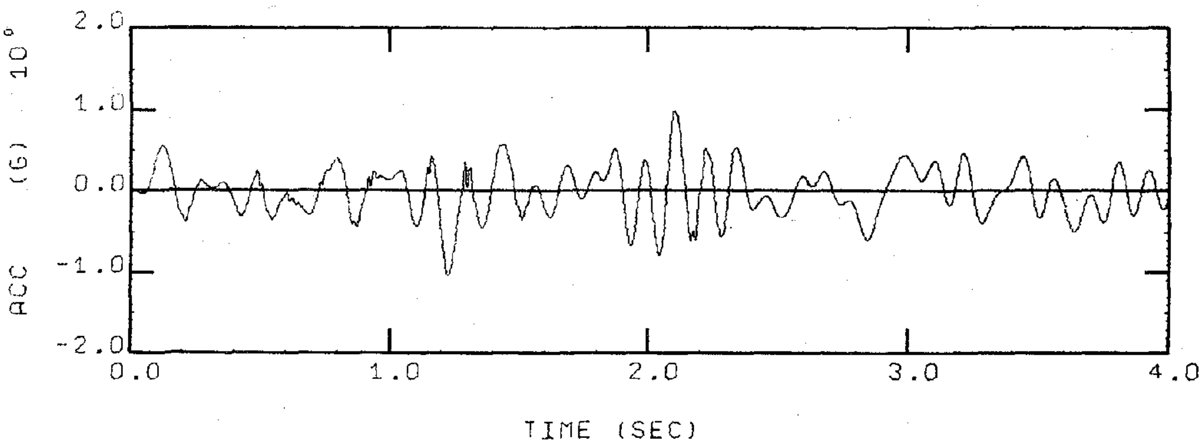


Fig. 21 Acceleration time history at contact point with impact - Model A



a) WITHOUT IMPACT EFFECT



b) WITH IMPACT EFFECT

Fig. 22 Comparison of time histories at top of left column without and with impact - Model A

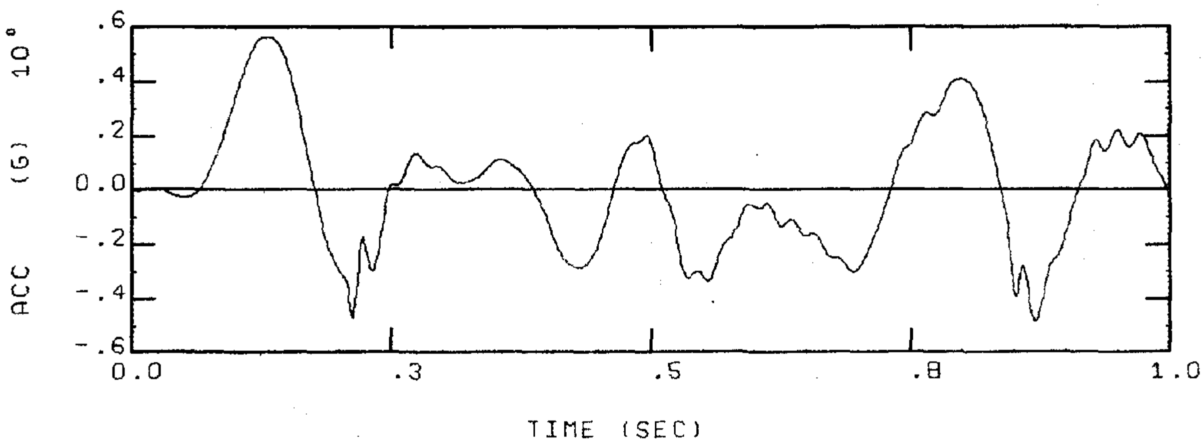
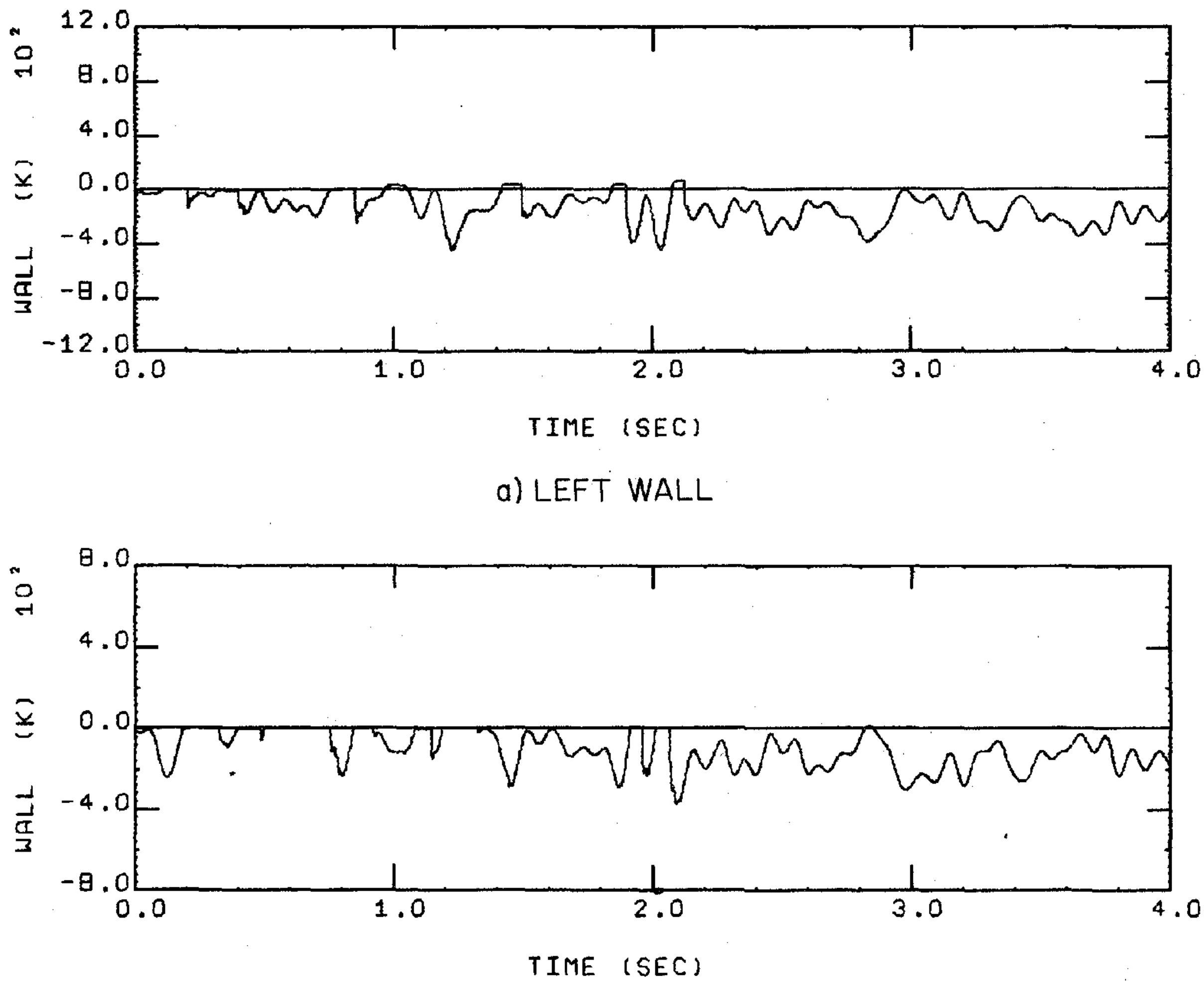


Fig. 23 Expanded scale view of effect of impact on acceleration - Model A



b) RIGHT WALL

Fig. 24 Non-linear response of wall pressure - Model B

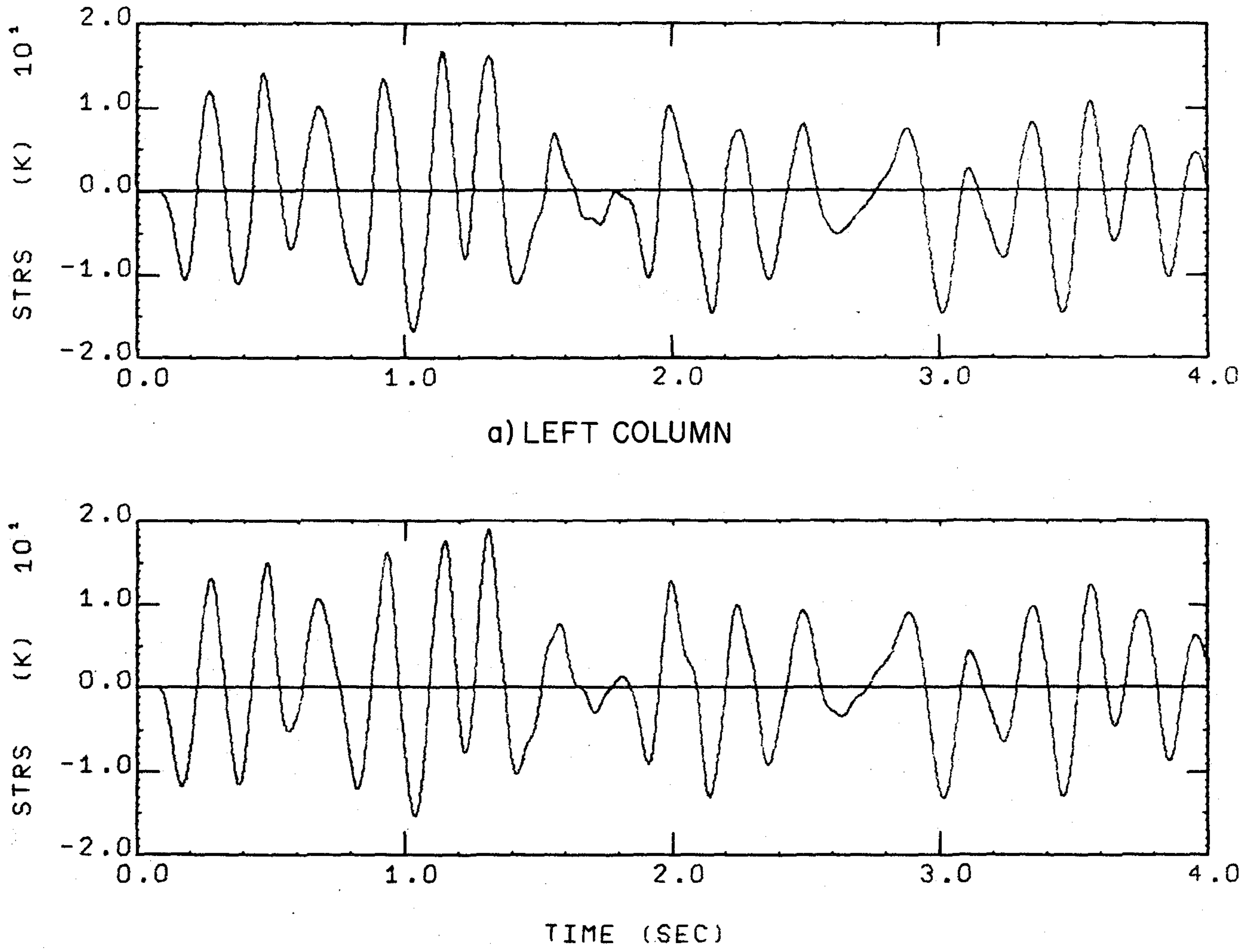


Fig. 25 Lateral column shears - Model B (non-linear)

```
      PROGRAM SKEW(INPUT,OUTPUT,TAPE1=OUTPUT,TAPE2,TAPE3,TAPE4,         SKEW.2
     1        TAPE5,TAPE6,TAPE7,TAPE8,TAPE9,TAPE10,TAPE11,TAPE12)       SKEW.3
C                                                                       SKEW.4
C     ******************************************************************SKEW.5
C     SKEWNESS EFFECTS OF BRIDGE DECK,AND THE IMPACT BETWEEN THE        SKEW.6
C     ABUTMENT AND BACKFILL SOILS,MARCH,1975                            SKEW.7
C     ******************************************************************SKEW.8
C                                                                       SKEW.9
      LARGE B(22000)                                                    SKEW.10
      COMMON A(30000)                                                   SKEW.11
      COMMON/TITLE/HEAD(12),EQNAME(12)                                  SKEW.12
      COMMON/ELPAR/NUMNP,NUMEL,NETYPE,NEQA,NEQC,MBANDA,MBANDO,KLIN,NLASTSKEW.13
      COMMON/MATER/NUMATS,NUMATC,NUMATF,NUMATB,NUMGE,NUMBC,MTYPE        SKEW.14
      COMMON/DAMP2/NDAMF,NROOT,NFP,XI(20),NXI(20),OMEGA(20)             SKEW.15
      COMMON/TIME/JUMP,T,DT,MPRTM,MTAPE,KPRINT                          SKEW.16
      COMMON/NEWAL/NTW,NTWEL                                            SKEW.17
      COMMON/NONL/NINDT,NINDTO,DKUO(200)                                SKEW.18
      COMMON/TATIME/NTIME,NB6E                                          SKEW.19
      DIMENSION S(20),IA(1),IWALL(2)                                    SKEW.20
      COMMON/STROUT/NSOLID,NCONC,NFR,NSPRIN                             SKEW.21
      EQUIVALENCE(A,IA)                                                 SKEW.22
C                                                                       SKEW.23
C     PROGRAM CONTROL DATA                                              SKEW.24
 1000 CALL SECOND(S(1))                                                 SKEW.25
      READ 1,HEAD,NUMNP,NUMEL,NETYPE,KLIN,NUMATS,NUMATC,NUMATF,         SKEW.26
     1       NUMATB,NUMGE,NUMBC                                         SKEW.27
      IF(NUMNP .EQ. 0) STOP                                             SKEW.28
      WRITE(1,101) HEAD,NUMNP,NUMEL,NETYPE,KLIN,NUMATS,NUMATC,          SKEW.29
     1           NUMATF,NUMATE,NUMGE,NUMBC                              SKEW.30
      READ 2,NFP,NROOT                                                  SKEW.31
      WRITE(1,103) NFF,NROOT                                            SKEW.32
C                                                                       SKEW.33
C     INPUT JOINT DATA-IDA(6,NUMNP),IDO(6,NUMNP)                        SKEW.34
      CALL OVERLAY(6HTHREED,1,0,0)                                      SKEW.35
      CALL SECOND(S(2))                                                 SKEW.36
C                                                                       SKEW.37
C     READ IN MATERIAL PROPERTIES,BEAM,COLUMN GEOMETRIC DATA            SKEW.38
      DO 301 I=1,NETYPE                                                 SKEW.39
      READ 2,MTYPE                                                      SKEW.40
      WRITE(1,102) MTYPE                                                SKEW.41
      CALL OVERLAY(6HTHREED,2,0,6HRECALL)                               SKEW.42
  301 CONTINUE                                                          SKEW.43
      CALL SECOND(S(3))                                                 SKEW.44
      N10E=NLAST+3*NUMATS+3*NUMATC+6*NUMGE+4*NUMATF+6*NUMATB            SKEW.45
      NLAST=N10E                                                        SKEW.46
C                                                                       SKEW.47
C     READ IN ELEMENT DATA                                              SKEW.48
      CALL OVERLAY(6HTHREED,3,0,0)                                      SKEW.49
      CALL SECOND(S(4))                                                 SKEW.50
C                                                                       SKEW.51
C     INPUT AND CALCULATE NODAL MASS,LOAD,AND FIXED END MOMENT OF BEAM  SKEW.52
      CALL OVERLAY(6HTHREED,4,0,0)                                      SKEW.53
      CALL SECOND(S(5))                                                 SKEW.54
C                                                                       SKEW.55
C     ASSEMBLE TOTAL STIFFNESS MATRIX                                   SKEW.56
      JUMP=0                                                            SKEW.57
      CALL OVERLAY(6HTHREED,5,0,0)                                      SKEW.58
      CALL SECOND(S(6))                                                 SKEW.59
C                                                                       SKEW.60
C     CALCULATE FREQUENCIES AND EIGENVECTORS FOR FORMING DAMPING MATRIX SKEW.61
      CALL OVERLAY(6HTHREED,6,0,0)                                      SKEW.62
      CALL SECOND(S(7))                                                 SKEW.63
C                                                                       SKEW.64
C     READ IN WALL DATA                                                 SKEW.65
      NTW=0                                                             SKEW.66
      NTWEL=0                                                           SKEW.67
      READ 2,NTW                                                        SKEW.68
      IF(NTW .EQ. 0) GO TO 403                                          SKEW.69
      READ 2,(IWALL(I),I=1,NTW)                                         SKEW.70
      WRITE(1,104) NTW,(IWALL(I),I=1,NTW)                               SKEW.71
      DO 302 I=1,NTW                                                    SKEW.72
      NTWEL=NTWEL+IWALL(I)                                              SKEW.73
  302 CONTINUE                                                          SKEW.74
  403 CONTINUE                                                          SKEW.75
C                                                                       SKEW.76
C     SOLVE FOR STATIC LOADING                                          SKEW.77
      CALL OVERLAY(6HTHREED,7,0,0)                                      SKEW.78
      N15=NLAST                                                         SKEW.79
      N16=N15+12*NUMEL                                                  SKEW.80
      N17=N16+12*NUMEL                                                  SKEW.81
      N18=N17+6*NFR                                                     SKEW.82
      N18E=N18-1                                                        SKEW.83
      IF(NTW .EQ. 0) GO TO 404                                          SKEW.84
      DO 304 I=1,NTW                                                    SKEW.85
      IA(N18E+I)=IWALL(I)                                               SKEW.86
  304 CONTINUE                                                          SKEW.87
  404 CONTINUE                                                          SKEW.88
      CALL SECOND(S(8))                                                 SKEW.89
C                                                                       SKEW.90
C     CALCULATE ELEMENT STRESS                                          SKEW.91
      CALL OVERLAY(6HTHREED,8,0,6HRECALL)                               SKEW.92
      CALL SECOND(S(9))                                                 SKEW.93
      NLAST=N17                                                         SKEW.94
      N19=N18+NTW                                                       SKEW.95
      N20=N19+NTW*NTWEL                                                 SKEW.96
      N21=N20+4*NTW                                                     SKEW.97
      N22=N21+NTW                                                       SKEW.98
      N23=N22+NTW                                                       SKEW.99
      N24=N23+NTW                                                       SKEW.100
      N25=N24+NTW                                                       SKEW.101
      N26E=N25+NTW-1                                                    SKEW.102
      IF(NTW .EQ. 0) GO TO 401                                          SKEW.103
C     INITIALIZATION                                                    SKEW.104
      DO 307 I=N21,N26E                                                 SKEW.105
      A(I)=0.                                                           SKEW.106
  307 CONTINUE                                                          SKEW.107
      CALL WDATA(A(N18),A(N19),A(N20),NTW,NTWEL)                        SKEW.108
  401 CONTINUE                                                          SKEW.109
      N1=1                                                              SKEW.110
      N2=N1+6*NUMNP                                                     SKEW.111
      N3=N2+4*NUMATF                                                    SKEW.112
      N4=N3+3*NUMEL                                                     SKEW.113
      N5=N4+NEQA                                                        SKEW.114
      N6=N5+NEQA                                                        SKEW.115
      N7=N6+NEQA                                                        SKEW.116
      N8=N7+NEQA                                                        SKEW.117
      N9=N8+NEQA                                                        SKEW.118
      N10=N9+NEQA                                                       SKEW.119
      N11=N10+NUMEL                                                     SKEW.120
      N12=N11+NSOLID                                                    SKEW.121
      N13=N12+NCONC                                                     SKEW.122
      N14=N13+NFR                                                       SKEW.123
      N15=N14+NSPRIN                                                    SKEW.124
      N26=N26E+1                                                        SKEW.125
```

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      N27=N26+NFR                                                       SKEW.126
      NINOT=0                                                           SKEW.127
C                                                                       SKEW.128
C     INITILIZATION                                                     SKEW.129
      N28E=N27+NEQA-1                                                   SKEW.130
      DC 303 I=N27,N28E                                                 SKEW.131
      A(I)=0.                                                           SKEW.132
  303 CONTINUE                                                          SKEW.133
C     STORE NONLINEAR INFORMATICN IN CCMMON A                           SKEW.134
      N28=N28E+1                                                        SKEW.135
      N28A=N28+157*NFR                                                  SKEW.136
      N29=N28A+157*NFR                                                  SKEW.137
      N30=N29+NEQA                                                      SKEW.138
      N31=N30+NEQA                                                      SKEW.139
      N40=N31+9*NEQA                                                    SKEW.140
      CALL NONLIN(A(N2),A(N3),A(N4),A(N5),A(N7),A(N8),A(N9),A(N13),     SKEW.141
     1            A(N15),A(N16),A(N17),A(N26),A(N27),A(N28),A(N28A),    SKEW.142
     2            A(N31),A(N40),NUMEL,NEQA,KLIN,NTWEL)                  SKEW.143
  402 CONTINUE                                                          SKEW.144
C                                                                       SKEW.145
      IF(NTW .EQ. 0) GO TO 405                                          SKEW.146
      CALL WFORCE(A(N10),A(N17),A(N18),A(N19),A(N20),A(N21),A(N22),     SKEW.147
     1            A(N23),A(N24),A(N25),NTW,NTWEL)                       SKEW.148
  405 CONTINUE                                                          SKEW.149
      CALL SECOND(S(10))                                                SKEW.150
C                                                                       SKEW.151
C     PRINT OUT RESULT                                                  SKEW.152
      CALL PRINTR(A(N1),A(N3),A(N4),A(N5),A(N6),A(N11),A(N12),A(N13),   SKEW.153
     1            A(N14),A(N16),A(N21),A(N22),A(N23),A(N24),A(N25),     SKEW.154
     2            A(N26),NTW,NTWEL)                                     SKEW.155
      CALL SECOND(S(11))                                                SKEW.156
      N32=N31+NEQA                                                      SKEW.157
      N33=N32+NEQA                                                      SKEW.158
      N34=N33+NEQA                                                      SKEW.159
      N35=N34+NEQA                                                      SKEW.160
      N36=N35+NEQA                                                      SKEW.161
      N37=N36+NEQA                                                      SKEW.162
      N38=N37+NEQA                                                      SKEW.163
      N39=N38+NEQA                                                      SKEW.164
      N40=N39+NEQA                                                      SKEW.165
      N41=N40+NEQA                                                      SKEW.166
      N42=N41+NEQA                                                      SKEW.167
      N43=N42+NEQA                                                      SKEW.168
      N44=N43+NEQA                                                      SKEW.169
      N45=N44+NEQA                                                      SKEW.170
      NLAST=N15                                                         SKEW.171
      NB1=1                                                             SKEW.172
      NB2=NB1+NEQA*MBANDA                                               SKEW.173
      NB3=NB2+NEQA*MBANDA                                               SKEW.174
      NB4=NB3+NEQA*MBANDA                                               SKEW.175
      NB5=NB4+NEQA*MBANDA                                               SKEW.176
      NB6=NB5+NEQA*MBANDA                                               SKEW.177
      NB6E=NB6-1                                                        SKEW.178
      CALL STEP(A(N1),A(N2),A(N3),A(N4),A(N5),A(N6),A(N7),A(N8),A(N9),  SKEW.179
     1         A(N10),A(N11),A(N12),A(N13),A(N14),A(N15),A(N16),A(N17),SKEW.180
     2         A(N18),A(N19),A(N20),A(N21),A(N22),A(N23),A(N24),A(N25),SKEW.181
     3 A(N26),A(N27),A(N28),A(N28A),A(N29),A(N30),A(N31),A(N32),A(N33), SKEW.182
     4         A(N34),A(N35),A(N36),A(N37),A(N38),A(N39),A(N40),A(N41),SKEW.183
     5         A(N42),A(N43),A(N44),B(1),B(NB2),B(NB3),B(NB4),B(NB5),   SKEW.184
     6         B(NB6),NEQA,NTW,NTWEL,NUMEL,NUMNP,KLIN,MBANDA)           SKEW.185
      CALL SECOND(S(12))                                                SKEW.186
C     OUTPUT TIME HISTORY                                               SKEW.187
      CALL OVERLAY(6HTHREED,11,0,0)                                     SKEW.188
      CALL SECOND(S(13))                                                SKEW.189
      DO 305 I=1,12                                                     SKEW.190
  305 S(I)=S(I+1)-S(I)                                                  SKEW.191
      TT=0.                                                             SKEW.192
      DO 306 I=1,12                                                     SKEW.193
  306 TT=TT+S(I)                                                        SKEW.194
      S(13)=TT                                                          SKEW.195
      WRITE(1,105) (S(I),I=1,13)                                        SKEW.196
      WRITE(1,106) N45                                                  SKEW.197
    1 FORMAT(12A6/(10I5))                                               SKEW.198
    2 FORMAT(10I5)                                                      SKEW.199
  101 FORMAT(1H1,12A6//                                                 SKEW.200
     1       * NO. OF NODAL POINTS                                *I5/  SKEW.201
     2       * NO. OF ELEMENTS                                    *,I5/ SKEW.202
     3       * NO. OF ELEMENT TYPE                                *,I5/ SKEW.203
     4       * LINEAR OR NONLINEAR ANALYSIS,0-LINEAR,1-NONLINEAR*,I5/   SKEW.204
     5       * NO. OF SOLID MATERIAL TYPE                         *,I5/ SKEW.205
     6       * NO. OF COLUMN OR BEAM MATERIAL TYPES               *,I5/ SKEW.206
     7       * NO. OF FRICTION ELEMENT TYPES                      *,I5/ SKEW.207
     8       * NO. OF BOUNDARY SPRING ELEMENT TYPES               *,I5/ SKEW.208
     9       * NO. OF CONCRETE GEOMETRIC PROPERTIES               *,I5/ SKEW.209
     .       * NO. OF BEAM OR COLUMN ELEMENT                      *,I5//) SKEW.210
  102 FORMAT(*1MATERIAL PROPERTIES TYPE MTYPE=*,I5)                     SKEW.211
  103 FORMAT(* NO. OF FREQUENCIES TO BE CALCULATED*,I5/                 SKEW.212
     1       * HIGHEST NON-ZERO DIRECT DAMPING MODES*,I5//)             SKEW.213
  104 FORMAT(* NO. OF ABUTMENT WALLS*,I5//                              SKEW.214
     1       * NO. OF ELEMENT AGAINST WALL,1,2,...*,10I5//)             SKEW.215
  105 FORMAT(*1TIME LOG*//                                              SKEW.216
     1       * NODAL POINT INPUT                    *,F8.2//            SKEW.217
     2       * INPUT MATERIAL PROPERTIES            *,F8.2//            SKEW.218
     3       * INPUT ELEMENT DATA                   *,F8.2//            SKEW.219
     4       * INPUT AND CALCULATE NODAL MASS,LOAD*,F8.2//              SKEW.220
     5       * FORM ELASTIC STRESS-STRAIN RELATION*,F8.2//              SKEW.221
     6       * CALCULATE FREQUENCY                  *,F8.2//            SKEW.222
     7       * STATIC SOLUTION                      *,F8.2//            SKEW.223
     8       * COMPUTE STRESS                       *,F8.2//            SKEW.224
     9       * WALL                                 *,F8.2//            SKEW.225
     .       * PRINT                                *,F8.2//            SKEW.226
     .       * DYNAMIC SOLUTION                     *,F8.2//            SKEW.227
     .       * TIME HISTORY                         *,F8.2//            SKEW.228
     .       * TOTAL SOLUTION                       *,F8.2)             SKEW.229
  106 FORMAT(* LENGTH OF BLANK COMMON A*,I8)                            SKEW.230
      END                                                               SKEW.231
      SUBROUTINE LAM(IX,IND)                                            LAM.2
C                                                                       LAM.3
C     ******************************************************************LAM.4
C     CALCULATE LOCATION OF MASS MATRIX LMA(36),LMO(36)                 LAM.5
C     LMA ? THE REMAINED DEGREE OF FREEDOM                              LAM.6
C     LMO ? THE ELIMINATED D O F AFTER GUYAN REDUCTION                  LAM.7
C     ******************************************************************LAM.8
C                                                                       LAM.9
      COMMON A(30000)                                                   LAM.10
      COMMON/ELPAR/NUMNP,NUMEL,NETYPE,NEQA,NEQC,MBANDA,MBANDO,KLIN,NLASTLAM.11
      COMMON/MATER/NUMATS,NUMATC,NUMATF,NUMATB,NUMGE,NUMBC,MTYPE        LAM.12
      COMMON/LMC/LMA(36),LMO(36),XX(8),YY(8),ZZ(8)                      LAM.13
      COMMON/TOPEL/NFB(4,50),ITOPN                                      LAM.14
      DIMENSION IX(11),IA(1)                                            LAM.15
      EQUIVALENCE(A,IA)                                                 LAM.16
C                                                                       LAM.17
C     INITILIZATION                                                     LAM.18
      DO 300 I=1,36                                                     LAM.19
```

