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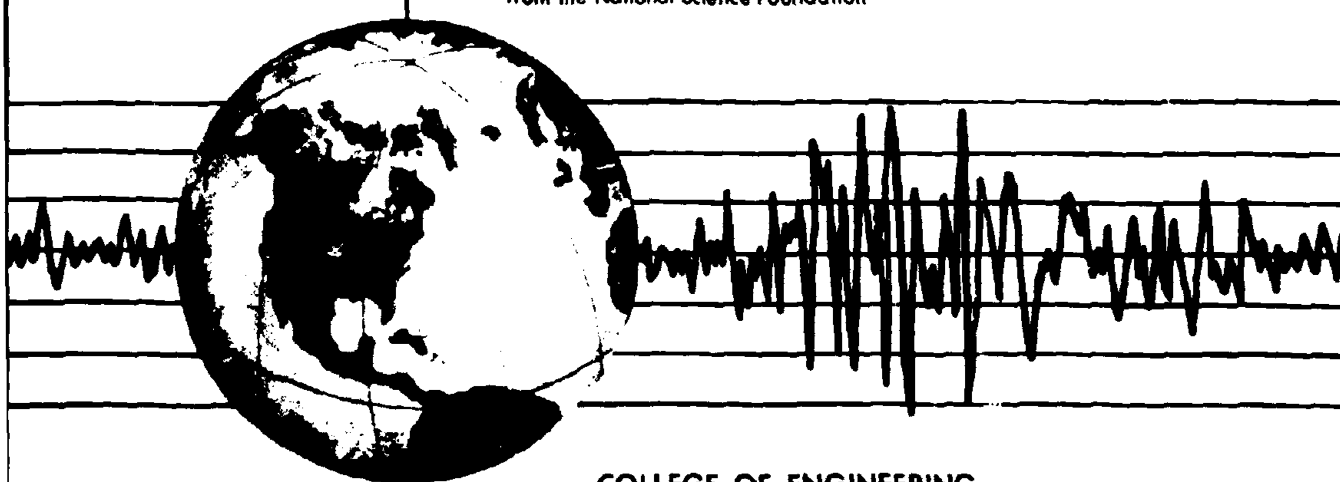
EAGD-84
A COMPUTER PROGRAM FOR EARTHQUAKE ANALYSIS OF CONCRETE GRAVITY DAMS

by

GREGORY FENVES
ANIL K. CHOPRA

A Report on Research Conducted Under
Grants CEE-8120308 and CEE-8401439
from the National Science Foundation



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This report documents the use of the computer program EAGD-84 which implements a general analytical procedure for the evaluation of the earthquake response of concrete gravity dams, including the effects of dam-water-foundation rock interaction and of materials such as alluvium and sediments, at the bottom of reservoirs. The development of an appropriate idealization of the system is discussed, the required input data to the computer program are described, the output is explained, and the response results from a sample analysis are presented. The present version of the computer program incorporates major extensions and improvements of the earlier version.

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1. INTRODUCTION

A general analytical procedure has been developed [5] to evaluate the earthquake response of concrete gravity dams, including the effects of dam-water-foundation rock interaction and of materials, such as alluvium and sediments, at the bottom of reservoirs. This report is concerned with the computer program EAGD-84 that implements the analytical procedure

At small vibration amplitudes a concrete gravity dam will behave as a solid even though the joints between the monoliths may slip [9]. However, during large-amplitude motion, the behavior of a dam depends on the extent to which the inertia forces can be transmitted across the joints. For dams with straight contraction joints, either grouted or ungrouted, the inertia forces that develop during large-amplitude motion are much greater than the shear forces that the joints can transmit. Consequently, the joints would slip and the monoliths vibrate independently, as evidenced by the spalled concrete and water leakage at the joints of the Koyna Dam during the Koyna earthquake of 11 December 1967 [2]. For such dams, a two-dimensional, plane stress model of the individual monoliths appears to be appropriate for predicting the earthquake response. On the other hand, for dams with keyed contraction joints, it may be inappropriate to assume that the monoliths vibrate independently. A two-dimensional, plane strain model would be better for such dams. The analytical procedure and computer program are restricted to systems assumed to be in generalized plane stress or plane strain. The same assumption should be chosen for the dam and the foundation rock.

Because the dimensions and dynamic properties of the monoliths differ, the effects that a dam has on the deformations and stresses in the foundation rock vary along the length of the dam. A three-dimensional model for the foundation-rock region would seem necessary for this reason and because the rock is fractured and fissured, unlike a continuum.

The hydrodynamic effects of the water impounded in the reservoir are assumed to be adequately modelled by the two-dimensional wave equation. Water compressibility is included in the analysis, because it can significantly affect the earthquake response of concrete gravity dams [1]. The system is analyzed under the assumption of linear behavior for the concrete dam, impounded water and foundation rock. Thus, the possibilities of concrete cracking [8] or water cavitation [11] are not considered.

This report documents the use of the computer program EAGD-84. The development of an appropriate idealization of the system is discussed, the required input data to the computer program are described, the output is explained, and the response results from a sample analysis are presented. The present version of the computer program incorporates major extensions and improvements of the original version [3].

2. SYSTEM AND GROUND MOTION

The system considered consists of a concrete gravity dam supported on the horizontal surface of underlying flexible foundation rock and impounding a reservoir of water (Figure 1). The selected monolith or dam cross-section is idealized as a two-dimensional finite element system in order to model arbitrary geometry and elastic material properties of the dam. Hence, non-overflow sections, overflow sections and appurtenant structures can be modelled. However, certain restrictions are imposed on the geometry of the dam to permit a continuum solution for hydrodynamic pressure in the impounded water. For the purpose of determining hydrodynamic effects, and only for this purpose, the upstream face of the dam is assumed to be vertical. This assumption is reasonable for actual concrete gravity dams because their upstream face is vertical or almost vertical for most of the height, and the hydrodynamic pressure acting the dam face is insensitive to small departures of the face slope from vertical, especially if these departures are near the base of the dam, which is usually the case. The water impounded in the reservoir is idealized as a fluid domain of constant depth and infinite length in the upstream direction. The foundation rock underlying the dam and reservoir bottom materials is idealized as a homogeneous, isotropic, viscoelastic half-plane.

The viscoelastic half-plane idealization of the foundation-rock region is not appropriate for representing the effects of interaction between the impounded water and the foundation rock. These interaction effects are dominated by the overlying reservoir bottom materials that may consist of variable layers of alluvium, silt and other sediments, possibly deposited to a significant depth, which are highly saturated and have a small shear modulus. A hydrodynamic pressure wave impinging on such materials will partially reflect back into the water and partially refract, primarily as a dilatational wave, into the layers of reservoir bottom materials. Because of the considerable energy dissipation that results from hysteretic behavior and particle turbulence in the layer of saturated materials, the refracted wave is essentially dissipated before reaching the underlying foundation rock. The dissipation of hydrodynamic pressure waves in the reservoir bottom materials is modelled approximately by a boundary condition at the reservoir bottom that partially absorbs incident hydrodynamic pressure waves [5].

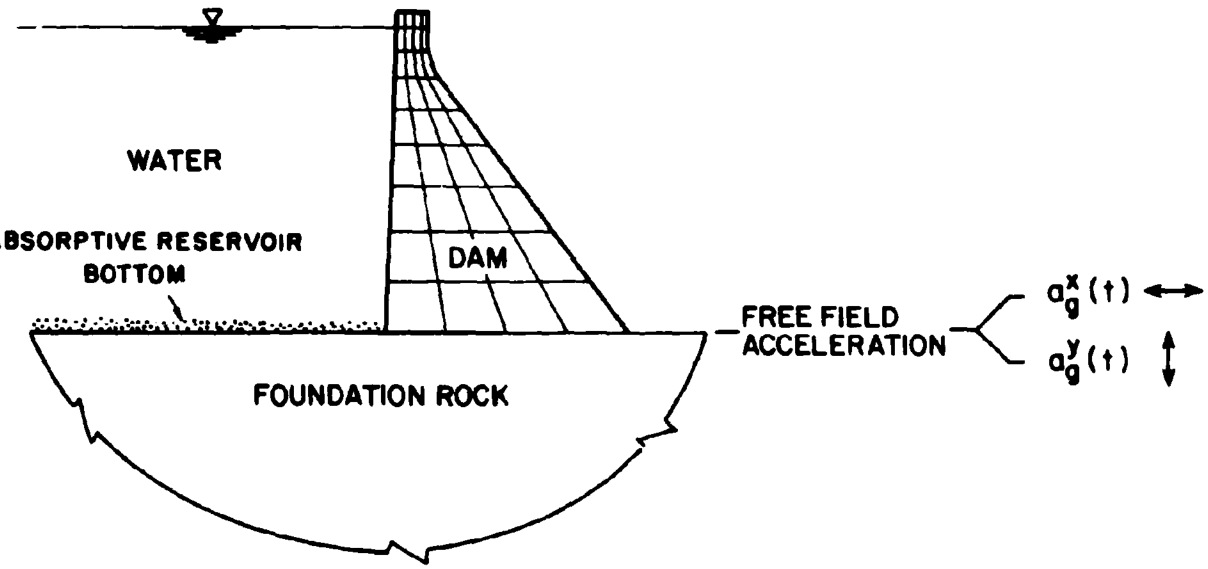

FIGURE 1   Dam-water-foundation rock system.

Over a long time, sediments may deposit to a significant depth at the bottom of some reservoirs. The thickness of the sediment layer can be recognized by defining the reservoir bottom at the surface of the sediments, which correspondingly reduces the depth of the fluid domain. However, the computer analysis does not consider the influence of the reservoir bottom materials on the static stresses and vibration properties of the dam because these effects should be small, as the materials are very soft, highly saturated and exert forces only on the lower part of the dam.

The earthquake excitation for the dam-water-foundation rock system is defined by the two components of free-field ground acceleration in a cross-sectional plane of the dam: the horizontal component transverse to the dam axis, and the vertical component. The free-field ground acceleration is assumed to be identical at all points on the base of the dam.

3. SYSTEM IDEALIZATION AND PROPERTIES

The dam monolith is idealized as an assemblage of planar, four-node non-conforming finite elements [10]. The finite element system is obtained by dividing the dam cross-section into quadrilateral or triangular elements connected at nodal points. Elements in the shape of parallelograms with an aspect ratio near unity give the most accurate results. The elastic properties of the materials in the dam can be defined independently for each finite element. Therefore, variations in the properties of the dam concrete and appurtenant structures can be represented conveniently.

The nodal points in the finite element system are located with reference to an x,y-coordinate system. The y-axis must be vertical with the positive direction upwards; the x-axis must be horizontal with the positive direction either downstream or upstream. Each nodal point is identified by a nodal point number and x,y-coordinates. If the effects of dam-foundation rock interaction are included, the nodal points at the base of the dam must be equally spaced on a horizontal line. Mesh generation facilities are available in EAGD-84 to reduce the amount of input data required to describe the finite element system.

Each finite element is numbered and defined by the nodal points at its vertices listed by number in a counter-clockwise direction around the element. The numbering of the elements is arbitrary because it does not influence the computational cost. The numbering of the nodal points, however, determines the bandwidth of the structural stiffness matrix, and hence it affects the computational cost. The smallest bandwidth results when the maximum difference in nodal point numbers for each element is minimized over all the elements. Judicious numbering of the nodal points can achieve this goal. Numbering the nodal points in the direction of the monolith cross-section with the smallest number of elements usually results in the minimum bandwidth.

Energy dissipation in the dam concrete is represented by constant hysteretic damping with a damping factor η_s. A viscous damping ratio ξ, the same for all the natural vibration modes of the dam on rigid foundation rock with an empty reservoir, corresponds to a constant hysteretic damping factor of $\eta_s = 2\xi$. Forced vibration field tests on dams indicate that the viscous damping ratio is in the range of 1 to 3 percent, fairly independent of the vibration mode number [9]. A constant hysteretic damping factor of η_s=0.1, which corresponds to a 5 percent viscous damping ratio in all vibration modes of the dam, is a reasonable value for the much larger motion and higher stresses expected in a dam during strong earthquake ground motion.

The water impounded in the reservoir is idealized as a fluid domain of constant depth and infinite length in the upstream direction. The elevation of the free-surface is the only parameter specified for the impounded water. The computer program uses the following properties for the impounded water: velocity of pressure waves C=4720 ft/sec, and unit weight =62.4 lb/ft^3. The reservoir bottom is assumed to be horizontal, but it may be specified at any elevation.

The absorptiveness of the reservoir bottom materials is characterized by the wave reflection coefficient α, which is defined as the ratio of the amplitude of the reflected hydrodynamic pressure wave to the amplitude of a vertically propagating pressure wave incident on the reservoir bottom. A wave reflection coefficient of unity indicates that pressure waves are reflected from the reservoir bottom without attenuation; a wave reflection coefficient of zero indicates that vertically propagating pressure waves are fully absorbed into the reservoir bottom materials without reflection. The materials at the bottom of the reservoir determine the value of the wave reflection coefficient α according to the following equation [5]:

$$\alpha = \frac{1-k}{1+k}$$

where $k=\rho C/\rho_r C_r$, C is the velocity of pressure waves and ρ is the density of water, $C_r=\sqrt{E_r/\rho_r}$, and E_r is the Young's modulus of elasticity and ρ_r is the density of the reservoir bottom materials.

A basis needs to be developed for the selection of the wave reflection coefficient α before reservoir bottom absorption effects can be reliably included in practical analyses. Because reservoir bottom materials may consist of highly variable layers of exposed bedrock, alluvium, silt and other sediments, it is difficult to estimate the value of α based on analysis alone. Field tests on existing dams and reservoirs may provide useful data that could aid the selection of an appropriate wave reflection coefficient for response analysis.

If the effects of dam-foundation rock interaction are included, the dynamic stiffness matrix for the foundation-rock region appears in the equations of motion for the dam [5]. This frequency-dependent matrix is defined with respect to the degrees-of-freedom of the nodal points at the dam base. A file of numerical data is supplied with EAGD-84 for the frequency-dependent compliance functions, determined by the procedures described in reference 4, for a homogeneous viscoelastic half-plane with Poisson's ratio of 1/3 and the following values of the constant hysteretic damping factor: η_f=0.01, 0.10, 0.25 or 0.50. The value of the constant hysteretic damping factor η_f for the foundation rock should preferably be determined from experimental tests of appropriate rock samples subject to harmonically varying stress and strain. For such tests, η_f can be obtained from:

$$\eta_f = \frac{1}{2\pi} \frac{\Delta W}{W}$$

where ΔW is the energy loss per cycle, given by the area of the stress-strain loop, and W is the strain energy stored in an elastic material under the same stress-strain cycle as the viscoelastic material. One of the available values of η_f mentioned above can then be chosen to approximate the experimentally determined value. Alternatively, the compliance functions for the experimental η_f value can be computed by the procedures described in reference 4.

The dam-foundation rock system may be assumed to behave in either a state of generalized plane stress or plane strain. Although the difference between the dam responses computed under the two assumptions is small [3], the generalized plane stress assumption is recommended for practical analysis.

4. OUTLINE OF ANALYTICAL PROCEDURE

The analytical procedure, which is described in references 5 and 6, is outlined here. The frequency domain equations for the three substructures in the system, dam, impounded water and foundation rock, are formulated from their respective governing equations. The frequency domain equations for the substructures are then combined to obtain the frequency domain equations for the complete system. The structural displacements of the dam are expressed in terms of generalized coordinates, which results in a large reduction in the number of degrees-of-freedom and corresponding computational effort.

If the effects of dam-foundation rock interaction are included in the analysis by recognizing the flexibility of the foundation rock, the frequency domain equations for the system contain the dynamic stiffness matrix for the foundation-rock region [5]. Reference 4 presents a procedure for evaluating the compliance functions at uniformly spaced nodal points on the surface of a homogeneous, isotropic, viscoelastic half-plane. The compliance function data, which is stored on a file supplied with EAGD-84, is assembled and inverted in the computer program to give the dynamic stiffness matrix for the viscoelastic half-plane idealization of the foundation-rock region. For foundation-rock regions with complicated geometry or material properties, the dynamic stiffness matrix can be computed by the finite element method and the results used as input to EAGD-84.

To evaluate the dynamic response of dams to earthquake ground motion, the complex-valued frequency response functions for the generalized coordinates are first computed by solving the frequency domain equations. Fourier synthesis techniques are then employed to compute the response history of the generalized coordinates due to a specified earthquake ground motion. The Fast Fourier Transform (FFT) algorithm used in EAGD-84 recognizes that ground acceleration records and response histories are real-valued functions to reduce the computation time and storage requirements [7]. Nodal point displacement histories are subsequently obtained from the generalized coordinates, and the stresses at the centroid of each finite element are computed using the elements' stress-displacement matrix. The structural displacements due to static forces (weight of the dam and hydrostatic pressure of the impounded water) are computed relative to the rigid-body displacements of the dam [3].

5. SELECTION OF RESPONSE PARAMETERS

To ensure that the computer program gives accurate dynamic response of a dam, the parameters that govern the response computation must be carefully selected. This section gives guidelines to aid in the selection of the response parameters.