```
      LMA(I)=0                                                          LAM.20
      LMO(I)=0                                                          LAM.21
  300 CONTINUE                                                          LAM.22
      IT=8                                                              LAM.23
      IF(IX(9) .EQ. 3) IT=4                                             LAM.24
C                                                                       LAM.25
C     HEXAHEDRON ELEMENT-SOLID ELEMENT,FRICTICNAL ELEMENT               LAM.26
      NOO=6*NUMNP                                                       LAM.27
      N2=12*NUMNP                                                       LAM.28
      N3=N2+NUMNP                                                       LAM.29
      N4=N3+NUMNP                                                       LAM.30
      IF(IX(4) .EQ. 0) GO TO 401                                        LAM.31
      DO 301 I=1,IT                                                     LAM.32
      NODE=IX(I)                                                        LAM.33
      J3=3*I                                                            LAM.34
      J2=J3-1                                                           LAM.35
      J1=J2-1                                                           LAM.36
      NN=6*NODE                                                         LAM.37
      NNO=NN+NOC                                                        LAM.38
      NI=NN+1                                                           LAM.39
      NIO=NNO+1                                                         LAM.40
      LMA(J3)=IA(NN-3)                                                  LAM.41
      LMA(J2)=IA(NN-4)                                                  LAM.42
      LMA(J1)=IA(NN-5)                                                  LAM.43
      LMO(J3)=IA(NNO-3)                                                 LAM.44
      LMO(J2)=IA(NNO-4)                                                 LAM.45
      LMO(J1)=IA(NNO-5)                                                 LAM.46
      IF(IND .EG. 0) GO TO 301                                          LAM.47
      XX(I)=A(N2+NODE)                                                  LAM.48
      YY(I)=A(N3+NODE)                                                  LAM.49
      ZZ(I)=A(N4+NODE)                                                  LAM.50
  301 CONTINUE                                                          LAM.51
      IF(IX(11) .LE. 3) GC TO 402                                       LAM.52
C                                                                       LAM.53
C     TOP SOIL ELEMENT NEXT TO FRICTION JOINT                           LAM.54
      DO 303 I=1,4                                                      LAM.55
      NODE=NFB(I,ITOPN)                                                 LAM.56
      J3=3*I+24                                                         LAM.57
      J2=J3-1                                                           LAM.58
      J1=J2-1                                                           LAM.59
      NN=6*NODE                                                         LAM.60
      NNO=NN+NOC                                                        LAM.61
      LMA(J3)=IA(NN-3)                                                  LAM.62
      LMA(J2)=IA(NN-4)                                                  LAM.63
      LMA(J1)=IA(NN-5)                                                  LAM.64
      LMO(J3)=IA(NNO-3)                                                 LAM.65
      LMO(J2)=IA(NNO-4)                                                 LAM.66
      LMO(J1)=IA(NNO-5)                                                 LAM.67
  303 CONTINUE                                                          LAM.68
      GO TO 402                                                         LAM.69
C                                                                       LAM.70
C     ONE-DIMENSIONAL ELEMENT-BEAM COLUMN SPRING                        LAM.71
  401 CONTINUE                                                          LAM.72
      NO=2                                                              LAM.73
      IF(IX(9) .EQ. 2) NO=3                                             LAM.74
      DO 302 I=1,NO                                                     LAM.75
      NODE=IX(I)                                                        LAM.76
      J6=6*I                                                            LAM.77
      J5=J6-1                                                           LAM.78
      J4=J5-1                                                           LAM.79
      J3=J4-1                                                           LAM.80
      J2=J3-1                                                           LAM.81
      J1=J2-1                                                           LAM.82
      NN=6*NODE                                                         LAM.83
      NNO=NN+NOC                                                        LAM.84
      NI=NN+1                                                           LAM.85
      NIO=NNO+1                                                         LAM.86
      LMA(J6)=IA(NN)                                                    LAM.87
      LMA(J5)=IA(NN-1)                                                  LAM.88
      LMA(J4)=IA(NN-2)                                                  LAM.89
      LMA(J3)=IA(NN-3)                                                  LAM.90
      LMA(J2)=IA(NN-4)                                                  LAM.91
      LMA(J1)=IA(NN-5)                                                  LAM.92
      LMO(J6)=IA(NNO)                                                   LAM.93
      LMO(J5)=IA(NNO-1)                                                 LAM.94
      LMO(J4)=IA(NNO-2)                                                 LAM.95
      LMO(J3)=IA(NNO-3)                                                 LAM.96
      LMO(J2)=IA(NNO-4)                                                 LAM.97
      LMO(J1)=IA(NNC-5)                                                 LAM.98
      IF(IND .EQ. 0) GO TO 302                                          LAM.99
      XX(I)=A(N2+NCDE)                                                  LAM.100
      YY(I)=A(N3+NODE)                                                  LAM.101
      ZZ(I)=A(N4+NODE)                                                  LAM.102
  302 CONTINUE                                                          LAM.103
  402 CONTINUE                                                          LAM.104
      RETURN                                                            LAM.105
      END                                                               LAM.106
      SUBROUTINE MULT                                                   MULT.2
C                                                                       MULT.3
C     ******************************************************************MULT.4
C     MULTIPLICATION ANC ADDITICN OF C=C+A*B                            MULT.5
C     TAKE ADVANTAGE CF DIAGONAL PRCPERTY OF A,AND SYMMETRY IN RESULTINGMULT.6
C     MATRIX C                                                          MULT.7
C     A , B , C STOREC IN CCMMON ELANK COLUMN WISE                      MULT.8
C     NA , NB , NC=LCCATION OF A11,B11,C11 IN CCMMCN BLCCK A            MULT.9
C     NRA , NRB=NO. CF ROW OF MATRIX A AND B                            MULT.10
C     NCA=NO. OF COLUMN OF MATRIX A,EQUAL TO 1 IF CIAGONAL MATRIX       MULT.11
C     NCB=NC. OF COLUMN OF MATRIX B                                     MULT.12
C     K=INDICATOR OF RESULTING MATRIX                                   MULT.13
C     K = 1  C IS UNSYMMETRICAL                                         MULT.14
C     K = 2  C IS BANCEC AND SYMMETRICAL                                MULT.15
C     MBANDR=HALF BAND WIDTH OF RESULTING MATRIX                        MULT.16
C     ******************************************************************MULT.17
      LARGE B(22000)                                                    MULT.18
      COMMON A(30000)                                                   MULT.19
      CCMMON/MULTP/NA,NB,NC,NRA,NCA,NRB,NCB,K,MBANDR                    MULT.20
      LARGE C(8000)                                                     MULT.21
C     MULTIPLICATICN IN ROW WISE                                        MULT.22
      MBANDR=1                                                          MULT.23
C     INITILIZATION                                                     MULT.24
      DC 301 I=1,NRA                                                    MULT.25
      J=1                                                               MULT.26
      II=NC+I-1                                                         MULT.27
      IIIBE=NC+I-1                                                      MULT.28
C     SYMMETRICAL CASE                                                  MULT.29
      IF(K .EQ. 2) J=I                                                  MULT.30
 1000 CONTINUE                                                          MULT.31
      JJ=NA+I-1                                                         MULT.32
      KK=NB+NRB*(J-1)                                                   MULT.33
      IF(NCA .EG. 1) KK=KK+(I-1)                                        MULT.34
      DC 302 N=1,NCA                                                    MULT.35
      IF(B(JJ) .EQ. 0.0 .OR. B(KK) .EQ. 0.0) GO TO 403                  MULT.36
      TEMP=B(JJ)*B(KK)                                                  MULT.37
      C(II)=C(II)+TEMP                                                  MULT.38
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  403 CONTINUE                                                          MULT.39
      KK=KK+1                                                           MULT.40
      JJ=JJ+NRA                                                         MULT.41
  302 CCNTINUE                                                          MULT.42
      II=II+NRA                                                         MULT.43
      IF(J .EQ. NCB) GC TO 401                                          MULT.44
      J=J+1                                                             MULT.45
      III=II                                                            MULT.46
      GC TO 1000                                                        MULT.47
  401 CONTINUE                                                          MULT.48
      IF(K .NE. 2) GO TC 301                                            MULT.49
C     CALCULATE HALF EANDWIDTH                                          MULT.50
 2000 CONTINUE                                                          MULT.51
      IF(C(III) .EQ. 0.C) GO TO 402                                     MULT.52
      MB=(III-NC-I+1)/NRA+1                                             MULT.53
      IF(MB .GT. MEANCR) MBANDR=MB                                      MULT.54
      GC TO 301                                                         MULT.55
  402 CONTINUE                                                          MULT.56
      III=III-NRA                                                       MULT.57
      IF(III .LE. IIIBE) GO TO 301                                      MULT.58
      GO TO 2000                                                        MULT.59
  301 CONTINUE                                                          MULT.60
      RETURN                                                            MULT.61
      END                                                               MULT.62
      SUBROUTINE WFORCE(ICOL,WALL,NELW,INFW,WGEOM,WFX,WFY,WFZ,YABV,ZEDG,WFORCE.2
     1                    NTW,NTWEL)                                    WFORCE.3
C     ******************************************************************WFORCE.4
C     CALCULATE THE TOTAL PERPENDICLLAR FORCE AGAINST WALL,WFX,         WFORCE.5
C     VERTICAL SHEAR,WFY,HORIZONTAL SHEAR,WFZ(LCCAL COORD)              WFORCE.6
C     AND THE LINE OF ACTION RELATIVE TO WALL PCSITION                  WFORCE.7
C     ******************************************************************WFORCE.8
      CCMMON/TIME/JUMP,T,DT,MPRTM,MTAPE,KPRINT                          WFORCE.9
      DIMENSION WALL(6,1),INFW(NTW,1),WGEOM(NTW,1),WFX(NTW),            WFORCE.10
     1WFY(1),WFZ(1),YABV(1),ZEDG(1),NELW(1),ICCL(1)                     WFORCE.11
C     CALCULATE WALL BY WALL                                            WFORCE.12
C     INITILIZATION                                                     WFORCE.13
      DO 301 I=1,NTW                                                    WFORCE.14
      WMTY=0.0                                                          WFORCE.15
      WMTZ=0.0                                                          WFORCE.16
      WFX(I)=0.0                                                        WFORCE.17
      WFY(I)=0.0                                                        WFORCE.18
      WFZ(I)=0.0                                                        WFORCE.19
      NEL=NELW(I)                                                       WFORCE.20
      THETA=WGECM(I,1)                                                  WFORCE.21
      YBAR=WGEOM(I,2)                                                   WFORCE.22
      ZBAR=WGEOM(I,3)                                                   WFORCE.23
      AREA=WGEOM(I,4)                                                   WFORCE.24
      AREA=AREA*144.0                                                   WFORCE.25
      AFEA=AREA/FLCAT(NEL)                                              WFORCE.26
      DO 302 II=1,NEL                                                   WFORCE.27
      NOEL=INFW(I,II)                                                   WFORCE.28
      IICOL=ICOL(NOEL)                                                  WFORCE.29
      WF1=WALL(1,IICOL)                                                 WFORCE.30
      WFX(I)=WFX(I)+WF1                                                 WFORCE.31
      WF2=WALL(2,IICOL)                                                 WFORCE.32
      WFY(I)=WFY(I)+WF2                                                 WFORCE.33
      WF3=WALL(3,IICOL)                                                 WFORCE.34
      WFZ(I)=WFZ(I)+WF3                                                 WFORCE.35
C     RESULTANT OF NORMAL FORCE ABOVE BASE                              WFORCE.36
      YY=WALL(5,IICOL)                                                  WFORCE.37
      WMTY=WMTY+WF1*(YY-YBAR)                                           WFORCE.38
      ZZ=WALL(6,IICOL)                                                  WFORCE.39
      WMTZ=WMTZ+WF1*(ZZ-ZBAR)                                           WFORCE.40
  302 CONTINUE                                                          WFORCE.41
      YABV(I)=WMTY/WFX(I)                                               WFORCE.42
      ZEDG(I)=WMTZ/WFX(I)                                               WFORCE.43
      WFX(I)=WFX(I)*AREA                                                WFORCE.44
      WFY(I)=WFY(I)*AREA                                                WFORCE.45
      WFZ(I)=WFZ(I)*AREA                                                WFORCE.46
  301 CCNTINUE                                                          WFORCE.47
      RETURN                                                            WFORCE.48
      END                                                               WFORCE.49
      SUBROUTINE PRINTR(IDA,IX,UA,VA,ACCA,ISOL,ICON,IFR,ISP,SIG,WFX,    PRINTR.2
     1                  WFY,WFZ,YABV,ZEDG,NIND,NTW,NTWEL)               PRINTR.3
      COMMON/ELPAR/NUMNP,NUMEL,NETYPE,NEQA,NEQO,MBANDA,MBANDO,KLIN,NLASTPRINTR.4
      COMMON/TIME/JUMP,T,DT,MPRTM,MTAPE,KPRINT                          PRINTR.5
      COMMON/ABS/UGXT,UGYT,UGZT,VGXT,VGYT,VGZT,CACCX,OACCY,OACCZ        PRINTR.6
      COMMON/STROUT/NSOLIC,NCONC,NFR,NSFRIN                             PRINTR.7
      DIMENSION IDA(6,1),IX(3,1),UA(1),VA(1),ACCA(1),ISOL(1),ICON(1)    PRINTR.8
      DIMENSION IFR(1),ISP(1),SIG(12,1),WFX(1),WFY(1),WFZ(1),YABV(1)    PRINTR.9
      DIMENSION ZEDG(1),NIND(1),D(6)                                    PRINTR.10
      COMMON/TATIME/NTIME,NB6E                                          PRINTR.11
C                                                                       PRINTR.12
C      DETERMINE TO BE PRINT OR NOT                                     PRINTR.13
      IF(MPRTM .EQ. 1) GO TO 402                                        PRINTR.14
      IF(JUMP .EQ. 1) KPRINT=MPRTM                                      PRINTR.15
      IF(JUMP .EQ. 1) GC TO 401                                         PRINTR.16
      IF(JUMP .NE. KPRINT) GO TO 408                                    PRINTR.17
      KPRINT=KPRINT+MPRTM                                               PRINTR.18
C                                                                       PRINTR.19
C     STATIC RESULT                                                     PRINTR.20
      IF(JUMP .NE. 0) GC TO 401                                         PRINTR.21
      NTIME=0                                                           PRINTR.22
      IF(NTWEL .EQ. 0) GO TO 412                                        PRINTR.23
      REWIND 6                                                          PRINTR.24
      DO 301 I=1,NFR                                                    PRINTR.25
      NIND(I)=0                                                         PRINTR.26
  301 CONTINUE                                                          PRINTR.27
  412 CONTINUE                                                          PRINTR.28
      WRITE(1,501)                                                      PRINTR.29
      GO TO 402                                                         PRINTR.30
  401 CCNTINUE                                                          PRINTR.31
      WRITE(1,502)                                                      PRINTR.32
  402 CCNTINUE                                                          PRINTR.33
C                                                                       PRINTR.34
C     NODAL POINT DISPLACEMENT                                          PRINTR.35
      WRITE(1,503)                                                      PRINTR.36
      WRITE(1,101) JUMP,T                                               PRINTR.37
      IF(JUMP .EQ. 0) GC TO 403                                         PRINTR.38
      WRITE(1,102) UGXT,UGYT,UGZT                                       PRINTR.39
  403 CONTINUE                                                          PRINTR.40
      DO 302 N=1,NUMNP                                                  PRINTR.41
      DO 304 I=1,6                                                      PRINTR.42
      D(I)=0.                                                           PRINTR.43
      M=IDA(I,N)                                                        PRINTR.44
      IF(M .EQ. 0) GO TO 304                                            PRINTR.45
      D(I)=UA(M)                                                        PRINTR.46
  304 CONTINUE                                                          PRINTR.47
      WRITE(1,103) N,(D(I),I=1,6)                                       PRINTR.48
  302 CCNTINUE                                                          PRINTR.49
C     NODAL VELCCITY                                                    PRINTR.50
      IF(JUMP .EQ. 0) GC TO 404                                         PRINTR.51
      WRITE(1,504)                                                      PRINTR.52
      WRITE(1,101) JUMP,T                                               PRINTR.53
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      WRITE(1,102) VGXT,VGYT,VGZT
      DO 305 N=1,NUMNP
      DO 307 I=1,6
      D(I)=0.
      M=IDA(I,N)
      IF(M .EQ. 0) GO TO 307
      D(I)=VA(M)
  307 CONTINUE
      WRITE(1,103) N,(D(I),I=1,6)
  305 CONTINUE
  404 CONTINUE
      IF(JUMP .EQ. 0) GC TO 405
C
C     NODAL ACCELERATION
      WRITE(1,505)
      WRITE(1,101) JUMP,T
      WRITE(1,102) OACCX,OACCY,OACCZ
      DO 308 N=1,NUMNP
      DO 310 I=1,6
      D(I)=0.
      M=IDA(I,N)
      IF(M .EQ. 0) GO TO 310
      D(I)=ACCA(M)
  310 CONTINUE
      WRITE(1,103) N,(D(I),I=1,6)
  308 CCNTINUE
  405 CONTINUE
C
C     STRESS AT CENTER CF SOIL ELEMENT
      WRITE(1,506)
      IF(NSOLID .EQ. 0) GO TO 413
      DC 311 IN=1,NSOLID
      N=ISOL(IN)
      DO 313 I=1,6
      D(I)=SIG(I,N)
  313 CONTINUE
      WRITE(1,103) N,(D(I),I=1,6)
  311 CONTINUE
  413 CONTINUE
C
C     END FORCES OF BEAM OR COLUMN AT ENDS
      WRITE(1,507)
      IF(NCONC .EQ. 0) GO TO 414
      DO 314 IN=1,NCONC
      N=ICON(IN)
      DO 315 I=1,6
      D(I)=SIG(I,N)
  315 CCNTINUE
      WRITE(1,103) N,(D(I),I=1,6)
      DO 316 I=7,12
      II=I-6
      D(II)=SIG(I,N)
  316 CONTINUE
      WRITE(1,104) (D(I),I=1,6)
  314 CONTINUE
  414 CONTINUE
C
C     AXIAL FORCE AT BOUNDARY SPRING
      WRITE(1,509)
      IF(NSPRIN .EQ. 0) GO TO 415
      DO 322 IN=1,NSPRIN
      N=ISP(IN)
      DO 323 I=1,3
      D(I)=SIG(I,N)
  323 CONTINUE
      WRITE(1,103) N,(D(I),I=1,3)
  322 CONTINUE
  415 CONTINUE
C
C     FORCES AGAINST WALL
      IF(NTW .EQ. 0) GO TO 410
      WRITE(1,510)
      DO 324 N=1,NTW
      WRITE(1,103) N,WFX(N),WFY(N),WFZ(N),YABV(N),ZEDG(N)
  324 CCNTINUE
C
C     WRITE INFCRMATICN ON TAPE   AT EVERY MTAPE A
  410 CONTINUE
C
C     NODAL FORCE AT FRICTIONAL ELEMENT
      WRITE(1,508)
  406 CONTINUE
      IF(NTWEL .EQ. 0) GO TO 408
      DO 317 IN=1,NFR
      N=IFR(IN)
      DO 318 I=1,4
      D(I)=SIG(I,N)
  318 CONTINUE
      WRITE(1,105) N
      WRITE(1,106) (D(I),I=1,4)
  317 CONTINUE
  408 CONTINUE
      KJJ=(JUMP/MTAPE)*MTAPE
      IF(KJJ .NE. JUMP) GC TO 407
C     WRITE INFCRMATICN ON TAPE AT EVERY MTAPE STEPS
      NTIME=NTIME+1
      WRITE(6) (UA(I),I=1,NEQA),(ACCA(I),I=1,NEQA)
      WRITE(8) ((SIG(I,N),I=1,6),N=1,NUMEL)
      IF(NTW .EQ. 0) GO TO 407
      WRITE(10) (WFX(I),WFY(I),WFZ(I),YABV(I),ZEDG(I),I=1,NTW)
  407 CCNTINUE
      RETURN
  101 FORMAT(I5,F10.4)
  102 FORMAT(* GROUND MCTION*,6X,3E12.4)
  103 FCRMAT(15X,I5,6E12.4)
  104 FCRMAT(20X,6E12.4)
  105 FORMAT(15X,I5)
  106 FCRMAT(32X,4E12.4)
  501 FORMAT(*1STATIC ANALYSIS RESULT*//)
  502 FCRMAT(*1CYNAMIC ANALYSIS RESULT*//)
  503 FORMAT(* RELATIVE DISPLACEMENT-U*//
     1       * TIME      TIME NODE*,
     2       8X,* U-X*,8X,* U-Y*,8X,* U-Z*,8X,*U-XX*,8X,*U-YY*,
     3       8X,*U-ZZ*/
     4       * STEP      SEC  NO.*,
     5       8X,*INCH*,8X,*INCH*,8X,*INCH*,8X,*RAD.*,8X,*RAD.*,
     6       8X,*RAD.*//)
  504 FORMAT(5X,*-RELATIVE VELOCITY-V*//
     1       * TIME      TIME NODE*,
     2       8X,* V-X*,8X,* V-Y*,8X,* V-Z*,8X,*V-XX*,8X,*V-YY*,8X,*V-ZZ*
     3       /* STEP      SEC  NO.*,
     4       4X,*INCH/SEC*,4X,*INCH/SEC*,4X,*INCH/SEC*,4X,*RAD./SEC*,
     5       4X,*RAD./SEC*,4X,*RAD./SEC*//)
  505 FORMAT(5X,*-ACCELERATION-ACC*//
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     1         * TIME        TIME NODE*,
     2         6X,* ACC-X*,6X,* ACC-Y*,6X,* ACC-Z*,6X,* ACC-XX*,
     3         6X,*ACC-YY*,6X,*ACC-ZZ*/
     4         * STEP          SEC   NO.*,
     5         5X,*IN/S--2*,5X,*IN/S--2*,5X,*IN/S--2*,5X,*RAD/S-2*,
     6         5X,*RAD/S-2*,5X,*RAD/S-2*//)
  506 FORMAT(5X,*-STRESS AT CENTER CF SCIL ELEMENT*//
     1         12X,* ELEMENT*,
     2         7X,* SIGX*,7X,* SIGY*,7X,* SIGZ*,7X,*SIGXY*,7X,*SIGYZ*,
     3         7X,*SIGXZ*/
     4         16X,* NO.*,8X,* KSI*//)
  507 FORMAT(5X,*-BEAM,COLUMN FORCES,MOMENT AT I ENC*/
     1         *                                    AND J END*//
     2         12X,* ELEMENT*,
     3         4X,* AXIAL-X*,4X,* SHEAR-Y*,4X,* SHEAR-Z*,6X,* BM-XX*,
     4         5X,* BM-YY*,6X,* BM-ZZ*/
     5         16X,* NO.*,8X,* KIP*,29X,* KIP-IN*//)
  508 FORMAT(5X,* STRESS AT CENTER CF FRICTION ELEMENT*/
     1         5X,* IT IS 1 STEP LATER THAN CTHER LINEAR ELEMENT*//
     2         12X,* ELEMENT NO.   KSI*/
     5         4X,* SHEAR-U*,4X,* SHEAR-V*,4X,* NORML*,6X,* YIELD*//)
  509 FORMAT(5X,*-AXIAL FORCE AT BOUNDARY SPRING*//
     1         12X,* ELEMENT*,11X,*X*,11X,*Y*,11X,*Z*/
     2         16X,* NO.*,9X,*KIP*/)
  510 FORMAT(5X,*-TOTAL FORCES ACTING ON THE WALL*/
     1         15X,* WALL*,4X,*NORMAL-X*,4X,*VERTIC-Y*,4X,*HORIZT-Z*,
     2         8X,* YBAR*,8X,* ZBAR*/
     3         17X,* NO.*,10X,*FT*,9X,*KIP*//)
      END
      SUBROUTINE NCNLIN(PARAFR,IX,TRUA,TRVA,DUA,DVA,DAA,IFR,DSIG,SIG,
     1                  WALL,NIND,DKU,DSTIF,DSTIFP,TRAA,FKDA,NUMEL,
     2                  NEQA,KLIN,NTHEL)
C
C     ******************************************************************
C     FORM DIFFERENTIAL LCAD VECTOR CKU=(DK)*(DL)
C     DUE TO CHANGE OF STIFFNESS OF FRICTION ELEMENT
C     ******************************************************************
C
      COMMON/NONL/NINDT,NINDTO,DKUO(200)
      DIMENSION PARAFR(4,1),IX(3,1),CUA(1),SIG(12,1),NIND(1),DKU(1)
      COMMON/TIME/JUMP,T,DT,MPRTM,MTAPE,KPRINT
      COMMON/UVCOD/U(4),V(4)
      COMMON/LMC/LMA(36),LMO(36),XX(8),YY(8),ZZ(8)
      COMMON/MAXS/MAX1,MAX2
      COMMON/STROUT/NSOLID,NCONC,NFR,NSPRIN
      REAL MAX1,MAX2
      DIMENSION SS(758),ISS(758),DTU(12),F(3),TT(3,3),W(5),DASA(12,12),
     1          ASA1(12,12),ASA2(12,12),ASA4(12,12),SA(3,12),SA1(3,12),
     2          SA2(3,12),SA4(3,12),CSIG(12,1),SC(3,12)
      DIMENSION TRUA(1),TRVA(1),DVA(1),DAA(1),IFR(1),WALL(6,1),DSTIF(1),
     1          DSTIFP(1),TRAA(1),DASAP(12,12),FKDA(1)
      COMMON/BOUND/CBCUND(50),TBOUNC(50),CENTER(50),WS(50),WT(50),DW(50)
      COMMON/IRATON/NCRP,NPROC,ITERAL,ERROR,SUSTEP
      COMMON/EQ/DURAKA,CDT
      COMMON/NDIVI/MASTEP,NYIELC,NSTEP,NCHANG,NINDPA(50)
      EQUIVALENCE(SS,ISS)
      NINDT=0
      NINDTO=0
      REWINC 11
C     INITILIZATION
      IF(JUMP .NE. 0) GO TO 414
      DO 322 I=1,50
      WT(I)=0.
  322 CONTINUE
      MAX1=0.
      MAX2=0.
      NYIELC=0
      NCHANG=0
      MASTEP=0
      SUSTEP=1.0
  414 CONTINUE
C
C     CHECK YIELD CONDITION OF FRICTION ELEMENT ONE BY CNE
      DO 301 NWEL=1,NFR
      N=IFR(NWEL)
      MATYPE=IX(2,N)
C     READ ELEMENT INFORMATION FROM TAPE 11
      READ(11) (SS(I),I=1,758)
C
C     TYPE 3,FRICTION ELEMENT,THE ONLY NON-LINEAR ELEMENT TO BE CHECKED
C     SET UP STRESS(LCCAL)-DISPLACEMENT(GLOBAL) MATRIX SA(12,12)
C     AND DASA-THE DIFFERENTIAL STIFFNESS MATRIX
      DO 302 I=1,12
      LMA(I)=ISS(I+2)
      LMO(I)=ISS(I+14)
  302 CONTINUE
      KK=23
      KK1=59
      KK2=95
      KK4=131
      DO 303 I=1,12
      KI=KK+3*I
      KI1=KK1+3*I
      KI2=KK2+3*I
      KI4=KK4+3*I
      DO 303 J=1,3
      JI=KI+J
      JI1=KI1+J
      JI2=KI2+J
      JI4=KI4+J
      SA(J,I)=SS(JI)
      SA1(J,I)=SS(JI1)
      SA2(J,I)=SS(JI2)
      SA4(J,I)=SS(JI4)
  303 CONTINUE
      IF(KLIN .EQ. 0) GC TO 442
C     STORE UNYIELC SA
      DO 330 I=1,3
      DO 330 J=1,12
      SC(I,J)=SA(I,J)
  330 CONTINUE
      KK=158
      KK1=302
      KK2=446
      KK4=590
      DO 304 I=1,12
      KI=KK+12*I
      KI1=KK1+12*I
      KI2=KK2+12*I
      KI4=KK4+12*I
      DO 304 J=1,12
      JI=KI+J
      JI1=KI1+J
      JI2=KI2+J
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      JI4=KI4+J
      DASA(J,I)=SS(JI)
      DASAP(J,I)=SS(JI)
      ASA1(J,I)=SS(JI1)
      ASA2(J,I)=SS(JI2)
      ASA4(J,I)=SS(JI4)
  304 CONTINUE
      KT=743
      DO 308 I=1,3
      KI=KT+3*I
      DO 308 J=1,3
      JI=KI+J
      TT(J,I)=SS(JI)
  308 CONTINUE
  442 CONTINUE
      XXA=SS(756)
      YYA=SS(757)
      ZZA=SS(758)
C
C     FIND INCREMENTAL NODAL DISPLACEMENT AND STRESS
      DO 305 I=1,12
      IO=LMO(I)
      IF(IO .EQ. 0) GO TO 401
      PRINT 1,I,IO
    1 FORMAT(* THE PROGRAM MUST BE STOP,D O F AT LOCAL AND GLOBAL IS*,
     1       2I5/
     2       * WHICH IS MISTAKENLY ELIMINATED,AT NONLIN.50*)
  401 CONTINUE
      IA=LMA(I)
      IF(IA .NE. 0) GO TO 402
      DTU(I)=0.
      GO TO 403
  402 CONTINUE
      DTU(I)=DUA(IA)
  403 CONTINUE
  305 CONTINUE
      IF(KLIN .EQ. 0) GC TO 409
C     SEPARATION IN LOCAL DIRECTION
      W(1)=TT(3,1)*DTU(1)+TT(3,2)*DTU(2)+TT(3,3)*DTU(3)
      W(2)=TT(3,1)*DTU(4)+TT(3,2)*DTU(5)+TT(3,3)*DTU(6)
      W(3)=TT(3,1)*DTU(7)+TT(3,2)*DTU(8)+TT(3,3)*DTU(9)
      W(4)=TT(3,1)*DTU(10)+TT(3,2)*DTU(11)+TT(3,3)*DTU(12)
      W(5)=W(1)+W(2)+W(3)+W(4)
      DW(NWEL)=W(5)
C
      WT(NWEL)=WT(NWEL)+W(5)
      IF(JUMP .NE. 0) GC TO 416
C     STORE STATIC SEPARATION AS NECESSARY GAP WITHOUT YIELD
C     SHIFT YIELD BY COHESION
C     C IS MINUS SIGN IF INITIALLY SEPARATION
      EN=PARAFR(2,MATYPE)
      C=PARAFR(4,MATYPE)
      CC=C/EN
      WS(NWEL)=W(5)
C     INITIALLY COMPRESSION CASE,SET BOUNDS
      IF(WS(NWEL) .GT. (.0) GO TO 417
      CBOUND(NWEL)=0.
      CENTER(NWEL)=-WS(NWEL)
      TBOUND(NWEL)=-2.0*WS(NWEL)
      WS(NWEL)=0.
      CBOUND(NWEL)=CBCUND(NWEL)+CC
      CENTER(NWEL)=CENTER(NWEL)+CC
      TBOUND(NWEL)=TBCUND(NWEL)+CC
      GO TO 418
  417 CONTINUE
C     INITIALLY TENSION CASE,SHIFT ZERO LINE
      IF(WS(NWEL) .LT. 0.0) GO TO 418
      CBOUND(NWEL)=WS(NWEL)
      CENTER(NWEL)=2.0*WS(NWEL)
      TBOUND(NWEL)=3.0*WS(NWEL)
      CENTER(NWEL)=CENTER(NWEL)+CC
      CBOUNC(NWEL)=CBCUND(NWEL)+CC
      TBOUND(NWEL)=TBOUND(NWEL)+CC
      WS(NWEL)=0.
  418 CONTINUE
      PRINT 204,CBOUNC(NWEL),TBOUND(NWEL)
  204 FORMAT(* BOUN*,2E12.4)
  416 CONTINUE
      IF(JUMP .EQ. 0) GC TO 409
      DO 318 I=1,3
      F(I)=SIG(I,N)
  318 CONTINUE
C     FORM STRESS(LOCAL)-DISPLACEMENT(GLOBAL) MATRIX SA
C     FRCM PREVIOUS YIELD CONDITION
      IF(NIND(NWEL) .EQ. 0) GO TO 425
      IF(NIND(NWEL) .EQ. 1) GO TO 421
      IF(NIND(NWEL) .EQ. 2) GO TO 422
      IF(NIND(NWEL) .EQ. 3) GO TO 426
      IF(NIND(NWEL) .EQ. 4) GO TO 424
  421 CONTINUE
C     YIELD IN U1 DIRECTION
      DO 321 I=1,3
      DO 321 J=1,12
      SA(I,J)=SA1(I,J)
  321 CONTINUE
      DO 351 I=1,12
      DO 351 J=1,12
      DASAP(I,J)=ASA1(I,J)
  351 CONTINUE
      GO TO 425
  422 CONTINUE
C     YIELD IN V2 DIRECTION
      DO 323 I=1,3
      DO 323 J=1,12
      SA(I,J)=SA2(I,J)
  323 CONTINUE
C
      DO 352 I=1,12
      DO 352 J=1,12
      DASAP(I,J)=ASA2(I,J)
  352 CONTINUE
      GO TO 425
  424 CONTINUE
C     YIELD IN BOTH U-V DIRECTION
      DO 327 I=1,3
      DO 327 J=1,12
      SA(I,J)=SA4(I,J)
  327 CONTINUE
C
      DO 353 I=1,12
      DO 353 J=1,12
      DASAP(I,J)=ASA4(I,J)
  353 CONTINUE
C     CALCULATE SUMMATION OF DK(T)*DU(T) AS PART OF INTERNAL ELASTIC
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C     FORCE
  426 CONTINUE
      DO 361 I=1,12
      XA=0.
      IA=LMA(I)
      IF(IA .EQ. 0) GO TO 361
      DO 362 J=1,12
      XA=XA+DASAP(I,J)*DTU(J)
  362 CONTINUE
      FKDA(IA)=FKDA(IA)+XA
  361 CONTINUE
  425 CONTINUE
C     KEEP PREVIOUS CASE CONDITION
      NINDP=NIND(NWEL)
      NINDPA(NWEL)=NINDP
      IF(NINDP .NE. 0) NINDTO=NINDTO+1
      IF(NINDP .EQ. 0) GO TO 441
      IBEGP=1+(NWEL-1)*157
      DSTIFP(IBEGP)=FLOAT(NWEL)
      DO 354 I=1,12
      IL=LMA(I)
      DSTIFP(IBEGP+I)=FLOAT(IL)
  354 CONTINUE
C
      DO 355 I=1,12
      IBP=IBEGP+12*I
      DO 355 J=1,12
      IPP=IBP+J
      DSTIFP(IPP)=DASAP(I,J)
  355 CONTINUE
  441 CONTINUE
  410 CONTINUE
      CALL PFRICT(PARAFR(1,MATYPE),SC,DTU,F,NINC(NWEL),WS(NWEL),
     1     WT(NWEL),CBOUND(NWEL),TBCUND(NWEL),CENTER(NWEL),W(5))
C
C     CHECK IF IT IS YIELD
C     FORM PROPER DIFFERENTIAL STIFFNESS DASA
      IF(NIND(NWEL) .EQ. 0) GO TO 411
      IF(NIND(NWEL) .EQ. 1) GO TO 431
      IF(NIND(NWEL) .EQ. 2) GO TO 432
      IF(NIND(NWEL) .EQ. 3) GO TO 435
      IF(NIND(NWEL) .EQ. 4) GO TO 434
  431 CONTINUE
C     YIELD IN U-1 DIRECTION
      DO 326 I=1,12
      DO 326 J=1,12
      DASA(I,J)=ASA1(I,J)
  326 CONTINUE
      GO TO 435
  432 CONTINUE
C     YIELD IN V-2 DIRECTION
      DO 324 I=1,12
      DO 324 J=1,12
      DASA(I,J)=ASA2(I,J)
  324 CONTINUE
      GO TO 435
  434 CONTINUE
C     YIELD U-V
      DO 328 I=1,12
      DO 328 J=1,12
      DASA(I,J)=ASA4(I,J)
  328 CONTINUE
  435 CONTINUE
      NINDT=NINDT+1
C     FORM DIFFERENTIAL STIFFNESS DASA
C     FORM DIFFERENTIAL LOAD VECTOR DK(T)*DU(T-1) ON RIGHT HAND
C     SIDE AS LOAD VECTOR,AS STARTING FOR ITERATION SOLUTION
      DO 306 I=1,12
      XA=0.0
      IA=LMA(I)
      IF(IA .EQ. 0) GO TO 306
      DO 307 J=1,12
      XA=XA+DASA(I,J)*DTU(J)
  307 CONTINUE
      DKU(IA)=DKU(IA)+XA
  306 CONTINUE
C     STORE FRICTION ELEMENT INFORMATION ON TAPE12,FOR ITERATION
      ND=12
      IBEG=1+(NWEL-1)*157
      DSTIF(IBEG)=FLOAT(NWEL)
      DO 329 I=1,12
      IL=LMA(I)
      DSTIF(IBEG+I)=FLOAT(IL)
  329 CONTINUE
      DO 331 I=1,12
      IB=IBEG+12*I
      DO 331 J=1,12
      IP=IB+J
      DSTIF(IP)=DASA(I,J)
  331 CONTINUE
C     CALCULATE INCREMENTAL STRESS AND ADD UP AS TOTAL STRESS
      GO TO 411
  409 CONTINUE
      NIND(NWEL)=0
      NINDP=0
      NINDPA(NWEL)=NINDP
      IF(KLIN .EQ. 0) GO TO 440
  411 CONTINUE
C     CHECK IF THE YIELD CONDITION CHANGED
C     EITHER FROM TENSION TO COMPRESSION,OR COMPRESSION TO TENSION
      NINDNW=NIND(NWEL)
      IF(NYIELD .NE. 0) GO TO 438
      IF(SUSTEP .EQ. 1.0) GO TO 436
      IF(NINDP .EQ. 3 .AND. NINDNW .EQ. 3) GO TO 436
      IF(NINDP .NE. 3 .AND. NINDNW .NE. 3) GO TO 436
      TW=WT(NWEL)
      TB=TBOUND(NWEL)
      IF(NINDNW .EQ. 3 .AND. TW .LE. TB) GO TO 436
      IF(NINDNW .EQ. 3 .AND. TW .GT. TB) GO TO 439
      CB=CBOUND(NWEL)
      IF(NINDNW .EQ. 0 .AND. TW .GE. CB) GO TO 436
  439 CONTINUE
C
C     STEP SIZE
      DIVID=0.5*(TBOUND(NWEL)-CBOUND(NWEL))
      SSTEP=W(5)/DIVID
      SSTEP=ABS(SSTEP)
      IF(SSTEP .LT. 2.0) GO TO 436
      NCHANG=NCHANG+1
      NSTEP=IFIX(SSTEP)
      IF(NSTEP .GE. MASTEP) MASTEP=NSTEP
  438 CONTINUE
  436 CONTINUE
      IF(NINDP .NE. 3) GO TO 440
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      DO 311 I=1,3                                                      NONLIN.345
      DSIG(I,N)=0.                                                      NONLIN.346
  311 CONTINUE                                                          NONLIN.347
      GO TO 412                                                         NONLIN.348
  440 CONTINUE                                                          NONLIN.349
      DO 309 I=1,3                                                      NONLIN.350
      DSIG(I,N)=0.0                                                     NONLIN.351
      DO 310 J=1,12                                                     NONLIN.352
      DSIG(I,N)=DSIG(I,N)+SA(I,J)*DTU(J)                                NONLIN.353
  310 CONTINUE                                                          NONLIN.354
      SIG(I,N)=SIG(I,N)+DSIG(I,N)                                       NONLIN.355
  309 CONTINUE                                                          NONLIN.356
  412 CONTINUE                                                          NONLIN.357
      SIG(4,N)=FLOAT(NIND(NWEL))                                        NONLIN.358
      WALL(1,NWEL)=SIG(3,N)                                             NONLIN.359
      WALL(2,NWEL)=SIG(2,N)                                             NONLIN.360
      WALL(3,NWEL)=SIG(1,N)                                             NONLIN.361
      WALL(4,NWEL)=XXA                                                  NONLIN.362
      WALL(5,NWEL)=YYA                                                  NONLIN.363
      WALL(6,NWEL)=ZZA                                                  NONLIN.364
C     STORE STAIC MAXIMUM SHEAR STRESS                                  NONLIN.365
      IF(JUMP .NE. 0) GO TO 415                                         NONLIN.366
      SHEAR1=ABS(SIG(1,N))                                              NONLIN.367
      SHEAR2=ABS(SIG(2,N))                                              NONLIN.368
      IF(SHEAR1 .GT. MAX1)MAX1=SHEAR1                                   NONLIN.369
      IF(SHEAR2 .GT. MAX2)MAX2=SHEAR2                                   NONLIN.370
  415 CONTINUE                                                          NONLIN.371
  301 CONTINUE                                                          NONLIN.372
C     CHECK IF IT IS NECESSARY TO RESET                                 NONLIN.373
      IF(NYIELD .NE. 0) GO TO 437                                       NONLIN.374
      IF(NCHANG .EQ. 0) GO TO 437                                       NONLIN.375
      CALL RESET(TRUA,TRVA,DUA,DVA,DAA,DSIG,SIG,NIND,DKU,DSTIF,         NONLIN.376
     1                DSTIFF,TRAA)                                      NONLIN.377
  437 CONTINUE                                                          NONLIN.378
      RETURN                                                            NONLIN.379
      END                                                               NONLIN.380
      SUBROUTINE RESET(TRUA,TRVA,DUA,DVA,DAA,DSIG,SIG,NIND,DKU,DSTIF,   RESET.2
     1                DSTIFP,TRAA)                                      RESET.3
C                                                                       RESET.4
C     SET PRESENT VALUE TO ONE STEP BEFORE                              RESET.5
C     SET TIME STEP SIZE                                                RESET.6
C                                                                       RESET.7
      COMMON/STROUT/NSOLID,NCONC,NFR,NSFRIN                             RESET.8
      COMMON/IRATON/NCRP,NPROC,ITERAL,ERROR,SUSTEP                      RESET.9
      COMMON/NONL/NINDT,NINDTO,DKUO(200)                                RESET.10
      COMMON/TIME/JUMP,T,DT,MPRTM,MTAPE,KPRINT                          RESET.11
      COMMON/NDIVI/MASTEP,NYIELD,NSTEP,NCHANG,NINDPA(50)                RESET.12
      COMMON/ELPAR/NUMNP,NUMEL,NETYPE,NEQA,NEQO,MBANDA,MBANDO,KLIN,NLASTRESET.13
      COMMON/NEWAL/NTW,NTWEL                                            RESET.14
      COMMON/EQ/DURANA,DDT                                              RESET.15
      COMMON/BOUND/CBOUND(50),TBOUND(50),CENTER(50),WS(50),WT(50),DW(50)RESET.16
      DIMENSION TRUA(1),TRVA(1),DUA(1),DVA(1),DAA(1),DSIG(12,1),        RESET.17
     1          SIG(12,1),NIND(1),DKU(1),DSTIF(1),DSTIFF(1),TRAA(1)     RESET.18
      T=T-DT                                                            RESET.19
      JUMP=JUMP-1                                                       RESET.20
C                                                                       RESET.21
      DO 301 I=1,NEQA                                                   RESET.22
      TRUA(I)=TRUA(I)-DUA(I)                                            RESET.23
      TRVA(I)=TRVA(I)-DVA(I)                                            RESET.24
      TRAA(I)=TRAA(I)-DAA(I)                                            RESET.25
  301 CONTINUE                                                          RESET.26
C                                                                       RESET.27
      DO 302 I=1,NFR                                                    RESET.28
      NIND(I)=NINDPA(I)                                                 RESET.29
  302 CONTINUE                                                          RESET.30
C                                                                       RESET.31
      DO 303 I=1,NFR                                                    RESET.32
      WT(I)=WT(I)-DW(I)                                                 RESET.33
  303 CONTINUE                                                          RESET.34
      DO 304 N=1,NUMEL                                                  RESET.35
      DC 304 I=1,12                                                     RESET.36
      SIG(I,N)=SIG(I,N)-DSIG(I,N)                                       RESET.37
  304 CONTINUE                                                          RESET.38
C                                                                       RESET.39
      DO 305 I=1,NEQA                                                   RESET.40
      DKU(I)=DKUO(I)                                                    RESET.41
  305 CONTINUE                                                          RESET.42
C                                                                       RESET.43
      NN=157*NFR                                                        RESET.44
      DO 306 I=1,NN                                                     RESET.45
      DSTIF(I)=DSTIFP(I)                                                RESET.46
  306 CONTINUE                                                          RESET.47
      PRINT 1,JUMP,MASTEP,SUSTEP                                        RESET.48
    1 FORMAT(* JUMP,MASTEP,SUSTEP*,2I5,E12.4)                           RESET.49
      PRINT 215,JUMP,MASTEP,(DW(I),I=1,NFR),(WT(I),I=1,NFR)             RESET.50
  215 FORMAT(* RESET*,2I5/(8E12.4))                                     RESET.51
      RETURN                                                            RESET.52
      END                                                               RESET.53
      SUBROUTINE STEP(IDA,PARAFR,IX,TRUA,TRVA,ACCA,DUA,DVA,DAA,         STEP.2
     1             ICOL,ISOL,ICON,IFR,ISP,DSIG,SIG,WALL,NELW,INFW,      STEP.3
     2        WGEOM,WFX,WFY,WFZ,YAEV,ZEDG,NINC,DKU,DSTIF,DSTIFP,U,V,    STEP.4
     3             TRAA,OTRUA,OTRVA,OTRAA,RMASSX,FGRA,FIA,FMA,FMB,      STEP.5
     4             FKDA,US,UNEW,UOLD,PLOAD,TMASSA,EKAA,EKABAR,CA,       STEP.6
     5             EKA1,TIMEB,NEQA,NTW,NTWEL,NUMEL,NUMNP,KLIN,MBANDA)STEP.7
      COMMON/TITLE/HEAD(12),EQNAME(12)                                  STEP.8
      COMMON/TIME/JUMP,T,DT,MPRTM,MTAPE,KPRINT                          STEP.9
      COMMON/ABS/UGXT,UGYT,UGZT,VGXT,VGYT,VGZT,OACCX,OACCY,OACCZ        STEP.10
      COMMON/DAMP2/NDAMP,NROOT,NFP,XI(20),NXI(20),OMEGA(20)             STEP.11
      COMMON/CONSTA/CCM,COM1,COM2,D3,A0,A1,A2,A3,A4,A5,A6,A7,A8,AT1,BT1 STEP.12
      COMMON/EQ/DURANA,DDT                                              STEP.13
      DIMENSION IDA(6,1),PARAFR(4,1),IX(3,1),TRUA(1),TRVA(1),ACCA(1)    STEP.14
      DIMENSION DUA(1),DVA(1),DAA(1),DSIG(12,1),SIG(12,1),WALL(6,1)     STEP.15
      DIMENSION NELW(1),INFW(1),WGEOM(1),WFX(1),WFY(1),WFZ(1)           STEP.16
      DIMENSION YAEV(1),ZEDG(1),NINC(1),DKU(1),U(1),V(1),TRAA(1)        STEP.17
      DIMENSION ICOL(1),ISOL(1),ICON(1),IFR(1),ISP(1),DSTIF(1),DSTIFP(1)STEP.18
      DIMENSION UOLDD(150)                                              STEP.19
      LARGE TMASSA(NEQA,MBANDA),EKAA(NEQA,MBANDA),EKABAR(NEQA,MBANDA)   STEP.20
      LARGE CA(NEQA,MBANDA),EKA1(NEQA,MBANDA),TIMEB(1)                  STEP.21
      COMMON/NDIVI/MASTEP,NYIELD,NSTEP,NCHANG,NINDPA(50)                STEP.22
      COMMON/TATIME/NTIME,NB6E                                          STEP.23
      DIMENSION OTRUA(1),OTRVA(1),OTRAA(1),RMASSX(1),FGRA(1),FMA(1)     STEP.24
      DIMENSION FMB(1),FKDA(1),FIA(1),US(1),U2G(9)                      STEP.25
      COMMON/NONL/NINDT,NINDTO,DKUO(200)                                STEP.26
      COMMON/IRATON/NCRP,NPROC,ITERAL,ERROR,SUSTEP                      STEP.27
      DIMENSION UOLD(1),UNEW(1),PLOAD(1)                                STEP.28
      READ 1,EQNAME                                                     STEP.29
      PRINT 101,EQNAME                                                  STEP.30
      READ 2,EQMUL,DTEQ,DT,DUREQ,DURANA,MPRTM,MTAPE,KPRINT              STEP.31
      WRITE(1,102) EQMUL,DTEQ,DT,DUREQ,DURANA,MPRTM,MTAPE,KPRINT        STEP.32
      DTO=DT                                                            STEP.33
      READ 3,IDAMP                                                      STEP.34
      PRINT 103,IDAMP                                                   STEP.35
      READ 4,INTEGR,THETA                                               STEP.36
      PRINT 104,INTEGR,THETA                                            STEP.37
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C     FCRM RAYLEIGH DAMFING ALFA,BETA                                    STEP.38
      IF(IDAMP .NE. 1) GO TO 401                                         STEP.39
      READ 5,N1,N2,XI(1),XI(2)                                           STEP.40
      OMEGA(1)=OMEGA(N1)                                                 STEP.41
      OMEGA(2)=OMEGA(N2)                                                 STEP.42
      PRINT 105,XI(1),XI(2),OMEGA(1),OMEGA(2),N1,N2                      STEP.43
      T1=XI(2)*OMEGA(1)-XI(1)*OMEGA(2)                                   STEP.44
      T2=2.0*OMEGA(1)*CMEGA(2)                                           STEP.45
      TC=OMEGA(1)**2-CMEGA(2)**2                                         STEP.46
      ALFA=T1*T2/TC                                                      STEP.47
      T3=2.0*(XI(1)*OMEGA(1)-XI(2)*CMEGA(2))                             STEP.48
      BETA=T3/TC                                                         STEP.49
      GO TO 441                                                          STEP.50
  401 CONTINUE                                                           STEP.51
C                                                                        STEP.52
C     DIRECT DAMPING BY PEZIEN,WILSCN                                    STEP.53
      IF(IDAMP .NE. 2) GO TO 403                                         STEP.54
      CALL OVERLAY(6HTHREED,9,0,0)                                       STEP.55
      GO TO 441                                                          STEP.56
  403 CONTINUE                                                           STEP.57
C     STRUCTURAL DAMPING                                                 STEP.58
      IF(IDAMP .NE. 3) GO TO 441                                         STEP.59
      CALL OVERLAY(6HTHREED,10,0,0)                                      STEP.60
  441 CCNTINUE                                                           STEP.61
C     INPUT ITERATION PARAMETER                                          STEP.62
      READ 6,NORM,NPRCC,ITERAL,ERROR,SUSTEP                              STEP.63
      WRITE(1,106) NORM,NPROC,ITERAL,ERROR,SUSTEP                        STEP.64
C                                                                        STEP.65
C     FORM CONSTANTS FOR INTEGRATION METHOD                              STEP.66
      CALL CCNST(INTEGR,DT,THETA)                                        STEP.67
C                                                                        STEP.68
C     READ IN EARTHQUAKE ACCELERATICN 8 STEPS EACH TIME                  STEP.69
      G=386.07                                                           STEP.70
      DO 301 I=1,9                                                       STEP.71
      U2G(I)=0.                                                          STEP.72
  301 CONTINUE                                                           STEP.73
      READ 9,(U2G(I),I=2,9)                                              STEP.74
      WRITE(1,109) (U2G(I),I=1,9)                                        STEP.75
      ACCX=U2G(2)*EQMUL*G                                                STEP.76
      DUR7=7.0*DTEQ                                                      STEP.77
      DUR8=8.0*DTEQ                                                      STEP.78
C                                                                        STEP.79
C     INITILIZATION,WITH ACCX=-GROUNC ACC AS INITIAL CONDITION           STEP.80
      DO 302 I=1,NEQA                                                    STEP.81
      U(I)=TRUA(I)                                                       STEP.82
      TRUA(I)=0.                                                         STEP.83
      TRVA(I)=0.                                                         STEP.84
      TRAA(I)=0.                                                         STEP.85
  302 CONTINUE                                                           STEP.86
      DC 303 I=1,NUMNP                                                   STEP.87
      MX=IDA(1,I)                                                        STEP.88
      IF(MX .EQ. 0) GO TO 303                                            STEP.89
      TRAA(MX)=-ACCX                                                     STEP.90
  303 CONTINUE                                                           STEP.91
      UGXT=0.                                                            STEP.92
      VGXT=0.                                                            STEP.93
      OACCX=ACCX                                                         STEP.94
C                                                                        STEP.95
      UGYT=0.                                                            STEP.96
      UGZT=0.                                                            STEP.97
      VGYT=0.                                                            STEP.98
      VGZT=0.                                                            STEP.99
      OACCY=0.0                                                          STEP.100
      OACCZ=0.                                                           STEP.101
C     STORE TMASSA                                                       STEP.102
      REWIND 5                                                           STEP.103
      DO 307 I=1,NEQA                                                    STEP.104
      DO 307 J=1,MBANDA                                                  STEP.105
      TMASSA(I,J)=0.                                                     STEP.106
      EKAA(I,J)=0.                                                       STEP.107
  307 CONTINUE                                                           STEP.108
      READ(5) ((TMASSA(I,J),I=1,NEQA),J=1,MBANDA)                        STEP.109
C     STORE RMASSX                                                       STEP.110
      READ(5) (RMASSX(I),I=1,NEQA)                                       STEP.111
C     STORE EKAA                                                         STEP.112
      REWIND 2                                                           STEP.113
      READ(2) ((EKAA(I,J),I=1,NEQA),J=1,MBANDA)                          STEP.114
C     SAVE STIFFNESS MATRIX                                              STEP.115
      DC 335 I=1,NEQA                                                    STEP.116
      DO 335 J=1,MBANDA                                                  STEP.117
      EKABAR(I,J)=EKAA(I,J)                                              STEP.118
  335 CONTINUE                                                           STEP.119
C                                                                        STEP.120
C     FCRM EFFECTIVE MATRIX KBAR=EKAA(I,J)                               STEP.121
C     IN CONSTANT ACCELERATION,RAILEIGH METHOD KBAR=K+C1*M               STEP.122
C     FORM DAMPING MATRIX IF IT IS RAYLEIGH DAMFING                      STEP.123
      IF(IDAMP .NE. 1) GO TO 406                                         STEP.124
      DO 333 I=1,NEQA                                                    STEP.125
      DO 333 J=1,MBANDA                                                  STEP.126
      CA(I,J)=ALFA*TMASSA(I,J)+BETA*EKAA(I,J)                            STEP.127
  333 CONTINUE                                                           STEP.128
  406 CONTINUE                                                           STEP.129
C                                                                        STEP.130
C     CONSTANT ACCELERATION                                              STEP.131
      IF(INTEGR .NE. 0) GO TO 407                                        STEP.132
      IF(KLIN .EQ. 0 .OR. SUSTEP .EQ. 1.0) GO TO 471                     STEP.133
      DO 338 I=1,NEQA                                                    STEP.134
      DC 338 J=1,MBANCA                                                  STEP.135
      TAM=COM*SUSTEP*SUSTEP*TMASSA(I,J)                                  STEP.136
      TAC=D3*SUSTEP*CA(I,J)                                              STEP.137
      EKA1(I,J)=EKAA(I,J)+TAM+TAC                                        STEP.138
  338 CONTINUE                                                           STEP.139
  471 CONTINUE                                                           STEP.140
      DO 312 I=1,NEQA                                                    STEP.141
      DO 312 J=1,MBANCA                                                  STEP.142
      TAM=COM*TMASSA(I,J)                                                STEP.143
      TAC=D3*CA(I,J)                                                     STEP.144
      EKAA(I,J)=EKAA(I,J)+TAM+TAC                                        STEP.145
  312 CONTINUE                                                           STEP.146
      GO TO 408                                                          STEP.147
  407 CONTINUE                                                           STEP.148
C                                                                        STEP.149
C     WILSON THETA METHCD                                                STEP.150
      IF(INTEGR .NE. 1) GO TO 408                                        STEP.151
      IF(KLIN .EQ. 0 .OR. SUSTEP .EC. 1.0) GO TC 472                     STEP.152
      DO 339 I=1,NEQA                                                    STEP.153
      DO 339 J=1,MBANDA                                                  STEP.154
      TAM=SUSTEP*SUSTEP*AO*TMASSA(I,J)                                   STEP.155
      TAC=A1*SUSTEP*CA(I,J)                                              STEP.156
      EKA1(I,J)=EKAA(I,J)+TAM+TAC                                        STEP.157
  339 CCNTINUE                                                           STEP.158
  472 CONTINUE                                                           STEP.159
      DO 311 I=1,NEQA                                                    STEP.160
      DC 311 J=1,MBANCA                                                  STEP.161
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      TAM=AO*THASSA(I,J)                                                STEP.162
      TAC=A1*CA(I,J)                                                    STEP.163
      EKAA(I,J)=EKAA(I,J)+TAM+TAC                                       STEP.164
  311 CONTINUE                                                          STEP.165
  408 CONTINUE                                                          STEP.166
C                                                                       STEP.167
C     TRIANGULIZATION EKAA                                              STEP.168
      CALL TRIA(EKAA,NEQA,MBANDA)                                       STEP.169
      IF(KLIN .EQ. 0 .OR. SUSTEP .EQ. 1.0) GC TO 473                    STEP.170
      CALL TRIA(EKA1,NEQA,MBANDA)                                       STEP.171
  473 CONTINUE                                                          STEP.172
C     INITILIZATION                                                     STEP.173
      DO 306 I=1,NEQA                                                   STEP.174
      FIA(I)=0.                                                         STEP.175
  306 CCNTINUE                                                          STEP.176
C                                                                       STEP.177
C     LOADING TERMS WITH MASS OR DAMFING                                STEP.178
      IF(INTEGR .NE. 0) GO TO 433                                       STEP.179
C     CONSTANT ACCELERATION                                             STEP.180
      DO 330 I=1,NEQA                                                   STEP.181
      FMB(I)=0.                                                         STEP.182
  330 CONTINUE                                                          STEP.183
      CALL MULTBA(THASSA,TRAA,FMA,NEQA,MBANDA)                          STEP.184
      GO TO 434                                                         STEP.185
  433 CONTINUE                                                          STEP.186
C     WILSON METHOD                                                     STEP.187
      IF(INTEGR .NE. 1) GO TO 434                                       STEP.188
      CALL MULTBA(THASSA,TRAA,FMA,NECA,MBANDA)                          STEP.189
      CALL MULTBA(CA,TRAA,FMB,NEQA,MBANDA)                              STEP.190
      DO 331 I=1,NEQA                                                   STEP.191
      FMA(I)=2.0*FMA(I)                                                 STEP.192
      FMB(I)=A3*FMB(I)                                                  STEP.193
  331 CONTINUE                                                          STEP.194
  434 CONTINUE                                                          STEP.195
      DO 332 I=1,NEQA                                                   STEP.196
      FKDA(I)=0.                                                        STEP.197
  332 CCNTINUE                                                          STEP.198
      IF(KLIN .NE. 0) GO TO 428                                         STEP.199
      DO 336 I=1,NEQA                                                   STEP.200
      DKU(I)=0.                                                         STEP.201
  336 CONTINUE                                                          STEP.202
  428 CONTINUE                                                          STEP.203
      CALL SETFLL(55000B)                                               STEP.204
      CALL REWUNL(2)                                                    STEP.205
      CALL REWUNL(3)                                                    STEP.206
      CALL REWUNL(5)                                                    STEP.207
      CALL REWUNL(7)                                                    STEP.208
      CALL REWUNL(9)                                                    STEP.209
      CALL REWUNL(11)                                                   STEP.210
      CALL REWUNL(12)                                                   STEP.211
C     ***************************                                       STEP.212
C     START OF STEP-BY-STEP CYCLE                                       STEP.213
C     ***************************                                       STEP.214
      TIMEB(1)=0.                                                       STEP.215
      NYIELD=0                                                          STEP.216
      MASTEP=0                                                          STEP.217
      NCHANG=0                                                          STEP.218
      NSTEP=0                                                           STEP.219
      IF(SUSTEP .EQ. 1.C) DDT=DT                                        STEP.220
 1000 CONTINUE                                                          STEP.221
      IF(KLIN .EQ. 0 .CR. SUSTEP .EQ. 1.0) GO TO 474                    STEP.222
C     IF SUSTEP .EQ. 1,THERE IS NO VARIABLE STEP                        STEP.223
      IF(MASTEP .EQ. 0) GO TO 454                                       STEP.224
C     RECALCULATE INTEGRATION CONSTANTS                                 STEP.225
      DCT=DTO/SUSTEP                                                    STEP.226
      CALL CCNST(INTEGR,DDT,THETA)                                      STEP.227
      NYIELD=NYIELD+1                                                   STEP.228
      MSTEP=IFI)(SUSTEP)                                                STEP.229
      IF(NYIELD .GT. MSTEP) GO TO 454                                   STEP.230
  456 CONTINUE                                                          STEP.231
      DT=DDT                                                            STEP.232
      T=T+DDT                                                           STEP.233
      GO TO 457                                                         STEP.234
  454 CCNTINUE                                                          STEP.235
C     RECALCULATE CONSTANT IF RETURN TO NORMAL STEPS                    STEP.236
      DT=DTO                                                            STEP.237
      CALL CONST(INTEGR,DT,THETA)                                       STEP.238
  458 CONTINUE                                                          STEP.239
      NYIELD=0                                                          STEP.240
      MASTEP=0                                                          STEP.241
      NCHANG=0                                                          STEP.242
      NSTEP=0                                                           STEP.243
  474 CONTINUE                                                          STEP.244
      T=T+DT                                                            STEP.245
  457 CONTINUE                                                          STEP.246
      JUMP=JUMP+1                                                       STEP.247
      TIMEB(JUMP+1)=T                                                   STEP.248
      IF(T .GT. DURANA) GO TO 424                                       STEP.249
      IF(T .GT. DUREQ) GO TO 410                                        STEP.250
      IF(T .LE. DUR7) GC TO 409                                         STEP.251
      U2G(1)=U2G(9)                                                     STEP.252
      READ 9,(U2G(I),I=2,9)                                             STEP.253
      WRITE(1,109) (U2G(I),I=1,9)                                       STEP.254
      DUR7=DUR7+DUR8                                                    STEP.255
  409 CONTINUE                                                          STEP.256
C                                                                       STEP.257
C     INTEPLOLATION OF EARTHQUAKE INFUT IF DT NCT EQUAL DTEQ            STEP.258
      PUGXT=UGXT                                                        STEP.259
      PVGXT=VGXT                                                        STEP.260
      PACCX=ACCX                                                        STEP.261
      TEMP=(DUR7-T)/DTEC                                                STEP.262
      IND=IFIX(TEMP)                                                    STEP.263
      FRACT=TEMP-FLOAT(IND)                                             STEP.264
      IND=9-IND                                                         STEP.265
      ACCX=(U2G(IND)+FRACT*(U2G(IND-1)-U2G(IND)))*EGMUL*G               STEP.266
      GC TO 411                                                         STEP.267
  410 CONTINUE                                                          STEP.268
      ACCX=0.                                                           STEP.269
  411 CONTINUE                                                          STEP.270
C     CALCULATE INERTIA TERM FRCM GRCUNC MOTICN                         STEP.271
C     CONSTANT ACCELERATION                                             STEP.272
      IF(INTEGR .NE. 0) GO TO 429                                       STEP.273
      DO 304 I=1,NEQA                                                   STEP.274
      FGRA(I)=-ACCX*RMASSX(I)                                           STEP.275
  304 CONTINUE                                                          STEP.276
C                                                                       STEP.277
  429 CCNTINUE                                                          STEP.278
C     WILSON THETA METHCD                                               STEP.279
      IF(INTEGR .NE. 1) GO TO 435                                       STEP.280
      DO 305 I=1,NEQA                                                   STEP.281
      FGRA(I)=-OACCX*RMASSX(I)*(1.0-THETA)-THETA*ACCX*RMASSX(I)         STEP.282
  305 CCNTINUE                                                          STEP.283
  435 CONTINUE                                                          STEP.284
      DO 308 I=1,NEQA                                                   STEP.285
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  308 DUA(I)=0.
C     1ST STEP IN DYNAMIC
      IF(JUMP .NE. 1 .OR. KLIN .EQ. 0) GO TO 442
      DO 337 I=1,NEQA
      UOLD(I)=0.0
  337 CONTINUE
  442 CONTINUE
C     INCREMENTAL LOADING VECTOR
      DO 309 I=1,NEQA
      DUA(I)=FGRA(I)+FIA(I)+FMA(I)+FMB(I)+DKU(I)
  309 CONTINUE
C     INTEGRATICN OF EQ ACCELERATION RECORD INTC VELO. AND DISP.
C     OF GROUND MCTION
      UGXT=UGXT+DT*VGXT+COM1*OACCX+COM2*ACCX
      VGXT=VGXT+0.5*DT*(OACCX+ACCX)
      OACCX=ACCX
C     SAVE INCREMENTAL LOAD VECTOR
      IF(KLIN .EQ. 0) GC TO 452
      IF(NPROC .NE. 1) GO TO 451
      DO 341 I=1,NEQA
      PLOAD(I)=CUA(I)
  341 CONTINUE
      GO TO 452
  451 CCNTINUE
      DO 342 I=1,NEQA
      PLOAD(I)=0.
  342 CONTINUE
  452 CONTINUE
      IF(NYIELD .NE. 0) GO TO 461
      CALL BACKS(EKAA,DUA,NEQA,MBANDA)
      IF(KLIN .EQ. 0) GC TO 453
C     NO ITERATION,IF NC YIELD
      IF(NINDT .EQ. 0) GO TO 412
      GO TO 463
  461 CONTINUE
C     SAVE NEW INCREMENTAL DISPLACEMENT VECTOR AFTER 1ST SOLUTICN
      CALL BACKS(EKA1,CUA,NEQA,MBANDA)
C     NO ITERATION,IF NC YIELD
      IF(NYIELD .EQ. 1 .AND. NINDTO .EQ. 0) GO TO 412
      IF(NINDT .EQ. 0) GO TO 412
  463 CONTINUE
      DO 343 I=1,NEQA
      UNEW(I)=DUA(I)
  343 CONTINUE
C     BEGIN ITERATION
      IF(SUSTEP .EQ. 1.0) CALL ITERAT(EKAA,UOLD,UNEW,PLCAD,NIND,DSTIF)
      IF(SUSTEP .NE. 1.0) CALL ITERAT(EKA1,UOLC,UNEW,PLCAD,NIND,DSTIF)
C     SAVE CLD INCREMENTAL VECTOR FCR NEXT STEP
      DO 344 I=1,NEQA
      DUA(I)=UNEW(I)
      UOLD(I)=UNEW(I)
  344 CONTINUE
      GO TO 453
C     CALCULATE TOTAL DISP,VELO,ACC AT THE END CF STEP
  412 CONTINUE
      DO 345 I=1,NEQA
      UOLD(I)=DUA(I)
  345 CONTINUE
  453 CCNTINUE
C     CONSTANT ACCELERATION METHOD
      IF(INTEGR .NE. 0) GO TO 413
      DO 313 I=1,NEQA
      DISP=DUA(I)
      VEL=DISP*D3-BT1*TRVA(I)
      DVA(I)=VEL
      ACCE=DISP*COM-AT1*TRVA(I)-BT1*TRAA(I)
      DAA(I)=ACCE
  313 CONTINUE
C
C     UPDATE RELATIVE QUANTITIES
      DO 334 I=1,NEQA
      TRUA(I)=TRUA(I)+DUA(I)
      TRVA(I)=TRVA(I)+DVA(I)
      TRAA(I)=TRAA(I)+DAA(I)
  334 CONTINUE
      GO TO 414
  413 CONTINUE
C     WILSON METHOD
      DO 314 I=1,NEQA
      TRAA(I)=A4*DUA(I)+A5*OTRVA(I)+A6*OTRAA(I)
      TRVA(I)=OTRVA(I)+A7*(TRAA(I)+CTRAA(I))
      TRUA(I)=CTRUA(I)+CT*OTRVA(I)+A8*(TRAA(I)+2.0*CTRAA(I))
  314 CONTINUE
      DO 315 I=1,NEQA
      OTRAA(I)=TRAA(I)
      OTRVA(I)=TRVA(I)
      OTRUA(I)=TRUA(I)
  315 CONTINUE
  414 CONTINUE
C
C     CALCULATE STRESS
      CALL CVERLAY(6HTHREED,8,0,6HRECALL)
C
C     CALCULATE TOTAL RESPONSE INCLUDING STATIC
      IF(JUMP .GT. 1) GC TO 415
C     SAVE STATIC RESULT
      DO 316 I=1,NEQA
  316 US(I)=U(I)
      GO TO 416
  415 CONTINUE
      DO 317 I=1,NEQA
  317 US(I)=0.
  416 CCNTINUE
      DO 318 I=1,NUMNP
      NX=IDA(1,I)
      IF(NX .EQ. 0) GO TO 417
      U(NX)=TRUA(NX)+US(NX)+UGXT
      V(NX)=TRVA(NX)+VGXT
      ACCA(NX)=TRAA(NX)+ACCX
  417 CONTINUE
      NY=IDA(2,I)
      IF(NY .EQ. 0) GO TO 418
      U(NY)=TRUA(NY)+US(NY)
      V(NY)=TRVA(NY)
      ACCA(NY)=TRAA(NY)
  418 CCNTINUE
      NZ=IDA(3,I)
      IF(NZ .EQ. 0) GO TO 419
      U(NZ)=TRUA(NZ)+US(NZ)
      V(NZ)=TRVA(NZ)
      ACCA(NZ)=TRAA(NZ)
  419 CONTINUE
      NXX=IDA(4,I)
      IF(NXX .EQ. 0) GO TO 420
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      U(NXX)=TRUA(NXX)+US(NXX)
      V(NXX)=TRVA(NXX)
      ACCA(NXX)=TRAA(NXX)
  420 CONTINUE
      NYY=IDA(5,I)
      IF(NYY .EQ. 0) GO TO 421
      U(NYY)=TRUA(NYY)+US(NYY)
      V(NYY)=TRVA(NYY)
      ACCA(NYY)=TRAA(NYY)
  421 CONTINUE
      NZZ=IDA(6,I)
      IF(NZZ .EQ. 0) GO TO 422
      U(NZZ)=TRUA(NZZ)+US(NZZ)
      V(NZZ)=TRVA(NZZ)
      ACCA(NZZ)=TRAA(NZZ)
  422 CONTINUE
  318 CONTINUE
C
C     SUM UP TOTAL RESISTANCE FORCE FROM STIFFNESS TERM
      CALL MULTBA(EKAEAR,TRUA,FIA,NEGA,MBANDA)
      IF(KLIN .NE. 0) GC TO 476
      DO 377 I=1,NEQA
      FIA(I)=-FIA(I)
  377 CONTINUE
      GO TO 475
  476 CONTINUE
C
      DO 348 I=1,NEQA
C     SAVE DKU FOR VARIABLE TIME STEF RETREAT
      DKUO(I)=DKU(I)
      DKU(I)=0.
  348 CONTINUE
  475 CONTINUE
      CALL NONLIN(PARAFR,IX,TRUA,TRVA,CUA,DVA,CAA,IFR,DSIG,SIG,WALL,
     1            NINC,CKU,DSTIF,DSTIFP,TRAA,FKDA,NUMEL,NEQA,
     2            KLIN,NTWEL)
C
      IF(KLIN .EQ. 0) GC TO 427
      DO 323 I=1,NEQA
      FIA(I)=FKCA(I)-FIA(I)
  323 CONTINUE
  427 CONTINUE
      IF(MASTEP .NE. 0 .AND. NYIELD .EQ. 0) GC TO 465
C
      IF(NTW .EQ. 0) GO TO 425
C     CALCULATE EARTHPRESSURE ON WALL
      CALL WFORCE(ICOL,WALL,NELW,INFW,WGEOM,WFX,WFY,WFZ,YABV,ZEDG,NTW,
     1            NTWEL)
  425 CONTINUE
C
C     PRINT OUT RESULTS
      CALL PRINTR(IDA,IX,TRUA,TRVA,ACCA,ISOL,ICCN,IFR,ISP,SIG,WFX,WFY,
     1            WFZ,YABV,ZEDG,NINC,NTW,NTWEL)
      GC TO 466
  465 CONTINUE
      UGXT=PUGXT
      VGXT=PVGXT
      OACCX=PACCX
      CDT=DTO/SUSTEP
      CALL CONST(INTEGR,DDT,THETA)
      CALL MULTBA(EKAEAR,TRUA,FIA,NECA,MBANDA)
      DC 350 I=1,NEQA
      FKDA(I)=FKDA(I)-DKUO(I)
      FIA(I)=FKCA(I)-FIA(I)
      OTRUA(I)=TRUA(I)
      OTRVA(I)=TRVA(I)
      OTRAA(I)=TRAA(I)
  350 CONTINUE
  466 CONTINUE
      IF(MASTEP .NE. 0 .AND. NYIELD .EQ. 5) CALL CONST(INTEGR,DTO,THETA)
C
C     CALCULATE PART CF LOADING TERM FOR NEXT STEP
C
C     CONSTANT ACCELERATION
      IF(INTEGR .NE. 0) GO TO 423
      DO 319 I=1,NEQA
C     USE FMB TEMPORARY
      FMB(I)=AT1*TRVA(I)+TRAA(I)
  319 CONTINUE
      CALL MULTBA(TMASSA,FMB,FMA,NEQA,MBANDA)
      CALL MULTBA(CA,TRVA,FMB,NEQA,MBANDA)
      GO TO 426
  423 CCNTINUE
C
C     WILSON THETA METHCD
      IF(INTEGR .NE. 1) GO TO 426
      DO 320 I=1,NEQA
C     USE FMB,FGRA TEMPCRAILY
      FGRA(I)=2.0*TRVA(I)+A3*TRAA(I)
      FMB(I)=A2*TRVA(I)+2.0*TRAA(I)
  320 CONTINUE
      CALL MULTBA(TMASSA,FMB,FMA,NEQA,MBANDA)
      CALL MULTBA(CA,FGRA,FMB,NEQA,MEANCA)
  426 CONTINUE
      GO TO 1000
  424 CCNTINUE
      RETURN
C
    1 FORMAT(12A6)
    2 FORMAT(5F10.5,3I5)
    3 FORMAT(I5)
    4 FORMAT(I5,F10.5)
    5 FORMAT(2I5,2F10.3)
    6 FORMAT(3I5,2F10.0)
  106 FORMAT(* ITERATION CONTROL DATA*//
     1       * TYPE OF NORM,=1 EUCLIDEAN NORM,=2 MAXIMUM NORM*,I5/
     2       * PROCEDURE OF ITERATION,=1 TOTAL,=2 INCREMENTAL ITERATION*
     3  ,I5/* LIMIT OF ITERATICN   ITERAL=*,I5/
     4       * TOLERANCE OF ERROR    ERROR=*,E12.4/
     5       * SUBCIVICE STEP WHEN YIELC  SUSTEP=*,E12.4//)
    9 FCRMAT(10F7.3)
  101 FORMAT(1H1,12A6)
  102 FCRMAT(* EARTHQUAKE MULTIPLICATION FACTCR EQMUL *,F10.5/
     1       * TIME INTERVAL ON DATA CARDS        DTEQ *,F10.5/
     2       * TIME INCREMENT OF ANALYSIS           DT *,F10.5/
     3       * DURATION OF EQ INPUT              DUREQ *,F10.5/
     4       * DURATICN OF ANALYSIS             DURANA *,F10.5/
     5       * TIME INCREMENT OF OUTPUT/DT       MPRTM *,   I5/
     6       * STEPS CN WRITING TAPE             MTAPE *,   I5/
     7       * STEP OF 1ST PRINTOUT             KPRINT *,   I5//)
  103 FCRMAT(* CHOICE OF DAMPING*/
     1       * IDAMP=1 RALEIGH, =2 PENZIEN, =3 STRUCTURAL*, I5//)
  104 FORMAT(* CHOICE OF DIRECT INTEGRATION METHOD*/
     1       * INTEGR=0 CONSTANT ACCELERATION, =1 WILSON THETA METHCD*,
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  2    I5/* IF WILSCN METHOD THEN THETA=*,F10.5//)
  105 FCRMAT(* DAMPING RATIO 1ST MODE*,F10.6/
    1        * DAMPING RATIO 2NC MODE*,F10.6/
    2        * 1ST MCDE FREQUENCY    *,F10.6/
    3        * 2ND MCDE FREQUENCY    *,F10.6/
    4        * CONTROL MODES N1,N2   *,2I5)
  109 FCRMAT(* INPUT EARTHQUAKE*/(9F7.4))
      END
      SUBROUTINE ITERAT(EKAA,UOLD,UNEW,PLOAD,NIND,SS)
C
C     ********************************************************
C     ITERATION PROCECURE COMBINED WITH GAUSSIAN ELIMINATION FOR
C     SOLVE NON-LINEAR EQUATION
C     ********************************************************
      COMMON/ELPAR/NUMNP,NUMEL,NETYPE,NEQA,NEQC,MBANDA,MBANDO,KLIN,NLAST
      COMMON/IRATON/NCRM,NPROC,ITERAL,ERROR,SUSTEP
      COMMON/NEWAL/NTK,NTWEL
      DIMENSION UOLD(1),UNEW(1),PLOAC(1),NIND(1)
      COMMON/STROUT/NSOLID,NCONC,NFR,NSPRIN
      LARGE EKAA(1)
      DIMENSION SS(1),LMA(12),DASA(12,12)
      NOIT=0
 1000 CONTINUE
      NOIT=NOIT+1
C     CALCULATE VECTOR NORM AND CHECK TOLERANCE
      IF(NORM .NE. 2) GC TO 401
C     MAXIMUM NORM
      UOLDMA=0.
      UNEWMA=0.
      DO 301 I=1,NEQA
      OABS=ABS(UOLD(I))
      UABS=ABS(UNEW(I))
      IF(OABS .GT. UOLDMA) UOLDMA=OAES
      IF(UABS .GT. UNEWMA) UNEWMA=UAES
  301 CONTINUE
      QUATIO=UOLDMA/UNEWMA-1.0
      QUA=ABS(QUATIO)
      IF(QUA .GT. ERROR) GO TO 402
      RETURN
  401 CONTINUE
C
C     EUCLIDEAN NCRM
      OSUM=0.
      USUM=0.
      DO 303 I=1,NEQA
      OSUM=OSUM+UCLD(I)*UOLD(I)
      USUM=USUM+UNEW(I)*UNEW(I)
  303 CONTINUE
      OSUM=SQRT(OSUM)
      USUM=SQRT(USUM)
      OSUM=ABS(OSUM)
      USUM=ABS(USUM)
      QUATIO=OSUM/USUM-1.0
      QUA=ABS(QUATIO)
      IF(QUA .GT. ERRCR) GO TO 402
      RETURN
C
C     ITERATION PROCEDURE 1,TOTAL INCREMENTAL VECTOR AS ITERATION RESULT
C     SET UP DIFFERENCE VECTOR
  402 CCNTINUE
      DO 304 I=1,NEQA
      UOLD(I)=UNEW(I)-UCLD(I)
  304 CONTINUE
C     SET UP PART OF LOAD VECTOR (DK)*(CU)
      DC 307 II=1,NFR
      IF(NIND(II) .EQ. 0) GO TO 307
C     READ NON-LINEAR ELEMENT INFCRMATION FRCM TAPE 12,WHICH WAS SET
C     UP AT SUBROUTINE NONLIN
      IBEG=(II-1)*157+1
      BEG=SS(IBEG)
      NEL=IFIX(BEG)
      IF(NEL .NE. II) STOP 12
      DO 305 I=1,12
      RLMA=SS(IBEG+I)
      LMA(I)=IFIX(RLMA)
  305 CCNTINUE
      KK=IBEG
      DC 306 I=1,12
      KI=KK+12*I
      DO 306 J=1,12
      JI=KI+J
      DASA(J,I)=SS(JI)
  306 CONTINUE
      DO 308 I=1,12
      XA=0.0
      IA=LMA(I)
      DO 309 J=1,12
      JJ=LMA(J)
      IF(JJ .EQ. 0) GO TO 309
      XA=XA+DASA(I,J)*UCLD(JJ)
C     INITILIZATION
  309 CONTINUE
      PLOAD(IA)=PLOAD(IA)+XA
  308 CONTINUE
  307 CONTINUE
      DO 310 I=1,NEQA
      UOLD(I)=PLOAD(I)
  310 CONTINUE
C     SOLVE FOR NEW INCREMENTAL VECTOR
      NTB=1
      CALL BACKS(EKAA,UCLD,NEQA,MBANCA)
C     UPDATE DISPLACEMENT AND LCAD VECTOR
C     TOTAL INCREMENTAL METHOD
      IF(NPROC .NE. 1) GO TO 404
      DO 311 I=1,NEQA
      TEMP=UNEW(I)
      UNEW(I)=UOLD(I)
      UOLD(I)=TEMP
  311 CONTINUE
C
C     CHECK IF I HAVE TC GIVE UP FOR TCO MANY ITERATION
      IF(NCIT .LE. ITERAL) GO TO 1000
      WRITE(1,500) NOIT
  500 FCRMAT(* NO CONVERGENCE AFTER NOIT TIMES ITERATION*,I5)
      STOP
  404 CONTINUE
C     INCREMENTAL VECTOR ITERATION METHCD
      IF(NPROC .NE. 2) GO TO 405
      DO 312 I=1,NEQA
      TEMP=UNEW(I)
      UNEW(I)=TEMP+UOLD(I)
      UOLD(I)=TEMP
      PLOAD(I)=0.
  312 CONTINUE
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  405 CONTINUE
      IF(NOIT .LE. ITERAL) GO TO 1000
      WRITE(1,500) NOIT
      STOP
      RETURN
      END
      OVERLAY(1,0)
      PROGRAM INPUTJ
C
C     *******************************************************************
C     READ AND GENERATE NODAL PCINT CATA
C     CALCULATE EQUATION NO. AND BANDWIDTH OF DEGREE OF FREEDOM TC BE
C     REMAINED  NEQA , MBANDA ,
C     AND THOSE TO BE ELIMINATED  NEQO , MBANDO
C     *******************************************************************
C
C
      COMMON A(30000)
      COMMON/ELPAR/NUMNP,NUMEL,NETYFE,NEQA,NEQC,MBANDA,MBANDO,KLIN,NLAST
      DIMENSION IA(1),ICODE(6)
      EQUIVALENCE(A,IA)
      N1=1
      NOO=6*NUMNP
      N2=N1+12*NUMNP
      N2E=N2-1
      N3=N2+NUMNP
      N3E=N3-1
      N4=N3+NUMNP
      N4E=N4-1
      WRITE(1,501)
      WRITE(1,502)
      NOLD=0
 1000 CCNTINUE
C
C     NODE CODE ? 0 DEGREE OF FREEDCM TO BE FIXED
C                 1                     REMAINED
C                 2                     ELIMINATED
      READ 1,N,(ICODE(I),I=1,6),X,Y,Z,KN
      I1=6*N-5
      I6=6*N
C     PUT INTO CCMMON BLOCK A
      IA(I1)=ICODE(1)
      IA(I1+1)=ICODE(2)
      IA(I1+2)=ICODE(3)
      IA(I1+3)=ICODE(4)
      IA(I1+4)=ICODE(5)
      IA(I6)=ICODE(6)
      A(N2E+N)=X
      A(N3E+N)=Y
      A(N4E+N)=Z
      WRITE(1,101) N,(A(I),I=I1,I6),A(N2E+N),A(N3E+N),A(N4E+N),KN
      IF(NOLD .EQ. 0) GO TO 401
C
C     CHECK IF GENERATICN REQUIRED
      IF(KN .EQ. 0) GO TO 401
C
C     NUM=NO. OF INTERVAL BETWEEN INPUT NODE
C     NUMN=NO. CF NODES TO BE GENERATED
C     DX,DY,DZ=THE LENGTH OF INTERVAL
      NUM=N-NOLD
      NUMN=NUM-1
      IF(NUMN .LT. 1) GO TO 401
```

```
      XNUM=NUM
      DX=(A(N2E+N)-A(N2E+NOLD))/XNUM
      DY=(A(N3E+N)-A(N3E+NOLD))/XNUM
      DZ=(A(N4E+N)-A(N4E+NOLD))/XNUM
C
C     GENERATE NEW NOCAL POINT
      K=NOLD
      DO 301 J=1,NUMN
      KK=K
      K=K+1
C
C     X Y Z COORDINATES
      A(N2E+K)=A(N2E+KK)+DX
      A(N3E+K)=A(N3E+KK)+DY
      A(N4E+K)=A(N4E+KK)+DZ
      DO 302 I=1,6
C
C     NODE CODE AS PREVIOUS ONE
      IA(6*K-6+I)=IA(6*KK-6+I)
  302 CONTINUE
  301 CONTINUE
  401 CONTINUE
      NOLD=N
      IF(N .NE. NUMNP) GO TO 1000
C
C     PRINT ALL NODAL PCINT DATA
      WRITE(1,503)
      WRITE(1,5C2)
      DO 304 N=1,NUMNP
      I1=6*N-5
      I6=6*N
      WRITE(1,102) N,(A(I),I=I1,I6),A(N2E+N),A(N3E+N),A(N4E+N)
  304 CONTINUE
C
C     CALCULATE THE EQUATION NUMBERS FOR EVERY CEGREE CF FREEDOM
      NEQA=0
      NEQO=0
      DO 303 N=1,NUMNP
      DO 303 I=1,6
      NN=6*N-6+I
      IF(IA(NN)-1) 402,403,404
  403 CONTINUE
      NEQA=NEQA+1
      IA(NN)=NEQA
      A(NN+NOO)=0
      GC TO 303
  404 CONTINUE
      NEQO=NEQO+1
      IA(NOO+NN)=NEQO
      A(NN)=0
      GO TO 303
  402 CONTINUE
      A(NN)=0
      A(NOO+NN)=0
  303 CCNTINUE
C
C     WRITE EQUATION NUMBERS
      WRITE(1,504)
      DC 305 N=1,NUMNP
      I1=6*N-5
      I6=6*N
      WRITE(1,1C3) N,(A(I),I=I1,I6)
```