5.1 Maximum Excitation Frequency

Two considerations govern the selection of the excitation frequency range 0 to F for which the response of the dam is computed:

1. The maximum excitation frequency F should be greater than the frequencies of all the significant harmonics contained in the free-field ground acceleration records. Earthquake data processed by modern techniques accurately reproduces frequencies up to about 25 Hertz. Thus, it is recommended that:

$$F \geqslant 25 \text{ Hz.}$$

2. The maximum excitation frequency F should be large enough to include the range of frequencies over which the dam has significant dynamic response. This criterion is met in conjunction with the selection of the number NEV of generalized coordinates included in the analysis, as described below. It is recommended that $F > f_{\text{NEV}}$, where f_{NEV} is the vibration frequency, in Hertz, of the highest vibration mode included in the analysis. EAGD-84 prints the vibration frequencies of the associated dam-foundation rock system to help in satisfying this criterion.

5.2 Number of Generalized Coordinates

The number NEV of generalized coordinates required to represent the earthquake response of a dam is much less than the number of degrees-of-freedom in the finite element system. Each generalized coordinate corresponds to a vibration mode (Ritz vector) of an associated dam-foundation rock system. A general rule is to include all the vibration modes that significantly contribute to the earthquake response of the dam. One or two additional modes should be included for accurate response results at the high-frequency end of the frequency range. Typically, five generalized coordinates are necessary if the foundation rock is assumed to be rigid; and ten generalized coordinates are necessary if foundation-rock flexibility is included. A final check that enough generalized coordinates are used, is to ascertain that the maximum stresses in the dam do not change if the number of generalized coordinates is increased.

5.3 Number of Excitation Frequencies and Time Interval

For a specified maximum excitation frequency F, the computation of the frequency response functions and earthquake response, via the FFT algorithm, depends on two parameters: NEXP, which is related to the number of excitation frequencies and time intervals; and the time interval DT, in seconds. These two parameters determine other response parameters as follows (see Figure 2):

Number of excitation frequencies (and number of time intervals):	$N = 2^{NEXP}$
Duration of response history:	$T = N * DT$
Frequency increment:	$\Delta f = \frac{1}{2T}$
Maximum frequency represented:	$F = N \Delta f$

A "quiet zone" with N points of zero acceleration is automatically appended at the end of the ground acceleration records to reduce the aliasing error inherent in the discrete Fourier transform.

It is important to choose the values of NEXP (thus N) and DT that are appropriate for the system and ground motion. The following considerations govern the selection of NEXP and DT:

1. The frequency increment Δf must be small enough to represent the frequency response functions for the generalized coordinates, especially near the fundamental resonant peak. It is recommended that:

$$\Delta f \leqslant \frac{f_1}{50}$$

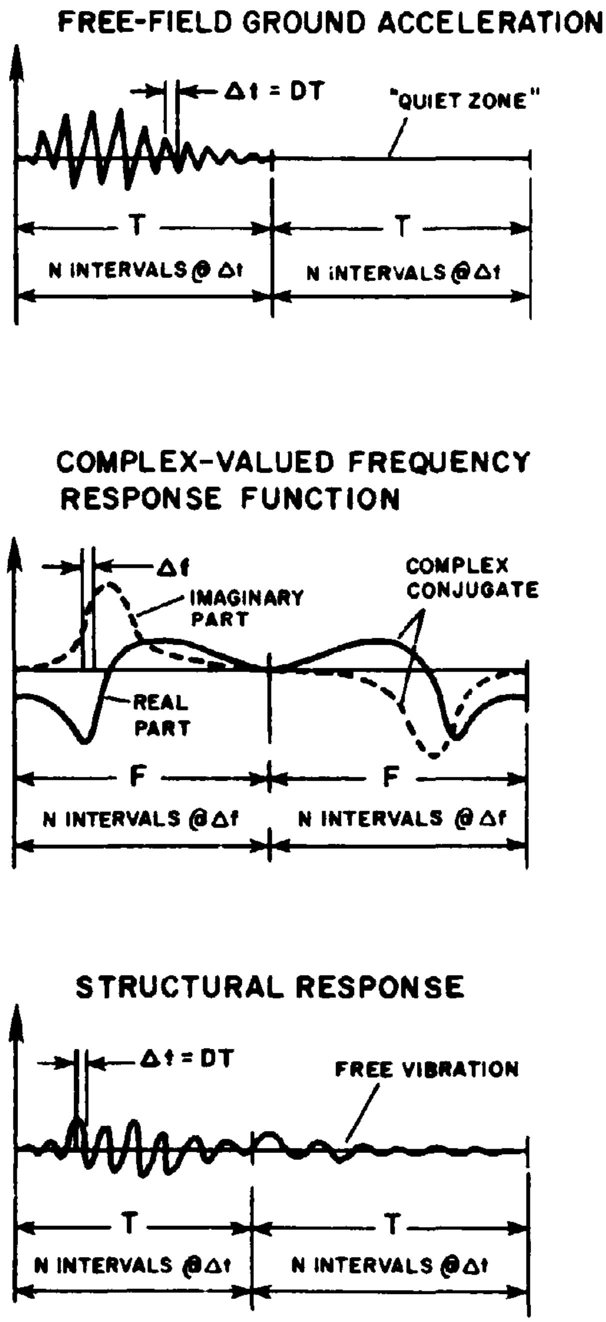

FIGURE 2 Phases of dynamic response computation and relationships between response parameters.

where f_1 is the fundamental resonant frequency, in Hertz, of the associated dam-foundation rock system.

2. To reduce further the aliasing error, it is recommended that:

$$T > \frac{1.5}{\eta_s}\frac{1}{f_1}$$

where η_s is the constant hysteretic damping factor for the dam concrete.

For a given value of the maximum excitation frequency F, as determined in Section 5.1, the above guidelines are met if NEXP and DT satisfy the following two conditions:

$$\text{DT} \leqslant \frac{1}{2F}$$

$$\text{DT} \cdot 2^{\text{NEXP}} \geqslant \frac{1}{f_1} \max\left\{25, \frac{1.5}{\eta_s}\right\}$$

5.4 Excitation Frequency Limit of Dynamic Stiffness Matrix

The computer program includes a file of numerical data for the frequency-dependent compliance functions for a viscoelastic half-plane idealization of the foundation-rock region. From these compliance functions, EAGD-84 computes the dynamic stiffness matrix $\mathbf{S}_f(\omega)$ for the foundation-rock region. The compliance functions, and hence $\mathbf{S}_f(\omega)$, are defined for a limited excitation frequency range. The maximum excitation frequency for which they are defined is $\omega_{max}=(5\,C_f)/\,b$, where $C_f=\sqrt{G_f/\rho_f}$, G_f is the elastic shear modulus and ρ_f is the density of the foundation rock, and b is the distance between the equally spaced nodal points at the dam base. If the effects of dam-foundation rock interaction are included, the maximum excitation frequency F must be less than $(5C_f)/\,(2\pi b)$, or:

$$F \leqslant \frac{5}{2}\frac{C_f}{\pi b}$$

in addition ot the aforementioned criteria in Section 5.3.

6. INPUT DATA DESCRIPTION

The input data for the computer program EAGD-84 are entered by cards divided into fields according to the formats described in this section. Each field is identified by inclusive card column numbers and one of three field-types: (I), integer; (F), floating point; or (E), exponential. An integer field (I) is a number without a decimal point that is right-justified in the field. A floating point field (F) type is a number with a decimal point located anywhere in the field. An exponential field (E) is a number located anywhere in the field with a decimal point and optional exponential specification that follows FORTRAN rules.

Card Set A - Title

1 - 80	Title of problem or informational message printed with results of the analysis.

Card Set B - Program Control Data

Specify the parameters for the finite element idealization of the dam monolith and the control of program execution.

1 - 5 (I)	NUMNP	Number of nodal points in the finite element idealization.
6 - 10 (I)	NUMEL	Number of elements in the finite element idealization.
11 - 15 (I)	NUMMAT	Number of different materials in the finite element idealization.
16 - 20 (I)	NBASE	Number of nodal points at the base of the dam, in contact with the foundation rock.
21 - 25 (I)	NEV	Number of generalized coordinates included in the response computation. See Section 5.2 for guidelines.

26 - 35 (F)	WL	Elevation, in feet, of the free-surface of the impounded water.
36 - 40 (I)	NPP	Number of nodal points at the upstream face of the dam affected by the impounded water. NPP=0 indicates an empty reservoir. See Card Set C for definition of the water nodal points.
41 - 45 (I)	IGRAV	=0, do not perform static analysis. =1, perform static analysis due to weight of the dam and hydrostatic pressure of the impounded water.
46 - 50 (F)	PSP	=0.0, dam and foundation rock are in generalized plane stress. =1.0, dam and foundation rock are in plane strain.
51 - 55 (I)	IRES	=0, compute the dynamic response due to earthquake ground motion. =1, only perform static analysis and compute vibration properties.
56 - 60 (I)	IOPR	=0, compute vibration frequencies and mode shapes. =1, read vibration frequencies and mode shapes from cards.
61 - 65 (I)	IOPP	=0, do not punch vibration frequencies and mode shapes. =1, punch vibration frequencies and mode shapes on cards.
66 - 70 (I)	IRIG	=0, foundation rock is flexible, include dam-foundation rock interaction effects. =1, foundation rock is rigid, exclude dam-foundation rock interaction effects.
71 - 75 (I)	IGEN	=0, read the dynamic stiffness matrix from TAPE90. =1, generate the dynamic stiffness matrix from the data in TAPE80. IGEN is ignored if IRIG=1.

Card Set C - Foundation Rock Properties

Specify the properties of the foundation rock. Include this card set if the foundation rock is flexible (IRIG=0, Card Set B).

1 - 10 (F)	Young's modulus of elasticity, in ksf, of the foundation rock.
11 - 20 (F)	Mass density, in k-s ^{2}/ft ^{4}, of the foundation rock.
21 - 30 (F)	Constant hysteretic damping factor η_f for the foundation rock. See Note C.1 for possible damping coefficients.
31 - 40 (F)	Spacing, in feet, between the nodal points at the base of the dam. The nodal points at the base must be equally spaced.

If IGEN=1 (Card Set B), the dynamic stiffness matrix for the foundation-rock region is generated from the compliance data on TAPE80 and stored on TAPE90. If IGEN=0, EAGD-84 assumes that the dynamic stiffness matrix was generated in a previous program execution and is available on TAPE90. The Young's modulus and density of the foundation rock may differ from the values used in the previous execution that generated TAPE90.

Note C.1: Possible Damping Factors

Foundation rock compliance data are available on TAPE80 for the following constant hysteretic damping factors: 0.01, 0.10, 0.25, 0.50. Section 3 gives guidelines for selecting the damping factor.

Card Set D - Material Properties

Specify material properties used in the finite element idealization of the dam monolith. One card for each NUMMAT (Card Set B) materials.

1 - 5 (I) Material number (less than or equal to NUMMAT).

6 - 15 (F) Young's modulus of elasticity, in ksf, of the material.

16 - 25 (F) Poisson's ratio of the material.

26 -35 (F) Mass density, in k-s ^{2}/ft ^{4}, of the material.

Card Set E - Nodal Point Coordinates

Define the x,y-coordinates of the nodal points in the finite element idealization of the dam monolith.

1 - 5 (I) Nodal point number.

6 - 10 (F) Displacement boundary condition code. See Note E.1.

11 - 20 (F) x-coordinate, in feet, of nodal point.

21 - 30 (F) y-coordinate, in feet, of nodal point.

Leave remainder of card blank if layer generation of nodal points is not desired (See Note E.3).

31 - 35 (I) m, module for nodal point increment (greater than zero).

36 - 40 (I) NLIM, nodal point limit of layer generation.

41 - 50 (F) f_x, amplification factor for x-coordinate. If blank, assumed to be unity.

51 - 60 (F) f_y, amplification factor for y-coordinate. If blank, assumed to be unity.

Repeat cards until all NUMNP (Card Set B) nodal points are specified either explicitly or by nodal point generation. Nodal points must be listed in numerically ascending order. If cards are omitted and Columns 31-60 are blank, the coordinates of the omitted nodal points are generated along the straight line connecting the defined nodal points (see Note E.2). If Columns 31-60 are used, as described above, the nodal point coordinates are generated in layers (see Note E.3).

Note E.1: Boundary Condition Code

The displacement boundary condition code for a nodal point is specified in Columns 6-10 as follows:

0.0 Both x,y-direction displacements unknown.

1.0 Zero displacement in the x-direction.
Unknown displacement in the y-direction.

2.0 Unknown displacement in the x-direction.
Zero displacement in the y-direction.

3.0 Zero displacement in the x-direction.
Zero displacement in the y-direction.

Typically, a 0.0 boundary condition code is used for nodal points above the dam base. If the foundation rock is rigid (IRIG=1, Card Set B), a boundary condition code of 3.0 is used for the nodal points on the base. If the foundation rock is flexible (IRIG=0, Card Set B), a boundary condition code of 0.0 is used for the nodal points on the base. However, various combinations of the boundary condition code for the nodal points can represent other displacement boundary conditions appropriate for the system.

Note E.2: Straight Line Generation

If the (L-1) cards for nodal points N+1, N+2, · · · N+L-1 are omitted and Columns 31 - 60 of the card for nodal point N are blank, the omitted nodal points are generated at equal intervals on the straight line joining nodal points N and N+L. The boundary condition code for the generated nodal points is set to 0.0.

Note E.3: Layer Generation

Layer generation may be used with two rows of completely defined nodal points. If the parameters in Columns 31 - 60 are specified on the card for nodal point N, the x,y-coordinates of nodal points N+1, N+2, · · · NLIM are generated by the following rule:

$$x_k = x_{k-m} + f_x(x_{k-m} - x_{k-2m})$$

$$y_k = y_{k-m} + f_y(y_{k-m} - y_{k-2m})$$

for $k = \text{N}+1, \cdots \text{NLIM}$. If, NLIM = NUMNP, no more nodal point cards are required. If NLIM < NUMNP, the card for nodal point NLIM + 1 must follow. The boundary condition code for generated nodal points is set to 0.0.

Card Set F - Element Definition

List the nodal points at the vertices of each element, in addition to the material number for the element.

1 - 5 (I)	Element number.
6 - 10 (I)	Nodal point number at element vertex I.
11 - 15 (I)	Nodal point number at element vertex J.
16 - 20 (I)	Nodal point number at element vertex K.
21 - 25 (I)	Nodal point number at element vertex L.
26 - 30 (I)	Material number for element (from Card Set D).

The nodal point numbers at the element vertices I, J, K and L must be ordered in a counter-clockwise direction around the element (See Figure 3). Triangular elements are permitted; they are identified by the same first and last nodal point number (i.e. I, J, K and I).

All NUMEL (Card Set B) elements must be specified in numerically ascending order, either explicitly or by element generation. If element cards are omitted, EAGD-84 generates the information for the omitted element numbers by incrementing by one the preceding I, J, K and L nodal point numbers. The material number for the generated elements is set to the corresponding value on the last card. The element card for element number NUMEL must always be supplied.

The maximum difference between nodal point numbers for each element over all the elements determines the bandwidth of the structural stiffness matrix. The bandwidth is minimized by judicious numbering of the nodal points as described in Section 3.

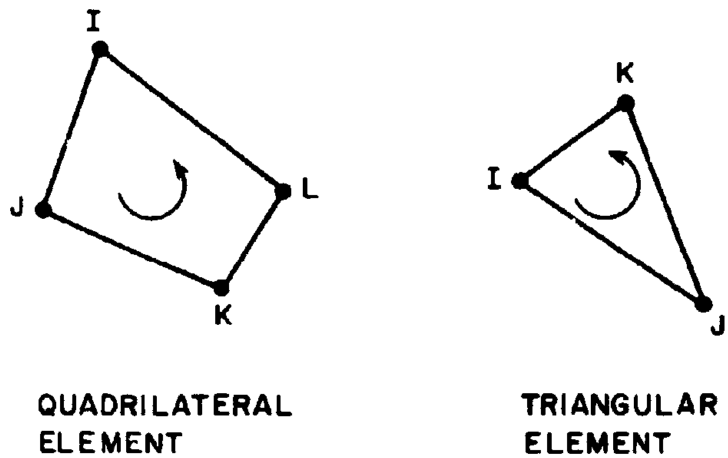

FIGURE 3 Order of nodal point numbers for finite elements.

Card Set G - Water Nodal Points

Specify the nodal points at the upstream face of the dam affected by the water impounded in the reservoir. Omit this card set if NPP=0 (Card Set B).

1 - 5 (I)	=0, the positive x-direction is downstream. =1, the positive x-direction is upstream.
6 - 10 (I)	
11 - 15 (I) • • •	List of nodal point numbers at the upstream face of the dam that are affected by the impounded water. The NPP (Card Set B) nodal points must be listed from the free-surface to the reservoir bottom (See Figure 4). If the free-surface is between two upstream nodal points, both nodal points must be included.
76 - 80 (I)	

If more than 15 upstream nodal points are affected by the impounded water, repeat this card until all the nodal points are listed. After the first card, however, the list begins in Columns 1-5.

Card Set H - Base Nodal Points

Specify the nodal points at the base of the dam in contact with the flexible foundation rock. Include this card set if IRIG=0 (Card Set B).