```
  305 CONTINUE                                                          INPUTJ.120
      WRITE(1,505)                                                      INPUTJ.121
      DO 306 N=1,NUMNP                                                  INPUTJ.122
      I1=6*N-5                                                          INPUTJ.123
      I6=6*N                                                            INPUTJ.124
      WRITE(1,103) N,(A(I+NOO),I=I1,I6)                                 INPUTJ.125
  306 CONTINUE                                                          INPUTJ.126
      NLAST=N4+NUMNP-1                                                  INPUTJ.127
      RETURN                                                            INPUTJ.128
    1 FORMAT(7I5,3F10.0,I5)                                             INPUTJ.129
  101 FORMAT(7I5,3F10.2,I5)                                             INPUTJ.130
  102 FORMAT(7I5,3F10.2)                                                INPUTJ.131
  103 FORMAT(7I5)                                                       INPUTJ.132
  501 FORMAT(//* NODAL POINT INPUT DATA*//)                             INPUTJ.133
  502 FORMAT(* NODE   BOUNDARY    CONDITION   CODE     NODAL POINT*,    INPUTJ.134
     1        * COORDINATES*/                                           INPUTJ.135
     2        * NODE     X     Y     Z   XX   YY   ZZ          X         Y*, INPUTJ.136
     3        *                Z   KN*//)                               INPUTJ.137
  503 FORMAT(* COMPLETE NODAL DATA*//)                                  INPUTJ.138
  504 FORMAT(*1EQUATIONS NUMBERS*//                                     INPUTJ.139
     1        * DEGREE OF FREEDOM TO BE REMAINED*//                     INPUTJ.140
     2        * NODE     X     Y     Z   XX   YY   ZZ*//)              INPUTJ.141
  505 FORMAT(///* DEGREES TO BE ELIMINATED*)                            INPUTJ.142
      END                                                               INPUTJ.143
      OVERLAY(2,0)                                                      MATPRO.2
      PROGRAM MATPRO                                                    MATPRO.3
C                                                                       MATPRO.4
C     *****************************************************************MATPRO.5
C     INPUT MATERIAL PROPERTIES,BEAM,COLUMN GEOMATRIC PROPERTIES        MATPRO.6
C     *****************************************************************MATPRO.7
C                                                                       MATPRO.8
      COMMON A(30000)                                                   MATPRO.9
      COMMON/ELPAR/NUMNP,NUMEL,NETYPE,NEQA,NEQC,MBANDA,MBANDO,KLIN,NLASTMATPRO.10
      COMMON/MATER/NUMATS,NUMATC,NUMATF,NUMATB,NUMGE,NUMBC,MTYPE        MATPRO.11
      DIMENSION PARASO(3,20),PARACO(3,20),PARAFR(4,10),PARABO(6,20),    MATPRO.12
     1          COPROP(6,10)                                            MATPRO.13
      GO TO (401,402,403,404),MTYPE                                     MATPRO.14
C                                                                       MATPRO.15
C     READ IN SOLID ELEMENT DATA,INCLUDING SOIL OR SOLID CONCRETE DECK  MATPRO.16
  401 CONTINUE                                                          MATPRO.17
      WRITE(1,501)                                                      MATPRO.18
      DO 301 I=1,NUMATS                                                 MATPRO.19
      READ 1,N,(PARASC(J,N),J=1,3)                                      MATPRO.20
      WRITE(1,101) N,(PARASO(J,N),J=1,3)                                MATPRO.21
  301 CONTINUE                                                          MATPRO.22
C                                                                       MATPRO.23
C     STORE IN BLANK CCMMON A                                           MATPRO.24
      DO 302 I=1,3                                                      MATPRO.25
      DO 302 J=1,NUMATS                                                 MATPRO.26
      N5=NLAST+3*(J-1)+I                                                MATPRO.27
      A(N5)=PARASO(I,J)                                                 MATPRO.28
  302 CONTINUE                                                          MATPRO.29
      GO TO 410                                                         MATPRO.30
C                                                                       MATPRO.31
C     READ IN CONCRETE BEAM OR COLUMN PROPERTIES DATA                   MATPRO.32
  402 CONTINUE                                                          MATPRO.33
      WRITE(1,502)                                                      MATPRO.34
      DO 303 I=1,NUMATC                                                 MATPRO.35
      READ 1,N,(PARACC(J,N),J=1,3)                                      MATPRO.36
      WRITE(1,101) N,(PARACO(J,N),J=1,3)                                MATPRO.37
  303 CONTINUE                                                          MATPRO.38
C                                                                       MATPRO.39
C     STORE IN COMMON BLANK A                                           MATPRO.40
      M2=NLAST+3*NUMATS                                                 MATPRO.41
      DO 304 I=1,3                                                      MATPRO.42
      DO 304 J=1,NUMATC                                                 MATPRO.43
      N6=M2+3*(J-1)+I                                                   MATPRO.44
      A(N6)=PARACC(I,J)                                                 MATPRO.45
  304 CONTINUE                                                          MATPRO.46
C                                                                       MATPRO.47
C     READ IN BEAM,COLUMN GEOMETRIC DATA                                MATPRO.48
      WRITE(1,503)                                                      MATPRO.49
      DO 305 I=1,NUMGE                                                  MATPRO.50
      READ 1,N,(COPROP(J,N),J=1,6)                                      MATPRO.51
      WRITE(1,101) N,(CCPROP(J,N),J=1,6)                                MATPRO.52
  305 CONTINUE                                                          MATPRO.53
C                                                                       MATPRO.54
C     STORE IN COMMON BLANK A                                           MATPRO.55
      M3=M2+3*NUMATC                                                    MATPRO.56
      DO 306 I=1,6                                                      MATPRO.57
      DO 306 J=1,NUMGE                                                  MATPRO.58
      N7=M3+6*(J-1)+I                                                   MATPRO.59
      A(N7)=COPROP(I,J)                                                 MATPRO.60
  306 CONTINUE                                                          MATPRO.61
      GO TO 410                                                         MATPRO.62
  403 CONTINUE                                                          MATPRO.63
      WRITE(1,504)                                                      MATPRO.64
      DO 307 I=1,NUMATF                                                 MATPRO.65
      READ 2,N,(PARAFR(J,N),J=1,4)                                      MATPRO.66
      WRITE(1,101) N,(PARAFR(J,N),J=1,4)                                MATPRO.67
  307 CONTINUE                                                          MATPRO.68
C                                                                       MATPRO.69
C     STORE IN BLANK COMMON A                                           MATPRO.70
      M4=NLAST+3*NUMATS+3*NUMATC+6*NUMGE                                MATPRO.71
      DO 308 I=1,4                                                      MATPRO.72
      DO 308 J=1,NUMATF                                                 MATPRO.73
      N8=M4+4*(J-1)+I                                                   MATPRO.74
      A(N8)=PARAFR(I,J)                                                 MATPRO.75
  308 CONTINUE                                                          MATPRO.76
      GO TO 410                                                         MATPRO.77
C                                                                       MATPRO.78
C     READ IN BOUNDARY ELEMENT DATA                                     MATPRO.79
  404 CONTINUE                                                          MATPRO.80
      WRITE(1,505)                                                      MATPRO.81
      DO 309 I=1,NUMATB                                                 MATPRO.82
      READ 1,N,(PARABO(J,N),J=1,6)                                      MATPRO.83
      WRITE(1,101) N,(PARABO(J,N),J=1,6)                                MATPRO.84
  309 CONTINUE                                                          MATPRO.85
C                                                                       MATPRO.86
C     STORE IN BLANK COMMON A                                           MATPRO.87
      M5=NLAST+3*NUMATS+3*NUMATC+6*NUMGE+4*NUMATF                       MATPRO.88
      DO 310 I=1,6                                                      MATPRO.89
      DO 310 J=1,NUMATB                                                 MATPRO.90
      N9=M5+6*(J-1)+I                                                   MATPRO.91
      A(N9)=PARABO(I,J)                                                 MATPRO.92
  310 CONTINUE                                                          MATPRO.93
  410 CONTINUE                                                          MATPRO.94
      RETURN                                                            MATPRO.95
    1 FORMAT(I10/(8F10.3))                                              MATPRO.96
    2 FORMAT(I10/4E10.3))                                               MATPRO.97
  101 FORMAT(I3,8E10.3)                                                 MATPRO.98
  501 FORMAT(//* SOLID ELEMENT PROPERTY DATA      */                    MATPRO.99
     1        * ELACTIC SHEAR MODULUS=GS       KSI*/                    MATPRO.100
     2        * POISSON RATIO        =NU         */                     MATPRO.101
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     3          * UNIT WEIGHT OF SOIL  =WT LB/CU.FT*//                          MATPRO.102
     4          3H  N,8X,2HGS,8X,2HNU,8X,2HWT//)                                MATPRO.103
  502 FCRMAT(//* CCNCRETE PROPERTY DATA    */                                   MATPRO.104
     1          * ELASTIC MODULUS=E    KSI  */                                  MATPRO.105
     2          * POISSON RATIO  =NU        */                                  MATPRO.106
     3          * UNIT WEIGHT    =WT LB/CUFT*/                                  MATPRO.107
     4          3H  N,9X,1HE,8X,2HNU,8X,2HWT//)                                 MATPRO.108
  503 FORMAT(//* GEOMETRIC PROPERTY CF BEAM,COLUMN  *//                         MATPRO.109
     1          * GEOMETRIC PROPERTY NUMBER      =N  */                         MATPRO.110
     2          * AXIAL AREA SQ.INCH             =A  */                         MATPRO.111
     3          * SHEAR AREA IN LOCAL 2-DIRECTICN=AV2*/                         MATPRO.112
     4          *                     3          =AV3*/                         MATPRO.113
     5          * TORSIONAL INERTIA INCH         =J  */                         MATPRO.114
     6          * FLEXURAL INERTIA ABOUT 2-AXIS  =M2 */                         MATPRO.115
     7          *                        3       =M3 */                         MATPRO.116
     8          3H  N,9X,1HA,7X,3HAV2,7X,3HAV3,9X,1HJ,8X,2HM2,8X,2HM3//)        MATPRO.117
  504 FORMAT(//* FRICTION ELEMENT DATA        *//                               MATPRO.118
     1          * SHEAR STIFF          =KS KSI*/                                MATPRO.119
     2          * NORMAL STIFF         =KN KSI*/                                MATPRO.120
     3          * FRICTION COEFFICIENT=U     */                                 MATPRO.121
     4          * COHENSION            =C  KSI*/                                MATPRO.122
     5          3H  N,8X,2HKS,8X,2HKN,9X,1HU,9X,1HC//)                          MATPRO.123
  505 FORMAT(//* BOUNDARY ELEMENT DATA                               */         MATPRO.124
     1          * LINEAR SPRING IN X DIRECTION      =EX KIP-IN       */         MATPRO.125
     2          * LINEAR SPRING IN Y DIRECTION      =EY KIP-IN       */         MATPRO.126
     3          * LINEAR SPRING IN Z DIRECTION      =EZ KIP-IN       */         MATPRO.127
     4          * ROTATICNAL SPRING IN X DIRECTION =EXX KIP-IN/RAD*/            MATPRO.128
     5          * ROTATICNAL SPRING IN Y DIRECTICN =EYY KIP-IN/RAD*/            MATPRO.129
     6          * ROTATICNAL SPRING IN Z DIRECTION =EZZ KIP-IN/RAD*//           MATPRO.130
     7          3H  N,8X,2HEX,8X,2HEY,8X,2HEZ,7X,3HEXX,7X,3HEYY,7X,             MATPRO.131
     8          3HEZZ//)                                                        MATPRO.132
      END                                                                       MATPRO.133
      OVERLAY(3,0)                                                              ELDATA.2
      PROGRAM ELDATA                                                            ELDATA.3
C                                                                               ELDATA.4
C     *******************************************************************ELDATA.5
C     DEAD IN ELEMENT DATA,INCLUDING NODAL POINT,ELEMENT TYPE,MATERIAL   ELDATA.6
C     TYPE,BEAM COLUMN GEOMETRIC NO. ENC RELEASE CCDE                    ELDATA.7
C     *******************************************************************ELDATA.8
C                                                                               ELDATA.9
      COMMON A(30000)                                                           ELDATA.10
      COMMON/ELPAR/NUMNF,NUMEL,NETYPE,NEQA,NEQC,MBANDA,MBANDO,KLIN,NLASTELDATA.11
      COMMON/MATER/NUMATS,NUMATC,NUMATF,NUMATB,NUMGE,NUMBC,MTYPE         ELDATA.12
      COMMON/LMC/LMA(36),LMO(36),XX(8),YY(8),ZZ(8)                       ELDATA.13
      COMMON/TOPEL/NFB(4,50),ITOPN                                       ELDATA.14
      DIMENSION IDE(14)                                                  ELDATA.15
      DIMENSION IA(1)                                                    ELDATA.16
      EQUIVALENCE(A,IA)                                                  ELDATA.17
      WRITE(1,501)                                                       ELDATA.18
      N=0                                                                ELDATA.19
      NBC=0                                                              ELDATA.20
      MBANDA=0                                                           ELDATA.21
      MBANDO=0                                                           ELDATA.22
      N11E=NLAST+11*NUMEL                                                ELDATA.23
      ITOP=0                                                             ELDATA.24
      DO 301 I=1,14                                                      ELDATA.25
      IDE(I)=0                                                           ELDATA.26
  301 CONTINUE                                                           ELDATA.27
C     IDE(11) IS THE STIFFNESS AND STRESS CODE CF ELEMENT                ELDATA.28
C                                                                        ELDATA.29
C     NOT TOP ELEMENT OF JOINT                                           ELDATA.30
C     0 STIFFNESS AS PRECEEDING ELEMENT                                  ELDATA.31
C       NO STRESS OUTPUT REQUIRED                                        ELDATA.32
C     1 STIFFNESS AS PRECEEDING ELEMENT                                  ELDATA.33
C       NEED STRESS OUTPUT                                               ELDATA.34
C     2 REQUIRE CALCULATION OF STIFFNESS                                 ELDATA.35
C       NC STRESS OUTPUT                                                 ELDATA.36
C     3 REQUIRE CALCULATION OF STIFFNESS                                 ELDATA.37
C       STRESS CUTPUT                                                    ELDATA.38
C                                                                        ELDATA.39
C     TOP ELEMENT OF JOINT                                               ELDATA.40
C     4 STIFFNESS AS PRECEEDING ELEMENT                                  ELDATA.41
C     5 CALCULATION OF STIFFNESS                                         ELDATA.42
C                                                                        ELDATA.43
C     READ IN ELEMENT DATA                                               ELDATA.44
 1000 READ 1,M,(IDE(I),I=1,14)                                           ELDATA.45
C                                                                        ELDATA.46
C     IF THE TOP SOIL ELEMENT OF FRICTION JOINT,ADDITIONAL 4 NODES OF    ELDATA.47
C     BOTTOM FRICTION ELEMENT ARE NEEDED                                 ELDATA.48
      IF(IDE(11) .LE. 3) GO TO 407                                       ELDATA.49
      READ 1,IFB,JFB,KFB,LFB                                             ELDATA.50
  407 CONTINUE                                                           ELDATA.51
 2000 N=N+1                                                              ELDATA.52
      IF(M .EQ. N) GO TC 401                                             ELDATA.53
C                                                                        ELDATA.54
C     ELEMENT DATA GENERATION NEEDEC                                     ELDATA.55
      DO 304 I=1,8                                                       ELDATA.56
      N10=NLAST+11*N-11                                                  ELDATA.57
      NN10=N10+I                                                         ELDATA.58
      IA(NN10)=IA(NN10-11)+1                                             ELDATA.59
      IF(IDE(3) .EQ. 0 .AND. I .GE. 3) A(NN10)=0                         ELDATA.60
  304 CONTINUE                                                           ELDATA.61
      DO 305 I=9,11                                                      ELDATA.62
      N10=NLAST+11*N-11                                                  ELDATA.63
      NN10=N10+I                                                         ELDATA.64
      A(NN10)=A(NN10-11)                                                 ELDATA.65
  305 CONTINUE                                                           ELDATA.66
      IF(IDE(12) .EQ. 0) GO TO 406                                       ELDATA.67
C                                                                        ELDATA.68
C     CONCRETE BEAM,COLUMN ELEMENT                                       ELDATA.69
      NBC=NBC+1                                                          ELDATA.70
      DO 306 I=1,3                                                       ELDATA.71
      N11=N11E+3*NBC-3                                                   ELDATA.72
      NN11=N11+I                                                         ELDATA.73
      A(NN11)=A(NN11-3)                                                  ELDATA.74
  306 CONTINUE                                                           ELDATA.75
      GC TO 406                                                          ELDATA.76
C                                                                        ELDATA.77
C     STORE INPUT DATA INTO COMMON BLANK A                               ELDATA.78
  401 CONTINUE                                                           ELDATA.79
      DO 307 I=1,11                                                      ELDATA.80
      N10=NLAST+11*N-11                                                  ELDATA.81
      NN10=N10+I                                                         ELDATA.82
      IA(NN10)=IDE(I)                                                    ELDATA.83
  307 CONTINUE                                                           ELDATA.84
C                                                                        ELDATA.85
C     TOP ELEMENT NEXT TO JOINT                                          ELDATA.86
      IF(IDE(11) .LE. 3) GO TO 408                                       ELDATA.87
      ITOP=ITOP+1                                                        ELDATA.88
      ITOPN=ITOP                                                         ELDATA.89
      NFB(1,ITOPN)=IFB                                                   ELDATA.90
      NFB(2,ITOPN)=JFB                                                   ELDATA.91
      NFB(3,ITOPN)=KFB                                                   ELDATA.92
      NFB(4,ITOPN)=LFB                                                   ELDATA.93
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  408 CONTINUE
      IF(IDE(12) .EQ. 0) GO TO 406
      NBC=NBC+1
      DO 308 I=1,3
      N11=N11E+3*NBC-3
      NN11=N11+I
      IA(NN11)=IDE(11+I)
  308 CONTINUE
  406 CONTINUE
C
C     CALCULATE BANDWIDTH
      IX=N10+1
      CALL LAM(IA(IX),0)
      MAXA=0
      MAXO=0
      MINA=10000
      MINO=10000
      DO 309 L=1,36
      IF(LMA(L) .EQ. 0) GO TO 309
      IF(LMA(L) .GT. MAXA) MAXA=LMA(L)
      IF(LMA(L) .LT. MINA) MINA=LMA(L)
  309 CONTINUE
      DO 310 L=1,36
      IF(LMO(L) .EQ. 0) GO TO 310
      IF(LMO(L) .GT. MAXO) MAXO=LMO(L)
      IF(LMO(L) .LT. MINO) MINO=LMO(L)
  310 CONTINUE
      IF(MAXA .EQ. 0) MINA=1
      MBA=MAXA-MINA+1
      IF(MBA .GT. MBANDA) MBANDA=MBA
      IF(MAXO .EQ. 0) MINO=1
      MBO=MAXO-MINO+1
      IF(MBO .GT. MBANDO) MBANDO=MBO
C
C     CONCRETE BEAM OR COLUMN ELEMENT
      IF(IDE(12) .EQ. 0) GO TO 402
      GO TO 403
  402 CONTINUE
      WRITE(1,101) N,(A(N10+I),I=1,11),MBA,MBO
      IF(IDE(11) .LE. 3) GO TO 404
      WRITE(1,103) (NFB(I,ITOPN),I=1,4)
      GO TO 404
  403 CONTINUE
      WRITE(1,102) N,(A(N10+I),I=1,11),(A(N11+I),I=1,3),MBA,MBO
  404 CONTINUE
      IF(N .EQ. NUMEL) GO TO 405
      IF(N .EQ. M) GO TO 1000
      GO TO 2000
  405 CONTINUE
      NLAST=N11E+3*NUMBC
      RETURN
    1 FORMAT(13I5,2I6)
  101 FORMAT(9X,I3,8I5,2I10,I5,26X,2I5)
  102 FORMAT(9X,I3,8I5,2I10,I5,I10,2I8,2I5)
  103 FORMAT(12X,4I5)
  501 FORMAT('1ELEMENT NO.   IB    JB    KB    LB    IT    JT    KT    LT',
     1      '   EL TYPE  MATL NO INTE  GEOM NO. END REL I       J BAND',
     2      ' WIDTH'//)
      END
      OVERLAY(4,0)
      PROGRAM LOAD
C
C     ******************************************************************
C     CALCULATE STATIC LOAD VECTOR SLVA,SLVO ASSOCIATED RESPECTIVELY
C     WITH REMAINED AND ELIMINATED D O F AFTER GUYAN REDUCTION
C     DYNAMIC LOAD DUE TO GRAVITY LOAD IN X Y Z-DLXA,DLXO,DLYA,DLYO,
C     DLZA,DLZO, AND DIAGONAL MASS TMASSA,TMASSO
C     ******************************************************************
C
      COMMON/MASS/AMASS,WT,RF(12),L
      COMMON A(30000)
      COMMON/ELPAR/NUMNP,NUMEL,NETYPE,NEQA,NEQO,MBANDA,MBANDO,KLIN,NLAST
      COMMON/MATER/NUMATS,NUMATC,NUMATF,NUMATB,NUMGE,NUMBC,MTYPE
      COMMON/TOPEL/NFB(4,50),ITOPN
      DIMENSION TMASSA(300),TMASSO(300),TLOADA(300),TLOADO(300)
      DIMENSION PARASC(3,20),PARACO(3,10),COPROP(6,10)
      DIMENSION XX(8),YY(8),ZZ(8)
      DIMENSION IA(1)
      EQUIVALENCE(A,IA)
      ITOP=0
      NBC=0
      NOO=6*NUMNP
      N2=NOO+6*NUMNP
      N3=N2+NUMNP
      N4=N3+NUMNP
      N5E=NOO+9*NUMNP
      N6E=N5E+3*NUMATS
      N7E=N6E+3*NUMATC
      N12E=NLAST
      N12=N12E+1
      N11=N12-3*NUMBC
      N10=N11-11*NUMEL
      N10E=N10-1
      N13E=N12E+NEQA
      N14E=N13E+NEQO
      N15E=N14E+NEQA
      N16E=N15E+NEQO
      N17E=N16E+NEQA
      N18E=N17E+NEQO
      N19E=N18E+NEQA
      N20E=N19E+NEQO
      NLAST=N20E
C
C     INITILIZATION
      DO 300 I=N12,N20E
      A(I)=0.0
  300 CONTINUE
      DO 301 I=1,3
      DO 301 J=1,NUMATS
      N5=(J-1)*3+I+N5E
      PARASO(I,J)=A(N5)
  301 CONTINUE
      DO 302 I=1,3
      DO 302 J=1,NUMATC
      N6=(J-1)*3+I+N6E
      PARACO(I,J)=A(N6)
  302 CONTINUE
      DO 303 I=1,6
      DO 303 J=1,NUMGE
      N7=(J-1)*6+I+N7E
      COPROP(I,J)=A(N7)
  303 CONTINUE
C
C     CALCULATE GRAVITY LOAD ELEMENT BY ELEMENT
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      DO 304 N=1,NUMEL
      NN10=N10+11*N-3
C
C      DETERMINE ELEMENT TYPE
      NTYPE=IA(NN10)
      MATYPE=IA(NN10+1)
      INTER=IA(NN10+2)
      GO TO (401,402,304,304) NTYPE
C
  401 CONTINUE
C     TYPE 1,SOLID ELEMENT
      IF(INTER .EQ. 0 .OR. INTER .EQ. 1
     1 .OR. INTER .EQ. 4 .OR. INTER .EQ. 6) GO TO 403
      DO 305 J=1,8
      NN=N10E+(N-1)*11+J
      NODE=IA(NN)
      NXA=6*NODE-5
      NXO=NXA+6*NUMNP
      XX(J)=A(N2+NODE)
      YY(J)=A(N3+NODE)
      ZZ(J)=A(N4+NODE)
  305 CONTINUE
      CALL FSOLID(XX,YY,ZZ,PARASO(1,MATYPE))
  403 CONTINUE
C     SAME AS PREVIOUS ELEMENT
      DO 306 J=1,8
      NN=N10E+(N-1)*11+J
      NODE=IA(NN)
      NXA=6*NODE-5
      NXO=NXA+6*NUMNP
      IA1=IA(NXA)
      IA2=IA(NXA+1)
      IA3=IA(NXA+2)
      IO1=IA(NXC)
      IO2=IA(NXC+1)
      IO3=IA(NXC+2)
C
C     Z DIRECTION
      IF(IA3 .EQ. 0) GO TO 404
C     MASS VECTOR OF D C F REMAINED AFTER GUYAN REDUCTICN
      A(IA3+N18E)=AMASS+A(IA3+N18E)
      GO TO 405
  404 CONTINUE
      IF(IO3 .EQ. 0) GO TO 405
C     MASS OF D O F ELIMENATED
      A(IO3+N19E)=AMASS+A(IO3+N19E)
  405 CONTINUE
C     Y DIRECTICN
      IF(IA2 .EQ. 0) GO TO 406
C     STATIC LOAD OF D C F REMAINED
      A(N12E+IA2)=-WT+A(N12E+IA2)
C     MASS OF D O F REMAINED
      A(N16E+IA2)=AMASS+A(N16E+IA2)
      GC TO 407
  406 CONTINUE
      IF(IO2 .EQ. 0) GO TO 407
C     STATIC LOAD VECTOR OF D O F ELIMINATED
      A(N13E+IO2)=-WT+A(N13E+IO2)
C     MASS VECTCR OF D C F ELIMINATED
      A(N17E+IO2)=AMASS+A(N17E+IO2)
  407 CONTINUE
C     X DIRECTION
      IF(IA1 .EC. 0) GO TO 408
C
C     MASS VECTOR OF C C F REMAINED
      A(N14E+IA1)=AMASS+A(N14E+IA1)
      GO TO 306
  408 CONTINUE
      IF(IO1 .EQ. 0) GO TO 306
C
C     MASS VECTCR CF D C F ELIMINATED
      A(N15E+IO1)=AMASS+A(N15E+IO1)
  306 CONTINUE
      IF(INTER .LE. 3) GO TO 304
C     TOP SOIL ELEMENT CF FRICTION JCINT,NEED TRANSFORM LOAD VECTCR
      ITOP =ITOP+1
      DO 311 I=1,4
      NODE=NFB(I,ITOP)
      NXA=6*NODE-5
      NXO=NXA+6*NUMNP
      IA1=IA(NXA)
      IA2=IA(NXA+1)
      IA3=IA(NXA+2)
      IO1=IA(NXO)
      IO2=IA(NXC+1)
      IC3=IA(NXC+2)
C
C     Z DIRECTION
      IF(IA3 .EQ. 0) GO TO 424
C     MASS VECTOR OF D C F REMAINED AFTER GUYAN RECUCTICN
      A(IA3+N18E)=AMASS+A(IA3+N18E)
      GO TO 425
  424 CONTINUE
      IF(IO3 .EQ. 0) GO TO 425
C    MASS OF D C F ELIMINATED
      A(IO3+N19E)=AMASS+A(IO3+N19E)
  425 CONTINUE
C     Y DIRECTION
      IF(IA2 .EQ. 0) GC TO 426
C     STATIC LOAD OF D C F REMAINED
      A(IA2+N12E)=-WT+A(N12E+IA2)
C      MASS OF D O F REMAINED
      A(N16E+IA2)=AMASS+A(N16E+IA2)
      GC TO 427
  426 CONTINUE
      IF(IO2 .EQ. 0) GO TO 427
C     STATIC LOAD VECTOR OF D O F ELIMINATED
      A(N13E+IO2)=-WT+A(N13E+IO2)
C     MASS VECTOR OF D C F ELIMINATED
      A(N17E+IO2)=AMASS+A(N17E+IO2)
  427 CONTINUE
C     X DIRECTION
      IF(IA1 .EQ. 0) GO TO 428
C     MASS VECTOR OF D O F REMAINED
      A(N14E+IA1)=AMASS+A(N14E+IA1)
      GC TO 311
  428 CONTINUE
      IF(IO1 .EQ. 0) GC TO 311
C     MASS VECTOR OF D C F ELIMINATED
      A(N15E+IO1)=AMASS+A(N15E+IO1)
  311 CCNTINUE
      GO TO 304
C
  402 CONTINUE
```

```
C     TYPE 2,CONCRETE BEAM OR COLUMN
      NBC=NBC+1
      NGN=N11+3*(NBC-1)
      DO 307 J=1,2
      NN=N10E+(N-1)*11+J
      NODE=IA(NN)
      NXA=6*NODE-5
      NXO=NXA+6*NUMNP
      XX(J)=A(N2+NODE)
      YY(J)=A(N3+NODE)
      ZZ(J)=A(N4+NCDE)
  307 CONTINUE
      IF(INTER .EQ. 0 .OR. INTER .EQ. 1) GO TO 409
      NGEOM=IA(NGN)
      AXA=COPROP(1,NGEOM)
      WT=AXA*PARACO(3,MATYPE)/144.0
      L=1
      CALL FBECCL(XX,YY,ZZ)
  409 CONTINUE
      DO 308 J=1,2
      NN=N10E+(N-1)*11+J
      NODE=IA(NN)
      NXA=6*NODE-5
      NXO=NXA+6*NUMNP
      IA1=IA(NXA)
      IA2=IA(NXA+1)
      IA3=IA(NXA+2)
      IA4=IA(NXA+3)
      IA5=IA(NXA+4)
      IA6=IA(NXA+5)
      IC1=IA(NXO)
      IO2=IA(NXC+1)
      IO3=IA(NXC+2)
      IO4=IA(NXO+3)
      IO5=IA(NXC+4)
      IO6=IA(NXC+5)
      JM=(J-1)*6
C
C     X DIRECTICN
      IF(IA1 .EQ. 0) GO TO 400
C     MASS VECTOR OF D C F REMAINED AFTER GUYAN REDUCTICN
      A(IA1+N14E)=AMASS+A(IA1+N14E)
      GC TO 410
  400 CONTINUE
      IF(IO1 .EQ. 0) GC TO 410
C
C     D O F ELIMINATEC
      A(IO1+N15E)=AMASS+A(IO1+N15E)
C
C     Y DIRECTICN-VERTICAL
  410 CCNTINUE
      IF(IA2 .EC. 0) GO TO 411
      A(IA2+N16E)=AMASS+A(IA2+N16E)
      A(IA2+N12E)=-WT+A(IA2+N12E)
C
      GC TO 412
  411 CONTINUE
      IF(IO2 .EQ. 0) GO TO 412
      A(IO2+N17E)=AMASS+A(IO2+N17E)
      A(IO2+N13E)=-WT+A(IO2+N13E)
C
C     Z DIRECTION
  412 CCNTINUE
      IF(IA3 .EQ. 0) GO TO 413
      A(IA3+N18E)=AMASS+A(IA3+N18E)
      GO TO 414
  413 CONTINUE
      IF(IO3 .EQ. 0) GC TO 414
      A(IO3+N19E)=AMASS+A(IO3+N19E)
  414 CONTINUE
C     XX-MCMENT
      IF(IA4 .EC. 0) GC TO 415
      A(IA4+N12E)=RF(JM+4)+A(IA4+N12E)
      GO TO 416
  415 CCNTINUE
      IF(IO4 .EQ. 0) GO TO 416
      A(IO4+N13E)=RF(JM+4)+A(IO4+N13E)
  416 CONTINUE
C     YY-MOMENT
      IF(IA5 .EQ. 0) GC TO 417
      A(IA5+N12E)=RF(JM+5)+A(IA5+N12E)
      GC TO 418
  417 CONTINUE
      IF(IO5 .EC. 0) GO TO 418
      A(IO5+N13E)=RF(JM+5)+A(IO5+N13E)
  418 CONTINUE
C     ZZ-MOMENT
      IF(IA6 .EQ. 0) GO TO 419
      A(IA6+N12E)=RF(JM+6)+A(IA6+N12E)
      GC TO 308
  419 CONTINUE
      IF(IO6 .EC. 0) GO TO 308
      A(IO6+N13E)=RF(JM+6)+A(IO6+N13E)
  308 CONTINUE
  304 CCNTINUE
C
C     ADD UP INPUTED CONCENTRATED MASS OR LOAD
      NO=NOO+1
      N20T1E=N20E+NEQA+NEQO
      N20T1=N20T1E+1
      N20T2E=N20T1E+NEQA
      N20T2=N20T2E+1
      N21T1E=N20T2E+NEQA
      N21T1=N21T1E+1
      N21T2E=N21T1E+NEQC
      N21T2=N21T2E+1
      CALL INCML(A(1),A(NO),A(N20T1),A(N21T1),A(N20T2),A(N21T2),N)
      G=32.1725
      IF(N .EQ. 0) GC TC 420
      DO 309 I=1,NEQA
      A(N12E+I)=A(N12E+I)+A(N20T1E+I)*G+A(N20T2E+I)
      A(N14E+I)=A(N14E+I)+A(N20T1E+I)
      A(N16E+I)=A(N16E+I)+A(N20T1E+I)
      A(N18E+I)=A(N18E+I)+A(N20T1E+I)
  309 CONTINUE
C
      DO 310 I=1,NEQO
      A(N13E+I)=A(N13E+I)+A(N21T1E+I)*G+A(N21T2E+I)
      A(N15E+I)=A(N15E+I)+A(N21T1E+I)
      A(N17E+I)=A(N17E+I)+A(N21T1E+I)
      A(N19E+I)=A(N19E+I)+A(N21TE+I)
  310 CONTINUE
  420 CCNTINUE
C
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C     STORE DIAGONAL MASS TMASSA(NEQA) IN A(N20T) AND IN TAPE5             LOAD.315
C     FOR FREQUENCIES CALCULATION                                          LOAD.316
      DO 321 I=1,NEQA                                                      LOAD.317
      A(N20E+I)=A(N14E+I)+A(N16E+I)+A(N18E+I)                              LOAD.318
  321 CONTINUE                                                             LOAD.319
      N20T=N20E+1                                                          LOAD.320
      N21E=N20E+NEQA                                                       LOAD.321
      WRITE(5) (A(I),I=N20T,N21E)                                          LOAD.322
C     STORE DIAGONAL MASS TMASSO(NEQO) IN A(N21) AND IN TAPE5 AFTER        LOAD.323
C     TMASSA(NEQA) FOR EQUIVALENT MASS CALCULATION IN STATIC               LOAD.324
      N22E=N21E+NEQO                                                       LOAD.325
      N21T=N21E+1                                                          LOAD.326
      DO 312 I=1,NEQO                                                      LOAD.327
      A(N21E+I)=A(N15E+I)+A(N17E+I)+A(N19E+I)                              LOAD.328
  312 CONTINUE                                                             LOAD.329
      WRITE(5) (A(I),I=N21T,N22E)                                          LOAD.330
      WRITE(1,501)                                                         LOAD.331
      WRITE(1,101) (I,A(N12E+I),A(N14E+I),A(N16E+I),A(N18E+I),I=1,NEQA)    LOAD.332
      WRITE(1,502)                                                         LOAD.333
      WRITE(1,101) (I,A(N13E+I),A(N15E+I),A(N17E+I),A(N19E+I),I=1,NEQO)    LOAD.334
      N13=N13E+1                                                           LOAD.335
      N14=N14E+1                                                           LOAD.336
      N15=N15E+1                                                           LOAD.337
  101 FORMAT(I6,4E12.4)                                                    LOAD.338
  501 FORMAT(*1LOAD AND MASS VECTOR D O F REMAINED*//                      LOAD.339
     1      * D O F*,                                                      LOAD.340
     2      2X,4HSLVA,8X,4HDLXA,8X,4HDLYA,8X,4HDLZA)                       LOAD.341
  502 FORMAT(//* LOAD AND MASS VECTOR D O F ELIMINATED*//                  LOAD.342
     1      * D O F*,                                                      LOAD.343
     2      2X,4HSLVC,8X,4HDLXO,8X,4HDLYO,8X,4HDLZO)                       LOAD.344
      RETURN                                                               LOAD.345
      END                                                                  LOAD.346
      SUBROUTINE INCML(IDA,IDO,TMASSA,TMASSC,TLOADA,TLOADO,M)              INCML.2
C                                                                          INCML.3
C     *****************************************************************INCML.4
C     INPUT CONCENTRATED MASS OR LOAD                                      INCML.5
C     *****************************************************************INCML.6
C                                                                          INCML.7
      COMMON A(30000)                                                      INCML.8
      COMMON/ELPAR/NUMNP,NUMEL,NETYPE,NEQA,NEQO,MBANDA,MBANDO,KLIN,NLASTINCML.9
      COMMON/MATER/NUMATS,NUMATC,NUMATF,NUMATB,NUMGE,NUMBC,MTYPE           INCML.10
      DIMENSION IDA(6,1),IDO(6,1),TMASSA(1),TMASSO(1),TLOADA(1),           INCML.11
     1          TLOADO(1),RM(6),RL(6)                                      INCML.12
      WRITE(1,501)                                                         INCML.13
      DO 301 I=1,NEQA                                                      INCML.14
      TMASSA(I)=0.0                                                        INCML.15
      TLOADA(I)=0.0                                                        INCML.16
  301 CONTINUE                                                             INCML.17
      DO 302 I=1,NEQO                                                      INCML.18
      TMASSO(I)=0.0                                                        INCML.19
      TLOADO(I)=0.0                                                        INCML.20
  302 CONTINUE                                                             INCML.21
      M=0                                                                  INCML.22
 1000 CONTINUE                                                             INCML.23
      READ 1, N,(RM(J),J=1,6),(RL(J),J=1,6)                                INCML.24
      IF(N .NE. 0) GO TO 401                                               INCML.25
      M=N                                                                  INCML.26
      WRITE(1,502)                                                         INCML.27
      GO TO 402                                                            INCML.28
  401 CONTINUE                                                             INCML.29
      M=N                                                                  INCML.30
      WRITE(1,101) N,RM,RL                                                 INCML.31
      DO 303 J=1,6                                                         INCML.32
      N1=6*(N-1)+J                                                         INCML.33
      IIA=A(N1)                                                            INCML.34
      IF(IIA .EQ. 0) GO TO 403                                             INCML.35
      TMASSA(II)=RM(J)/12000.0                                             INCML.36
      TLOADA(II)=RL(J)/1000.0                                              INCML.37
      GO TO 303                                                            INCML.38
  403 CONTINUE                                                             INCML.39
      NOO=N1+6*NUMNP                                                       INCML.40
      IIO=A(NOO)                                                           INCML.41
      IF(IIO .EQ. 0) GO TO 303                                             INCML.42
      TMASSC(II)=RM(J)/12000.0                                             INCML.43
      TLOADO(II)=RL(J)/1000.0                                              INCML.44
  303 CONTINUE                                                             INCML.45
      IF(N .NE. NUMNP) GO TO 1000                                          INCML.46
  402 CONTINUE                                                             INCML.47
      RETURN                                                               INCML.48
    1 FORMAT(I5,12F5.3)                                                    INCML.49
  101 FORMAT(I5,12F10.3)                                                   INCML.50
  501 FORMAT(*1INPUT DATA OF CONCENTRATED MASS AND LOAD IN LB,FT,SEC*//  INCML.51
     2       5H NODE,4X,6HMASS X,4X,6HMASS-Y,4X,6HMASS Z,3X,7HMASS XX,    INCML.52
     3       3X,7HMASS YY,3X,7HMASS ZZ,6HLOAD X,4X,6HLOAD Y,4X,           INCML.53
     4       6HLOAD Z,3X,7HLOAD XX,7HLOAD YY,3X,7HLOAD ZZ//)              INCML.54
  502 FORMAT(* NO INPUT OF CONCENTRATED MASS OR LOAD*)                     INCML.55
      END                                                                  INCML.56
      OVERLAY(5,0)                                                         ESEPS.2
      PROGRAM ESEPS                                                        ESEPS.3
C                                                                          ESEPS.4
C     *****************************************************************ESEPS.5
C     CALCULATE ELASTIC STRESS-STRAIN OR ELEMENT FORCE-DEFORMATION         ESEPS.6
C     RELATION                                                             ESEPS.7
C     *****************************************************************ESEPS.8
C                                                                          ESEPS.9
      COMMON A(30000)                                                      ESEPS.10
      COMMON/ELPAR/NUMNP,NUMEL,NETYPE,NEQA,NEQC,MBANDA,MBANDO,KLIN,NLASTESEPS.11
      COMMON/MATER/NUMATS,NUMATC,NUMATF,NUMATB,NUMGE,NUMBC,MTYPE           ESEPS.12
      EQUIVALENCE(A,IA)                                                    ESEPS.13
      DIMENSION IA(1)                                                      ESEPS.14
      DIMENSION D1(3,20),D2(10,3,10),D3(4,20),D4(6,20),BCL(10),            ESEPS.15
     1          XX(2),YY(2),ZZ(2)                                          ESEPS.16
      NBC=0                                                                ESEPS.17
      N5=1+15*NUMNP                                                        ESEPS.18
      N6=N5+3*NUMATS                                                       ESEPS.19
      N7=N6+3*NUMATC                                                       ESEPS.20
      N8=N7+6*NUMGE                                                        ESEPS.21
      N9=N8+4*NUMATF                                                       ESEPS.22
      N10=N9+6*NUMATB                                                      ESEPS.23
      N10E=N10-1                                                           ESEPS.24
      N11=N10+11*NUMEL                                                     ESEPS.25
      N20=NLAST+1                                                          ESEPS.26
      N23T=N20                                                             ESEPS.27
      N24E=N23T+10*NUMEL-1                                                 ESEPS.28
C                                                                          ESEPS.29
C      INITILIZATION                                                       ESEPS.30
      DO 301 I=1,3                                                         ESEPS.31
      DO 301 J=1,NUMATS                                                    ESEPS.32
      D1(I,J)=0.0                                                          ESEPS.33
  301 CONTINUE                                                             ESEPS.34
      DO 302 I=1,4                                                         ESEPS.35
      DO 302 J=1,NUMATF                                                    ESEPS.36
      D3(I,J)=0.0                                                          ESEPS.37
  302 CONTINUE                                                             ESEPS.38
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      DO 304 I=1,10
      DO 304 J=1,NUMATC
      DO 304 K=1,NUMGE
      D2(I,J,K)=0.0
  304 CONTINUE
      DO 305 I=1,6
      DO 305 J=1,NUMATB
      D4(I,J)=0.0
  305 CONTINUE
      DO 306 I=N23T,N24E
      A(I)=0.0
  306 CONTINUE
C
C     SCLID ELEMENT,S(IL OR CONCRETE
      IF(NUMATS .EQ. 0) GO TO 401
      DO 307 I=1,NUMATS
      M1=N5+(I-1)*3
      G=A(M1)
      ANU=A(M1+1)
      COM=2.0*(1.0-ANU)/(1.0-2.0*ANU)
      D1(1,I)=COM*G
      D1(2,I)=COM*ANU*G/(1.0-ANU)
      D1(3,I)=G
  307 CONTINUE
C
C     CONCRETE COLUMN OR BEAM ELEMENT
  401 CONTINUE
      IF(NUMATC .EQ. 0) GO TO 402
      N2E=12*NUMNP
      N3E=N2E+NUMNP
      N4E=N3E+NUMNP
      DO 308 I=1,NUMGE
      BCL(I)=0.0
  308 CONTINUE
      DO 309 N=1,NUMEL
      NN10=N10+(N-1)*11+8
      NTYPE=IA(NN10)
      IF(NTYPE .NE. 2) GO TO 309
C
C     CALCULATE BEAM CR COLUMN LENGTH INCH
      NBC=NBC+1
      NN11=N11+(NBC-1)*3
      NG=IA(NN11)
      DO 310 J=1,2
      NED=N10E+11*(N-1)+J
      NED=IA(NED)
      NNX=N2E+NED
      NNY=N3E+NED
      NNZ=N4E+NED
      XX(J)=A(NNX)
      YY(J)=A(NNY)
      ZZ(J)=A(NNZ)
  310 CONTINUE
      XL=XX(2)-XX(1)
      YL=YY(2)-YY(1)
      ZL=ZZ(2)-ZZ(1)
      TL=SQRT(XL**2+YL**2+ZL**2)
      BCL(NG)=TL*12.0
  309 CONTINUE
      DO 311 I=1,NUMATC
      M2=N6+(I-1)*3
      E=A(M2)
      ANU=A(M2+1)
      G=E/(2.0+2.0*ANU)
      DO 311 J=1,NUMGE
      M21=N7+(J-1)*6
      A1=A(M21)
      A2=A(M21+1)
      A3=A(M21+2)
      T4=A(M21+3)
      B2=A(M21+4)
      B3=A(M21+5)
      PHI2=12.0*E*B3/(G*A2*(BCL(J)**2))
      PHI21=(1.0+PHI2)
      PHI24=4.0+PHI2
      PHI3=12.0*E*B2/(G*A3*BCL(J)**2)
      PHI31=(1.0+PHI3)
      PHI34=4.0+PHI3
      EZ=E*B3
      EY=E*B2
      D2(1,I,J)=E*A1/BCL(J)
      D2(2,I,J)=12.0*EZ/(BCL(J)**3*PHI21)
      D2(3,I,J)=12.0*EY/(BCL(J)**3*PHI31)
      D2(4,I,J)=G*T4/BCL(J)
      D2(5,I,J)=PHI34*EY/(BCL(J)*PHI31)
      D2(6,I,J)=PHI24*EZ/(BCL(J)*PHI21)
      D2(7,I,J)=6.0*EY/(BCL(J)**2*PHI31)
      D2(8,I,J)=6.0*EZ/(BCL(J)**2*PHI21)
      D2(9,I,J)=(2.0-PHI3)*EY/(BCL(J)*PHI31)
      D2(10,I,J)=(2.0-PHI2)*EZ/(BCL(J)*PHI21)
  311 CONTINUE
      NBC=0
C
  402 CONTINUE
C     FRICTIONAL ELEMENT STTESS-STRAIN RELATICN
      IF(NUMATF .EQ. 0) GO TO 403
      DO 312 I=1,NUMATF
      M3=N8+(I-1)*4
      D3(1,I)=A(M3)
      D3(2,I)=A(M3)
      D3(3,I)=A(M3+1)
  312 CONTINUE
C
  403 CONTINUE
C     BOUNDARY ELEMENT FORCE/DISPLACEMENT IN 6 DIRECTIONS
      IF(NUMATB .EQ. 0) GO TO 404
      DO 313 I=1,NUMATB
      M4=N9+(I-1)*6
      D4(1,I)=A(M4)
      D4(2,I)=A(M4+1)
      D4(3,I)=A(M4+2)
      D4(4,I)=A(M4+3)
      D4(5,I)=A(M4+4)
      D4(6,I)=A(M4+5)
  313 CONTINUE
C
  404 CONTINUE
C     FORM STRESS-STRAIN MATRIX--A(N23T TO N24E),ELEMENT BY ELEMENT
C     IN COMMON BLOCK
      DO 314 N=1,NUMEL
      NN10=N10+11*N-3
      NTYPE=IA(NN10)
      MAT=IA(NN10+1)
      NC=N23T+10*(N-1)-1
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      GO TO(405,406,407,408),NTYPE                                      ESEPS.163
C                                                                       ESEPS.164
  405 CONTINUE                                                          ESEPS.165
C     SOLID ELEMENT,SOIL OR CONCRETE                                    ESEPS.166
      A(NC+1)=D1(1,MAT)                                                 ESEPS.167
      A(NC+2)=D1(2,MAT)                                                 ESEPS.168
      A(NC+3)=D1(3,MAT)                                                 ESEPS.169
      GO TO 314                                                         ESEPS.170
C                                                                       ESEPS.171
  406 CONTINUE                                                          ESEPS.172
C     MATERIAL NO. AND GEOMETRIC NO.-MAT,NG                             ESEPS.173
      NBC=NBC+1                                                         ESEPS.174
      NG=N11+3*NBC-3                                                    ESEPS.175
      NG=IA(NG)                                                         ESEPS.176
      DO 315 I=1,10                                                     ESEPS.177
      A(NC+I)=D2(I,MAT,NG)                                              ESEPS.178
  315 CONTINUE                                                          ESEPS.179
      GO TO 314                                                         ESEPS.180
C                                                                       ESEPS.181
  407 CONTINUE                                                          ESEPS.182
C     FRICTIONAL ELEMENT                                                ESEPS.183
      A(NC+1)=D3(1,MAT)                                                 ESEPS.184
      A(NC+2)=D3(2,MAT)                                                 ESEPS.185
      A(NC+3)=D3(3,MAT)                                                 ESEPS.186
      GO TO 314                                                         ESEPS.187
C                                                                       ESEPS.188
  408 CONTINUE                                                          ESEPS.189
C      BOUNDARY ELEMENT                                                 ESEPS.190
      DO 316 I=1,6                                                      ESEPS.191
      A(NC+I)=D4(I,MAT)                                                 ESEPS.192
  316 CONTINUE                                                          ESEPS.193
  314 CONTINUE                                                          ESEPS.194
C                                                                       ESEPS.195
C     ASSEMBLE TOTAL EALSTIC STIFFNESS                                  ESEPS.196
      CALL ETSTIF                                                       ESEPS.197
      RETURN                                                            ESEPS.198
      END                                                               ESEPS.199
      SUBROUTINE ETSTIF                                                 ETSTIF.2
C                                                                       ETSTIF.3
C     *****************************************************************ETSTIF.4
C     FORM ELASTIC STIFFNESS MATRIX EKAA(NEQA,MEANCA),EKOO(NEQO,MBANCO),ETSTIF.5
C     EKAO(NEQA,NEQO)                                                   ETSTIF.6
C                                                                       ETSTIF.7
C                 * EKAA      EKAO *                                    ETSTIF.8
C                 *                *                                    ETSTIF.9
C     AND STORE IN TAPE                                                 ETSTIF.10
C     EKAA ? TAPE 2                                                     ETSTIF.11
C     EKAO ? TAPE 3                                                     ETSTIF.12
      LARGE B(22000)                                                    ETSTIF.13
      LARGE C(8000)                                                     ETSTIF.14
      COMMON A(30000)                                                   ETSTIF.15
      COMMON/ELPAR/NUMNP,NUMEL,NETYPE,NEQA,NEQO,MBANDA,MBANDO, KLIN,NLASTETSTIF.16
      COMMON/MATER/NUMATS,NUMATC,NUMATF,NUMATB,NUMGE,NUMBC,MTYPE        ETSTIF.17
      COMMON/LMC/LMA(36),LMO(36),XX(8),YY(8),ZZ(8)                      ETSTIF.18
      COMMON/NONL/NINDT,NINDTO,DKUO(200)                                ETSTIF.19
      COMMON/UVCOD/U(4),V(4)                                            ETSTIF.20
      COMMON/TOPEL/NFB(4,50),ITOPN                                      ETSTIF.21
      COMMON/STROUT/NSOLID,NCONC,NFR,NSPRIN                             ETSTIF.22
      EQUIVALENCE(A,IA)                                                 ETSTIF.23
      DIMENSION IA(1),ASA(36,36),TASA(36,36),SA(3,12)                   ETSTIF.24
C                                                                       ETSTIF.25
C     INITILIZATION                                                     ETSTIF.26
      ITOP=0                                                            ETSTIF.27
C     STRESS OUTPUT ELEMENT NO. OF SOLID,CONCRETE,AND SPRING ELEMENT    ETSTIF.28
      NSOLID=0                                                          ETSTIF.29
      NCONC=0                                                           ETSTIF.30
      NFR=0                                                             ETSTIF.31
      NSPRIN=0                                                          ETSTIF.32
      N6=1+15*NUMNP+3*NUMATS                                            ETSTIF.33
      N7=N6+3*NUMATC                                                    ETSTIF.34
      N10=N7+6*NUMGE+4*NUMATF+6*NUMATB                                  ETSTIF.35
      N11=N10+11*NUMEL                                                  ETSTIF.36
      N20E=NLAST                                                        ETSTIF.37
      N20=N20E+1                                                        ETSTIF.38
      N21E=N20E+10*NUMEL                                                ETSTIF.39
      N21T=N21E+1                                                       ETSTIF.40
      N22E=N21E+NUMEL                                                   ETSTIF.41
      N23E=N22E+NUMEL                                                   ETSTIF.42
      N24E=N23E+NUMEL                                                   ETSTIF.43
      N25E=N24E+NUMEL                                                   ETSTIF.44
      N26E=N25E+NUMEL                                                   ETSTIF.45
      NLAST=N26E                                                        ETSTIF.46
C     INITILIZATION                                                     ETSTIF.47
      DO 303 I=N21T,N26E                                                ETSTIF.48
      IA(I)=0                                                           ETSTIF.49
  303 CONTINUE                                                          ETSTIF.50
      NB1=1                                                             ETSTIF.51
      NB2=NB1+NEQO*MBANCO                                               ETSTIF.52
      NB2E=NB2-1                                                        ETSTIF.53
      NB3=NB2+NEQA*NECO                                                 ETSTIF.54
      NB3E=NB3-1                                                        ETSTIF.55
      NC2E=NEQA*NEQA-1                                                  ETSTIF.56
      NBC=0                                                             ETSTIF.57
      DC 301 I=NB1,NB3E                                                 ETSTIF.58
      B(I)=0.                                                           ETSTIF.59
  301 CONTINUE                                                          ETSTIF.60
      DO 304 I=1,NC2E                                                   ETSTIF.61
      C(I)=0.                                                           ETSTIF.62
  304 CONTINUE                                                          ETSTIF.63
      DO 302 N=1,NUMEL                                                  ETSTIF.64
      NN10=N10+11*N-3                                                   ETSTIF.65
C                                                                       ETSTIF.66
C     DETETMINE ELEMENT TYPE,MATERIAL NC.                               ETSTIF.67
C     INTER?INTEGRATICN NO. TO DENOTE WHETHER CALCULATICN OF STIFFNESS  ETSTIF.68
C     OR STRESS IS NEEDED,AND WHETHER IT IS UPPER ELEMENT OF JOINT CR NOETSTIF.69
C     0?NOT UPPER ELEMENT ,NO STIFFNESS ,NO STRESS                      ETSTIF.70
C     1?                   NO STIFFNESS ,BUT STRESS                     ETSTIF.71
C                                                                       ETSTIF.72
C     2?                   NEED STIFFNESS ,NO STRESS                    ETSTIF.73
C     3?                   NEED STIFFNESS ,AND STRESS                   ETSTIF.74
C                                                                       ETSTIF.75
C     4?UPPER ELEMENT ,NO STIFFNESS ,BUT STRESS                         ETSTIF.76
C     5                 NEED STIFFNESS AND STRESS                       ETSTIF.77
C     6                ,NO STIFFNESS,NO STRESS                          ETSTIF.78
C     7                ,NEED STIFFNESS,NC STRESS                        ETSTIF.79
C                                                                       ETSTIF.80
      NTYPE=IA(NN10)                                                    ETSTIF.81
      MATYPE=IA(NN10+1)                                                 ETSTIF.82
      INTER=IA(NN10+2)                                                  ETSTIF.83
      IX=N10+11*N-11                                                    ETSTIF.84
C                                                                       ETSTIF.85
C     STRESS-STRAIN MATRIX IN CCMMON BLCCK                              ETSTIF.86
      NC=N20+10*(N-1)                                                   ETSTIF.87
      GO TO(401,402,403,404),NTYPE                                      ETSTIF.88
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```
  401 CONTINUE
C
C     SOLID ELEMENT,SCIL OR CONCRETE
C
C     LOCATION OF MASS
      CALL LAM(IA(IX),1)
      IF(INTER .EQ. 0 .OR. INTER .EQ. 1
     1.OR. INTER .EQ. 4 .OR. INTER .EQ. 6) GO TO 405
C
C     FORM ELEMENT STIFFNESS
      CALL SOLID(ASA,A(NC))
  405 CONTINUE
      IF(INTER .EQ. 0 .OR. INTER .EQ. 2
     1.OR. INTER .EQ. 6 .OR. INTER .EQ. 7) GO TO 415
C     FORM STRESS-DISPLACEMENT MATRIX AT CENTER OF VOLUMN
C     CC1=1-NU,CC2=NU,CC3=0.5-NU,FAC=E/(1-2*NU)(1+NU),NU=POISSON RATIO
      P=A(NC+1)/A(NC)
      CC1=1.0/P
      CC2=1.0-CC1
      CC3=0.5-CC2
      FAC=A(NC)/CC1
      CALL STRDP(CC1,CC2,CC3,FAC)
C     ELEMENT NO. AND STRESS SEQUENCE TRANSFORMATION
      NSOLID=NSOLID+1
      IA(N22E+NSOLID)=N
  415 CONTINUE
C
      IF(INTER .LE. 3) GO TO 406
      CALL EJCINT(ASA,TASA)
      ITOP=ITOP+1
      ITOPN=ITOP
      CALL LAM(IA(IX),1)
      CALL STORE(B(NB1),B(NB2),C(1),TASA,NEQA,NEQO,MBANCA,MBANDO,36)
      GO TO 302
  406 CONTINUE
C     STORE STIFFNESS MATRIX KAA,KAO,KOO
      CALL STORE(B(NB1),B(NB2),C(1),ASA,NEQA,NEQO,MBANDA,MBANDO,24)
      GO TO 302
C
C     CONCRETE BEAM OR COLUMN ELEMENT
  402 CONTINUE
C
C     LOCATION OF MASS
      CALL LAM(IA(IX),1)
C
C     FORM ELEMENT STIFFNESS
      NBC=NBC+1
      N6B=N6+(MATYPE-1)*3
      N10B=N10+(N-1)*11
      NN10=N10B-1
      N11B=N11+(NBC-1)*3
      NGE=IA(N11B)
      N7B=N7+(NGE-1)*6
      IF(INTER .EQ. 0) GO TO 407
      CALL CONCTS(ASA,A(N6B),A(N7B),IA(IX),IA(N11B),A(NC),N10,NN10,
     1            INTER)
      IF(INTER .EQ. 2) GO TO 410
      IA(N23E+NCONC)=N
  410 CONTINUE
  407 CONTINUE
C
C     STORE STIFFNESS MATRIX
      CALL STORE(B(NB1),B(NB2),C(1),ASA,NEQA,NEQO,MBANDA,MBANDO,12)
      GO TO 302
  403 CONTINUE
C     FRICTION ELEMENT
C
C     LOCATION OF MASS
      CALL LAM(IA(IX),1)
C     TRANSFORM XY TO UV
C     LENGTH OF LINE 12=D12
      X2=XX(2)-XX(1)
      Y2=YY(2)-YY(1)
      Z2=ZZ(2)-ZZ(1)
      D12=X2**2+Y2**2+Z2**2
      D12=SQRT(D12)
C     DIRECTIONAL COSINE OF LINE 12=DCX2,DCY2,DCZ2
      DCX2=X2/D12
      DCY2=Y2/D12
      DCZ2=Z2/D12
C
C     LENGTH OF LINE 23=D23
      X3=XX(3)-XX(2)
      Y3=YY(3)-YY(2)
      Z3=ZZ(3)-ZZ(2)
      D23=X3**2+Y3**2+Z3**2
      D23=SQRT(D23)
C     DIRECTIONAL COSINE OF LINE 23
      DCX3=X3/D23
      DCY3=Y3/D23
      DCZ3=Z3/D23
C     ANGLE BETWEEN LINE 12 AND LINE 23
      TEMP1=DCX2*DCX3+DCY2*DCY3+DCZ2*DCZ3
      TH123=ACOS(TEMP1)
C     U,V COORDINATES OF POINT 1,2,3
      U(1)=0.
      V(1)=0.
      U(2)=D12
      V(2)=0.
      U(3)=U(2)+D23*COS(TH123)
      V(3)=D23*SIN(TH123)
C     LENGTH OF LINE 14
      X4=XX(4)-XX(1)
      Y4=YY(4)-YY(1)
      Z4=ZZ(4)-ZZ(1)
      D14=X4**2+Y4**2+Z4**2
      D14=SQRT(D14)
C     DIRECTIONAL COSINE OF LINE 14
      DCX4=X4/D14
      DCY4=Y4/D14
      DCZ4=Z4/D14
C     ANGLE BETWEEN LINE 12 AND LINE 14
      TEMP2=DCX2*DCX4+DCY2*DCY4+DCZ2*DCZ4
      TH412=ACOS(TEMP2)
      U(4)=D14*COS(TH412)
      V(4)=D14*SIN(TH412)
C
C     FORM ELEMENT STIFFNESS
      NFR=NFR+1
      IA(N21E+N)=NFR
      IA(N24E+NFR)=N
      NAA=N21E+N
      NBB=N24E+NFR
      IF(INTER .EQ. 0) GO TO 408
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      CALL FRICTS(ASA,SA,A(NC),INTER)                                   ETSTIF.213
  408 CONTINUE                                                          ETSTIF.214
C                                                                       ETSTIF.215
C     STORE STIFFNESS MATRIX                                            ETSTIF.216
      CALL STORE(B(NB1),B(NB2),C(1),ASA,NEQA,NEQO,MBANDA,MBANDO,12)     ETSTIF.217
      GO TO 302                                                         ETSTIF.218
C                                                                       ETSTIF.219
C     BOUNDARY ELEMENT                                                  ETSTIF.220
  404 CONTINUE                                                          ETSTIF.221
C                                                                       ETSTIF.222
C     LOCATION OF MASS                                                  ETSTIF.223
      CALL LAN(IA(IX),1)                                                ETSTIF.224
C                                                                       ETSTIF.225
C     FORM ELEMENT STIFFNESS                                            ETSTIF.226
      NSPRIN=NSPRIN+1                                                   ETSTIF.227
C                                                                       ETSTIF.228
      IF(INTER .EQ. 0) GO TO 409                                        ETSTIF.229
      CALL BOUNDS(ASA,A(NC),INTER)                                      ETSTIF.230
      IF(INTER .EQ. 2) GO TO 411                                        ETSTIF.231
      IA(N25E+NSPRIN)=N                                                 ETSTIF.232
  411 CONTINUE                                                          ETSTIF.233
  409 CONTINUE                                                          ETSTIF.234
C                                                                       ETSTIF.235
C     STORE                                                             ETSTIF.236
      CALL STORE(B(NB1),B(NB2),C(1),ASA,NEQA,NEQO,MBANDA,MBANDO,6)      ETSTIF.237
  302 CONTINUE                                                          ETSTIF.238
C     STORE (KAA),(KAO) IN TAPE2,(KOO) IN TAPE4                         ETSTIF.239
C     STORE KAA IN FULL MATRIX FOR USE THE OPERATION                    ETSTIF.240
C     KAABAR=KAA+KAO*GO                                                 ETSTIF.241
C     WHERE KAABAR IS UNSYMMETRICAL                                     ETSTIF.242
      NEQAA=NEQA*NEQA                                                   ETSTIF.243
C     STORE THE MBANDED KAA(NEQA,MBANDA) IN TAPE6,FOR FREQUENCY CALCUTN ETSTIF.244
      NB4E=NB3+NEQA*MBANDA-1                                            ETSTIF.245
      N12=N11+3*NUMBC                                                   ETSTIF.246
      N12E=N12-1                                                        ETSTIF.247
      REWIND 6                                                          ETSTIF.248
      WRITE(6) (C(I),I=1,NC2E)                                          ETSTIF.249
C     STORE IN TAPE2 FOR CALCULATE KAABAR IN STATIC                     ETSTIF.250
      REWIND 2                                                          ETSTIF.251
      WRITE(2) (C(I),I=1,NC2E)                                          ETSTIF.252
      WRITE(2) (B(I),I=NB2,NB3E)                                        ETSTIF.253
C     TRANSPOSE KAO INTO -KAOT,INTO SAME POSITION,AND READ AFTER        ETSTIF.254
C     KOO TO BE USED AS TAPE NTSTIF FOR SOLVING GO IN SESOL             ETSTIF.255
C     WHERE (KOO)*(GO)=-(KAO)T                                          ETSTIF.256
      NA=NB2                                                            ETSTIF.257
      K=1                                                               ETSTIF.258
      NC1E=NEQO*NEQA                                                    ETSTIF.259
      DO 306 I=1,NEQA                                                   ETSTIF.260
      L=NA+I-1                                                          ETSTIF.261
      DO 306 J=1,NEQO                                                   ETSTIF.262
      C(K)=-B(L)                                                        ETSTIF.263
      L=L+NEQA                                                          ETSTIF.264
      K=K+1                                                             ETSTIF.265
  306 CONTINUE                                                          ETSTIF.266
      WRITE(4) (B(I),I=1,NB2E),(C(I),I=1,NC1E)                          ETSTIF.267
      RETURN                                                            ETSTIF.268
      END                                                               ETSTIF.269
      SUBROUTINE CONCTS(ASA,PARACO,COPROP,IX,IBC,E,N10,NN10,INTER)      CONCTS.2
C                                                                       CONCTS.3
C     ******************************************************************CONCTS.4
C     ******************************************************************CONCTS.5
C     FORM ELEMENT STIFFNESS OF CONCRETE BEAM OR COLUMN IN GLOBAL       CONCTS.6
C     COORDINATE ASA(12,12)                                             CONCTS.7
C     ******************************************************************CONCTS.8
C                                                                       CONCTS.9
      COMMON/TRANS/T(3,3),SF(12)                                        CONCTS.10
      COMMON/MASS/AMASS,WT,RF(12),L                                     CONCTS.11
      COMMON/ELPAR/NUMNP,NUMEL,NETYPE,NEQA,NEQO,MBANDA,MBANDO,KLIN,NLASTCONCTS.12
      COMMON/MATER/NUMATS,NUMATC,NUMATF,NUMATB,NUMGE,NUMBC,MTYPE        CONCTS.13
      COMMON A(30000)                                                   CONCTS.14
      COMMON/LMC/LMA(36),LMO(36),XX(8),YY(8),ZZ(8)                      CONCTS.15
      DIMENSION PARACO(3),COPROP(6),IX(10),IBC(3),JK(2),E(10)           CONCTS.16
      COMMON/STREST/ND,NS,SA(12,24)                                     CONCTS.17
      COMMON/STROUT/NSOLID,NCONC,NFR,NSPRIN                             CONCTS.18
      DIMENSION ASA(36,36),S(12,12),R(12),C(12),RRF(12)                 CONCTS.19
      DIMENSION IA(1)                                                   CONCTS.20
      EQUIVALENCE(A,IA)                                                 CONCTS.21
      IF(INTER .EQ. 1) GO TO 412                                        CONCTS.22
      N12=N10+11*NUMEL+3*NUMBC                                          CONCTS.23
      N12E=N12-1                                                        CONCTS.24
      N13E=N12E+NEQA                                                    CONCTS.25
C                                                                       CONCTS.26
C     INITILIZATION                                                     CONCTS.27
      DO 300 I=1,144                                                    CONCTS.28
      S(I)=0.                                                           CONCTS.29
  300 CONTINUE                                                          CONCTS.30
C                                                                       CONCTS.31
C     FORM GLOBAL TO LOCAL COORDINATE TRANSFORMATION T(3,3)             CONCTS.32
      DX=XX(2)-XX(1)                                                    CONCTS.33
      DY=YY(2)-YY(1)                                                    CONCTS.34
      DZ=ZZ(2)-ZZ(1)                                                    CONCTS.35
      CALL TRANSF(DX,DY,DZ,XX,YY,ZZ)                                    CONCTS.36
C                                                                       CONCTS.37
C     BEAM ENDS RELEASE CODE                                            CONCTS.38
      JK(1)=IBC(2)                                                      CONCTS.39
      JK(2)=IBC(3)                                                      CONCTS.40
C                                                                       CONCTS.41
C     FORM ELEMENT STIFFNESS IN LOCAL COORDINATE S(12,12)               CONCTS.42
      S(1,1)=E(1)                                                       CONCTS.43
      S(2,2)=E(2)                                                       CONCTS.44
      S(3,3)=E(3)                                                       CONCTS.45
      S(4,4)=E(4)                                                       CONCTS.46
      S(5,5)=E(5)                                                       CONCTS.47
      S(6,6)=E(6)                                                       CONCTS.48
      S(3,5)=-E(7)                                                      CONCTS.49
      S(2,6)=E(8)                                                       CONCTS.50
C                                                                       CONCTS.51
      DO 301 I=1,6                                                      CONCTS.52
      J=I+6                                                             CONCTS.53
      S(J,J)=S(I,I)                                                     CONCTS.54
  301 CONTINUE                                                          CONCTS.55
      DO 302 I=1,4                                                      CONCTS.56
      J=I+6                                                             CONCTS.57
      S(I,J)=-S(I,I)                                                    CONCTS.58
  302 CONTINUE                                                          CONCTS.59
      S(5,11)=E(9)                                                      CONCTS.60
      S(6,12)=E(10)                                                     CONCTS.61
      S(2,12)=S(2,6)                                                    CONCTS.62
      S(6,8)=-S(2,6)                                                    CONCTS.63
      S(8,12)=-S(2,6)                                                   CONCTS.64
      S(3,11)=S(3,5)                                                    CONCTS.65
      S(5,9)=-S(3,5)                                                    CONCTS.66
      S(9,11)=-S(3,5)                                                   CONCTS.67
      DO 303 I=2,12                                                     CONCTS.68
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      K=I-1
      DO 303 J=1,K
      S(I,J)=S(J,I)
  303 CONTINUE
C
C     CALCULATE FIXED END FORCES IN LOCAL COORDINATES
      AX=COPROP(1)
      WT=AX*PARACO(3)
      L=0
      CALL FBECCL(XX,YY,ZZ)
C
C     MODIFY ELEMENT STIFFNESS AND ELEMENT FIXED END FORCES
C     FOR KNOWN ZERO MEMBER FORCES
      IF((JK(1)+JK(2)) .EQ. 0) GO TO 401
      DO 305 K=1,2
      KK=JK(K)
      KD=100000
      I1=6*(K-1)+1
      I2=I1+5
      DO 305 I=I1,I2
      IF(KK .LT. KD) GO TO 305
      SII=S(I,I)
      DO 306 N=1,12
      R(N)=S(I,N)
  306 CONTINUE
      DO 307 M=1,12
      C(M)=S(M,I)/SII
      DO 307 N=1,12
      S(M,N)=S(M,N)-C(M)*R(N)
  307 CONTINUE
      SFI=SF(I)
      DO 308 M=1,12
      SF(M)=SF(M)-C(M)*SFI
  308 CONTINUE
      KK=KK-KD
      KD=KD/10
  305 CONTINUE
  401 CONTINUE
C
C     OBTAIN SA(12,12) RELATING ELEMENT END FORCES(LOCAL) AND JOINT
C     DISPLACEMENT(GLOBAL)
      DO 309 I=1,288
      SA(I)=0.0
  309 CONTINUE
      DO 310 LA=1,10,3
      LB=LA+2
      DO 310 MA=1,10,3
      MB=MA-1
      DO 310 I=LA,LB
      DO 310 JM=1,3
      J=JM+MB
      X=0.
      DO 311 K=1,3
      X=X+S(I,K+MB)*T(K,JM)
  311 CONTINUE
      SA(I,J)=X
  310 CONTINUE
C
C     ELEMENT STIFF ASA(12,12) AND FIXED END FORCES RRF(12)
C     IN GLOBAL COORDINATES
      DO 312 I=1,1296
      ASA(I)=0.
  312 CONTINUE
      DO 313 LA=1,10,3
      LB=LA-1
      DO 313 MA=1,10,3
      MB=MA+2
      DO 313 IL=1,3
      I=IL+LB
      DO 313 J=MA,MB
      X=0.
      DO 314 K=1,3
      X=X+T(K,IL)*SA(K+LB,J)
  314 CONTINUE
      ASA(I,J)=X
  313 CONTINUE
C
      DO 315 LA=1,10,3
      LB=LA-1
      DO 315 IL=1,3
      I=IL+LB
      X=0.
      DO 316 K=1,3
      X=X-T(K,IL)*SF(K+LB)
  316 CONTINUE
      RRF(I)=X
  315 CONTINUE
      IF((JK(1)+JK(2)) .EQ. 0) GO TO 402
C
C     MODIFIED STATIC LOAD VECTOR DUE TO END RELEASE
      NOO=6*NUMNP
      DO 317 J=1,2
      NODE=IA(NN10+J)
      NXA=6*NODE-5
      NXO=NOO+NXA
      IA1=IA(NXA)
      IA2=IA(NXA+1)
      IA3=IA(NXA+2)
      IA4=IA(NXA+3)
      IA5=IA(NXA+4)
      IA6=IA(NXA+5)
      IO1=IA(NXO)
      IO2=IA(NXO+1)
      IO3=IA(NXO+2)
      IO4=IA(NXO+3)
      IO5=IA(NXO+4)
      IO6=IA(NXO+5)
      JM=(J-1)*6
C     XX MOMENT
      IF(IA4 .EQ. 0) GO TO 403
      A(IA4+N12E)=A(IA4+N12E)-RF(JM+4)+RRF(JM+4)
      GO TO 404
  403 CONTINUE
      IF(IO4 .EQ. 0) GO TO 404
      A(IO4+N13E)=A(IO4+N13E)-RF(JM+4)+RRF(JM+4)
  404 CONTINUE
C
C     YY MOMENT
      IF(IA5 .EQ. 0) GO TO 406
      A(IA5+N12E)=A(IA5+N12E)-RF(JM+5)+RRF(JM+5)
      GO TO 407
  406 CONTINUE
      IF(IO5 .EQ. 0) GO TO 407
      A(IO5+N13E)=A(IO5+N13E)-RF(JM+5)+RRF(JM+5)
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  407 CONTINUE                                                          CONCTS.193
C                                                                       CONCTS.194
C      ZZ MOMENT                                                        CONCTS.195
       IF(IA6 .EQ. 0) GO TO 408                                         CONCTS.196
       A(IA6+N12E)=A(IA6+N12E)-RF(JM+6)+RRF(JM+6)                       CONCTS.197
       GO TO 402                                                        CONCTS.198
  408 CONTINUE                                                          CONCTS.199
       IF(IO6 .EQ. 0) GO TO 402                                         CONCTS.200
       A(IO6+N13E)=A(IO6+N13E)-RF(JM+6)+RRF(JM+6)                       CONCTS.201
  317 CONTINUE                                                          CONCTS.202
  402 CONTINUE                                                          CONCTS.203
  412 CONTINUE                                                          CONCTS.204
       IF(INTER .EQ. 2) GO TO 413                                       CONCTS.205
       NCONC=NCONC+1                                                    CONCTS.206
C      WRITE ELEMENT STIFFNESS INFORMATION ON TAPE 9                    CONCTS.207
       ND=12                                                            CONCTS.208
       NS=12                                                            CONCTS.209
       WRITE(9) ND,NS,(LPA(I),I=1,ND),(LMO(I),I=1,NC),                  CONCTS.210
      1        ((SA(I,J),I=1,NS),J=1,ND),(SF(I),I=1,ND)                 CONCTS.211
  413 CONTINUE                                                          CONCTS.212
       RETURN                                                           CONCTS.213
       END                                                              CONCTS.214
       OVERLAY(6,0)                                                     MODES.2
       PROGRAM MODES                                                    MODES.3
       COMMON/TAPES/NSTIF,NMASS,NT                                      MODES.4
       COMMON A(30000)                                                  MODES.5
       COMMON/DAMP2/NDAMP,NROOT,NFP,XI(20),NXI(20),OMEGA(20)            MODES.6
       COMMON/ELPAR/NUMNP,NUMEL,NETYPE,NEQA,NEQC,MBANDA,MBANDO,KLIN,NLASTMODES.7
       MTOT=20000                                                       MODES.8