1 - 5 (I)	
6 - 20 (I) • • •	List of nodal point numbers at the base of the dam that are in contact with the flexible foundation rock. The NBASE (Card Set B) nodal points must be listed in order of increasing x-coordinate (See Figure 5).
76 - 80 (I)	

If there are more than 16 base nodal points, repeat this card until all the nodal points are listed.

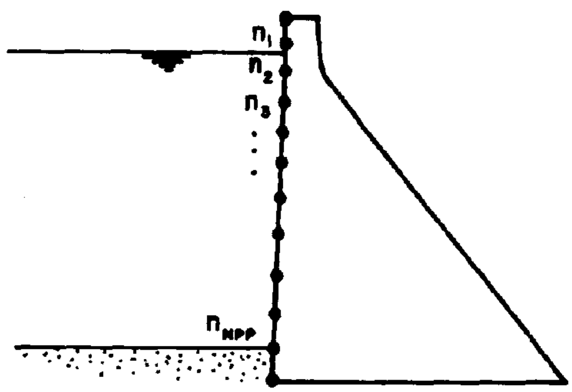

FIGURE 4 Nodal points at upstream face of the dam affected by the impounded water.

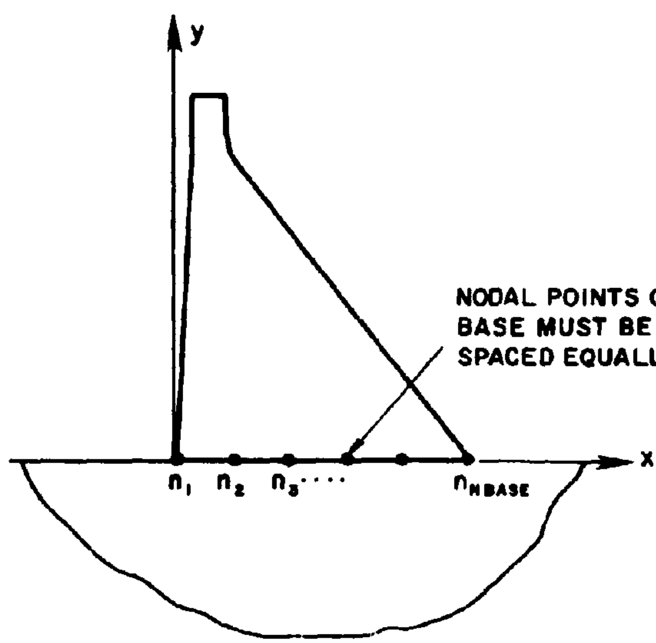

FIGURE 5 Nodal points at the base of the dam in contact with flexible foundation rock.

Card Set I - Vibration Frequencies

Input the natural vibration frequencies of an associated dam-foundation rock system. Include this card set if IOPR=1 (Card Set B). Input one vibration frequency per card in order of increasing mode number. NEV cards are required (Card Set B).

1 - 12 (I)	Vibration mode number.
13 - 27 (F)	Natural vibration frequency, in radians/sec, of the vibration mode.

Card Set J - Vibration Mode Shapes

Input the natural vibration mode shapes of the associated dam-foundation rock system. Include this card set if IOPR=1 (Card Set B). The mode shapes must be normalized such that $\mathbf{\Psi}^T\mathbf{m}\mathbf{\Psi}=\mathbf{I}$, where $\mathbf{\Psi}$ is the matrix of mode shapes, **m** is the mass matrix of the dam, and **I** is the identity matrix. If the data for this card set are the punched card output from a previous EAGD-84 program execution, the mode shapes are already normalized.

One card for each nodal point.
NUMNP (Card Set B) cards required.

1 - 12 (I)	Nodal point number.
13 - 27 (E)	x-ordinate of mode shape.
28 - 42 (E)	y-ordinate of mode shape.

One set for each vibration mode shape.
NEV (Card Set B) sets required.

Card Set K - Dynamic Response Parameters

Specify the parameters for the computation of dynamic response.

1 - 5 (I)	IHV	=0, Compute response due to the horizontal component, only, of the ground motion. =1, Compute response due to the vertical component, only, of the ground motion. =2, Compute response due to the horizontal and vertical components, simultaneously, of the ground motion.
6 - 10 (I)	NEXP	Compute the complex frequency response function for the generalized coordinates at $N = 2^{NEXP}$ harmonic excitation frequencies. The response history of the dam is computed at N time intervals (See Section 5.3).
11 - 20 (F)	DT	Time interval, in seconds, for which response history is computed. Also determines the maximum excitation frequency represented in the response (See Section 5.3).
21 - 30 (F)	ALPHA	Wave reflection coefficient α for the reservoir bottom materials, such as alluvium and sediments. Section 3 gives guidelines for the selection of α. $0 \leq$ ALPHA ≤ 1.
31 - 40 (F)	DFAC	Constant hysteretic damping factor η_s for the dam concrete (See Section 3).

Card Set L - Ground Motion Data

Specify the horizontal and vertical components of the free-field ground acceleration at the base of the dam.

1. Ground motion parameters

1 - 5 (I)	NXUGH	Number of ordinates in the record for the horizontal component of the free-field ground acceleration. Set NXUGH = 0 if IHV = 1 (Card Set K).
6 - 10 (I)	NXUGV	Number of ordinates in the record for the vertical component of the free-field ground acceleration. Set NXUGV = 0 if IHV = 0 (Card Set K).
11 - 20 (F)	TD	Duration of response history computation; TD $\leq$ DT $*2^{NEXP}$, where DT and NEXP are specified in Card Set K.

2. Record for the horizontal component of free-field ground acceleration
   Omit these cards if IHV = 1 (Card Set K).

1 - 5 (F)	Time
6 - 12 (F)	Acceleration
13 - 18 (F)	Time
19 - 24 (F)	Acceleration
•	
•	
•	
61 - 66 (F)	Time
67 - 72 (F)	Acceleration

List six time-acceleration pairs per card in order of increasing time. Repeat cards until NXUGH pairs are specified. The ordinates need not be specified at equal time intervals. Time is in seconds and acceleration is in g's, acceleration due to gravity.

3. Record for the vertical component of free-field ground acceleration
Omit these cards if IHV=0 (Card Set K).

1 - 5 (F)	Time
6 - 12 (F)	Acceleration
13 - 18 (F)	Time
19 - 24 (F)	Acceleration
•	
•	
•	
61 - 66 (F)	Time
67 - 72 (F)	Acceleration

List six time-acceleration pairs per card in order of increasing time. Repeat cards until NXUGV pairs are specified. The ordinates need not be specified at equal time intervals. Time is in seconds and acceleration is in g's, acceleration due to gravity.

Card Set M - Output Control Parameters

Specify parameters that control the printing of response results.

1. Parameters for printed output

1 - 5 (I)	NPRINT	Print nodal point displacements and element stresses every NPRINT time intervals.
6 - 10 (I)	ICOMB	=0, Compute only dynamic response. =1, Compute dynamic response and combine with response due to the static loads.
11 - 15 (I)	ISEL	=0, Print displacements of each nodal point and stresses in each element. =1, Print displacements and stresses for selected nodal points and elements.

If ISEL = 0, leave the remainder of this card blank.

16 - 20 (I) NNODE Number of nodal points for which displacements are printed.

21 - 25 (I) NNELM Number of elements for which stresses are printed.

2. Nodal point selection

Omit these cards if ISEL = 0 or NNODE = 0.

1 - 5 (I)

6 - 10 (I)

•
•
• Nodal point numbers, sixteen per card, for which displacements are printed. Repeat cards until NNODE nodal points are specified.

75 - 80 (I)

3. Element selection

Omit these cards if ISEL = 0 or NNELM = 0.

1 - 5 (I)

6 - 10 (I)

•
•
• Element numbers, sixteen per card, for which stresses are printed. Repeat cards until NNELM elements are specified.

75 - 80 (I)

7. DESCRIPTION OF OUTPUT

7.1 Printed Output

EAGD-84 prints the following information. Some output is suppressed according to the options specified in Card Set B.

1. Program control data
2. Foundation rock properties, including the computed shear wave velocity C_f
3. Material properties, nodal point coordinates and finite element specifications
4. Hydrostatic loads, i.e. the forces on the nodal points at the upstream face of the dam due to hydrostatic pressure of the impounded water. These forces provide a convenient check that the nodal points affected by the impounded water are specified correctly in Card Set G.
5. Nodal point displacements and element stresses due to static loads (weight of the dam and hydrostatic loads)
6. Natural vibration frequencies and mode shapes of the dam if the foundation rock is assumed to be rigid, or of an associated dam-foundation rock system if dam-foundation rock interaction effects are included. A check of the orthogonality relation ensures that the structural stiffness matrix is not numerically ill-conditioned.
7. Absolute value of the complex-valued frequency response functions for acceleration of the generalized coordinates at each excitation frequency
8. The free-field ground acceleration records
9. Nodal point displacements and element stresses at the specified time intervals
10. The largest major principal stress and smallest minor principal stress in each finite element and the times at which they occur
11. A summary of common storage available and used, and an itemization of CPU time for the various computational phases

7.2 Description of TAPE3 Format

The file associated with TAPE3 contains the history of horizontal and vertical displacements at each nodal point and the three planar stress components at the centroid of each finite element. This data may be used for plotting and other post-analysis processing if the file is saved after program execution. TAPE3 is an unformatted FORTRAN file that contains a header record and two records of response results for each of ND time intervals, DT in length, starting at time equals zero. The records are as follows:

Record 1:	NUMNP, NUMEL, NEV, ND, DT
Record 2:	X(2*NUMNP)
Record 3:	S(3*NUMEL)
•	
•	
•	
Record (2*ND):	X(2*NUMNP)
Record (2*ND+1):	S(3*NUMEL)

where NUMNP, NUMEL and NEV are defined in Card Set B; DT is defined in Card Set K; and ND is the number of time intervals for which the response is computed (determined from DT and TD, Card Set L).

X is a one-dimensional array where X(2*I-1) and X(2*I) are the x- and y-components of displacement, respectively, at nodal point I, for I = 1, 2, · · · , NUMNP.

S is a one-dimensional array where S(3*N-2), S(3*N-1) and S(3*N) are the σ_{xx}, σ_{yy} and σ_{xy} components of the stress tensor, respectively, at the centroid of element N, for N = 1, 2, · · · , NUMEL.

7.3 Tape Disposition

EAGD-84 uses files associated with the following logical units:

TAPE1 - scratch tape

TAPE2 - scratch tape

TAPE3 - response history; the format is described in Section 7.2

TAPE5 - input data

TAPE6 - printed output

TAPE80 - Compliance data supplied with EAGD-84 for viscoelastic half-planes. This file is read if IRIG-0 and IGEN=1 (Card Set B).

TAPE90 - Dynamic stiffness matrix for the foundation-rock region. This file is read if IRIG=0 and IGEN=0 (Card Set B). If this file is generated from the compliance data (IRIG-0 and IGEN=1, Card Set B), save it for subsequent program execution.

PUNCH - Vibration frequencies and mode shapes of the dam-foundation rock system; only produced if IOPP=1 (Card Set B).

8. MEMORY STORAGE REQUIREMENTS

The memory storage requirements for EAGD-84 are divided into fixed and variable sectors of core. The fixed sector consists of executable instructions, non-subscripted variables and arrays whose length are independent of the problem size. The variable sector of core is assigned to blank COMMON under the array name A in the main program. The length of the variable sector can be changed as required by the size of the problem. This is done by changing two statements in the main program, as follows:

COMMON A(N)

MSTOR = N

where N is the number of words available in blank common.

The number of words of blank common required for each computational phase of EAGD-84 depends on input parameters that define the size of the problem. The value of N must be greater than the requirements for all the phases, as specified in the criteria listed below:

1. 546*NBASE + 32*NBASE*NBASE
2. N_0 + 12*NBASE
3. N_0 + 41*NUMEL
4. N_0 + 6*NUMNP + NEV*NEV
5. 4*NUMNP + 6*NBASE + 8*NBASE*NBASE + NBC + NPP + 7*NEV + 9*NEV*NEV
   + 2*NEV*NUMNP + 203*NEV*NCOMP + 10*NTERM + 4*(NEV*NTERM+1)
6. 202*NEV + 4*NDATA + 2*NEV*NDATA + 2*max(NXUGH,NXUGV)
7. 5*NUMNP + 43*NUMEL + 2*NEV*NUMNP + 201*NEV

where

N_0 = 2*NUMNP*(MBAND+3) + NBC + NPP + NEV + 2*NBASE + 8*NBASE*NBASE and

MBAND The bandwidth of the structural stiffness matrix. It is equal to:

$$2 * \max_i (mb_i + 1), \quad i=1,2, \cdots \text{NUMEL}$$

where mb_i is the difference between the largest and smallest nodal point numbers for element i.

NBASE Number of nodal points at the base of the dam (Card Set B). It is set to zero if IRIG = 1.

NBC Number of displacement constraints on the nodal points that arise from the boundary condition codes in Card Set E.

NCOMP Number of ground motion components (one or two) included in the response analysis. It is determined from IHV, Card Set K.

NDATA Number of excitation frequencies and time intervals. It is equal to 2^{NEXP}, where NEXP is defined in Card Set K.

NEV Number of generalized coordinates included in the analysis (Card Set B)

NPP Number of nodal points at the upstream face of the dam that are affected by the impounded water (Card Sets B and G).

NTERM Number of natural vibration modes of the impounded water included in the computation of the hydrodynamic pressure. It is equal to:

$$\frac{H}{C * \text{DT}} + 5$$

where H is the depth, in feet, of the impounded water, C=4720 ft/sec, and DT is the time interval (Card Set K).

NUMEL Number of elements (Card Set B).

NUMMAT Number of different materials in the dam (Card Set B).

NUMNP Number of nodal points (Card Set B).

NXUGH Number of horizontal ground acceleration ordinates (Card Set L).

NXUGV Number of vertical ground acceleration ordinates (Card Set L).

If only the static response and vibration properties of the dam are computed (IRES = 1, Card Set B), it suffices to check only criteria (1) to (4) above. If the dynamic stiffness matrix is read from TAPE90 (IGEN = 0, Card Set B), criterion (1) need not be satisfied.

9. EXAMPLE EARTHQUAKE RESPONSE ANALYSIS OF PINE FLAT DAM

To demonstrate the use of the computer program EAGD-84, this section presents an earthquake response analysis of Pine Flat Dam due to the Taft ground motion. The selection of the response parameters is described, the input data card deck is listed, and selected response results are plotted.

9.1 Pine Flat Dam and Ground Motion

Pine Flat concrete gravity dam is constructed of thirty-six monoliths and has a total crest length of 1840 ft [9]. The tallest, non-overflow monolith is 400 ft high, and is selected for analysis. The two-dimensional finite element idealization for this monolith, shown in Figure 6, consists of 136 quadrilateral elements with 162 nodal points. With foundation-rock flexibility considered, the finite element idealization has 324 degrees of freedom. The mass concrete in the dam is assumed to be a homogeneous, isotropic, linear elastic solid with the following properties based, in part, on forced vibration tests of the dam [9]: Young's modulus of elasticity $E_s = 3.25$ million psi, unit weight $= 155$ lb/ft^3, and Poisson's ratio $= 0.2$. Energy dissipation in the dam is represented by a constant hysteretic damping factor of $\eta_s = 0.10$. This value corresponds to a viscous damping ratio of 5% in all natural vibration modes of the dam (without impounded water) on rigid foundation rock, which is higher than the 2 to 3.5% determined from forced vibration tests because of the much larger motions and stress levels expected during strong earthquake ground shaking.

The foundation-rock region supporting the dam monolith is idealized as a homogeneous, isotropic, viscoelastic half-plane. The assumed material properties of the foundation rock are: Young's modulus of elasticity $E_f = 3.25$ million psi, a value which may be reasonable for the fissured granites and basalts at the site; unit weight $= 165$ lb/ft^3, Poisson's ratio $= 1/3$, which gives $C_f = 5852$ ft/sec; and a constant hysteretic damping factor of $\eta_f = 0.10$.