       NSTIF=6                                                          MODES.9
       NMASS=5                                                          MODES.10
       NT=7                                                             MODES.11
       NEQ=NEQA                                                         MODES.12
       MBAND=MBANDA                                                     MODES.13
       NBLOCK=1                                                         MODES.14
       N26E=NLAST                                                       MODES.15
       N18=N26E+1                                                       MODES.16
       NF=NROOT                                                         MODES.17
       IF(NROOT .GT. 20) WRITE(1,101)                                   MODES.18
  101 FORMAT(* THE DIMENSION OF OMEGA IS NOT ENOUGH AT MODES*)          MODES.19
       WRITE(1,103) NEQ,MBAND,NF                                        MODES.20
       NIM=3                                                            MODES.21
       NC=NF+NIM                                                        MODES.22
       NWA=NEQ*MBAND                                                    MODES.23
       NM2=N18+NWA                                                      MODES.24
       NM3=NM2+NEQ                                                      MODES.25
       NM4=NM3+NEQ                                                      MODES.26
       NM5=NM4+NEQ                                                      MODES.27
       NM6=NM5+NEQ                                                      MODES.28
       NM7=NM6+NEQ*NC                                                   MODES.29
       NM8=NM7+NEQ*NC                                                   MODES.30
       NM9=NM8+NC                                                       MODES.31
       NM10=NM9+NC                                                      MODES.32
       NM11=NM10+NC                                                     MODES.33
       NM12=NM11+NC                                                     MODES.34
       NM13=NM12+NC                                                     MODES.35
       IF(MTOT-NM13) 401,402,402                                        MODES.36
  401 WRITE(1,102) NM13                                                 MODES.37
       STOP                                                             MODES.38
  402 CONTINUE                                                          MODES.39
       CALL SECANTD(A(N18),A(NM2),A(NM3),A(NM4),A(NM5),A(NM6),A(NM7),   MODES.40
      1A(NM8),A(NM9),A(NM10),A(NM11),A(NM12),NEQ,MBAND,NWA,NF,NC)       MODES.41
       NM8E=NM8-1                                                       MODES.42
       DO 301 I=1,NROOT                                                 MODES.43
       OMEGA(I)=6.28318/A(NM8E+I)                                       MODES.44
  301 CONTINUE                                                          MODES.45
        RETURN                                                          MODES.46
  103 FORMAT(*1PROBLEM INFORMATION      *,//                            MODES.47
      1        * NO. OF EQUATIONS       *,I4/                           MODES.48
      2        * NO. OF BANDWIDTH OF A  *,I4/                           MODES.49
      3        * NO. OF FREQUENCIESREQ  *,I4)                           MODES.50
  102 FORMAT(* FOR EXECUTION NEED TO INCREASE MTOT TO*,I6)              MODES.51
        END                                                             MODES.52
        SUBROUTINE SECANTD (A,B,V,MAXA,W,VV,WW,ROOT,TIM,ERRVL,ERRVR,    MODES.53
      .                   NITE,N,MA,NWA,NROOT,NC)                       MODES.54
C                                                                       MODES.55
       COMMON/TAPES/NSTIF,NMASS,NT                                      MODES.56
        DIMENSION A(NWA),B(N),V(N),VS(1),W(N),VV(N,NC),WW(N,NC),ROOT(NC),MODES.57
      .         TIM(NC),ERRVL(NC),ERRVR(NC)                             MODES.58
        INTEGER NITE(NC),MAXA(NC)                                       MODES.59
C                                                                       MODES.60
C       FOLLOWING TOLERANCES ARE SET FOR CDC 6400.....                  MODES.61
C                                                                       MODES.62
        ACTOL=1.0E-04                                                   MODES.63
        RCBTOL=1.0E-06                                                  MODES.64
        RTCL=1.0E-10                                                    MODES.65
        RQTOL=1.0E-12                                                   MODES.66
        SCALE=2.0**900                                                  MODES.67
       NNROOT=NROOT                                                     MODES.68
C                                                                       MODES.69
        NTF=5                                                           MODES.70
        IITEM=10                                                        MODES.71
        NITEM=40                                                        MODES.72
C                                                                       MODES.73
        REWIND NMASS                                                    MODES.74
        READ (NMASS) B                                                  MODES.75
C                                                                       MODES.76
        ETA=2.0                                                         MODES.77
        NOV=0                                                           MODES.78
        JR=1                                                            MODES.79
        NSK=0                                                           MODES.80
        NWA=N*MA                                                        MODES.81
        ISC=1000                                                        MODES.82
C                                                                       MODES.83
        CALL SECOND (TIM1)                                              MODES.84
        RA=0.0                                                          MODES.85
        RR=0.0                                                          MODES.86
        CALL BANDET (A,B,V,MAXA,N,NWA,RA,NSCH,DETA,ISC,1)               MODES.87
        FA=DETA                                                         MODES.88
        FR=FA                                                           MODES.89
        DETR=DETA                                                       MODES.90
C                                                                       MODES.91
C       FIND LOWER BOUND ON SMALLEST EIGENVALUE                         MODES.92
C                                                                       MODES.93
        WRITE(1,1010)                                                   MODES.94
        DO 100 I=1,N                                                    MODES.95
  100   W(I)=B(I)                                                       MODES.96
        RT=0.0                                                          MODES.97
        IITE=0                                                          MODES.98
       KK=2                                                             MODES.99
  110   IITE=IITE+1                                                     MODES.100
        DO 120 I=1,N                                                    MODES.101
  120   V(I)=W(I)                                                       MODES.102
        CALL BANDET (A,B,V,MAXA,N,NWA,RA,NSCH,DETA,ISC,KK)              MODES.103
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      KK=2                                                              MODES.104
      RQT=0.0                                                           MODES.105
      DO 130 I=1,N                                                      MODES.106
  130 RQT=RQT+W(I)*V(I)                                                 MODES.107
      DO 180 I=1,N                                                      MODES.108
  180 W(I)=B(I)*V(I)                                                    MODES.109
      RQB=0.0                                                           MODES.110
      DO 140 I=1,N                                                      MODES.111
  140 RQB=RQB+W(I)*V(I)                                                 MODES.112
      RQ=RQT/RQB                                                        MODES.113
      WRITE(1,1004) RQ                                                  MODES.114
      BS=SQRT(RQB)                                                      MODES.115
      TOL=ABS(RQ-RT)/RQ                                                 MODES.116
      IF (TOL.LT.RCBTOL) GO TO 150                                      MODES.117
      DO 160 I=1,N                                                      MODES.118
  160 W(I)=W(I)/BS                                                      MODES.119
      RT=RQ                                                             MODES.120
      IF (IITE.LT.IITEM) GO TO 110                                      MODES.121
C                                                                       MODES.122
  150 DO 170 I=1,N                                                      MODES.123
  170 V(I)=V(I)/BS                                                      MODES.124
      RB=RQ*(1.0-AMIN1(0.1,100*TOL))                                    MODES.125
      IS=0                                                              MODES.126
  230 CALL BANDET (A,B,V,MAXA,N,NWA,RB,NSCH,DETB,ISC,1)                 MODES.127
      WRITE(1,1020) RB,NSCH                                             MODES.128
      FB=DETB                                                           MODES.129
      IF (NSCH.EQ.0) GO TO 300                                          MODES.130
      IS=IS+1                                                           MODES.131
      IF (IS.LE.NTF) GO TO 240                                          MODES.132
      WRITE(1,1030)                                                     MODES.133
      STOP                                                              MODES.134
  240 RB=RB/(NSCH+1)                                                    MODES.135
      GO TO 230                                                         MODES.136
C                                                                       MODES.137
C     ITERATION FOR INDIVIDUAL ROOT                                     MODES.138
C                                                                       MODES.139
  300 WRITE(1,1040)                                                     MODES.140
      NITE(JR)=1                                                        MODES.141
      WRITE(1,1050) JR,NITE(JR),RA,DETA,FA,ETA,ISC                      MODES.142
      NITE(JR)=2                                                        MODES.143
      WRITE(1,1050) JR,NITE(JR),RB,DETB,FB,ETA,ISC                      MODES.144
C                                                                       MODES.145
C     STOP WHEN REQUIRED NO. OF ROOTS SMALLER THAN RC AND NOV=0 FOUND   MODES.146
C                                                                       MODES.147
  310 IF (NSCH.GE.NROOT) GO TO 900                                      MODES.148
C                                                                       MODES.149
      DIF=FB-FA                                                         MODES.150
      IF (DIF.NE.0.0) GO TO 320                                         MODES.151
      WRITE(1,1060)                                                     MODES.152
      GO TO 900                                                         MODES.153
  320 DEL=FB*(RB-RA)/DIF                                                MODES.154
      RC=RB-ETA*DEL                                                     MODES.155
      TOL=RCBTOL*RC                                                     MODES.156
      IF (ABS(RC-RB).GT.TOL) GO TO 330                                  MODES.157
      WRITE(1,1070)                                                     MODES.158
      ROOT(JR)=RB                                                       MODES.159
      GO TO 400                                                         MODES.160
C                                                                       MODES.161
  330 CALL BANDET (A,B,V,MAXA,N,NWA,RC,NSCH,DETC,ISC,1)                 MODES.162
      FC=DETC                                                           MODES.163
      NITE(JR)=NITE(JR)+1                                               MODES.164
      IF (JR.EQ.1) GO TO 340                                            MODES.165
      JJ=JR-1                                                           MODES.166
      DO 350 K=1,JJ                                                     MODES.167
  350 FC=FC/(RC-ROOT(K))                                                MODES.168
  340 WRITE(1,1050) JR,NITE(JR),RC,DETC,FC,ETA,ISC                      MODES.169
C                                                                       MODES.170
C     START INVERSE ITERATIONS                                          MODES.171
C                                                                       MODES.172
      NES=0                                                             MODES.173
      IF (JR.EQ.1) GO TO 380                                            MODES.174
      DO 360 I=1,JJ                                                     MODES.175
  360 IF (ROOT(I).LT.RC) NES=NES+1                                      MODES.176
  380 NOV=NSCH-NES                                                      MODES.177
      IF (NOV.EQ.0) GO TO 370                                           MODES.178
      WRITE(1,1080) NOV                                                 MODES.179
      ROOT(JR)=RC                                                       MODES.180
      IF (NOV.GT.1) NSK=1                                               MODES.181
C                                                                       MODES.182
      GO TO 400                                                         MODES.183
  370 RR=RA                                                             MODES.184
      FR=FA                                                             MODES.185
      DETR=DETA                                                         MODES.186
      RA=RB                                                             MODES.187
      FA=FB                                                             MODES.188
      DETA=DETB                                                         MODES.189
      RB=RC                                                             MODES.190
      FB=FC                                                             MODES.191
      DETB=DETC                                                         MODES.192
C                                                                       MODES.193
C     RESET ETA IF NECESSARY                                            MODES.194
C                                                                       MODES.195
      TOL=RB*ACTOL                                                      MODES.196
      IF (ABS(RA-RB).LT.TOL) ETA=ETA*2                                  MODES.197
      IF (NITE(JR).LE.NITEM) GO TO 310                                  MODES.198
      WRITE(1,1015) NITE(JR),JR                                         MODES.199
      GO TO 900                                                         MODES.200
C                                                                       MODES.201
C     CHECK FOR STORAGE                                                 MODES.202
C                                                                       MODES.203
  400 IF (JR.LE.NC) GO TO 405                                           MODES.204
      WRITE(1,1090)                                                     MODES.205
      GO TO 900                                                         MODES.206
C                                                                       MODES.207
  405 NOR=JR-1                                                          MODES.208
      CALL SECOND (TIM3)                                                MODES.209
      WRITE(1,1100) NOR                                                 MODES.210
      IF (JR.EQ.1) GO TO 410                                            MODES.211
      DO 420 I=1,N                                                      MODES.212
  420 V(I)=1.0                                                          MODES.213
     KK=2                                                               MODES.214
  410 DO 430 I=1,N                                                      MODES.215
  430 W(I)=B(I)*V(I)                                                    MODES.216
      IS=0                                                              MODES.217
      RTA=0.0                                                           MODES.218
      GO TO 510                                                         MODES.219
C                                                                       MODES.220
C     INVERSE ITERATION                                                 MODES.221
C                                                                       MODES.222
  440 NITE(JR)=NITE(JR)+1                                               MODES.223
      DO 450 I=1,N                                                      MODES.224
  450 V(I)=W(I)                                                         MODES.225
      CALL BANDET (A,B,V,MAXA,N,NWA,RC,NSCH,DETC,ISC,KK)                MODES.226
      IF (IS.EQ.1) GO TO 460                                            MODES.227
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      KK=2
      RQT=0.0
      DO 470 I=1,N
  470 RQT=RQT+W(I)*V(I)
      DO 475 I=1,N
  475 W(I)=B(I)*V(I)
      RQB=0.0
      DO 480 I=1,N
  480 RQB=RQB+W(I)*V(I)
      RQ=RQT/RQB
      RT=ROOT(JR)+RQ
      WRITE(1,1110) JR,NITE(JR),RT,RQ
      TOL=RT*RQTOL
      IF (ABS(RT-RTA).GT.TOL) GO TO 510
      IS=1
      GO TO 440
C
  510 RTA=RT
      BS=SQRT(RQB)
      DO 490 I=1,N
  490 W(I)=W(I)/BS
      IF (NOR.EQ.0) GO TO 550
      DO 520 K=1,NOR
      AL=0.0
      DO 530 I=1,N
  530 AL=AL+VV(I,K)*W(I)
      DO 540 I=1,N
  540 W(I)=W(I)-AL*WW(I,K)
  520 CONTINUE
C
  550 IF (NITE(JR).LE.NITEM) GC TO 440
      WRITE(1,1015) NITE(JR),JR
      GO TO 900
C
  460 RQT=0.0
      ERRT=RQB
      DO 570 I=1,N
  570 RQT=RQT+V(I)*W(I)
      DO 560 I=1,N
  560 W(I)=B(I)*V(I)
      RQB=0.0
      DO 580 I=1,N
  580 RQB=RQB+V(I)*W(I)
C
C     OBTAIN A RATHER LARGE ERROR BOUND
C
      RQ=RQT/RQB
      ROOT(JR)=ROOT(JR)+RQ
      ERR=SQRT(ERRT/RQB)
      ERRVL(JR)=ROOT(JR)-ERR
      ERRVR(JR)=ROOT(JR)+ERR
C
      BS=SQRT(RQB)
      DO 590 I=1,N
      W(I)=W(I)/BS
  590 V(I)=V(I)/BS
      DO 600 I=1,N
      WW(I,JR)=W(I)
  600 VV(I,JR)=V(I)
C
      CALL SECOND (TIM2)
      TIM3=TIM2-TIM3
      WRITE(1,1120) TIM3
      TIM(JR)=TIM2-TIM1
      TIM1=TIM2
C
C     DECIDE STRTEGY FOR ITERATION TOWARD NEXT ROOT
C
      TOL=RTOL*ROOT(JR)
      IF (NOV.GT.0) GO TO 700
      IF (ABS(ROOT(JR)-RB).GT.TOL) GO TO 710
      IF (RA.GT.0.0) GO TO 720
      RA=RB/2.
      CALL BANDET (A,B,V,MAXA,N,NWA,RA,NSCH,DETA,ISC,1)
      FA=DETA
  720 RB=RA
      FB=FA
      DETB=DETA
      RA=RR
      FA=FR
      DETA=DETR
      GO TO 710
C
  700 IF (ROOT(JR).GT.RC) NSK=1
      IF (NSK.EQ.1) GC TO 730
      IF (ABS(RC-ROOT(JR)).LT.TOL) GO TO 740
      IF (ABS(ROOT(JR)-RB).LT.TOL) GO TO 750
      RA=RB
      FA=FB
      DETA=DETB
  750 RB=RC
      FB=FC
      DETB=DETC
      GO TO 710
  740 IF (ABS(ROOT(JR)-RB).GT.TOL) GO TO 710
      IF (RA.GT.0.0) GC TO 760
      RA=RB/2.
      CALL BANDET (A,B,V,MAXA,N,NWA,RA,NSCH,DETA,ISC,1)
      FA=DETA
  760 RB=RA
      FB=FA
      DETB=DETA
      RA=RR
      FA=FR
      DETA=DETR
  710 FA=FA/(RA-ROOT(JR))
      FB=FB/(RB-ROOT(JR))
      JR=JR+1
      ETA=2.0
      GO TO 300
C
  730 IF (RA.GT.0.0) GC TO 780
      RA=RB/2.
      CALL BANDET (A,B,V,MAXA,N,NWA,RA,NSCH,DETA,ISC,1)
      FA=DETA
  780 IF (ABS(ROOT(JR)-RB).GT.TOL) GO TO 770
      RB=RA
      FB=FA
      DETB=DETA
      RA=RR
      FA=FR
      DETA=DETR
  770 FA=FA/(RA-ROOT(JR))
      FB=FB/(RB-ROOT(JR))
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      FR=FR/(RR-RCOT(JR))                                        MODES.352
      IF (ROOT(JR).LE.RC) NOV=NOV-1                              MODES.353
      JR=JR+1                                                    MODES.354
      NITE(JR)=0                                                 MODES.355
      ROOT(JR)=RC                                                MODES.356
      IF (NOV.GT.0) GO TO 400                                    MODES.357
      NSK=0                                                      MODES.358
      ETA=2.0                                                    MODES.359
      GO TO 300                                                  MODES.360
C                                                                MODES.361
 900  NROOT=JR-1                                                 MODES.362
      IF (NROOT.EQ.0) RETURN                                     MODES.363
      WRITE(1,1130)                                              MODES.364
      WRITE(1,1140)                                              MODES.365
      WRITE(1,1004)  (ROOT(J),J=1,NRCOT)                         MODES.366
      WRITE(1,1006)  (NITE(J),J=1,NRCOT)                         MODES.367
      WRITE(1,1150)                                              MODES.368
      WRITE(1,1008)  (TIM(J),J=1,NRCCT)                          MODES.369
      WRITE(1,1160)                                              MODES.370
      WRITE(1,1004)  (ERRVL(J),J=1,NROOT)                        MODES.371
      WRITE(1,1004)  (ERRVR(J),J=1,NFOOT)                        MODES.372
C                                                                MODES.373
C     ARRANGE EIGENVALUES AND VECTORS IN ASCENCING ORDER         MODES.374
C                                                                MODES.375
      IF (JR.EQ.2) GC TO 950                                     MODES.376
      JR=JR-2                                                    MODES.377
 910  IS=0                                                       MODES.378
      DO 920 I=1,JR                                              MODES.379
      IF (ROOT(I+1).GE.ROOT(I)) GO TO 920                        MODES.380
      IS=IS+1                                                    MODES.381
      RT=ROOT(I+1)                                               MODES.382
      ROOT(I+1)=ROOT(I)                                          MODES.383
      RCOT(I)=RT                                                 MODES.384
      DO 930 K=1,N                                               MODES.385
      RT=VV(K,I+1)                                               MODES.386
      VV(K,I+1)=VV(K,I)                                          MODES.387
 930  VV(K,I)=RT                                                 MODES.388
 920  CONTINUE                                                   MODES.389
      IF (IS.GT.0) GO TO 910                                     MODES.390
C                                                                MODES.391
 950  WRITE(1,1170)                                              MODES.392
      NROOT=NSCH                                                 MODES.393
     NROOT=NNRCOT                                                MODES.394
      DO 960 I=1,NROOT                                           MODES.395
      IF (ROOT(I).LE.0.0) GO TO 960                              MODES.396
      ROOT(I)=SQRT(RCOT(I))                                      MODES.397
 960  CONTINUE                                                   MODES.398
      WRITE(1,3000) NT                                           MODES.399
      IF (NT.NE.7) NT=7                                          MODES.400
      REWINC NT                                                  MODES.401
      WRITE (NT) (RCCT(I),I=1,NROOT)                             MODES.402
C                                                                MODES.403
C     PRINT FREQUENCIES AND MODE SHAPES                          MODES.404
C                                                                MODES.405
      WRITE(1,2000)                                              MODES.406
      DO 990 I=1,NROCT                                           MODES.407
      PERIOD=6.2831853/ROOT(I)                                   MODES.408
      WRITE(1,2001) I,ROOT(I),PERIOC                             MODES.409
 990  ROOT(I)=PERIOD                                             MODES.410
C                                                                MODES.411
      WRITE (NT) ((VV(I,J),I=1,N),J=1,NROOT)                     MODES.412
      RETURN                                                     MODES.413
C                                                                MODES.414
 1002 FORMAT (1H ,12E11.4)                                       MODES.415
 1004 FORMAT (1H0,6E20.12)                                       MODES.416
 1006 FORMAT (1H0,6I20)                                          MODES.417
 1008 FORMAT (1H0,6F20.2)                                        MODES.418
 1010 FORMAT (1H1,63HINVERSE ITERN GIVES FOLLCWING APPFOXIMATN TC LCWESMODES.419
    1T EIGENVALUE  )                                             MODES.420
 1015 FORMAT (41HOWE ABANDON ITERN BECAUSE NO CF ITERN IS I3,9H FOF RCQMODES.421
    1T I3 )                                                      MODES.422
 1020 FORMAT (5HORB = E20.12,7H NSCH = I4)                       MODES.423
 1030 FORMAT (30HOWE BETTER CHECK THE MATRICES  )                MODES.424
 1040 FORMAT (1H1,4X,4HROOT,4X,4HNITE,18X,2HRC,15X,12HCET (A-RC*B) ,15X,MODES.425
    /2HFC,13X,3HETA,4X,3HISC)                                    MODES.426
 1050 FORMAT (1H0,4X,I4,4X,I4,8X,3E22.14,F7.2,I6)                MODES.427
 1060 FORMAT (42HOTHE CEFLATED POLYNOMIAL HAS NO MCRE ROOTS  )   MODES.428
 1070 FORMAT (29H0(RC-RB) IS SMALLEF THAN TOL )                  MODES.429
 1080 FORMAT (16HOWE JUMPED OVER I4,16H UNKNOWN RCOT(S)  )       MODES.430
 1090 FORMAT (1H1,36HNC MORE STORAGE FOR VECTORS  WE QLIT  )     MODES.431
 1100 FORMAT (1H0,34X,4HROOT,18X,2HRQ,18X,4HNOR=,I2)             MODES.432
 1110 FORMAT (1H0,4X,I4,4X,I4,8X,2E22.14)                        MODES.433
 1120 FORMAT (20HOTIME FOR INV ITERN F5.2)                       MODES.434
 1130 FORMAT (20HOTHE EIGENVALUES ARE  /)                        MODES.435
 1140 FORMAT (42HONO OF ITERATIONS FOR EACH EIGENVALUE ARE   /)  MODES.436
 1150 FORMAT (30HOTIME USED FOR EACH EIGENVALUE /)               MODES.437
 1160 FORMAT (43HOFOLLCWING ARE ERROR BOUNDS CN EIGENVALUES )    MODES.438
 1170 FORMAT (1H1,62HWE ACCEPT FOLLCWING FREQUENCIES AND MODES ARRANGEDMODES.439
    . IN ORDER    )                                              MODES.440
 2000 FORMAT (39H1......PRINT CF FREQUENCIES AND PERIOCS//       MODES.441
    .  6X,4HMODE,9X,11HFREQUENCIES,13X,7HPERIOCS /               MODES.442
    .  6X,4H NC ,9X,11H (RAD/SEC) ,13X,7H (SEC)  /)              MODES.443
 2001 FORMAT (I10,2F20.4)                                        MODES.444
 3000 FORMAT (////46H EIGENVALUE ANC EIGENVECTOR ARE STORED IN TAPE,I3)MODES.445
C                                                                MODES.446
      END                                                        MODES.447
$                                                                MODES.448
      SUBRCUTINE BANCET (A,B,V,MAXA,NN,NWA,RA,NSCH,DET,ISCALE,KK) MODES.449
C                                                                MODES.450
      DIMENSION A(NWA),B(1),V(1),MAXA(1)                         MODES.451
     COMMON/TAPES/NSTIF,NMASS                                    MODES.452
C                                                                MODES.453
C     TRIANGULARIZE BANDED STIFFNESS MATRIX                      MODES.454
C                                                                MODES.455
      NR=NN-1                                                    MODES.456
      IF (KK-2) 100,700,800                                      MODES.457
C                                                                MODES.458
 100  TOL=1.0E+07                                                MODES.459
      RTOL=1.0E-10                                               MODES.460
      SCALE=2.0**900                                             MODES.461
      NTF=3                                                      MODES.462
      IS=1                                                       MODES.463
 120  REWIND NSTIF                                               MODES.464
      READ (NSTIF) A                                             MODES.465
      DO 140 I=1,NN                                              MODES.466
 140  A(I)=A(I)-RA*B(I)                                          MODES.467
 160  IF (NWA.EQ.NN) GC TO 230                                   MODES.468
      DO 200 N=1,NR                                              MODES.469
      IH=N+NWA-NN                                                MODES.470
 210  IF (A(IH)) 220,215,220                                     MODES.471
 215  IH=IH-NN                                                   MODES.472
      GO TO 210                                                  MODES.473
 220  MAXA(N)=IH                                                 MODES.474
      PIV=A(N)                                                   MODES.475
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      IF (PIV) 221,226,221                                              MODES.476
221   IL=N+NN                                                           MODES.477
      L=N                                                               MODES.478
      DO 240 I=IL,IH,NN                                                 MODES.479
      L=L+1                                                             MODES.480
      C=A(I)                                                            MODES.481
      IF (C) 225,240,225                                                MODES.482
225   C=C/PIV                                                           MODES.483
      IF (ABS(C).LT.TOL) GO TO 235                                      MODES.484
226   IS=IS+1                                                           MODES.485
      IF (IS.LE.NTF) GC TO 245                                          MODES.486
      WRITE(1,1000) NTF                                                 MODES.487
      STOP                                                              MODES.488
245   RA=RA*(1.0-RTOL)                                                  MODES.489
      GO TO 120                                                         MODES.490
235   J=L-I                                                             MODES.491
      DO 260 K=I,IH,NN                                                  MODES.492
260   A(K+J)=A(K+J)-C*A(K)                                              MODES.493
      A(I)=C                                                            MODES.494
240   CONTINUE                                                          MODES.495
200   CONTINUE                                                          MODES.496
230   IF (A(NN).NE.0.0) GO TO 280                                       MODES.497
      AA=ABS(A(1))                                                      MODES.498
      DO 290 I=2,NR                                                     MODES.499
290   AA=AA+ABS(A(I))                                                   MODES.500
      A(NN)=-(AA/NR)*1.0E-16                                            MODES.501
C                                                                       MODES.502
280   NSCH=0                                                            MODES.503
      ISC=0                                                             MODES.504
      DET=1.0                                                           MODES.505
      DO 300 I=1,NN                                                     MODES.506
      IF (ABS(DET).LT.SCALE) GO TO 320                                  MODES.507
      DET=DET/SCALE                                                     MODES.508
      ISC=ISC+1                                                         MODES.509
320   DET=DET*A(I)                                                      MODES.510
300   IF (A(I).LT.0.) NSCH=NSCH+1                                       MODES.511
C                                                                       MODES.512
      IF (ISCALE.LT.1000) GO TO 340                                     MODES.513
      ISCALE=ISC                                                        MODES.514
      GO TO 900                                                         MODES.515
340   IF (ISC-ISCALE) 350,900,370                                       MODES.516
350   DET=DET/SCALE                                                     MODES.517
      GO TO 900                                                         MODES.518
370   DET=DET*SCALE                                                     MODES.519
      GO TO 900                                                         MODES.520
C                                                                       MODES.521
700   IL=NN                                                             MODES.522
      DO 400 N=1,NR                                                     MODES.523
      C=V(N)                                                            MODES.524
      V(N)=C/A(N)                                                       MODES.525
      IF (NWA-NN) 410,400,410                                           MODES.526
410   IL=IL+1                                                           MODES.527
      IH=MAXA(N)                                                        MODES.528
      K=N                                                               MODES.529
      DO 420 I=IL,IH,NN                                                 MODES.530
      K=K+1                                                             MODES.531
420   V(K)=V(K)-C*A(I)                                                  MODES.532
400   CONTINUE                                                          MODES.533
      V(NN)=V(NN)/A(NN)                                                 MODES.534
C                                                                       MODES.535
800   IF (NWA-NN) 430,900,430                                           MODES.536
430   N=NN                                                              MODES.537
       DO 440 L=2,NN                                                    MODES.538
       N=N-1                                                            MODES.539
       IL=N+NN                                                          MODES.540
       IH=MAXA(N)                                                       MODES.541
       K=N                                                              MODES.542
       DO 460 I=IL,IH,NN                                                MODES.543
       K=K+1                                                            MODES.544
460    V(N)=V(N)-A(I)*V(K)                                              MODES.545
440    CONTINUE                                                         MODES.546
900    RETURN                                                           MODES.547
1000   FORMAT (1H1,20H TRIANG FACTORIZATN I3,32H TIMES ABONDONED,CHECK  MODES.548
      1MATRICES  )                                                      MODES.549
      END                                                               MODES.550
      OVERLAY(7,0)                                                      STATIC.2
      PROGRAM STATIC                                                    STATIC.3
C     ******************************************************************STATIC.4
C     SOLUTION CF STATIC CASE-DISPLACEMENT OF NCDES                     STATIC.5
C     FORM CONDENSED STIFFNESS KAABAR, AND STORE TRANGLIZED STIFFNESS   STATIC.6
C     KAABAR IN TAPE 7=NRED                                             STATIC.7
C     FORM CONDENSED MASS MAABAR ANC STORE IN TAPE 5                    STATIC.8
C     ******************************************************************STATIC.9
      LARGE B(22000)                                                    STATIC.10
      LARGE C(8000)                                                     STATIC.11
      COMMON A(30000)                                                   STATIC.12
      COMMON/ELPAR/NUMNP,NUMEL,NETYPE,NEQA,NEQO,MBANDA,MBANDO,KLIN,NLASTSTATIC.13
      COMMON/MULTP/NA,NB,NC,NRA,NCA,NRB,NCB,K,MBANDR                    STATIC.14
      COMMON/SOL/IND                                                    STATIC.15
      COMMON/TIME/JUMF,T,CT,MPRTM,MTAPE,KPRINT                          STATIC.16
      COMMON/NONL/NINDT,NINDTO,OKUO(200)                                STATIC.17
      COMMON/STROUT/NSOLID,NCONC,NFR,NSPRIN                             STATIC.18
      COMMON/NEWAL/NTW,NTWEL                                            STATIC.19
      COMMCN/MATER/NUMATS,NUMATC,NUMATF,NUMATB,NUMGE,NUMBC,MTYPE        STATIC.20
      DIMENSION IA(1)                                                   STATIC.21
      EQUIVALENCE(A,IA)                                                 STATIC.22
      JUMP=0                                                            STATIC.23
      MPRTM=0                                                           STATIC.24
      KPRINT=0                                                          STATIC.25
      NSAFT=0                                                           STATIC.26
      T=0.0                                                             STATIC.27
      N26E=NLAST                                                        STATIC.28
      N25E=N26E-NUMEL                                                   STATIC.29
      N24E=N25E-NUMEL                                                   STATIC.30
      N23E=N24E-NUMEL                                                   STATIC.31
      N22E=N23E-NUMEL                                                   STATIC.32
      N21E=N22E-NUMEL                                                   STATIC.33
      N25EP=N25E                                                        STATIC.34
      N24EP=N24E                                                        STATIC.35
      N23EP=N23E                                                        STATIC.36
      N22EP=N22E                                                        STATIC.37
      N21EP=N21E                                                        STATIC.38
      NB1=1                                                             STATIC.39
      NB2=NB1+NEQA                                                      STATIC.40
      NB2E=NB2-1                                                        STATIC.41
      NB3=NB2+NEQO                                                      STATIC.42
      NB3E=NB3-1                                                        STATIC.43
      NB4=NB3+NEQA                                                      STATIC.44
      NB4E=NB4-1                                                        STATIC.45
      NB5=NB4+NEQO                                                      STATIC.46
      NB5E=NB5-1                                                        STATIC.47
      N20T=NB5                                                          STATIC.48
      N13E=N21E-10*NUMEL-4*NEQO-3*NEQA                                  STATIC.49
      N14E=N13E+NEQO                                                    STATIC.50
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      N14=N14E+1
      N15=N14+NEQA
      N15E=N15-1
      N16=N15+NEQO
      N16E=N16-1
      N17=N16+NEQA
      N17E=N17-1
      N18=N17+NEQO
      N18E=N18-1
      N19=N18+NEQA
      N19E=N19-1
      N13=N13E+1
      N12=N13-NEQA
      N12E=N12-1
      N10P=N12-11*NUMEL-3*NUMBC
      N8=N10P-6*NUMATE-4*NUMATF
      N8EP=N8-1
      N12P=N12E
      N21T=N21E+1
      NAV=NEQO*(MBANDO+NEQA)
      N20A=N20T
      N21B=N20A+NAV
      NAB=NEQA*NEQO*((MEANDO-2)/NEQC+2)
      N22M=N21B+NAB
      MI=MBANDO+NEGO-1
C     SOLVE FOR GO, AND STORE IN TAPE 6
C     WHERE KOO*GO=-(KAO)T
C     THE DIMENSIONS ARE (NEQO*MBANDC)*(NEQO*NEQA)=(NEQC*NEQA)
C     CHECK DIMENSION B,C,REQUIRED
      NBD1=N21B+MI
      NBD2=N20T+2*NEQA*NEQO
      NCD=NAB
      PRINT 1,NBD1,NBD2,NCD
    1 FCRMAT(* LARGE CORE FOR B IS NBD1,NBD2*,2I10/
     1       *                    C     NCD       *,I10/
     2       * CHECK LARGE STATEMENT IN STATIC AND RFL CARD*)
      CALL SESOL(B(N20A),C(1),B(N21B),NEQO,MBANDO,NEQA,1,NEQO,NAV,MI,
     1     4,10,6,8)
C     REWIND FOR GO
      REWIND 6
C     REWIND FOR KAA,STCRE IN C(N22T),(KAO) IN E(N21T)
      REWIND 2
C
      N21T=N20T+NEQA*NECO
      N21E=N21T-1
      N22T=1
      N22E=N21E+NEQA*NEQO
      N23T=N22T+NEQA*NEQA
      N23E=N23T-1
      NA=N21T
      NB=N20T
      NC=N22T
      NCA=NEQO
      NRA=NEQA
      NCB=NEQA
      NRB=NEQO
      K=2
C     MULTIPLICATION ANC SUMMATION KAABAR=KAA+KAO*GO
C     THE DIMENSION ARE
C     (NEQA*MBANDR)=≠NEQA*MBANDA)+(NEQA*NEQO)*(NEQO*NEQA)
      DO 300 I=N22T,N23E
      C(I)=0.
  300 CONTINUE
      N23EBA=NEQA*MBANDA
      READ(2) (C(I),I=N22T,N23EBA)
      READ(2) (B(I),I=N21T,N22E)
      READ(6) (B(I),I=N20T,N21E)
      CALL MULT
C     STORE KAAEAR INTO TAPE 2
      REWIND 2
      MBANDK=MBANDR
      PRINT 21,MEANDK
   21 FORMAT(* BAND WIDTH OF KAABAR IS*,I5)
      N23EBK=NEQA*MBANDK
      WRITE(2) (C(I),I=N22T,N23EBK)
C     MULTIPLICATICN INSIDE LARGE CORE,SLVA,OLXA
      DO 308 I=1,NEQA
      C(I)=A(N12E+I)
      B(NB3E+I)=A(N14E+I)
  308 CONTINUE
C
C     SLVO,OLXO
      DO 309 I=1,NEQO
      B(NB2E+I)=A(N13E+I)
      B(NB4E+I)=A(N15E+I)
  309 CCNTINUE
C
C     CALCULATE CONDENSED LOAD VECTCR
C     PABAR=PA+(GO)T*PO
C     THE DIMENSIONS ARE (NEQA*1)=(NEQA*1)+(NEQA*NEQO)*(NEQO*1)
C     TRANSPOSE (GO) TO (GO)T AND STCRE IN A(N21T)
      NA=N20T
      K=N21T
      DO 301 I=1,NEQO
      L=NA+I-1
      DO 301 J=1,NEQA
      B(K)=B(L)
      L=L+NEQO
      K=K+1
  301 CONTINUE
      NA=N21T
      NB=NB2
      NC=1
      NCA=NEQO
      NRA=NEQA
      NCB=1
      NRB=NEQO
      K=1
      CALL MULT
      DO 307 I=1,NEQA
      A(N12E+I)=C(I)
  307 CONTINUE
C     MULTIPLICATION AND SUMMATION OF CCNDENSED MASS VECTOR,STORE IN
C     TAPE 5
C     MAABAR=MAA+(GO)T*(MOO)*(GO)
C     THE DIMENSION ARE
C     (NEQA*NEQA)=(NEQA*NEQA)+(NEQA*NEQO)*(NEQO*NEQO)*(NEQO*NEQA)
C     IS BAND AND SYMMETRICAL WITH WIDTH MBANDM
C     BUT MAA,MCO ARE ORIGINALLY DIAGONAL
C     STORE MAA IN B(1),MOO IN B(NB2)
      REWIND 5
      N22T=1
      N23T=1+NEQA*NEQO
      N23E=N23T-1
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      N24E=N23E+NEQA*NEQA
      N24T=N24E+1
      READ(5) (B(I),I=1,NB2E)
      READ(5) (B(I),I=NB2,NB3E)
      DO 302 I=N22T,N23E
      C(I)=0.
  302 CONTINUE
      NA=NB2
      NB=N20T
      NC=N22T
      NCA=1
      NRA=NEQO
      NCB=NEQA
      NRB=NEQO
      K=1
      CALL MULT
C
      N20ET=N20T-1
      N22ET=N22T-1
      MM=NEQA*NEQO
      DO 600 I=1,MM
      B(N20ET+I)=C(N22ET+I)
  600 CONTINUE
      N23E=0
      N24E=N23E+NEQA*NEQA
      N23T=N23E+1
      DO 303 I=N23T,N24E
      C(I)=0.
  303 CONTINUE
      DC 304 I=1,NEQA
      C(N23E+I)=B(I)
  304 CCNTINUE
      NA=N21T
      NB=N20T
      NC=N23T
      NCA=NEQO
      NRA=NEQA
      NCB=NEQA
      NRB=NEQO
      K=2
      CALL MULT
C     STORE IN TAPE 5 MAABAR(NEQA,MEANCM)
      MBANDM=MBANDR
      PRINT 22, MBANDM
   22 FORMAT(* BNAC WICTH MAABAR*,I5)
      IF(MBANDM .GE. MBANDK) MBANDA=MBANDM
      IF(MBANDM .LT. MBANDK) MBANDA=MBANDK
      N24E=N23E+NEQA*MBANDM
      REWIND 5
      WRITE(5) (C(I),I=N23T,N24E)
C     CALCULATE
C     RMASSA(X)=MAA(X)+(GO)T*MOC(X)
C     AND WRITE IN TAPE5,AFTER MAABAR,FOR DYNAMIC INERTIA FORCE
C     THE DIMENSION ARE
C     (NEQA)=NEQA+(NECA*NEQO)*(NEQO*1)
      NA=N21T
      NB=NB4
      NC=1
      DO 601 I=1,NEQA
      C(I)=B(NB3E+I)
  601 CONTINUE
      NCA=NEQO
      NRA=NEQA
      NCB=1
      NRB=NEQO
      K=1
      CALL MULT
      WRITE(5) (C(I),I=1,NB2E)
C     THE DISPLACEMENT FOR D O F REMAINED AND ELIMINATEC WILL REPLACE
C     THE DISPLACEMENT FOR D O F REMAINED AND ELIMINATEC WILL REPLACE
C     LCAD VECTOR IN A(N12),A(N13)
C     UNSYMMETRICAL SOLUTION
C     KAABAR*UA=PAABAR
      REWIND 2
      N21E=N20T+NEQA*MBANDK-1
      READ(2) (B(I),I=N20T,N21E)
      CALL TRIA(B(N20T),NEQA,MBANDK)
      CALL BACKS(B(N20T),A(N12),NEQA,MBANDK)
C     STORE DISPLACEMENT AT REMAINEC NODE UA IN COMMON BLANK A
C     INITILIZATION
C     NEW SEQUENCE IN CCMMON A
      N1=1
      N2=N1+6*NUMNP
      N2E=N2-1
      N3=N2+4*NUMATF
      N3E=N3-1
      N4=N3+3*NUMEL
      N5=N4+NEQA
      N6=N5+NEQA
      N7=N6+NEQA
      N8=N7+NEQA
      N9=N8+NEQA
      N9E=N9-1
      N10=N9+NEQA
      N10E=N10-1
      N11=N10+NUMEL
      N11E=N11-1
      N12=N11+NSOLID
      N12E=N12-1
      N13=N12+NCONC
      N13E=N13-1
      N14=N13+NFR
      N14E=N14-1
      N15=N14+NSPRIN
      NLAST=N15
      NN=4*NUMATF
      IF(NUMATF .EQ. 0) GO TO 406
      DO 315 I=1,NN
      A(N2E+I)=A(N8EP+I)
  315 CONTINUE
  406 CCNTINUE
C
C     STRESS OUTPUT ELEMENT TRANSFORMATION VECTOR
      DO 310 I=1,NUMEL
C     SHIFT ICOL TO A(N10)
      IF(NTM .EQ. 0) GO TO 401
      NN10=N10P+(I-1)*11
      IA(N10E+I)=IA(N21EP+I)
  401 CONTINUE
C     SHIFT ELEMENT TYPE,MATERIAL TYFE AND INTEGRATION NO. INTO IX(3)
      NN3=N3+(I-1)*3
      IA(NN3)=IA(NN10+8)
      IA(NN3+1)=IA(NN10+9)
      IA(NN3+2)=IA(NN10+10)
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  310 CONTINUE                                                          STATIC.299
C     SHIFT ISOL,ICON,IFR,ISP                                           STATIC.300
      IF(NSOLID .EQ. 0) GO TO 402                                       STATIC.301
      DO 311 I=1,NSOLID                                                 STATIC.302
      IA(N11E+I)=IA(N22EP+I)                                            STATIC.303
  311 CONTINUE                                                          STATIC.304
  402 CONTINUE                                                          STATIC.305
C                                                                       STATIC.306
      IF(NCONC .EQ. 0) GO TO 403                                        STATIC.307
      DC 312 I=1,NCONC                                                  STATIC.308
      IA(N12E+I)=IA(N23EP+I)                                            STATIC.309
  312 CONTINUE                                                          STATIC.310
  403 CONTINUE                                                          STATIC.311
C                                                                       STATIC.312
      IF(NTWEL .EQ. 0) GO TO 404                                        STATIC.313
C                                                                       STATIC.314
      DO 313 I=1,NFR                                                    STATIC.315
      IA(N13E+I)=IA(N24EP+I)                                            STATIC.316
  313 CONTINUE                                                          STATIC.317
  404 CONTINUE                                                          STATIC.318
C                                                                       STATIC.319
      IF(NSPRIN .EQ. 0) GO TO 405                                       STATIC.320
C                                                                       STATIC.321
      DO 314 I=1,NSPRIN                                                 STATIC.322
      IA(N14E+I)=IA(N25EP+I)                                            STATIC.323
  314 CONTINUE                                                          STATIC.324
  405 CONTINUE                                                          STATIC.325
      N15E=N15-1                                                        STATIC.326
      DO 305 I=N4,N10E                                                  STATIC.327
      A(I)=0.                                                           STATIC.328
  305 CONTINUE                                                          STATIC.329
C     STATIC DISPLACEMENT AS INCREMENT                                  STATIC.330
      N4E=N4-1                                                          STATIC.331
      N7E=N7-1                                                          STATIC.332
      DO 306 I=1,NEQA                                                   STATIC.333
      A(N4E+I)=A(N12P+I)                                                STATIC.334
      A(N7E+I)=A(N12P+I)                                                STATIC.335
  306 CONTINUE                                                          STATIC.336
      RETURN                                                            STATIC.337
      END                                                               STATIC.338
      OVERLAY(10,0)                                                     STRESS.2
      PROGRAM STRESS                                                    STRESS.3
C     ******************************************************************STRESS.4
C     REQUIRED,12 COMPONENTS AT TWO ENDS FOR BEAM OR COLUMN ELEMENT     STRESS.5
C     CALCULATE INCREMENTAL STRESS AND THEN TOTAL STRESS OF THE ELEMENT STRESS.6
C     AT CENTER OF VOLUMN AND CENTER OF IE,JB,KE,LE FACE FOR SOIL ELEMENSTRESS.7
C     3 FORCES, 1 NORMAL AND 2 SHEAR FOR FRICTICN ELEMENT               STRESS.8
C     6 COMPONENTS FOR BOUNDARY ELEMENT                                 STRESS.9
C     ******************************************************************STRESS.10
      COMMON/STROUT/NSOLID,NCONC,NFR,NSPRIN                             STRESS.11
      COMMON A(30000)                                                   STRESS.12
      COMMON/ELPAR/NUMNP,NUMEL,NETYPE,NEQA,NEQO,MBANDA,MBANDO,KLIN,NLASTSTRESS.13
      COMMON/MATER/NUMATS,NUMATC,NUMATF,NUMATB,NUMGE,NUMBC,MTYPE        STRESS.14
      COMMON/TIME/JUMP,T,DT,MPRTM,MTAPE,KPRINT                          STRESS.15
      COMMON/NEWAL/NTW,NTWEL                                            STRESS.16
      DIMENSION SS(338),XYZ(8,3),XYZB(4,3),LMA(24),LMO(24),             STRESS.17
     1SA1(12,24),SA2(12,12),SA4(6),ISS(1),IA(1)                         STRESS.18
      EQUIVALENCE(ISS,SS)                                               STRESS.19
      EQUIVALENCE(A,IA)                                                 STRESS.20
C                                                                       STRESS.21
      N15=NLAST                                                         STRESS.22
      N16=N15+12*NUMEL                                                  STRESS.23
      N17=N16+12*NUMEL                                                  STRESS.24
      N17E=N17-1                                                        STRESS.25
      N7=N15-NSPRIN-NFR-NCONC-NSOLID-NUMEL-3*NEQA                       STRESS.26
      N7E=N7-1                                                          STRESS.27
      N3=N7-3*NEQA-3*NUMEL                                              STRESS.28
      IF(JUMP .EQ. 0) NLAST=N17                                         STRESS.29
      IF(JUMP .NE. 0) GO TO 405                                         STRESS.30
      DO 301 I=N15,N17E                                                 STRESS.31
      A(I)=0.0                                                          STRESS.32
  301 CONTINUE                                                          STRESS.33
  405 CONTINUE                                                          STRESS.34
      REWIND 9                                                          STRESS.35
      DO 302 N=1,NUMEL                                                  STRESS.36
      NN3=N3+(N-1)*3                                                    STRESS.37
      N15EL=N15+12*(N-1)-1                                              STRESS.38
      N16EL=N16+12*(N-1)-1                                              STRESS.39
C                                                                       STRESS.40
C     DETERMINE ELEMENT TYPE,INTEPRATION NO.                            STRESS.41
      NTYPE=IA(NN3)                                                     STRESS.42
      INTER=IA(NN3+2)                                                   STRESS.43
C     INTER=0,OR 2 NO STRESS REQUIREC                                   STRESS.44
      IF(INTER .EQ. 0 .CR. INTER .EQ. 2                                 STRESS.45
     1.OR. INTER .EQ. 6 .OR. INTER .EQ. 7) GO TO 302                    STRESS.46
C     DETERMINE ELEMENT TYPE                                            STRESS.47
      GO TO (401,402,202,404),NTYPE                                     STRESS.48
  401 CONTINUE                                                          STRESS.49
C     TYPE 1, SOIL ELEMENT                                              STRESS.50
C      SET UP STRESS-STRAIN MATRIX S1(3)                                STRESS.51
      READ(9) (SS(I),I=1,218)                                           STRESS.52
      KK=44                                                             STRESS.53
      DO 303 I=1,24                                                     STRESS.54
      KI=KK+6*I                                                         STRESS.55
      DO 303 J=1,6                                                      STRESS.56
      JI=KI+J                                                           STRESS.57
      SA1(J,I)=SS(JI)                                                   STRESS.58
  303 CONTINUE                                                          STRESS.59
      KK=186                                                            STRESS.60
      DO 304 I=1,3                                                      STRESS.61
      KI=KK+8*I                                                         STRESS.62
      DO 304 J=1,8                                                      STRESS.63
      JI=KI+J                                                           STRESS.64
      XYZ(J,I)=SS(JI)                                                   STRESS.65
  304 CONTINUE                                                          STRESS.66
C     SET UP LOCATION OF MASS                                           STRESS.67
      DO 305 I=1,24                                                     STRESS.68
      LMA(I)=ISS(2+I)                                                   STRESS.69
      LMO(I)=ISS(26+I)                                                  STRESS.70
  305 CONTINUE                                                          STRESS.71
C                                                                       STRESS.72
C     CALCULATE INCREMENTAL STRESS A(N18) OR A(NDSIG) AND THE TOTAL     STRESS.73
C     STRESS A(N19) OR A(NSIG)                                          STRESS.74
      DO 307 I=1,6                                                      STRESS.75
      NDSIG=N15EL+I                                                     STRESS.76
      NSIG=N16EL+I                                                      STRESS.77
      A(NDSIG)=0.                                                       STRESS.78
      DO 308 J=1,24                                                     STRESS.79
      JJA=LMA(J)                                                        STRESS.80
      IF(JJA .EQ. 0) GO TO 308                                          STRESS.81
      NDUA=N7E+JJA                                                      STRESS.82
C     CKECK IF IT IS TCP ELEMENT OF JOINT                               STRESS.83
C     DISPLACEMENT MUST BE MODIFIED                                     STRESS.84
      IF(INTER .LE. 3) GO TO 406                                        STRESS.85
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      IF(J .GE. 13) GO TO 406                                           STRESS.86
      JJB=LMA(J+24)                                                     STRESS.87
      NOUB=N7E+JJB                                                      STRESS.88
      TODISP=A(NDUA)+A(NOUB)                                            STRESS.89
      A(NDSIG)=A(NDSIG)+SA1(I,J)*TODISP                                 STRESS.90
      GO TO 308                                                         STRESS.91
  406 CONTINUE                                                          STRESS.92
      A(NDSIG)=A(NDSIG)+SA1(I,J)*A(NCUA)                                STRESS.93
  308 CONTINUE                                                          STRESS.94
      A(NSIG)=A(NSIG)+A(NDSIG)                                          STRESS.95
  307 CONTINUE                                                          STRESS.96
      GO TO 302                                                         STRESS.97
  402 CONTINUE                                                          STRESS.98
C     TYPE 2,BEAM,COLUMN ELEMENT                                        STRESS.99
      READ(9) (SS(I),I=1,182)                                           STRESS.100
C     SET UP STRESS-DISFLACEMENT MATRIX SA2(12,12)                      STRESS.101
      KK=14                                                             STRESS.102
      DO 309 I=1,12                                                     STRESS.103
      KI=KK+12*I                                                        STRESS.104
      DO 309 J=1,12                                                     STRESS.105
      JI=KI+J                                                           STRESS.106
      SA2(J,I)=SS(JI)                                                   STRESS.107
  309 CONTINUE                                                          STRESS.108
C                                                                       STRESS.109
C     SET UP LOCATION OF MASS                                           STRESS.110
      DO 310 I=1,12                                                     STRESS.111
      LMA(I)=ISS(2+I)                                                   STRESS.112
      LMO(I)=ISS(14+I)                                                  STRESS.113
  310 CONTINUE                                                          STRESS.114
C     CALCULATE INCREFENTAL STRESS A(N18) OR A(NDSIG)                   STRESS.115
C     AND THE TOTAL STRESS A(N19) OR A(NSIG)                            STRESS.116
      DO 311 I=1,12                                                     STRESS.117
      NDSIG=N15EL+I                                                     STRESS.118
      NSIG=N16EL+I                                                      STRESS.119
      A(NDSIG)=0.                                                       STRESS.120
      DO 312 J=1,12                                                     STRESS.121
      JJA=LMA(J)                                                        STRESS.122
      IF(JJA .EQ. 0) GO TO 312                                          STRESS.123
      NOUA=N7E+JJA                                                      STRESS.124
      A(NDSIG)=A(NDSIG)+SA2(I,J)*A(NDUA)                                STRESS.125
  312 CONTINUE                                                          STRESS.126
      A(NSIG)=A(NSIG)+A(NDSIG)                                          STRESS.127
  311 CONTINUE                                                          STRESS.128
      GO TO 302                                                         STRESS.129
  404 CONTINUE                                                          STRESS.130
C                                                                       STRESS.131
C     TYPE 4,BOUNDARY ELEMENT                                           STRESS.132
      READ(9) (SS(I),I=1,20)                                            STRESS.133
C     SET UP STRESS-DISPLACEMENT MATRIX SA(6)                           STRESS.134
      KK=14                                                             STRESS.135
      DO 317 I=1,6                                                      STRESS.136
      SA4(I)=SS(I+KK)                                                   STRESS.137
  317 CONTINUE                                                          STRESS.138
C     LOCATION CF MASS                                                  STRESS.139
      DO 318 I=1,6                                                      STRESS.140
      LMA(I)=ISS(I+2)                                                   STRESS.141
  318 CONTINUE                                                          STRESS.142
C     CALCULATE INCREFENTAL STRESS A(N18) OR A(NDSIG)                   STRESS.143
C     AND THE TOTAL STRESS A(N19) OR A(NSIG)                            STRESS.144
      DO 319 I=1,6                                                      STRESS.145
      NDSIG=N15EL+I                                                     STRESS.146
      NSIG=N16EL+I                                                      STRESS.147
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      A(NDSIG)=0.                                                       STRESS.148
      JJA=LMA(I)                                                        STRESS.149
      IF(JJA .EQ. 0) GO TO 319                                          STRESS.150
      NOUA=N7E+JJA                                                      STRESS.151
      A(NDSIG)=A(NDSIG)+SA4(I)*A(NDUA)                                  STRESS.152
      A(NSIG)=A(NSIG)+A(NDSIG)                                          STRESS.153
  319 CONTINUE                                                          STRESS.154
  302 CONTINUE                                                          STRESS.155
      RETURN                                                            STRESS.156
      END                                                               STRESS.157
      OVERLAY(11,0)                                                     DIDAMP.2
      PROGRAM DIDAMP                                                    DIDAMP.3
C     ************************************                              DIDAMP.4
C     ASSEMBLE CIRECT DAMPING MATRIX C(I,J)                             DIDAMP.5
C     ************************************                              DIDAMP.6
      COMMON A(30000)                                                   DIDAMP.7
      COMMON/DAMP2/NDAMP,NROOT,NFP,XI(20),NXI(20),OMEGA(20)             DIDAMP.8
      COMMON/ELPAR/NUMNP,NUMEL,NETYPE,NEQA,NEQC,MBANDA,MBANDO,KLIN,NLASTDIDAMP.9
      WRITE(1,501)                                                      DIDAMP.10
      READ 1,NDAMP                                                      DIDAMP.11
      WRITE(1,101) NDAMF,NROOT                                          DIDAMP.12
      N37=NLAST                                                         DIDAMP.13
      N38E=N37+NEQA*NEQA-1                                              DIDAMP.14
      N38=N38E+1                                                        DIDAMP.15
      N39E=N38E+NEQA*NEQA                                               DIDAMP.16
      N39=N39E+1                                                        DIDAMP.17
      N40E=N39E+NEQA*NDAMP                                              DIDAMP.18
      N40=N40E+1                                                        DIDAMP.19
      N47=N37+3*NEQA*NEQA+7*NEQA                                        DIDAMP.20
C     READ TOTAL MASS MATRIX TMASSA(I,J) FROM TAPE5 INTC A(N37)         DIDAMP.21
      REWIND 5                                                          DIDAMP.22
      REWIND 7                                                          DIDAMP.23
      READ(5) (A(I),I=N37,N38E)                                         DIDAMP.24
C     READ EIGENVECTCR VV(I,J) FROM TAPE 7 INTO A(N38)                  DIDAMP.25
      READ(7) (A(I),I=N38,N39E)                                         DIDAMP.26
C     READ IN NON-ZERC CAMPING RATIO                                    DIDAMP.27
      WRITE(1,502)                                                      DIDAMP.28
      READ 2,(NXI(I),XI(I),I=1,NDAMP)                                   DIDAMP.29
      WRITE(1,102) (NXI(I),XI(I),I=1,NDAMP)                             DIDAMP.30
C     CONDESE EIGENVECTOR VV INTO BLANK COMMON A(N38)                   DIDAMP.31
      DO 301 N=1,NDAMF                                                  DIDAMP.32
      K=NXI(N)                                                          DIDAMP.33
      DO 301 J=1,NEQA                                                   DIDAMP.34
      N38L=N38E+(N-1)*NEQA+J                                            DIDAMP.35
      N38R=N38E+(K-1)*NEQA+J                                            DIDAMP.36
      A(N38L)=A(N38R)                                                   DIDAMP.37
  301 CONTINUE                                                          DIDAMP.38
C      THETA(I,J) MASS NORMALIZED MOCE SHAPE MATRIX INTC A(N39)         DIDAMP.39
      DO 302 I=N39,N40E                                                 DIDAMP.40
      A(I)=0.                                                           DIDAMP.41
  302 CONTINUE                                                          DIDAMP.42
      NA=N37                                                            DIDAMP.43
      NB=N38                                                            DIDAMP.44
      NC=N39                                                            DIDAMP.45
      NCA=NEQA                                                          DIDAMP.46
      NRA=NEQA                                                          DIDAMP.47
      NCB=NDAMP                                                         DIDAMP.48
      NRB=NEQA                                                          DIDAMP.49
      K=1                                                               DIDAMP.50
      CALL MULT                                                         DIDAMP.51
C     TRNASPOSE VV=A(N38) INTO (VV)T=A(N40)                             DIDAMP.52
      NA=N38                                                            DIDAMP.53
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      K=N40                                                           DIDAMP.54
      DO 303 I=1,NEQA                                                 DIDAMP.55
      L=NA+I-1                                                        DIDAMP.56
      DO 303 J=1,NDAMP                                                DIDAMP.57
      A(K)=A(L)                                                       DIDAMP.58
      L=L+NEQA                                                        DIDAMP.59
      K=K+1                                                           DIDAMP.60
  303 CCNTINUE                                                        DIDAMP.61
C     NORMALIZEC MASS(I,J) INTO A(N38)                                DIDAMP.62
      N39E=N38E+NDAMP*NCAMP                                           DIDAMP.63
      DC 304 I=N38,N39E                                               DIDAMP.64
      A(I)=0.                                                         DIDAMP.65
  304 CONTINUE                                                        DIDAMP.66
      NA=N40                                                          DIDAMP.67
      NB=N39                                                          DIDAMP.68
      NC=N38                                                          DIDAMP.69
      NCA=NEQA                                                        DIDAMP.70
      NRA=NDAMP                                                       DIDAMP.71
      NCB=NDAMP                                                       DIDAMP.72
      NRB=NEQA                                                        DIDAMP.73
      K=1                                                             DIDAMP.74
      CALL MULT                                                       DIDAMP.75
C     CONDENSED AMASS(I.J) TO AMASS(I) AT A(N38)                      DIDAMP.76
      DO 313 I=1,NDAMP                                                DIDAMP.77
      NR=N38+(I-1)*NDAMP+(I-1)                                        DIDAMP.78
      NDIA=N38E+I                                                     DIDAMP.79
      A(NDIA)=A(NR)                                                   DIDAMP.80
  313 CONTINUE                                                        DIDAMP.81
C     DIAGONAL MATRIX BETA INTO A(N40)                                DIDAMP.82
      DO 305 I=1,NDAMP                                                DIDAMP.83
      NBETA=N40+I-1                                                   DIDAMP.84
      K=NXI(I)                                                        DIDAMP.85
      NMASS=N38+I-1                                                   DIDAMP.86
      A(NBETA)=2.0*XI(I)*OMEGA(K)/A(NMASS)                            DIDAMP.87
  305 CONTINUE                                                        DIDAMP.88
      N41E=N40+1                                                      DIDAMP.89
C     TRANSPOSE THETA A(N39) INTO A(N38)                              DIDAMP.90
      NA=N39                                                          DIDAMP.91
      K=N38                                                           DIDAMP.92
      DO 306 I=1,NEQA                                                 DIDAMP.93
      L=NA+I-1                                                        DIDAMP.94
      DO 306 J=1,NDAMP                                                DIDAMP.95
      A(K)=A(L)                                                       DIDAMP.96
      L=L+NEQA                                                        DIDAMP.97
      K=K+1                                                           DIDAMP.98
  306 CONTINUE                                                        DIDAMP.99
      N41E=N40E+NEQA*NDAMP                                            DIDAMP.100
      N41=N41E+1                                                      DIDAMP.101
C     MULTIPLE BETA*(THETA)TRANSPOSE INTO A(N41)                      DIDAMP.102
      N42E=N41+NDAMP*NEQA                                             DIDAMP.103
      DO 307 I=N41,N42E                                               DIDAMP.104
      A(I)=0.                                                         DIDAMP.105
  307 CONTINUE                                                        DIDAMP.106
      NA=N40                                                          DIDAMP.107
      NB=N38                                                          DIDAMP.108
      NC=N41                                                          DIDAMP.109
      NCA=1                                                           DIDAMP.110
      NRA=NDAMP                                                       DIDAMP.111
      NCB=NEQA                                                        DIDAMP.112
      NRB=NDAMP                                                       DIDAMP.113
      K=1                                                             DIDAMP.114
      CALL MULT                                                       DIDAMP.115
C     MULTIPLE THETA*BETA*(THETA)TRANSPOSE INTO A(N38)                DIDAMP.116
      N41T=N40+1                                                      DIDAMP.117
      N48E=N47+NEQA*NEQA-1                                            DIDAMP.118
      DO 308 I=N47,N48E                                               DIDAMP.119
      A(I)=0.                                                         DIDAMP.120
  308 CONTINUE                                                        DIDAMP.121
      NA=N39                                                          DIDAMP.122
      NB=N41                                                          DIDAMP.123
      NC=N47                                                          DIDAMP.124
      NCA=NDAMP                                                       DIDAMP.125
      NRA=NEQA                                                        DIDAMP.126
      NCB=NEQA                                                        DIDAMP.127
      NRB=NDAMP                                                       DIDAMP.128
      K=1                                                             DIDAMP.129
      CALL MULT                                                       DIDAMP.130
C     ****************                                                DIDAMP.131
C     FORMAT STATEMENT                                                DIDAMP.132
C     ****************                                                DIDAMP.133
    1 FORMAT(2I5)                                                     DIDAMP.134
    2 FORMAT(8(I5,F5.0))                                              DIDAMP.135
  101 FORMAT(* NO. CF NCN ZERO MODE DAMPING RATIO*,I5/                DIDAMP.136
     1       * NO OF HIGHEST MODE WITH NONZERO CAMPING RATIO*,I5//)   DIDAMP.137
  501 FORMAT(*1INPUT DAMPING DATA*//)                                 DIDAMP.138
  502 FORMAT(* MODE DAMFING RATIO*//)                                 DIDAMP.139
  102 FORMAT(I5,F15.3)                                                DIDAMP.140
      RETURN                                                          DIDAMP.141
      END                                                             DIDAMP.142
      OVERLAY(12,0)                                                   STDAMP.2
      PROGRAM STDAMP                                                  STDAMP.3
C***************************************                             STDAMP.4
C     FORMULATE STRUCTURAL DAMPING C(I,J)                             STDAMP.5
C***************************************                             STDAMP.6
C     ASSEMBLE STRUCTURAL DAMPING                                     STDAMP.7
      COMMON A(30000)                                                 STDAMP.8
      DIMENSION B(300)                                                STDAMP.9
C     READ IN VISCOUS DAMPING RATIO CF EACH NODE                      STDAMP.10
      N37=NLAST                                                       STDAMP.11
      N47=N37+3*NEQA*NECA+7*NEQA                                      STDAMP.12
      N32=N37-5*NEQA                                                  STDAMP.13
      N32E=N32-1                                                      STDAMP.14
      N42=N42-5*NEQA                                                  STDAMP.15
      N42E=N42-1                                                      STDAMP.16
      NOLD=0                                                          STDAMP.17
 1000 CONTINUE                                                        STDAMP.18
      READ 1,NODE,RATIO,KN                                            STDAMP.19
    1 FORMAT(I5,F10.0,I5)                                             STDAMP.20
      PRINT 101,NODE,RATIO,KN                                         STDAMP.21
  500 FORMAT(*1INPUT DAMPING RATIO AT EACH NODE*//                    STDAMP.22
     1       * NODE DAMFING  RATIO   KN*//)                           STDAMP.23
  101 FORMAT(I5,F15.3,I5)                                             STDAMP.24
      IF(NOLD .EQ. 0) GC TO 401                                       STDAMP.25
C     NUMN=NO. CF NODES TO BE GENERATED                               STDAMP.26
      NUM=NODE-NOLD                                                   STDAMP.27
      NUMN=NUM-1                                                      STDAMP.28
      IF(NUMN .LT. 1) GO TO 401                                       STDAMP.29
C     GENERATE NEW NODE POINT                                         STDAMP.30
      K=NOLD                                                          STDAMP.31
      DO 301 J=1,NUMN                                                 STDAMP.32
      KK=K                                                            STDAMP.33
      K=K+1                                                           STDAMP.34
      B(K)=RATIO                                                      STDAMP.35
  301 CONTINUE                                                        STDAMP.36
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  401 CONTINUE                                                          STDAMP.37
      NOLD=NODE                                                         STDAMP.38
      IF(NODE .LT. NUMNP) GO TO 1000                                    STDAMP.39
C     PRINT OUT ALL NODAL DATA                                          STDAMP.40
      WRITE(1,501)                                                      STDAMP.41
  501 FORMAT(* NODE VISCOUS DAMPING RATIO DATA*/                        STDAMP.42
     1       * NODE DAMPING  RATIO              *//)                    STDAMP.43
      DO 302 N=1,NUMNP                                                  STDAMP.44
      WRITE(1,102) N,RATIO                                              STDAMP.45
  102 FORMAT(I5,F15.3)                                                  STDAMP.46
  302 CONTINUE                                                          STDAMP.47
C     FORM DAMPING FORCE VECTOR STORE IN A(N44)                         STDAMP.48
      PI=3.14159                                                        STDAMP.49
      DO 303 I=1,NEQA                                                   STDAMP.50
      VEL=A(N32E+I)                                                     STDAMP.51
      FORCE=A(N42E+I)                                                   STDAMP.52
      A(N47E+I)=B(I)*PI*SIGN(FORCE,VEL)                                 STDAMP.53
  303 CONTINUE                                                          STDAMP.54
      END                                                               STDAMP.55
      OVERLAY(13,0)                                                     OUTPUT.2
      PROGRAM OUTPUT                                                    OUTPUT.3
C                                                                       OUTPUT.4
C     *****************************************************************OUTPUT.5
C     OUTPUT THE SELECTED RESULTS IN TIME HISTORY                       OUTPUT.6
C     *****************************************************************OUTPUT.7
C                                                                       OUTPUT.8
      COMMON/ELPAR/NUMNP,NUMEL,NETYPE,NEQA,NEQO,MBANDA,MBANDO,KLIN,NLASTOUTPUT.9
      COMMON/NEWAL/NTW,NTWEL                                            OUTPUT.10
      COMMON/TATIME/NTIME,NB6E                                          OUTPUT.11
      COMMON A(30000)                                                   OUTPUT.12
      COMMON/TIME/JUMP,T,DT,MPRTM,MTAPE,KPRINT                          OUTPUT.13
      COMMON/BLOCK/NSD,NSS,NSW,KK1,KK2,KK3,MDIS,MSTR,MWAL,NBD,NBS,NBW   OUTPUT.14
      COMMON/EQ/DURANA,DDT                                              OUTPUT.15
      LARGE B(22000)                                                    OUTPUT.16
C                                                                       OUTPUT.17
C      INPUT SPECIFICATION FOR OUTPUT OF RESPONSE TIME HISTORY          OUTPUT.18
      REWIND 2                                                          OUTPUT.19
      REWIND 3                                                          OUTPUT.20
      REWIND 5                                                          OUTPUT.21
      REWIND 7                                                          OUTPUT.22
      REWIND 9                                                          OUTPUT.23
      REWIND 11                                                         OUTPUT.24
      REWIND 12                                                         OUTPUT.25
      NEQ=NEQA                                                          OUTPUT.26
      NH1=1                                                             OUTPUT.27
      NH2=NH1+6*NUMNP                                                   OUTPUT.28
      NH3=NH2+NEQ                                                       OUTPUT.29
      NH4=NH3+6*NUMEL                                                   OUTPUT.30
      NH5=NH4+5*NTW                                                     OUTPUT.31
      CALL INOUT(A(NH1),A(NH2),A(NH3),A(NH4),NUMNP,NUMEL,NEQ,NTW)       OUTPUT.32
C                                                                       OUTPUT.33
C     PACK TIME HISTORY IN BLOCK                                        OUTPUT.34
      MMTOT=30000                                                       OUTPUT.35
      NDS=NTIME                                                         OUTPUT.36
      NDISB=(MMTOT-NH5-NEQ*2)/(MDIS*2)                                  OUTPUT.37
      MDISB=(MMTOT-NH5-9*NDS)/(MDIS*2)                                  OUTPUT.38
      IF(NDISB .GT. MDISB) NDISB=MDISB                                  OUTPUT.39
      IF(NDISB .GT. NDS) NDISB=NDS                                      OUTPUT.40
      NBD=(NDS-1)/NDISB+1                                               OUTPUT.41
C                                                                       OUTPUT.42
      NSTRB=(MMTOT-NH5-6*NUMEL)/(MSTR*2)                                OUTPUT.43
      MSTRB=(MMTOT-NH5-9*NDS)/(MSTR*2)                                  OUTPUT.44
      IF(NSTRB .GT. MSTRB) NSTRB=MSTRB                                  OUTPUT.45
      IF(NSTRB .GT. NDS) NSTRB=NDS                                      OUTPUT.46
      NBS=(NDS-1)/NSTRB+1                                               OUTPUT.47
C                                                                       OUTPUT.48
      IF(MWAL .EQ. 0) GO TO 402                                         OUTPUT.49
      NWFB=(MMTOT-NH5-5*NTW)/MWAL                                       OUTPUT.50
      MWFB=(MMTOT-NH5-9*NDS)/MWAL                                       OUTPUT.51
      IF(NWFB .GT. MWFB) NWFB=MWFB                                      OUTPUT.52
      IF(NWFB .GT. NDS) NWFB=NDS                                        OUTPUT.53
      NBW=(NDS-1)/NWFB+1                                                OUTPUT.54
C                                                                       OUTPUT.55
      GO TO 403                                                         OUTPUT.56
  402 CONTINUE                                                          OUTPUT.57
      NWFB=0                                                            OUTPUT.58
      NBW=0                                                             OUTPUT.59
  403 CONTINUE                                                          OUTPUT.60
      NH6=NH5+NEQ                                                       OUTPUT.61
      NH7=NH6+NEQ                                                       OUTPUT.62
      NH8=NH7+MDIS*NDISB                                                OUTPUT.63
      NH10=NH5+6*NUMEL                                                  OUTPUT.64
      NH12=NH5+5*NTW                                                    OUTPUT.65
      NH13=NH12+MWAL*NWFB                                               OUTPUT.66
      CALL REPACK(A(NH1),A(NH2),A(NH3),A(NH4),A(NH5),A(NH6),A(NH7),     OUTPUT.67
     1          A(NH8),A(NH5),A(NH10),A(NH5),A(NH12),NDS,NEQ,MDIS,      OUTPUT.68
     2          NDISB,NUMEL,MSTR,NSTRB,NTW,MWAL,NWFB,NBD,NBS,NBW,       OUTPUT.69
     3          NUMNP)                                                  OUTPUT.70
C                                                                       OUTPUT.71
      MT=0                                                              OUTPUT.72
      NFILE=0                                                           OUTPUT.73
      IF(KK1 .EQ. 2) NFILE=NFILE+NSD*2                                  OUTPUT.74
      IF(KK2 .EQ. 2) NFILE=NFILE+NSS                                    OUTPUT.75
      IF(KK3 .EQ. 2) NFILE=NFILE+NSW                                    OUTPUT.76
      IF(NFILE .EQ. 0) GO TO 401                                        OUTPUT.77
      MT=4                                                              OUTPUT.78
      REWIND MT                                                         OUTPUT.79
      WRITE(MT) T                                                       OUTPUT.80
      WRITE(MT) NFILE,NDS,DDT                                           OUTPUT.81
      NB1=NB6E+1                                                        OUTPUT.82
      JUMP=JUMP+1                                                       OUTPUT.83
      NB2=NB6E+JUMP                                                     OUTPUT.84
      WRITE(MT) (B(I),I=NB1,NB2,MTAPE)                                  OUTPUT.85
      PRINT 1,NFILE,NDS,DDT,(B(I),I=NB1,NB2,MPRTM)                      OUTPUT.86
    1 FORMAT(* OUTPUT*,2I5/(10E12.4))                                   OUTPUT.87
  401 CONTINUE                                                          OUTPUT.88
      NH6=NH5+NDS                                                       OUTPUT.89
      NH7=NH6+8*NDS                                                     OUTPUT.90
      NH8=NH7+MDIS*NDISB                                                OUTPUT.91
      NH9=NH7+MSTR*NSTRB                                                OUTPUT.92
      NH10=NH7+MWAL*NWFB                                                OUTPUT.93
      IFF=0                                                             OUTPUT.94
C                                                                       OUTPUT.95
C      OUTPUT SELECTED ABSOLUTE DISPLACEMENT TIME HISTORY               OUTPUT.96
      REWIND 2                                                          OUTPUT.97
      CALL OUTHIS(A(NH1),A(NH2),A(NH3),A(NH4),A(NH5),A(NH6),A(NH7),     OUTPUT.98
     1          NUMNP,NUMEL,NTW,NDS,MDIS,NDISB,NSD,NBD,1,KK1,2,11,MT,   OUTPUT.99
     2          IFF,NEQ)                                                OUTPUT.100
C                                                                       OUTPUT.101
C      OUTPUT SELECTED ABSOLUTE ACCELERATION TIME HISTORY               OUTPUT.102
      REWIND 2                                                          OUTPUT.103
      CALL OUTHIS(A(NH1),A(NH2),A(NH3),A(NH4),A(NH5),A(NH6),A(NH7),     OUTPUT.104
     1          NUMNP,NUMEL,NTW,NDS,MDIS,NDISB,NSD,NBD,2,KK1,2,12,MT,   OUTPUT.105
     2          IFF,NEQ)                                                OUTPUT.106
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C
C     OUTPUT SELECTED STRESS TIME HISTORY
      REWIND 3
      CALL OUTHIS(A(NH1),A(NH2),A(NH3),A(NH4),A(NH5),A(NH6),A(NH7),
     1            NUMNP,NUMEL,NTW,NDS,MSTR,NSTRB,NSS,NBS,3,KK2,3,7,MT,
     2            IFF,NEQ)
C     CASE OF NO WALL
      IF(NTW .EQ. 0) GO TO 404
C
C     OUTPUT SELECTED WALL FORCES TIME HISTORY
      REWIND 5
      CALL OUTHIS(A(NH1),A(NH2),A(NH3),A(NH4),A(NH5),A(NH6),A(NH7),
     1            NUMNP,NUMEL,NTW,NDS,MWAL,NWFB,NSW,NBW,4,KK3,5,9,MT,
     2            IFF,NEQ)
  404 CONTINUE
      RETURN
      END
      SUBROUTINE OUTHIS(ID,IDIS,ISTR,IWALL,TA,X,UH,NUMNP,NUMEL,NTW,
     1                  NDS,NDI,NDJ,NOB,NHB,KKK,KKI,IT,JT,MT,IFF,NEQ)
C
C     ******************************************************************
C     OUTPUT RESPONSE TIME HISTORY ON SPECIFIED DISPLAY MEDIUM
C     ******************************************************************
C
      COMMON/TIME/JUMP,T,DT,MPRTM,MTAPE,KPRINT
      COMMON/EQ/DURANA,CDT
      DIMENSION TM(8),XM(8),ID(6,NUMNP),ISTR(6,NUMEL),IWALL(5,NTW),TA(1)
     1         ,X(8,NDS),UH(NDI,NDJ),IDIS(NEQ)
      COMMON/TATIME/NTIME,NB6E
      LARGE B(22000)
      DIMENSION KD(4,8)
C
C     TAPE IT INPUT TAPE STORE KD(4,8),L
C     TAPE JT INPUT TAPE STORE XH(MDIS,NDISB),X2H(MDIS,NDISB)
C                              STH(MSTR,NSTRB),WFH(MWAL,NWFB)
      IF(NOB .EQ. 0) RETURN
      DO 301 M=1,NOB
      IFF=IFF+1
      REWIND JT
      READ(IT) KD,L
      DO 302 I=1,8
      TM(I)=0.0
      XM(I)=0.0
  302 CONTINUE
C
C     PRINT APPROPRIATE TITLE
C
      GO TO (401,402,403,404) KKK
  401 CONTINUE
      WRITE(1,501) M,IFF
      WRITE(1,101) (KD(1,I),KD(2,I),I=1,L)
      GO TO 405
  402 CONTINUE
      WRITE(1,502) M,IFF
      WRITE(1,101) (KD(1,I),KD(2,I),I=1,L)
      GO TO 405
  403 CONTINUE
      WRITE(1,503) M,IFF
      WRITE(1,102) (KD(1,I),KD(2,I),KD(3,I),I=1,L)
      GO TO 405
  404 CONTINUE
      WRITE(1,504) M,IFF
      WRITE(1,103) (KD(1,I),KD(2,I),I=1,L)
C
C     ARRANGE TIME HISTORY IN OUTPUT FORM
  405 CONTINUE
      MPR=1-MTAPE
      N=0
      DO 303 NB=1,NHB
      READ(JT) K,UH
      DO 304 J=1,K
      N=N+1
      MPR=MPR+MTAPE
      TT=B(MPR+NB6E)
      DO 305 I=1,L
      GO TO (411,412,413,414) KKK
  411 CONTINUE
      JJ=KD(3,I)
      II=IDIS(JJ)
      XX=UH(II,J)
      GO TO 415
  412 CONTINUE
      JJ=KD(3,I)
      II=IDIS(JJ)
      XX=UH(II,J)
      GO TO 415
  413 CONTINUE
      LL=KD(2,I)
      II=KD(3,I)
      II=ISTR(II,LL)
      XX=UH(II,J)
      GO TO 415
  414 CONTINUE
      LL=KD(1,I)
      II=KD(2,I)
      II=IWALL(II,LL)
      XX=UH(II,J)
C     ABSOLUTE MAX
  415 CONTINUE
      AX=ABS(XX)
      IF(AX-XM(I)) 416,416,417
  417 CONTINUE
      XM(I)=AX
      TM(I)=TT
  416 CONTINUE
      X(I,N)=XX
      TA(N)=TT
  305 CONTINUE
  304 CONTINUE
  303 CONTINUE
C
      GO TO (418,419) KKI
  418 CONTINUE
      DO 306 N=1,NDS
      WRITE(1,104) TA(N),(X(I,N),I=1,L)
  306 CONTINUE
      WRITE(1,105) (XM(I),I=1,L)
      WRITE(1,106) (TM(I),I=1,L)
      GO TO 420
  419 CONTINUE
      IF(KKI .EQ. 2) WRITE(MT) IFF,KKK,L,KD,XM,X
      GO TO 418
  420 CONTINUE
  301 CONTINUE
```