The water in the reservoir impounded by the dam is idealized by a fluid domain that extends to infinity in the upstream direction and has a constant depth of 381 ft, with the water level at El. 951 (Figure 6). This water level is considered a full reservoir condition. The water is assumed to be compressible and have the following properties: velocity of pressure waves $C = 4720$ ft/sec, and unit

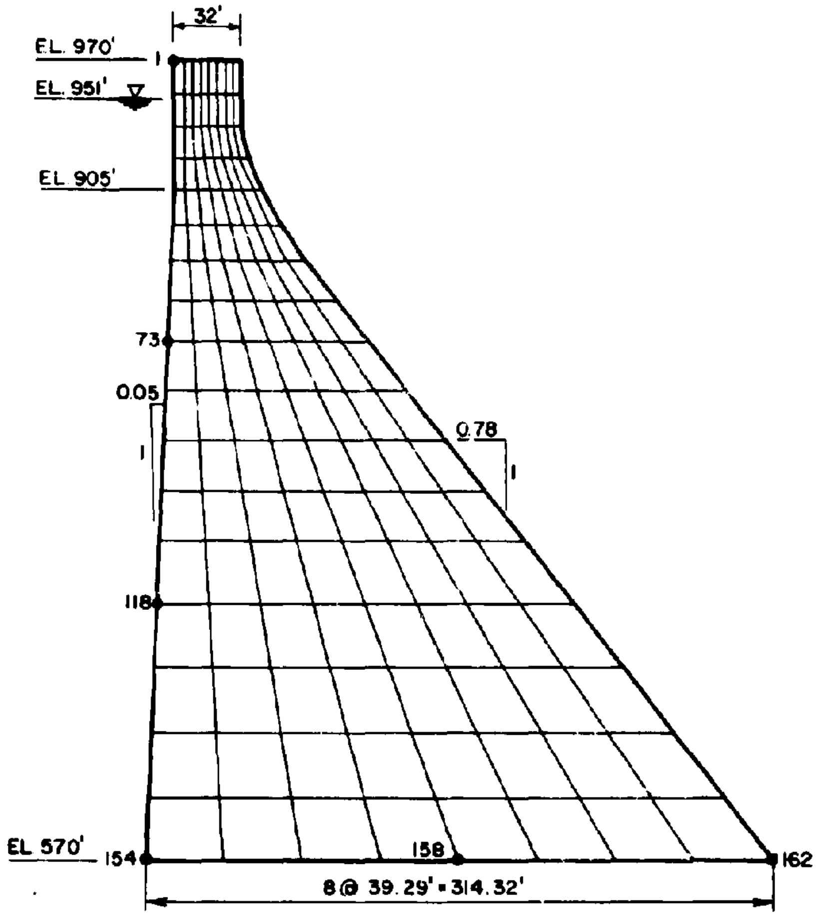

FIGURE 6 Finite element idealization of tallest, non-overflow monolith of Pine Flat Dam.

weight = 62.4 lb/ft^3.

The bottom of a reservoir upstream of a dam may consist of highly variable layers of exposed bedrock, alluvium, silt and other sedimentary material. The value of the wave reflection coefficient α that characterizes the reservoir bottom materials should be selected based on their actual properties, not on properties of the foundation rock. Because there are no available data on the properties of the reservoir bottom materials upstream of Pine Flat Dam, a wave reflection coefficient $\alpha = 0.5$ is arbitrarily selected for this example analysis.

The dam and foundation rock are assumed to be in a state of generalized plane stress. This assumption, though not strictly appropriate for the foundation rock, is dictated by the expected behavior of the non-keyed joints between the dam monoliths [2].

The ground motion recorded at Taft Lincoln School Tunnel during the Kern County, California, earthquake of 21 July 1952 is selected as the free-field ground acceleration for analysis of Pine Flat Dam. The ground motion acting in the horizontal direction, transverse to the axis of the dam, and in the vertical direction is defined as the S69E and vertical components of the recorded ground motion, respectively. These two components and their maximum values of acceleration are shown in Figure 7.

9.2 Response Parameters

The response parameters that govern the computation of the dynamic response must be selected carefully. The dynamic response of Pine Flat Dam is computed for the excitation frequency range 0 to 25 Hertz, i.e. $F = 25$ Hz, which is adequate for the recorded Taft ground motion records. To represent accurately the response of the dam in this frequency range, the first ten generalized coordinates are included in the analysis, i.e. NEV = 10. The vibration frequency of the tenth vibration mode of the associated dam-foundation rock system is $f_{10} = 23.4$ Hz, so the criteria stated in Sections 5.1 and 5.2 are satisfied. The fundamental vibration frequency of the associated dam-foundation rock system is $f_1 = 2.4$ Hz, so according to the criteria in Sections 5.3 and 5.4:

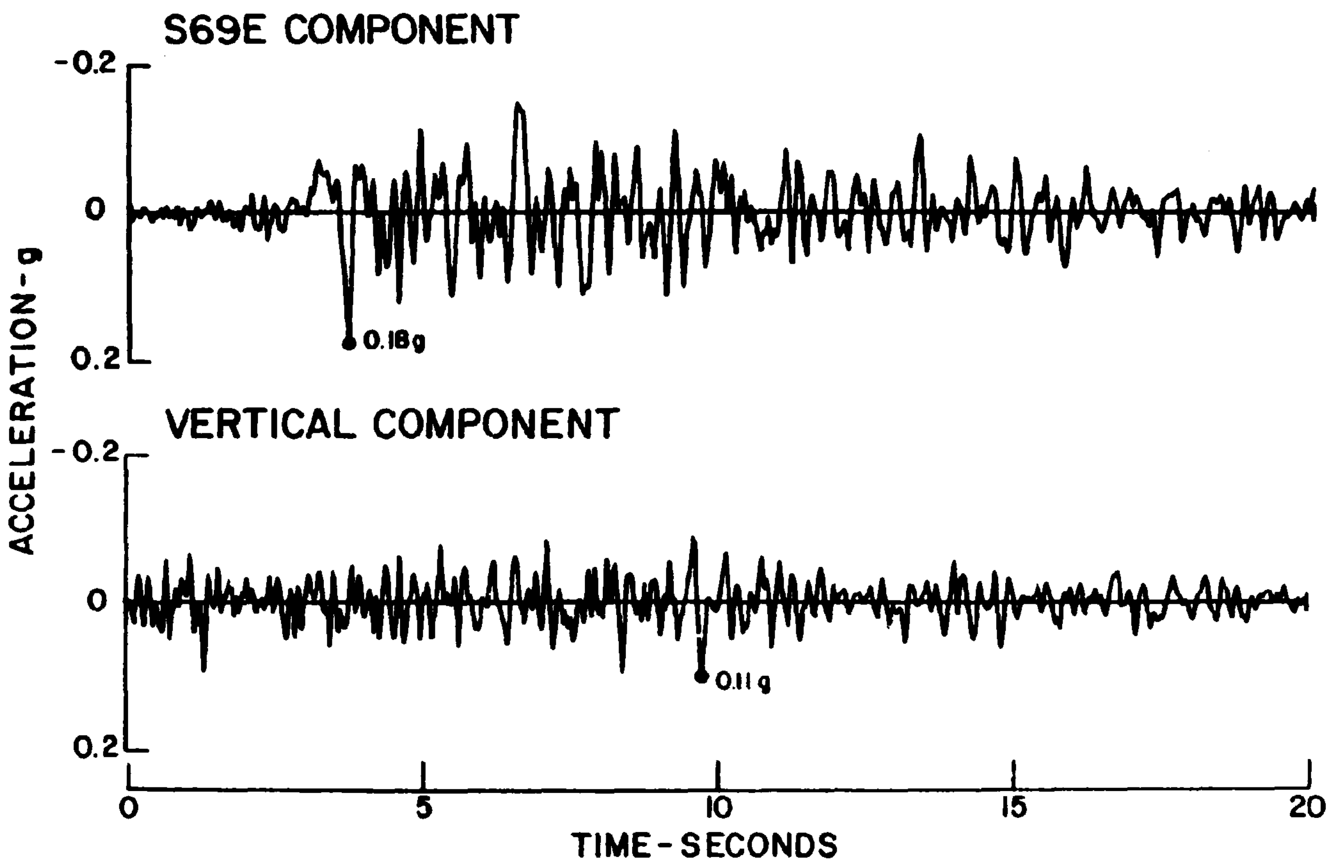

FIGURE 7 Ground motion recorded at Taft Lincoln School Tunnel, Kern County, California, Earthquake 21 July 1952.

$$DT \leq \frac{1}{(2)(25)} = 0.02 \text{ sec}$$

$$DT \cdot 2^{NEXP} \geq \frac{1}{(2.4)} \max\left\{25, \frac{1.5}{(0.10)}\right\} = 10.4 \text{ sec}$$

$$F \leq \frac{5}{2} \frac{5852}{\pi (39.29)} = 118.5 \text{ Hz}$$

The selection of DT=0.02 seconds and NEXP=10 (hence N=1024 and $DT \cdot 2^{NEXP}$=20.48 seconds), satisfies all the aforementioned criteria for the response parameters. With these parameters the response is computed for 20.48 seconds, which is nearly twice the required 10.4 seconds according to the criteria above. These parameters were selected because the number of excitation frequencies (and time intervals) can not be reduced by setting NEXP to 9 without violating the second equation above; and there is no value of setting DT less than 0.02 seconds because the Taft ground motion records are band-limited to 25 Hz. A "quiet zone" of 20.48 seconds is appended to the ground motion records in the computer program to reduce further the aliasing error.

The input data card deck for this example analysis is shown in Listing 1.

9.3 Response Results

A complete analysis of Pine Flat Dam was performed using EAGD-84. The horizontal and vertical displacements, relative to the free-field ground motion, at three levels on the upstream face of the dam (nodal points 1, 73 and 118) and three locations on the base (nodal points 154, 158 and 162) due to the S69E and vertical components, simultaneously, of Taft ground motion are shown in Figure 8. It can be seen that the horizontal and vertical motion of the dam base permitted by foundation-rock flexibility may not be inconsequential compared to the motion in the upper parts of the dam although it is much smaller. Figure 9 shows the distribution of envelope values of maximum principal stresses. Stress results such as these, that include the stresses due to the static loads, make it possible to identify the portions of the dam monolith that may crack during an earthquake. A more complete set of results and their interpretation is presented in the companion report [6].

Listing 1: Input Card Deck for Example Analysis


```
EXAMPLE RESPONSE ANALYSIS OF PINE FLAT DAM DUE TO TAFT GROUND MOTION
  162  136     1     9    10      381.0    17     1  0.0     0                      0     1
  468000.0    .005124       0.10        39.29
    1 468000.    .2          .004814
    1             16.750    400.000
    2             20.750    400.000
    3             24.750    400.000
    4             28.750    400.000
    5             32.750    400.000
    6             36.750    400.000
    7             40.750    400.000
    8             44.750    400.000
    9             48.750    400.000
   10             16.750    383.000
   11             20.750    383.000
   12             24.750    383.000
   13             28.750    383.000
   14             32.750    383.000
   15             36.750    383.000
   16             40.750    383.000
   17             44.750    383.000
   18             48.750    383.000
   19             16.750    367.000
   20             20.750    367.000
   21             24.750    367.000
   22             28.750    367.000
   23             32.750    367.000
   24             36.750    367.000
   25             40.750    367.000
   26             44.750    367.000
   27             48.750    367.000
   28             16.750    351.000
   29             21.156    351.000
   30             25.562    351.000
   31             29.969    351.000
   32             34.375    351.000
   33             38.781    351.000
   34             43.187    351.000
   35             47.594    351.000
   36             52.000    351.000
   37             16.750    335.000
   38             22.156    335.000
   39             27.562    335.000
   40             32.969    335.000
   41             38.375    335.000
   42             43.781    335.000
   43             49.187    335.000
   44             54.594    335.000
   45             60.000    335.000
   46             15.900    318.000
   47             22.662    318.000
   48             29.425    318.000
   49             36.187    318.000
   50             42.950    318.000
   51             49.712    318.000
   52             56.475    318.000
   53             63.237    318.000
   54             70.000    318.000
   55             15.000    300.000
   56             23.165    300.000
   57             31.330    300.000
```

58	39.495	300.000
59	47.660	300.000
60	55.825	300.000
61	63.990	300.000
62	72.155	300.000
63	80.320	300.000
64	14.000	280.000
65	24.240	280.000
66	34.480	280.000
67	44.720	280.000
68	54.960	280.000
69	65.200	280.000
70	75.440	280.000
71	85.680	280.000
72	95.920	280.000
73	13.000	260.000
74	25.315	260.000
75	37.630	260.000
76	49.945	260.000
77	62.260	260.000
78	74.575	260.000
79	86.890	260.000
80	99.205	260.000
81	111.520	260.000
82	11.750	235.000
83	26.659	235.000
84	41.567	235.000
85	56.476	235.000
86	71.385	235.000
87	86.294	235.000
88	101.202	235.000
89	116.111	235.000
90	131.020	235.000
91	10.500	210.000
92	28.002	210.000
93	45.505	210.000
94	63.007	210.000
95	80.510	210.000
96	98.012	210.000
97	115.515	210.000
98	133.017	210.000
99	150.520	210.000
100	9.250	185.000
101	29.346	185.000
102	49.442	185.000
103	69.539	185.000
104	89.635	185.000
105	109.731	185.000
106	129.827	185.000
107	149.924	185.000
108	170.020	185.000
109	8.000	160.000
110	30.690	160.000
111	53.380	160.000
112	76.070	160.000
113	98.760	160.000
114	121.450	160.000
115	144.140	160.000
116	166.830	160.000
117	189.520	160.000
118	6.400	128.000
119	32.410	128.000

120		58.420	128.000
121		84.430	128.000
122		110.440	128.000
123		136.450	128.000
124		162.460	128.000
125		188.470	128.000
126		214.480	128.000
127		4.800	96.000
128		34.130	96.000
129		63.460	96.000
130		92.790	96.000
131		122.120	96.000
132		151.450	96.000
133		180.780	96.000
134		210.110	96.000
135		239.440	96.000
136		3.200	64.000
137		35.850	64.000
138		68.500	64.000
139		101.150	64.000
140		133.800	64.000
141		166.450	64.000
142		199.100	64.000
143		231.750	64.000
144		264.400	64.000
145		1.600	32.000
146		37.570	32.000
147		73.540	32.000
148		109.510	32.000
149		145.480	32.000
150		181.450	32.000
151		217.420	32.000
152		253.390	32.000
153		289.360	32.000
154	0.0	0.	-0.
155	0.0	39.290	-0.
156	0.0	78.580	-0.
157	0.0	117.870	-0.
158	0.0	157.160	-0.
159	0.0	196.450	-0.
160	0.0	235.740	-0.
161	0.0	275.030	-0.
162	0.0	314.320	-0.

1	1	10	11	2	1
9	10	19	20	11	1
17	19	28	29	20	1
25	28	37	38	29	1
33	37	46	47	38	1
41	46	55	56	47	1
49	55	64	65	56	1
57	64	73	74	65	1
65	73	82	83	74	1
73	82	91	92	83	1
81	91	100	101	92	1
89	100	109	110	101	1
97	109	118	119	110	1
105	118	127	128	119	1
113	127	136	137	128	1
121	136	145	146	137	1
129	145	154	155	146	1
136	152	161	162	153	1