```
      RETURN                                                            OUTHIS.109
  101 FORMAT(8H    TIME,2X,8(I8,1H-,I2,X))                              OUTHIS.110
  102 FORMAT(8H    TIME,2X,8(I4,2H--,I3,1H-,I2))                        OUTHIS.111
  103 FORMAT(8H    TIME,2X,8(I8,1H-,I2,X))                              OUTHIS.112
  104 FORMAT(F8.4,2X,8E12.4)                                            OUTHIS.113
  105 FORMAT(* MAXIMUM ABSOLUTE VALUES*/,* MAXIMUM  *,8E12.4)           OUTHIS.114
  106 FORMAT(* MAXMUM VALUE TIME*,F10.5)                                OUTHIS.115
  501 FORMAT(*1TIME HISTORY FOR SELECTED DISPLACEMENT CCMPOENTS*,       OUTHIS.116
     1       5H.....I3,37X,*FILE NO.*,I3//                              OUTHIS.117
     2       20X,*NODE NUMBERS AND DISPLACEMENT COMPOENTS*)             OUTHIS.118
  502 FORMAT(*1TIME HISTORY FOR SELECTEC ACCELEFATION CCMPOENTS*,       OUTHIS.119
     1       5H......,I3,37X,*FILE NC.*,I3//                            OUTHIS.120
     2       20X,*NODE NUMBERS AND ACCELERATICN COMPOENTS*)             OUTHIS.121
  503 FORMAT(*1TIME HISTORY FOR SELECTEC STRESS COMPONENTS*,            OUTHIS.122
     1       5H......,I3,41X,*FILE NO.*,I3//                            OUTHIS.123
     2       20X,*ELEMENT TYPE-ELEMENT NO.-STRESS(1 TO 6),YIELD(4)*/)   OUTHIS.124
  504 FCRMAT(*1TIME HISTORY FOR SELECTEC WALL FCRCE*,                   OUTHIS.125
     1       5H......,I3,47X,*FILE NO.*,I3//                            OUTHIS.126
     2       20X,*WALL NO.-COMPCNENTS,1=U,2=V,3=N,4=YBAR,5=ZBAR*/)      OUTHIS.127
      END                                                               OUTHIS.128
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