0	10	19	28	37	46	55	64	73	82	91	100	109	118	127	136

```
145  154
154  155  156  157  158  159  160  161  162
  2   10        0.02        0.50        0.10
1024 1024       15.00
0.   -.0063    .02-.0019    .04 .0041    .06 .0101    .08 .0053    .10-.0003
 .12-.0043    .14-.0029    .16 .0012    .18 .0054    .20 .0040    .22-.0031
 .24-.0087    .26-.0087    .28-.0061    .30-.0008    .32-.0003    .34-.0002
 .36 .0041    .38 .0107    .40 .0116    .42 .0066    .44 .0045    .46 .0023
 .48 .0021    .50 .0019    .52-.0040    .54-.0075    .56-.0011    .58 .0059
 .60 .0029    .62-.0104    .64-.0115    .66-.0048    .68 .0050    .70 .0010
 .72-.0041    .74-.0025    .76 .0059    .78 .0073    .80-.0066    .82-.0109
 .84 .0033    .86 .0172    .88 .0101    .90-.0049    .92-.0066    .94 .0037
 .96 .0046    .98-.0029   1.00 .0036   1.02 .0146   1.04 .0232   1.06 .0181
1.08 .0186   1.10 .0125   1.12-.0013   1.14-.0087   1.16-.0068   1.18-.0048
1.20 .0041   1.22 .0056   1.24-.0014   1.26-.0041   1.28-.0001   1.30-.0022
1.32-.0087   1.34-.0113   1.36-.0153   1.38-.0187   1.40-.0160   1.42-.0080
1.44-.0003   1.46 .0083   1.48 .0043   1.50-.0078   1.52-.0182   1.54-.0116
1.56 .0009   1.58 .0107   1.60 .0087   1.62 .0075   1.64 .0090   1.66 .0098
1.68 .0016   1.70-.0053   1.72-.0008   1.74 .0068   1.76 .0171   1.78 .0199
1.80 .0138   1.82 .0051   1.84 .0032   1.86 .0119   1.88 .0238   1.90 .0241
1.92 .0063   1.94-.0069   1.96-.0114   1.98-.0097   2.00-.0039   2.02 .0022
2.04 .0023   2.06-.0161   2.08-.0265   2.10-.0092   2.12 .0163   2.14 .0223
2.16 .0170   2.18 .0214   2.20 .0248   2.22 .0187   2.24 .0043   2.26-.0106
2.28-.0238   2.30-.0090   2.32 .0142   2.34 .0369   2.36 .0309   2.38 .0160
2.40 .0115   2.42 .0073   2.44-.0080   2.46-.0134   2.48-.0127   2.50-.0077
2.52 .0068   2.54 .0226   2.56 .0229   2.58 .0199   2.60 .0259   2.62 .0236
2.64 .0120   2.66-.0010   2.68-.0037   2.70-.0114   2.72-.0146   2.74-.0208
2.76-.0200   2.78-.0169   2.80-.0185   2.82-.0178   2.84-.0090   2.86-.0015
2.88-.0050   2.90-.0053   2.92-.0041   2.94-.0093   2.96-.0079   2.98-.0021
3.00 .0035   3.02-.0051   3.04-.0222   3.06-.0363   3.08-.0326   3.10-.0245
3.12-.0326   3.14-.0492   3.16-.0578   3.18-.0620   3.20-.0721   3.22-.0663
3.24-.0545   3.26-.0526   3.28-.0497   3.30-.0507   3.32-.0528   3.34-.0572
3.36-.0490   3.38-.0354   3.40-.0260   3.42-.0172   3.44-.0148   3.46-.0261
3.48-.0402   3.50-.0458   3.52-.0440   3.54-.0240   3.56 .0034   3.58 .0327
3.60 .0556   3.62 .0758   3.64 .0941   3.66 .1204   3.68 .1492   3.70 .1792
3.72 .1637   3.74 .1194   3.76 .0694   3.78 .0187   3.80-.0350   3.82-.0652
3.84-.0623   3.86-.0563   3.88-.0460   3.90-.0477   3.92-.0563   3.94-.0659
3.96-.0574   3.98-.0377   4.00-.0165   4.02 .0047   4.04 .0047   4.06-.0088
4.08-.0227   4.10-.0402   4.12-.0467   4.14-.0214   4.16 .0137   4.18 .0507
4.20 .0350   4.22 .0688   4.24 .0373   4.26-.0015   4.28-.0015   4.30 .0306
4.32 .0564   4.34 .0763   4.36 .0706   4.38 .0630   4.40 .0341   4.42 .0033
4.44-.0323   4.46-.0456   4.48-.0449   4.50-.0166   4.52 .0357   4.54 .0938
4.56 .1234   4.58 .0837   4.60 .0341   4.62-.0220   4.64-.0377   4.66-.0540
4.68-.0564   4.70-.0373   4.72-.0146   4.74 .0111   4.76 .0348   4.78 .0620
4.80 .0695   4.82 .0463   4.84 .0214   4.86 .0005   4.88-.0318   4.90-.0863
4.92-.1133   4.94-.0884   4.96-.0509   4.98-.0098   5.00 .0314   5.02 .0399
5.04 .0281   5.06 .0112   5.08 .0051   5.10 .0006   5.12-.0187   5.14-.0404
5.16-.0526   5.18-.0426   5.20-.0290   5.22-.0182   5.24-.0276   5.26-.0411
5.28-.0575   5.30-.0682   5.32-.0464   5.34-.0153   5.36 .0193   5.38 .0531
5.40 .0883   5.42 .1109   5.44 .1141   5.46 .1046   5.48 .0896   5.50 .0632
5.52 .0277   5.54-.0085   5.56-.0439   5.58-.0506   5.60-.0419   5.62-.0374
5.64-.0481   5.66-.0627   5.68-.0785   5.70-.0929   5.72-.0740   5.74-.0356
5.76 .0071   5.78 .0431   5.80 .0305   5.82 .0019   5.84-.0152   5.86 .0075
5.88 .0368   5.90 .0731   5.92 .0905   5.94 .0640   5.96 .0299   5.98-.0119
6.00-.0217   6.02 .0046   6.04 .0244   6.06 .0328   6.08 .0419   6.10 .0368
6.12 .0233   6.14 .0080   6.16-.0067   6.18-.0154   6.20-.0150   6.22 .0009
6.24 .0293   6.26 .0329   6.28 .0165   6.30-.0069   6.32-.0021   6.34 .0342
6.36 .0761   6.38 .0957   6.40 .0732   6.42 .0632   6.44 .0324   6.46-.0079
6.48-.0525   6.50-.0966   6.52-.1395   6.54-.1492   6.56-.1460   6.58-.1410
6.60-.1364   6.62-.1366   6.64-.1368   6.66-.1111   6.68-.0775   6.70-.0417
6.72-.0053   6.74 .0303   6.76 .0682   6.78 .0847   6.80 .0587   6.82 .0293
6.84-.0095   6.86-.0225   6.88-.0088   6.90 .0089   6.92 .0284   6.94 .0491
```

6.96 .0561	6.98 .0369	7.00 .0144	7.02-.0117	7.04-.0367	7.06-.0599
7.08-.0520	7.10-.0332	7.12-.0116	7.14 .0107	7.16 .0324	7.18 .0550
7.20 .0761	7.22 .1005	7.24 .1029	7.26 .0707	7.28 .0350	7.30-.0068
7.32-.0326	7.34-.0128	7.36 .0009	7.38-.0158	7.40-.0395	7.42-.0592
7.44-.0386	7.46-.0168	7.48-.0225	7.50-.0398	7.52-.0388	7.54-.0139
7.56 .0119	7.58 .0422	7.60 .0691	7.62 .0959	7.64 .1124	7.66 .1086
7.68 .1013	7.70 .0984	7.72 .1033	7.74 .1040	7.76 .0742	7.78 .0364
7.80-.0058	7.82-.0455	7.84-.0906	7.86-.0969	7.88-.0417	7.90-.0158
7.92-.0369	7.94-.0694	7.96-.0834	7.98-.0454	8.00-.0371	8.02-.0206
8.04 .0223	8.06 .0678	8.08 .0849	8.10 .0566	8.12 .0138	8.14-.0306
8.16-.0777	8.18-.0802	8.20-.0438	8.22-.0074	8.24-.0036	8.26-.0150
8.28-.0140	8.30-.0101	8.32-.0140	8.34-.0223	8.36-.0075	8.38 .0173
8.40 .0443	8.42 .0386	8.44 .0094	8.46-.0184	8.48-.0372	8.50-.0534
8.52-.0731	8.54-.0894	8.56-.0897	8.58-.0602	8.60-.0147	8.62 .0378
8.64 .0636	8.66 .0543	8.68 .0422	8.70 .0306	8.72 .0302	8.74 .0237
8.76 .0139	8.78 .0141	8.80 .0318	8.82 .0550	8.84 .0632	8.86 .0439
8.88 .0215	8.90-.0042	8.92-.0288	8.94-.0327	8.96-.0146	8.98 .0026
9.00 .0292	9.02 .0635	9.04 .1005	9.06 .1141	9.08 .0849	9.10 .0500
9.12 .0093	9.14-.0313	9.16-.0718	9.18-.1114	9.20-.1048	9.22-.0656
9.24-.0339	9.26-.0179	9.28 .0127	9.30 .0492	9.32 .0923	9.34 .1029
9.36 .0795	9.38 .0516	9.40 .0257	9.42 .0147	9.44 .0057	9.46-.0020
9.48-.0155	9.50-.0295	9.52-.0455	9.54-.0574	9.56-.0483	9.58-.0325
9.60-.0216	9.62-.0273	9.64-.0156	9.66 .0153	9.68 .0490	9.70 .0771
9.72 .0675	9.74 .0525	9.76 .0424	9.78 .0318	9.80 .0026	9.82-.0295
9.84-.0489	9.86-.0660	9.88-.0715	9.90-.0593	9.92-.0463	9.94-.0287
9.96-.0253	9.98-.0402	10.00-.0602	10.02-.0677	10.04-.0478	10.06-.0244
10.080.	10.10-.0100	10.12-.0352	10.14-.0511	10.16-.0270	10.18 .0038
10.20 .0428	10.22 .0565	10.24 .0348	10.26 .0068	10.28-.0217	10.30-.0169
10.32-.0048	10.34-.0116	10.36-.0295	10.38-.0229	10.40-.0012	10.42 .0149
10.44 .0100	10.46 .0008	10.48-.0094	10.50-.0035	10.52 .0065	10.54 .0154
10.56 .0162	10.58 .0246	10.60 .0352	10.62 .0487	10.64 .0540	10.66 .0419
10.68 .0269	10.70 .0274	10.72 .0313	10.74 .0246	10.76 .0084	10.78 .0066
10.80 .0258	10.82 .0451	10.84 .0411	10.86 .0249	10.88 .0226	10.90 .0306
10.92 .0344	10.94 .0204	10.96 .0034	10.98-.0169	11.00-.0337	11.02-.0492
11.04-.0636	11.06-.0859	11.08-.0829	11.10-.0515	11.12-.0160	11.14 .0210
11.16 .0609	11.18 .0709	11.20 .0345	11.22-.0034	11.24-.0511	11.26-.0698
11.28-.0664	11.30-.0587	11.32-.0339	11.34-.0073	11.36 .0228	11.38 .0433
11.40 .0537	11.42 .0598	11.44 .0401	11.46 .0124	11.48-.0143	11.50-.0248
11.52-.0213	11.54-.0098	11.56 .0015	11.58-.0008	11.600.	11.62 .0128
11.64 .0254	11.66 .0404	11.68 .0347	11.70 .0151	11.72-.0071	11.74-.0303
11.76-.0527	11.78-.0565	11.80-.0505	11.82-.0509	11.84-.0552	11.86-.0484
11.88-.0269	11.90-.0051	11.92 .0205	11.94 .0331	11.96 .0358	11.98 .0324
12.00 .0268	12.02 .0209	12.04 .0161	12.06 .0108	12.08 .0237	12.10 .0422
12.12 .0531	12.14 .0357	12.16 .0129	12.18-.0130	12.20-.0284	12.22-.0387
12.24-.0483	12.26-.0515	12.28-.0386	12.30-.0226	12.32-.0083	12.34-.0111
12.36-.0176	12.38-.0259	12.40-.0167	12.42 .0069	12.44 .0311	12.46 .0564
12.48 .0428	12.50 .0094	12.52-.0301	12.54-.0458	12.56-.0365	12.58-.0268
12.60-.0158	12.62-.0013	12.64 .0164	12.66 .0233	12.68 .0170	12.70 .0258
12.72 .0364	12.74 .0454	12.76 .0451	12.78 .0420	12.80 .0265	12.82 .0371
12.84-.0152	12.86-.0273	12.88-.0267	12.90-.0259	12.92-.0327	12.94-.0416
12.96-.0341	12.98-.0198	13.00-.0038	13.02 .0128	13.04 .0291	13.06 .0386
13.08 .0408	13.10 .0365	13.12 .0301	13.14 .0244	13.16 .0341	13.18 .0483
13.20 .0278	13.22-.0024	13.24-.0371	13.26-.0669	13.28-.0828	13.30-.0932
13.32-.1053	13.34-.0994	13.36-.0696	13.38-.0366	13.40-.0016	13.42 .0345
13.44 .0547	13.46 .0434	13.48 .0285	13.50 .0091	13.52-.0087	13.54-.0254
13.56-.0150	13.58 .0015	13.60 .0220	13.62 .0262	13.64 .0171	13.66 .0064
13.68-.0057	13.70-.0074	13.72-.0024	13.74 .0006	13.76 .0052	13.78 .0095
13.80 .0136	13.82 .0122	13.84 .0158	13.86 .0326	13.88 .0424	13.90 .0285
13.92 .0109	13.94-.0111	13.96-.0195	13.98-.0141	14.00-.0093	14.02-.0357
14.04 .0003	14.06 .0129	14.08 .0283	14.10 .0339	14.12 .0028	14.14-.0288
14.16-.0663	14.18-.0775	14.20-.0658	14.22-.0508	14.24-.0414	14.26-.0360
14.28-.0150	14.30 .0044	14.32 .0163	14.34 .0103	14.36-.0060	14.38-.0098

14.40-.0031	14.42 .0074	14.44 .0036	14.46-.0121	14.48-.0180	14.50-.0253
14.52-.0334	14.54-.0363	14.56-.0338	14.58-.0321	14.60-.0275	14.62-.0104
14.64 .0098	14.66 .0316	14.68 .0431	14.70 .0455	14.72 .0463	14.74 .0399
14.76 .0354	14.78 .0422	14.80 .0544	14.82 .0555	14.84 .0464	14.86 .0301
14.88 .0036	14.90-.0227	14.92-.0517	14.94-.0737	14.96-.0710	14.98-.0606
15.00-.0489	15.02-.0328	15.04-.0107	15.06 .0123	15.08 .0361	15.10 .0581
15.12 .0591	15.14 .0508	15.16 .0407	15.18 .0300	15.20 .0194	15.22 .0088
15.24 .0028	15.26 .0012	15.28-.0087	15.30-.0173	15.32-.0249	15.34-.0273
15.36-.0205	15.38-.0133	15.40-.0203	15.42-.0336	15.44-.0508	15.46-.0412
15.48-.0154	15.50 .0129	15.52 .0410	15.54 .0399	15.56 .0238	15.58 .0077
15.60-.0037	15.62-.0123	15.64-.0218	15.66-.0164	15.68 .0042	15.70 .0255
15.72 .0495	15.74 .0647	15.76 .0710	15.78 .0771	15.80 .0747	15.82 .0579
15.84 .0391	15.86 .0185	15.88-.0016	15.90-.0201	15.92-.0145	15.94-.0026
15.96 .0126	15.98 .0230	16.00 .0194	16.02 .0115	16.04 .0078	16.06 .0008
16.08-.0156	16.10-.0328	16.12-.0527	16.14-.0624	16.16-.0489	16.18-.0303
16.20-.0124	16.22-.0069	16.24-.0006	16.26 .0042	16.28 .0061	16.30 .0083
16.32 .0119	16.34 .0155	16.36 .0217	16.38 .0259	16.40 .0281	16.42 .0269
16.44 .0199	16.46 .0132	16.48 .0095	16.50 .0013	16.52-.0094	16.54-.0201
16.56-.0294	16.58-.0331	16.60-.0264	16.62-.0179	16.64-.0107	16.66-.0064
16.68 .0025	16.70 .0138	16.72 .0213	16.74 .0127	16.76 .0002	16.78-.0107
16.80-.0140	16.82-.0172	16.84-.0222	16.86-.0318	16.88-.0293	16.90-.0179
16.92-.0063	16.94-.0088	16.96-.0158	16.98-.0228	17.00-.0201	17.02-.0151
17.04-.0087	17.06-.0028	17.08 .0039	17.10 .0092	17.12 .0096	17.14 .0071
17.16 .0100	17.18 .0147	17.20 .0207	17.22 .0176	17.24 .0068	17.26-.0035
17.28 .0043	17.30 .0228	17.32 .0422	17.34 .0621	17.36 .0589	17.38 .0431
17.40 .0247	17.42 .0056	17.44-.0131	17.46-.0197	17.48-.0177	17.50-.0180
17.52-.0221	17.54-.0236	17.56-.0208	17.58-.0202	17.60-.0256	17.62-.0280
17.64-.0273	17.66-.0274	17.68-.0316	17.70-.0172	17.72 .0020	17.74 .0254
17.76 .0392	17.78 .0421	17.80 .0348	17.82 .0196	17.84 .0036	17.86-.0031
17.88-.0006	17.90 .0009	17.92-.0042	17.94-.0120	17.96-.0079	17.98 .0017
18.00 .0124	18.02 .0124	18.04 .0075	18.06 .0110	18.08 .0165	18.10 .0219
18.12 .0268	18.14 .0320	18.16 .0343	18.18 .0235	18.20 .0092	18.22-.0057
18.24-.0123	18.26-.0170	18.28-.0187	18.30-.0154	18.32-.0139	18.34-.0101
18.36-.0110	18.38-.0159	18.40-.0222	18.42-.0225	18.44-.0147	18.46-.0064
18.48 .0022	18.50 .0003	18.52-.0058	18.54-.0131	18.56-.0193	18.58-.0114
18.60 .0017	18.62 .0109	18.64 .0196	18.66 .0319	18.68 .0457	18.70 .0552
18.72 .0520	18.74 .0429	18.76 .0244	18.78 .0042	18.80-.0170	18.82-.0366
18.84-.0327	18.86-.0166	18.88 .0017	18.90 .0179	18.92 .0129	18.94 .0026
18.96-.0103	18.98-.0175	19.00-.0199	19.02-.0241	19.04-.0331	19.06-.0365
19.08-.0223	19.10-.0023	19.12 .0180	19.14 .0395	19.16 .0368	19.18 .0169
19.20-.0065	19.22-.0229	19.24-.0269	19.26-.0276	19.28-.0229	19.30-.0146
19.32 .0009	19.34 .0163	19.36 .0342	19.38 .0398	19.40 .0317	19.42 .0257
19.44 .0224	19.46 .0183	19.48 .0119	19.50 .0058	19.52 .0048	19.54 .0079
19.56 .0080	19.58 .0051	19.60 .0025	19.62-.0004	19.64-.0050	19.66-.0115
19.68-.0133	19.70-.0083	19.72-.0050	19.74-.0030	19.76 .0022	19.78 .0112
19.80 .0106	19.82 .0045	19.84-.0030	19.86-.0109	19.88-.0172	19.90-.0142
19.92-.0076	19.94-.0064	19.96-.0175	19.98-.0264	20.00-.0325	20.02-.0262
20.04-.0161	20.06-.0043	20.08 .0041	20.10 .0067	20.12 .0041	20.14-.0018
20.16-.0095	20.18-.0146	20.20-.0164	20.22-.0115	20.24-.0010	20.26 .0115
20.28 .0193	20.30 .0164	20.32 .0119	20.34 .0100	20.36 .0103	20.38 .0080
20.40 .0107	20.42 .0194	20.44 .0296	20.46 .0258		
0. .0273	.02-.0050	.04 .0034	.06-.0017	.08-.0035	.10 .0067
.12 .0222	.14 .0289	.16 .0137	.18-.0051	.20-.0282	.22-.0370
.24-.0211	.26 .0003	.28 .0232	.30 .0323	.32 .0198	.34 .0004
.36-.0226	.38-.0353	.40-.0236	.42-.0033	.44 .0152	.46 .0326
.48 .0194	.50 .0017	.52 .0010	.54 .0156	.56 .0331	.58 .0371
.60 .0400	.62 .0377	.64 .0088	.66-.0277	.68-.0563	.70-.0321
.72 .0082	.74 .0488	.76 .0403	.78 .0178	.80 .0128	.82 .0056
.84-.0178	.86-.0187	.88-.0070	.90 .0073	.92-.0121	.94-.0318
.96-.0296	.98-.0257	1.00-.0169	1.02-.0073	1.04-.0101	1.06-.0363
1.08-.0645	1.10-.0535	1.12-.0239	1.14 .0086	1.16 .0399	1.18 .0338
1.20 .0210	1.22 .0131	1.24-.0008	1.26 .0001	1.28 .0286	1.30 .0607

1.32 .0941	1.34 .0778	1.36 .0381	1.38-.0112	1.40-.0371	1.42-.0258
1.44-.0060	1.46 .0008	1.48-.0019	1.50 .0087	1.52-.0001	1.54-.0255
1.56-.0466	1.58-.0322	1.60-.0008	1.62 .0137	1.64 .0045	1.66-.0086
1.68-.0097	1.70-.0067	1.72-.0159	1.74-.0245	1.76-.0300	1.78-.0333
1.80-.0233	1.82-.0002	1.84 .0188	1.86 .0095	1.88-.0106	1.90-.0066
1.92 .0137	1.94 .0067	1.96-.0098	1.98-.0144	2.00-.0071	2.02-.0148
2.04-.0333	2.06-.0278	2.08-.0059	2.10-.0021	2.12-.0141	2.14-.0186
2.16-.0168	2.18-.0074	2.20 .0103	2.22 .0141	2.24-.0016	2.26-.0018
2.28 .0067	2.30 .0013	2.32-.0062	2.34 .0019	2.36 .0105	2.38 .0033
2.40-.0093	2.42-.0235	2.44-.0353	2.46-.0242	2.48-.0045	2.50 .0144
2.52 .0091	2.54-.0049	2.56-.0216	2.58-.0340	2.60-.0275	2.62-.0147
2.64-.0004	2.66 .0142	2.68 .0282	2.70 .0428	2.72 .0505	2.74 .0382
2.76 .0182	2.78-.0028	2.80-.0181	2.82-.0134	2.84 .0093	2.86 .0433
2.88 .0465	2.90 .0136	2.92-.0209	2.94-.0170	2.96 .0090	2.98 .0365
3.00 .0357	3.02 .0080	3.04-.0060	3.06-.0094	3.08-.0247	3.10-.0380
3.12-.0333	3.14-.0195	3.16-.0138	3.18-.0116	3.20-.0047	3.22-.0068
3.24-.0175	3.26-.0282	3.28-.0416	3.30-.0406	3.32-.0249	3.34-.0064
3.36 .0119	3.38 .0151	3.40 .0062	3.42 .0075	3.44 .0349	3.46 .0600
3.48 .0374	3.50-.0038	3.52-.0416	3.54-.0346	3.56-.0123	3.58 .0141
3.60 .0391	3.62 .0298	3.64 .0178	3.66 .0096	3.68 .0235	3.70 .0357
3.72 .0341	3.74 .0316	3.76 .0285	3.78 .0088	3.80-.0134	3.82-.0398
3.84-.0494	3.86-.0282	3.88-.0022	3.90 .0141	3.92 .0063	3.94-.0146
3.96-.0372	3.98-.0345	4.00-.0147	4.02 .0070	4.04 .0205	4.06 .0185
4.08 .0115	4.10 .0020	4.12-.0060	4.14-.0168	4.16-.0115	4.18 .0151
4.20 .0411	4.22 .0264	4.24 .0080	4.26-.0094	4.28 .0134	4.30 .0483
4.32 .0374	4.34 .0182	4.36 .0020	4.38-.0251	4.40-.0503	4.42-.0477
4.44-.0329	4.46-.0183	4.48-.0002	4.50 .0201	4.52 .0400	4.54 .0493
4.56 .0479	4.58 .0430	4.60 .0121	4.62-.0247	4.64-.0617	4.66-.0443
4.68-.0038	4.70 .0439	4.72 .0562	4.74 .0444	4.76 .0349	4.78 .0167
4.80 .0008	4.82-.0041	4.84-.0117	4.86-.0259	4.88-.0394	4.90-.0348
4.92-.0247	4.94-.0159	4.96 .0042	4.98 .0296	5.00 .0506	5.02 .0321
5.04-.0026	5.06-.0132	5.08-.0060	5.10-.0136	5.12-.0239	5.14-.0142
5.16 .0159	5.18 .0488	5.20 .0484	5.22 .0208	5.24 .0161	5.26 .0160
5.28-.0021	5.30-.0295	5.32-.0598	5.34-.0768	5.36-.0566	5.38-.0280
5.40 .0008	5.42 .0013	5.44-.0055	5.46-.0145	5.48-.0109	5.50-.0059
5.52 .0047	5.54-.0011	5.56-.0155	5.58-.0349	5.60-.0208	5.62 .0167
5.64 .0593	5.66 .0575	5.68 .0239	5.70-.0156	5.72-.0389	5.74-.0440
5.76-.0465	5.78-.0398	5.80-.0090	5.82-.0018	5.84-.0078	5.86-.0093
5.88 .0050	5.90 .0222	5.92 .0367	5.94 .0307	5.96 .0301	5.98 .0384
6.00 .0344	6.02 .0199	6.04 .0026	6.06-.0076	6.08-.0023	6.10 .0019
6.12 .0058	6.14 .0076	6.16-.0046	6.18-.0257	6.20-.0460	6.22-.0548
6.24-.0554	6.26-.0297	6.28-.0102	6.30 .0039	6.32 .0048	6.34 .0036
6.36 .0074	6.38 .0167	6.40 .0244	6.42 .0321	6.44 .0417	6.46 .0548
6.48 .0574	6.50 .0379	6.52 .0130	6.54-.0134	6.56-.0398	6.58-.0555
6.60-.0615	6.62-.0595	6.64-.0443	6.66-.0264	6.68-.0065	6.70 .0088
6.72 .0089	6.74 .0145	6.76 .0280	6.78 .0211	6.80 .0038	6.82-.0164
6.84-.0184	6.86-.0088	6.88 .0052	6.90 .0089	6.92-.0077	6.94-.0319
6.96-.0415	6.98-.0211	7.00 .0058	7.02 .0301	7.04 .0335	7.06 .0379
7.08 .0234	7.10-.0116	7.12-.0487	7.14-.0827	7.16-.0565	7.18-.0182
7.20 .0046	7.22 .0362	7.24 .0632	7.26 .0573	7.28 .0399	7.30 .0188
7.32 .0026	7.34-.0062	7.36-.0183	7.38-.0087	7.40 .0200	7.42 .0305
7.44 .0219	7.46 .0111	7.48 .0207	7.50 .0350	7.52 .0315	7.54 .0207
7.56 .0338	7.58 .0533	7.60 .0510	7.62 .0388	7.64 .0229	7.66 .0087
7.68 .0015	7.70-.0045	7.72 .0014	7.74 .0123	7.76 .0262	7.78 .0281
7.80 .0089	7.82-.0126	7.84-.0386	7.86-.0437	7.88-.0048	7.90 .0198
7.92 .0029	7.94-.0286	7.96-.0469	7.98-.0235	8.00 .0080	8.02 .0164
8.04 .0051	8.06 .0079	8.08 .0182	8.10 .0221	8.12-.0008	8.14-.0281
8.16-.0584	8.18-.0535	8.20-.0296	8.22-.0019	8.24-.0052	8.26-.0230
8.28-.0481	8.30-.0520	8.32-.0241	8.34-.0035	8.36 .0143	8.38 .0378
8.40 .0065	8.42 .0957	8.44 .0862	8.46 .0487	8.48 .0059	8.50-.0310
8.52-.0379	8.54-.0384	8.56-.0399	8.58-.0354	8.60-.0207	8.62-.0051
8.64 .0120	8.66 .0169	8.68 .0069	8.70 .0032	8.72 .0133	8.74 .0261

8.76 .0165	8.78-.0046	8.80-.0260	8.82-.0161	8.84 .0169	8.86 .0249
8.88 .0090	8.90-.0120	8.92-.0285	8.94-.0282	8.96-.0295	8.98-.0313
9.00-.0195	9.02 .0025	9.04 .0269	9.06 .0445	9.08 .0336	9.10 .0157
9.12-.0072	9.14-.0109	9.16 .0115	9.18 .0002	9.20-.0261	9.22-.0555
9.24-.0484	9.26-.0152	9.28 .0035	9.30-.0062	9.32 .0065	9.34 .0333
9.36 .0511	9.38 .0384	9.40 .0240	9.42 .0157	9.44 .0144	9.46 .0068
9.48 .0005	9.50-.0086	9.52-.0236	9.54-.0318	9.56-.0365	9.58-.0506
9.60-.0700	9.62-.0863	9.64-.0819	9.66-.0508	9.68-.0143	9.70 .0253
9.72 .0636	9.74 .1016	9.76 .1048	9.78 .0868	9.80 .0647	9.82 .0419
9.84 .0183	9.86 .0002	9.88-.0061	9.90-.0044	9.92-.0003	9.94 .0042
9.96 .0098	9.98 .0101	10.00 .0128	10.02 .0134	10.04 .0070	10.06-.0028
10.08-.0129	10.10-.0254	10.12-.0393	10.14-.0535	10.16-.0659	10.18-.0670
10.20-.0453	10.22-.0141	10.24 .0176	10.26 .0498	10.28 .0493	10.30 .0259
10.32-.0017	10.34-.0200	10.36-.0235	10.38-.0226	10.40-.0138	10.42 .0052
10.44 .0293	10.46 .0419	10.48 .0340	10.50 .0286	10.52 .0353	10.54 .0312
10.56 .0145	10.58-.0051	10.60-.0144	10.62-.0084	10.64-.0021	10.66 .0103
10.68 .0144	10.70 .0017	10.72-.0173	10.74-.0358	10.76-.0575	10.78-.0606
10.80-.0366	10.82-.0183	10.84-.0166	10.86-.0257	10.88-.0305	10.90-.0059
10.92 .0275	10.94 .0623	10.96 .0570	10.98 .0300	11.00 .0109	11.02-.0011
11.04-.0193	11.06-.0375	11.08-.0544	11.10-.0367	11.12-.0143	11.14-.0068
11.16-.0047	11.18 .0069	11.20 .0216	11.22 .0320	11.24 .0142	11.26-.0117
11.28-.0355	11.30-.0367	11.32-.0325	11.34-.0212	11.36-.0016	11.38 .0188
11.40 .0409	11.42 .0532	11.44 .0421	11.46 .0281	11.48 .0085	11.50 .0058
11.52 .0082	11.54-.0043	11.56-.0172	11.58-.0288	11.60-.0198	11.62-.0059
11.64 .0098	11.66 .0166	11.68 .0206	11.70 .0069	11.72-.0131	11.74-.0335
11.76-.0414	11.78-.0462	11.80-.0402	11.82-.0239	11.84-.0038	11.86 .0097
11.88 .0123	11.90 .0215	11.92 .0271	11.94 .0217	11.96 .0076	11.98-.0105
12.00-.0228	12.02-.0140	12.04 .0007	12.06 .0024	12.08-.0045	12.10-.0115
12.12-.0134	12.14-.0142	12.16-.0159	12.18-.0170	12.20-.0101	12.22-.0002
12.24 .0113	12.26 .0170	12.28 .0128	12.30 .0075	12.32 .0017	12.34-.0049
12.36-.0108	12.38-.0110	12.40-.0095	12.42-.0106	12.44-.0124	12.46-.0077
12.48-.0015	12.50 .0024	12.52 .0012	12.54-.0054	12.56-.0089	12.58-.0068
12.60-.0134	12.62-.0214	12.64-.0186	12.66-.0038	12.68 .0062	12.70 .0113
12.72 .0160	12.74 .0225	12.76 .0151	12.78-.0059	12.80-.0246	12.82-.0310
12.84-.0194	12.86-.0083	12.88-.0025	12.90 .0101	12.92 .0272	12.94 .0358
12.96 .0244	12.98 .0112	13.00 .0055	13.02 .0087	13.04 .0143	13.06 .0165
13.08 .0141	13.10 .0113	13.12 .0077	13.14 .0113	13.16 .0246	13.18 .0377
13.20 .0546	13.22 .0469	13.24 .0238	13.26-.0031	13.28-.0221	13.30-.0169
13.32-.0148	13.34-.0211	13.36-.0156	13.38-.0056	13.40 .0051	13.42 .0052
13.44 .0036	13.46 .0023	13.48-.0011	13.50-.0086	13.52-.0116	13.54-.0144
13.56-.0202	13.58-.0276	13.60-.0203	13.62-.0036	13.64 .0132	13.66 .0124
13.68 .0018	13.70-.0097	13.72-.0222	13.74-.0223	13.76-.0127	13.78-.0014
13.80 .0104	13.82 .0222	13.84 .0337	13.86 .0456	13.88 .0445	13.90 .0305
13.92 .0162	13.94 .0050	13.96-.0021	13.98-.0139	14.00-.0301	14.02-.0518
14.04-.0549	14.06-.0263	14.08 .0095	14.10 .0178	14.12-.0003	14.14-.0207
14.16-.0340	14.18-.0357	14.20-.0360	14.22-.0289	14.24-.0161	14.26-.0021
14.28 .0123	14.30 .0264	14.32 .0413	14.34 .0507	14.36 .0517	14.38 .0499
14.40 .0366	14.42 .0184	14.44-.0001	14.46-.0205	14.48-.0268	14.50-.0065
14.52 .0013	14.54 .0033	14.56 .0055	14.58 .0110	14.60 .0111	14.62 .0095
14.64 .0058	14.66 .0035	14.68-.0072	14.70-.0239	14.72-.0407	14.74-.0306
14.76-.0055	14.78 .0226	14.80 .0501	14.82 .0624	14.84 .0548	14.86 .0410
14.88 .0258	14.90 .0104	14.92-.0048	14.94-.0205	14.96-.0314	14.98-.0276
15.00-.0199	15.02-.0108	15.04-.0006	15.06 .0106	15.08 .0218	15.10 .0238
15.12 .0180	15.14 .0112	15.16 .0038	15.18-.0038	15.20-.0088	15.22-.0065
15.24-.0039	15.26-.0029	15.28-.0040	15.30-.0051	15.32-.0015	15.34 .0010
15.36-.0020	15.38-.0062	15.40-.0085	15.42-.0100	15.44-.0165	15.46-.0226
15.48-.0085	15.50 .0090	15.52 .0154	15.54 .0079	15.56-.0068	15.58-.0200
15.60-.0259	15.62-.0221	15.64-.0103	15.66-.0059	15.68-.0035	15.70 .0091
15.72 .0255	15.74 .0311	15.76 .0246	15.78 .0213	15.80 .0286	15.82 .0373
15.84 .0276	15.86 .0089	15.88-.0060	15.90-.0108	15.92-.0071	15.94-.0037
15.96-.0086	15.98-.0153	16.00-.0191	16.02-.0080	16.04 .0077	16.06 .0192
16.08 .0124	16.10 .0019	16.12-.0116	16.14-.0183	16.16-.0231	16.18-.0239

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16.20-.0119 16.22 .0040 16.24 .0180 16.26 .0147 16.28 .0049 16.30-.0041
16.32-.0054 16.34-.0043 16.36-.0045 16.38-.0069 16.40-.0132 16.42-.0164
16.44-.0090 16.46 .0004 16.480.     16.50-.0042 16.52-.0086 16.54-.0032
16.56 .0055 16.58 .0164 16.60 .0202 16.62 .0130 16.64 .0037 16.66-.0065
16.68-.0166 16.70-.0268 16.72-.0350 16.74-.0352 16.76-.0336 16.78-.0352
16.80-.0408 16.82-.0333 16.84-.0159 16.86 .0024 16.88 .0066 16.90 .0036
16.92 .0019 16.94 .0035 16.96 .0003 16.98-.0108 17.00-.0151 17.02-.0085
17.04 .0038 17.06 .0188 17.08 .0345 17.10 .0455 17.12 .0344 17.14 .0158
17.16-.0002 17.18-.0083 17.20-.0160 17.22-.0207 17.24-.0229 17.26-.0208
17.28-.0113 17.30 .0043 17.32 .0200 17.34 .0360 17.36 .0359 17.38 .0262
17.40 .0164 17.42 .0160 17.44 .0220 17.46 .0269 17.48 .0266 17.50 .0227
17.52 .0187 17.54 .0205 17.56 .0236 17.58 .0198 17.60 .0134 17.62 .0065
17.64-.0004 17.66-.0074 17.68-.0145 17.70-.0214 17.72-.0285 17.74-.0346
17.76-.0298 17.78-.0194 17.80-.0124 17.82-.0080 17.84-.0060 17.86-.0072
17.88-.0050 17.90 .0035 17.92 .0056 17.94 .0021 17.96-.0026 17.98-.0002
18.00 .0071 18.02 .0159 18.04 .0217 18.06 .0244 18.08 .0217 18.10 .0128
18.12 .0055 18.14-.0020 18.16-.0086 18.18-.0110 18.20-.0119 18.22-.0170
18.24-.0231 18.26-.0295 18.28-.0318 18.30-.0323 18.32-.0239 18.34-.0110
18.36 .0023 18.38 .0090 18.40 .0121 18.42 .0163 18.44 .0208 18.46 .0264
18.48 .0257 18.50 .0150 18.52 .0023 18.54-.0109 18.56-.0248 18.58-.0308
18.60-.0231 18.62-.0178 18.64-.0168 18.66-.0154 18.68-.0045 18.70 .0083
18.72 .0225 18.74 .0217 18.76 .0095 18.78-.0051 18.80-.0174 18.82-.0213
18.84-.0148 18.86-.0024 18.88 .0106 18.90 .0225 18.92 .0226 18.94 .0201
18.96 .0231 18.98 .0281 19.00 .0228 19.02 .0133 19.04 .0028 19.06-.0046
19.08-.0065 19.10-.0014 19.12 .0071 19.14 .0126 19.16 .0072 19.18-.0012
19.20-.0085 19.22-.0102 19.24-.0090 19.26-.0069 19.28-.0084 19.30-.0107
19.32-.0136 19.34-.0146 19.36-.0144 19.38-.0136 19.40-.0091 19.42-.0029
19.44 .0007 19.46 .0003 19.48-.0048 19.50-.0105 19.52-.0086 19.54-.0020
19.56-.0009 19.58-.0094 19.60-.0173 19.62-.0220 19.64-.0181 19.66-.0095
19.68-.0005 19.70 .0015 19.72 .0004 19.74 .0037 19.76 .0094 19.78 .0164
19.80 .0159 19.82 .0079 19.84-.0015 19.86-.0045 19.88 .0031 19.90 .0055
19.92-.0001 19.94-.0036 19.96-.0041 19.98-.0020 20.00-.0023 20.02-.0069
20.04-.0124 20.06-.0186 20.08-.0211 20.10-.0190 20.12-.0174 20.14-.0158
20.16-.0109 20.18-.0042 20.20-.0018 20.22-.0044 20.24-.0022 20.26 .0037
20.28 .0104 20.30 .0175 20.32 .0232 20.34 .0262 20.36 .0274 20.38 .0261
20.40 .0254 20.42 .0270 20.44 .0299 20.46 .0265
   20     1     1     6     7
    1    73   118   154   158   162
    1    40    41    56   105   129   136
```

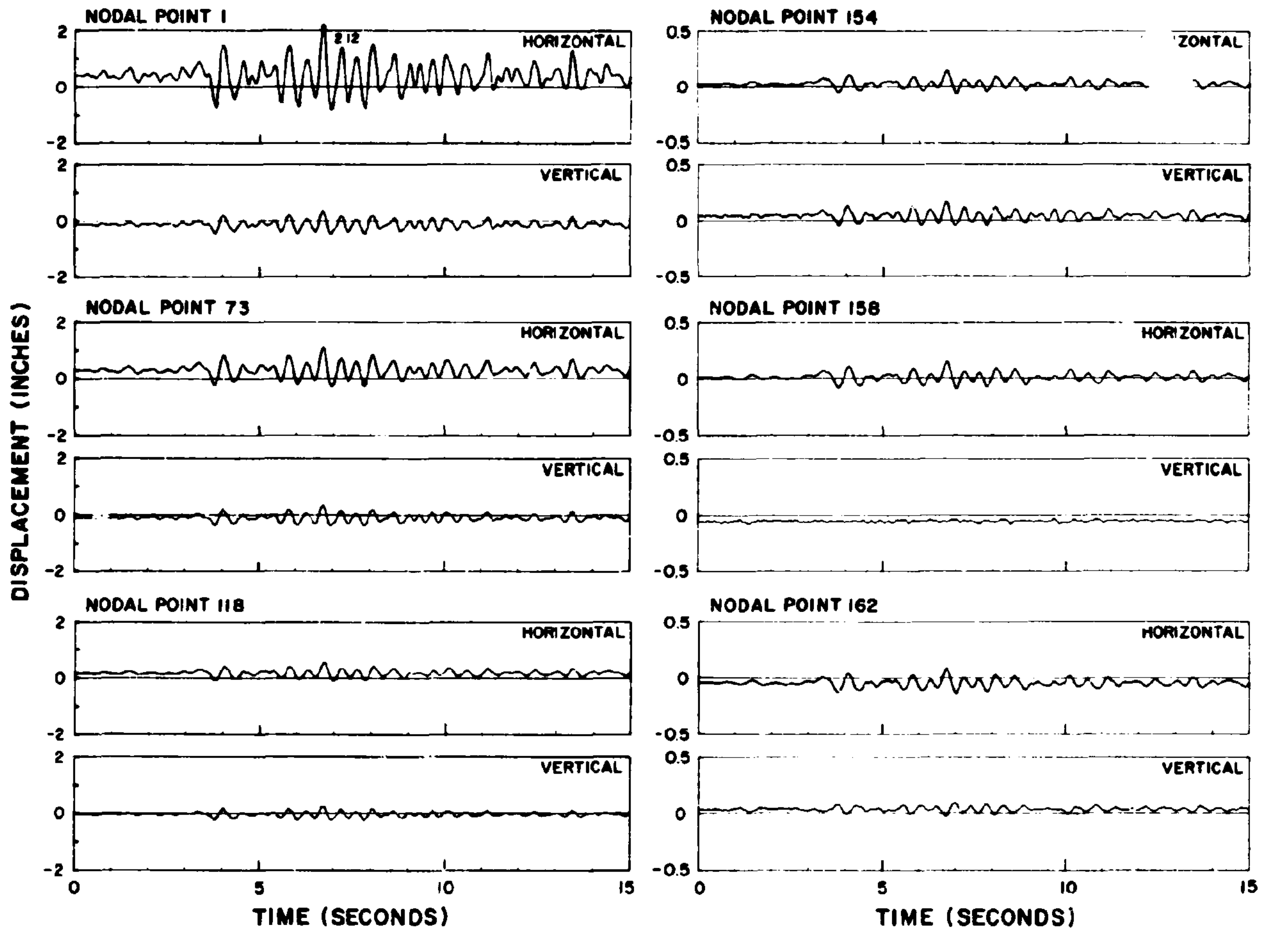

FIGURE 8 Displacement response of Pine Flat Dam on flexible foundation rock with full reservoir and absorptive reservoir bottom (with α=0.5) due to S69E and vertical components, simultaneously, of Taft ground motion.

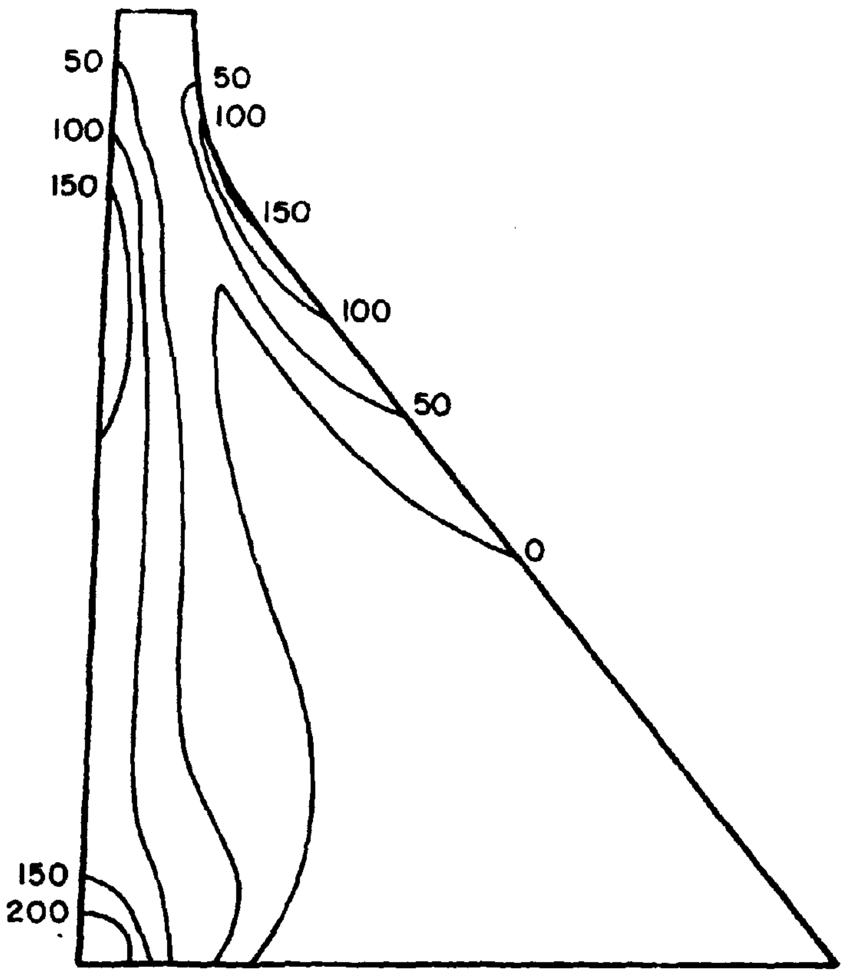

FIGURE 9 Envelope values of maximum principal stresses (in psi) in Pine Flat Dam on flexible foundation rock with full reservoir and absorptive reservoir bottom (with α=0.5) due to S69E and vertical components, simultaneously, of Taft ground motion. Initial static stresses are included.

The computation time required to obtain the complete history of displacements and stresses in the dam (including formation of the dynamic stiffness matrix for the foundation-rock region from the compliance data) is shown in Table 1 for Case 6. Table 1 also includes the computation times required for response analyses of the dam under the other assumptions for the impounded water, the foundation rock and the reservoir bottom materials. Although each of these effects significantly complicate the analysis, the additional computation time required to include them is small. In particular, the extra cost of including reservoir bottom absorption is modest. The efficiency of the analytical procedure, as demonstrated by Table 1, lies in the use of the substructure method along with the transformation of displacements to generalized coordinates.

Table 1 -- Computation Times for Complete Analysis of Pine Flat Dam to S69E and Vertical Components, Simultaneously, of Taft Ground Motion

Case	Foundation Rock	Water	Reservoir Bottom	No. of Generalized Coordinates	Central Processor Time* (sec)
1	rigid	none	-	5	9.2
2	rigid	full	rigid	5	10.0
3	rigid	full	absorptive	5	10.2
4	flexible	none	-	10	13.0
5	flexible	full	rigid	10	14.5
6	flexible	full	absorptive	10	14.8

*CDC 7600 Computer

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APPENDIX A: SOURCE CODE LISTING


```
      PROGRAM EAGD04 (TAPE1,TAPE2,TAPE3,TAPE80,TAPE90,INPUT,OUTPUT,
     *                PUNCH,TAPE5=INPUT,TAPE6=OUTPUT)
C
C**********************************************************************
C                                                                     *
C     PROGRAM IDENTIFICATION  - EAGD-84                               *
C     PROGRAM DESCRIPTION     - EARTHQUAKE ANALYSIS OF GRAVITY DAM -  *
C                               FOUNDATION ROCK - WATER SYSTEMS       *
C     PROGRAMMED BY           - P. CHAKRABARTI                        *
C     MODIFICATIONS BY        - SUNIL GUPTA, GAUTAM DASGUPTA,         *
C                               GREGORY FENVES                        *
C                               UNIVERSITY OF CALIFORNIA, BERKELEY    *
C                                                                     *
C**********************************************************************
C
C     CHANGE THE FOLLOWING TWO CARDS TO MODIFY THE AMOUNT OF AVAILABLE
C     COMMON STORAGE
C
      COMMON A(10000)
      MSTOR =  10000
C
      CALL EAGD1 (A,MSTOR)
      STOP
      END
      SUBROUTINE EAGD1 (A,MSTOR)
C
C     ****************************************************************
C     CONTROL EXECUTION AND ALLOCATE DYNAMIC STORAGE FOR SOLUTION
C     PHASES
C     ****************************************************************
C
      COMMON /CNTRL1/ NUMNP,NBAND,NUMEL,NBC,IGRAV,NPP,WL,TRACE,IOPR,
     *                IOPP,NBASE,IRIG,XJUNK(12)
      COMMON /LABEL/  HED(8)
      COMMON /CNTRL2/ NCATA,NUM,DT,NREST,NOUF,NBLOCK,INV,NCOMP,ISEL,
     *                ICOMB,NPRINT,NO
      COMMON /APCUNC/ NW,NDAMP,ADCSB(91),DMP(4)
C
      DIMENSION A(1)
      DATA T2,T3,T4,T5,T6/5*(0.0)/,PI/3.14159265358979/
C
      NBCON = 1
      N1 = 1
C
C     READ AND PRINT CONTROL INFORMATION
C
      READ  (5,1000) HED,NUMNP,NUMEL,NUMMAT,NBASE,NEV,WL,NPP,
     *               IGRAV,PSP,IRES,IOPR,IOPP,IRIG,IGEN
      WRITE (6,2000) HED,NUMNP,NUMEL,NUMMAT,NBASE,NEV,WL,NPP,
     *               IGRAV,PSP,IRES,IOPR,IOPP,IRIG,IGEN
C
      IF (PSP.EQ.0.0) WRITE (6,2020)
      IF (PSP.NE.0.0) WRITE (6,2021)
C
      CALL SECOND (T1)
      IF (IRIG.EQ.0) GO TO 100
      NBASE=0
      WRITE (6,2100)
      GO TO 105
C
C     READ FOUNDATION ROCK PROPERTIES
C
  100 READ (5,1050) E,RHO,DAMP,RBASE
      IF (IGEN.EQ.0) GO TO 30
C
C     GENERATE DYNAMIC STIFFNESS MATRIX
C
      REWIND 80
      READ (80,1060) MCODE,ES,RNU,NJ,NW,NDAMP,(DMP(I),I=1,NDAMP)
      READ (80,1070) (ADCSB(I+1),I=1,NW)
      ADCSB(1)=0.0
C
      DO 10 I=1,NDAMP
      IF (DAMP.EQ.DMP(I)) GO TO 20
   10 CONTINUE
      WRITE (6,2005) DAMP
      GO TO 200
   20 NREC=6*NW*NJ*(I-1)/4
      NW=NW+1
      REWIND 90
      WRITE (90) MCODE,ES,RNU,NBASE,NW,DAMP
      WRITE (90) (ADCSB(I),I=1,NW)
C
      NB2=NBASE*NBASE
      NNB=8*NBASE*NBASE
      N2=N1+6*NW*NBASE
      N3=N2+NNB
      N4=N3+NNB
      N5=N4+NNB
      NIPPD=N5+NNB
      NBCOM=MAX0(NBCOM,NIPPD)
      IF (NIPPD.GT.MSTOR) GO TO 190
      CALL DMMCTR (A(N1),A(N2),A(N3),A(N4),A(N5),NW,NBASE,
     1             NB2,NJ,NREC,RNU)
C
C     READ DYNAMIC STIFFNESS MATRIX
C
   30 REWIND 90
      READ (90) MCODE,ES,RNU,NJ,NW,XDAMP
      VS=SQRT(0.5*E/(RHO*(1.+RNU)))
      WRITE (6,2600) HED,E,RNU,RHO,DAMP,RBASE,VS
      IF (DAMP.EQ.XDAMP.AND.NBASE.EQ.NJ) GO TO 40
      WRITE (6,2007)
      GO TO 200
   40 READ (90) (ADCSB(I),I=1,NW)
      IF (PSP.EQ.0.) ES=ES*(1.+2.*RNU)/(1.+RNU)**2.
      ESCALE=E/ES
      DWS=VS/RBASE
      DO 50 I=1,NW
   50 ADCSB(I)=ADCSB(I)*DWS
C
C     READ DATA AND FORM ELEMENT PROPERTIES
C
  105 CALL SECOND (T2)
      NEQ=2*NUMNP
      NUM=3*NUMEL
      N2=N1+NUMNP
      N3=N2+NUMNP
      N4=N3+NEQ
      N5=N4+NUMNP
      N6=N5+NUMMAT
      N7=N6+NUMMAT
      NSTIFF=N7+NUMMAT
```

```
      NBCOM=MAX0(NBCCM,NSTIFF)
      IF (NSTIFF.GT.MSTOR) GO TO 190
      CALL STIFF(A(N1),A(N2),A(N3),A(N4),A(N5),A(N6),A(N7),NUMMAT,PSPI)
C
C     FORM TOTAL STIFFNESS AND MASS MATRICES
C
      N4=N3+NBC
      N5 =N4 +NPP
      N6 =N5 +NEQ
      MB2=MBASE*2
      N7=N6+NEV
      N8=N7+2*MB2*MB2
      N9=N8+MB2
      N10=N9+(NEQ*MBAND)
      N11=N10+NEQ
      N12=N11+MB2*3
      NTOTAL=N12+MB2*3
      NBCOM=MAX0(NBCOM,NTOTAL)
      IF (NTOTAL.GT.MSTOR) GO TO 190
      CALL TOTAL (A(N1),A(N2),A(N3),A(N4),A(N5),A(N7),A(N8),A(N9),
     .            A(N10),A(N11),A(N12),NEQ,MBAND,SGN,MB2,ESCALE)
C
C     SOLVE FOR STATIC LOADS
C
      IF (IGRAV.EQ.0) GC TO 140
      N12=N11+NUMEL
      N13=N12+NUMEL
      N14=N13+NUMEL
      N15=N14+NUMEL
      N16=N15+NUM
      N17=N16+24*NUMEL
      N18=N17+2*NUMEL
      NSTATC=N18+8*NUMEL
      NBCOM=MAX0(NBCCM,NSTATC)
      IF (NSTATC.GT.MSTOR) GO TO 190
      CALL STATIC (A(N3),A(N10),A(N9),A(N11),A(N12),A(N13),A(N14),
     .             A(N15),A(N16),A(N17),A(N18),NEQ,MBAND,NUM,NUMEL)
C
C     MODESHAPES AND FRECUENCIES
C
  140 CALL SECOND (T3)
      IF (NEV.LE.0) GC TG 200
      N12=N11+NEQ
      N13=N12+NEQ
      N14=N13+NEQ
      NEIGEN=N14+(NEV*NEV)
      NBCOM=MAX0(NBCCP,NEIGEN)
      IF (NEIGEN.GT.MSTOR) GO TO 190
      CALL EIGEN (A(N3),A(N5),A(N6),A(N7),A(N8),A(N9),A(N10),A(N11),
     .            A(N12),A(N13),A(N14),ESCALE,MB2,NEQ,NEV,MBAND)
      CALL SECOND (T4)
      IF (IRES.NE.0) GO TO 200
C
C     COMPUTE COMPLEX-VALUED FREQUENCY RESPONSE FUNCTIONS FOR
C     GENERALIZED CCCRDINATES
C
      READ (5,1020) INV,NEXP,DT,ALPHA,DFAC1
      NDATA=2**NEXP
      WRITE (6,2070) NEQ,INV,NDATA,DT,ALPHA,DFAC1
      IF (IRIG.NE.0) GO TO 150
      IF (PI/DT.LE.AOCSB(NW)) GO TO 150
      WRITE (6,2071) AOCSB(NW)
      GO TO 200
  150 NEV1=NEV+1
      NWR  =100
      NCOMP=1
      IF (INV.EQ.2) NCOMP=2
      INVD = 1
      IF (NPP.GT.0) INVC = 0
      CALL CCNNTR (A(N2),A(N4),NPP,INVD,DT,WL,NTERM)
      IF (NPP.EQ.0) WRITE (6,2095)
      N10=N9 +(NEQ*NEV)
      N11=N10+2*NEV*NEV
      N13=N11+2*NEV*NEV
      N14=N13+2*N22
      N15=N14+2*(NEV*NCOMP)
      N16=N15+2*(NEV*NEV)
      N17=N16+(NEV*NEV1)
      N18=N17+2*(NEV*NEV)
      N19=N18+NEV
      N20=N19+NEV*NCCMP
      N21=N20+2*NTERM
      N22=N21+2*NTERM
      N23=N22+2*NEV1*NTERM
      N24=N23+2*NEV1*NTERM
      N25=N24+2*NTERM
      N26=N25+2*NEV1
      N27=N26+2*NEV1
      NFR=NDATA+1
      IF (NWR.GT.NFR) NWR=NFR
      NBUF=NWR*NEV
      NKOMPX=N27+2*(NBUF*NCOMP)
      NBCOM=MAX0(NBCCP,NKCMPX)
      IF (NKOMPX.GT.MSTOR) GO TO 190
      CALL KOMPLX(A(N2),A(N4),A(N5),A(N6),A(N7),A(N8),A(N9),A(N10),
     .       A(N11),A(N7),A(N13),A(N14),A(N15),A(N16),A(N17),A(N13),
     .       A(N19),A(N20),A(N21),A(N22),A(N23),A(N24),A(N25),A(N26),
     .       A(N25),A(N25),A(N27),ALPHA,DFAC1,SGN,NEV,NEV1,NEC,NTERM,
     .       NBUF,ESCALE,MB2)
      CALL SECOND (T5)
C
C     TIME RESPONSES OF MCDAL DISPLACEMENTS
C
      READ (5,1030) NXUGH,NXUGV,TO
      NXUG=MAX0(NXUGH,NXUGV)
      IF (NXUG.LE.0) GO TG 200
      WRITE (6,2080) NEQ,NXUGH,NXUGV,TO
      N2=N1+2*(NFR*NEV1)
      N3=N2+2*(NDATA)
      N4=N3+2*NBUF
      N5=N4+NXUG
      NTRNSP=N5+NXUG
      NBCUM=MAX0(NBCCP,NTRNSM)
      IF (NTRNSM.GT.MSTOR) GO TO 190
      CALL TRNFRM (A(N1),A(N2),A(N3),A(N4),A(N5),NEXP,NFR,NEV,T,
     .             NXUGH,NXUGV)
C
C     SUPERPOSITION CF MCDES AND EVALUATION OF STRESSES
C
      READ (5,1040) NPRINT,ICOMB,ISEL,NNODE,NNELM
      WRITE (6,2090) NEQ,NPRINT,ICOMB,ISEL,NNODE,NNELM
      N2 =N1 +NEQ
      N3 =N2 +NEQ
      N4 =N3 +(NEQ*NEV)
```

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      N5 =N4 +NEV                                                       EAGD1.225
      N6 =N5 +2*NBUF                                                    EAGD1.226
      N7 =N6 +NUMEL                                                     EAGD1.227
      N8 =N7 +NUMEL                                                     EAGD1.228
      N9 =N8 +NUMEL                                                     EAGD1.229
      N10=N5 +NUMEL                                                     EAGD1.230
      N11=N10+NNODE                                                     EAGD1.231
      N12=N11+NNELM                                                     EAGD1.232
      N13=N12+ 3*NUMEL                                                  EAGD1.233
      N14=N13+24*NUPEL                                                  EAGD1.234
      N15=N14+ 2*NUPEL                                                  EAGD1.235
      NRESPN=N15+ 8*NUMEL                                               EAGD1.236
      NBCOM=MAX0(NBCCM,NRESPN)                                          EAGD1.237
      IF (NRESPN.GT.MSTGR) GO TO 190                                    EAGD1.238
      CALL RESPNS (A(N1),A(N2),A(N3),A(N4),A(N5),A(N6),A(N7),A(N8),     EAGD1.239
     .     A(N9),A(N10),A(N11),A(N12),A(N13),A(N14),A(N15),NNODE,NNELM, EAGD1.240
     .     NEQ,NEV,NUPEL,NUM)                                           EAGD1.241
      CALL SECOND (T6)                                                  EAGD1.242
      GO TO 200                                                         EAGD1.243
C                                                                       EAGD1.244
  190 WRITE (6,2010)                                                    EAGD1.245
  200 CALL JOBLOG (NSTOP,NBCOM,T1,T2,T3,T4,T5,T6)                       EAGD1.246
      RETURN                                                            EAGD1.247
C                                                                       EAGD1.248
 1000 FORMAT (8A10/5I5,F10.0,2I5, F5.0,4I5)                             EAGD1.249
 1020 FORMAT (2I5,3F10.0)                                               EAGD1.250
 1030 FORMAT (2I5, F10.0)                                               EAGD1.251
 1040 FORMAT (5I5)                                                      EAGD1.252
 1050 FORMAT (8F10.3)                                                   EAGD1.253
 1060 FORMAT (I2,2F10.0,3I5,4F8.0)                                      EAGD1.254
 1070 FORMAT (10F7.0)                                                   EAGD1.255
 2000 FORMAT (1H1,20X,8A10///                                           EAGD1.256
     . 1X,19(1H*)/20H CONTROL INFORMATION/1X,19(1H*)//                  EAGD1.257
     . 50H0NUMBER OF NODAL POINTS..............................I4/      EAGD1.258
     . 50H0NUMBER OF ELEMENTS..................................I4/      EAGD1.259
     . 50H0NUMBER OF DIFFERENT MATERIALS.......................I4/      EAGD1.260
     . 50H0NUMBER OF BASE CONNECTION NODES AT FOUNDATION....I4/         EAGD1.261
     . 50H0NUMBER OF GENERALIZED COORDINATES (EIGENVALUES)..I4/         EAGD1.262
     . 50H0WATER LEVEL IN THE RESERVOIR.....................F10.3,3H FT/EAGD1.263
     . 50H0NUMBER OF UPSTREAM NODES TOUCHING WATER..........I4/         EAGD1.264
     . 50H0CODE FOR STATIC ANALYSIS.........................I4/         EAGD1.265
     . 50H0CODE FOR PLANE STRESS/STRAIN MODEL...............1X,F5.1/    EAGD1.266
     . 50H0CODE FOR DYNAMIC ANALYSIS........................I4/         EAGD1.267
     . 50H0CODE FOR READING MODE SHAPES AND FREQUENCIES....I4/          EAGD1.268
     . 50H0CODE FOR PUNCHING MODE SHAPES AND FREQUENCIES....I4/         EAGD1.269
     . 50H0CODE FOR INCLUDING FOUNDATION-ROCK INTERACTION...I4/         EAGD1.270
     . 50H0CODE FOR GENERATING DYNAMIC STIFFNESS MATRIX.....I4/)        EAGD1.271
 2005 FORMAT (82H0***** FOUNDATION COMPLIANCE DATA NOT AVAILABLE FOR REQEAGD1.272
     .UESTED DAMPING COEFFICIENT  ,F10.5)                               EAGD1.273
 2007 FORMAT (91H0***** PROPERTIES OF  DYNAMIC  STIFFNESS  MATRIX ON TAEAGD1.274
     .E90 DO NOT MATCH THE SPECIFIED ONES )                             EAGD1.275
 2010 FORMAT(////42H ***** BLANK COMMON STORAGE EXCEEDED *****////)     EAGD1.276
 2020 FORMAT (///1X,5(1H*),40H THE FOLLOWING IS A PLANE STRESS PROBLEM, EAGD1.277
     .         5(1H*)////)                                              EAGD1.278
 2021 FORMAT (///1X,5(1H*),40H THE FOLLOWING IS A PLANE STRAIN PROBLEM, EAGD1.279
     .         5(1H*)////)                                              EAGD1.280
 2060 FORMAT (1H1,                                                      EAGD1.281
     . 20X,8A10//1X,29(1H*)/30H FOUNDATION ROCK SPECIFICATION /1X,      EAGD1.282
     . 29(1H*)///                                                       EAGD1.283
     . 31H YOUNGS MODULUS                = E12.5,7H K/SFT,//            EAGD1.284
     . 31H POISSONS RATIO                = F12.5//                      EAGD1.285
     . 31H MASS DENSITY                  = F12.5,15H K-SEC**2/FT**4//   EAGD1.286
     . 31H HYSTERETIC DAMPING FACTOR     = F12.5//                      EAGD1.287
     . 31H BASE NODE SPACING             = F12.5,4H FT.//               EAGD1.288
     . 31H SHEAR WAVE VELOCITY           = F12.5,7H FT/SEC//)           EAGD1.289
 2070 FORMAT (1H1,                                                      EAGD1.290
     . 20X,8A10//1X,16(1H*)/17H DYNAMIC ANALYSIS /1X,16(1H*)///         EAGD1.291
     . 50H0 CODE FOR GROUND MOTION COMPONENT, IHV...........I5/         EAGD1.292
     . 50H0 NUMBER OF POINTS FOR FREQUENCY RESPONSE.........I5/         EAGD1.293
     . 50H0 TIME STEP FOR RESPONSE..........................F10.5,5H SECEAGD1.294
     ../ 50H0 WAVE REFLECTION COEF FOR RESERVOIR BOTTOM.......F10.5/    EAGD1.295
     .    50H0 HYSTERETIC DAMPING FACTOR FOR DAM CONCRETE......F10.5)   EAGD1.296
 2071 FORMAT (63H0***** MAXIMUM FREQUENCY FOR  DYNAMIC  STIFFNESS  MATRIEAGD1.297
     .X IS ,F12.5,41H RAD/SEC,  TOO SMALL FOR REQUESTED RANGE. )        EAGD1.298
 2080 FORMAT (1H1/20X,8A10//                                            EAGD1.299
     . 55H0 NUMBER OF ORDINATES FOR HORIZONTAL EARTHQUAKE DATA...I5/    EAGD1.300
     . 55H0 NUMBER OF ORDINATES FOR   VERTICAL EARTHQUAKE DATA...I5/    EAGD1.301
     . 55H0 TIME DURATION OF RESPONSE...........................F10.3,5EAGD1.302
     .H SEC./)                                                          EAGD1.303
 2090 FORMAT (1H1,                                                      EAGD1.304
     . 20X,8A10//1X,32HCONTROL INFORMATION FOR RESPONSE /               EAGD1.305
     .          1X,32H--------------------------------//                EAGD1.306
     . 55H0 NUMBER OF PRINT INTERVALS...............................I4/ EAGD1.307
     . 55H0 CODE FOR COMBINING DYNAMIC AND STATIC STRESSES.........I4/  EAGD1.308
     . 55H0 CODE FOR SELECTION OF RESPONSE PRINT OUT...............I4/  EAGD1.309
     . 55H0 NUMBER OF   NODES  FOR WHICH RESPONSES ARE PRINTED...I4/    EAGD1.310
     . 55H0 NUMBER OF ELEMENTS FOR WHICH RESPONSES ARE PRINTED...I4)    EAGD1.311
 2095 FORMAT (////46H HYDRODYNAMIC EFFECT OF RESERVOIR NOT INCLUDED //) EAGD1.312
 2100 FORMAT (///1X,5(1H*),24H THE FOUNDATION IS RIGID,5(1H*)///)       EAGD1.313
      END                                                               EAGD1.314
      SUBROUTINE CONNTR (Z,IJBC,NPP,IHYD,DT,WL,NTERM)                   CONNTR.2
C                                                                       CONNTR.3
C     ******************************************************************CONNTR.4
C     COMPUTE NUMBER OF IMPOUNDED WATER MODES TO USE IN ANALYSIS        CONNTR.5
C     ******************************************************************CONNTR.6
C                                                                       CONNTR.7
      DIMENSION Z(1),IJBC(1)                                            CONNTR.8
      DATA CC/4720.0/,NTERM1/5/                                         CONNTR.9
C                                                                       CONNTR.10
      NTERM = 0                                                         CONNTR.11
      IF (IHYD.NE.0) RETURN                                             CONNTR.12
      LT = IJBC(NPP)                                                    CONNTR.13
      NTERM = (WL-Z(LT))/(CC*DT) + NTERM1                               CONNTR.14
      RETURN                                                            CONNTR.15
      END                                                               CONNTR.16
      SUBROUTINE BANEIG(NN,MM,NEV,NBC,EV,NEBC,SMASS,A,B,V,R,CN,SN,TRACE)BANEIG.2
C                                                                       BANEIG.3
C     ******************************************************************BANEIG.4
C     SOLVE THE SYMMETRIC BANDED EIGENVALUE PROBLEM                     BANEIG.5
C     ******************************************************************BANEIG.6
C                                                                       BANEIG.7
      DIMENSION EV(1),NEBC(1),SMASS(1), A(NN,1),B(1),R(1),SN(1),CN(1),  BANEIG.8
     1          V(1)                                                    BANEIG.9
C                                                                       BANEIG.10
C     INITIALIZE                                                        BANEIG.11
C                                                                       BANEIG.12
      TOL=1.0E-12                                                       BANEIG.13
      IFLAG = 0                                                         BANEIG.14
      NLOOP = 5                                                         BANEIG.15
      NSMAX = 50                                                        BANEIG.16
      PSHIFT = 0.                                                       BANEIG.17
      MM1 = MM + 1                                                      BANEIG.18
      NW = NN*MM                                                        BANEIG.19
      NEIG = 0                                                          BANEIG.20
```

```
      NR = NN
      NNR = NN - 1
      REWIND 2
C
C     REDUCE TO CLASSICAL EIGENVALUE PROBLEM  A*X = E*X
C
      DO 120  I = 1,NN
      X = SMASS(I)
      IF (X.GT.0.)  GO TO 110
      PRINT 12, I
   12 FORMAT (30HONEG. OR ZERO MASS, EQUATION = I5)
      IFLAG = 1
      GO TO 120
  110 SMASS(I) = 1./SQRT(X)
  120 CONTINUE
      IF (IFLAG.NE.0)  STOP
      DO 130  I = 1,NN
      L = I - 1
      NR = MINO (MM,NN-I+1)
      DO 130  J = 1,NR
      K = L + J
  130 A(I,J) = A(I,J)*SMASS(I)*SMASS(K)
C
C     IMPOSE BOUNDARY CONDITIONS ON A
C
      IF (NBC.LE.0)  GO TO 150
      DO 140  N = 1,NBC
      I = NBDC(N)
      A(I,1) = 100.*TRACE
      DO 140 J=2,MM
      A(I,J)=0.
      L=I-J+1
      IF (L.LE.0) GO TO 140
      A(L,J)=0.
  140 CONTINUE
C
C     COMPACT MATRIX A INTO A ONE-DIMENSIONAL ARRAY V
C
  150 DO 160  J = 1,MM
      L = NN*(J-1)
      M = NN - J + 1
      DO 160  I = 1,M
      K = L + I
  160 V(K) = A(I,J)
      WRITE (2) (V(I),I=1,NN)
C
C     COMPUTE SMALLEST EIGENVALUE AND ASSOCIATE EIGENVECTOR OF A
C     BY INVERSE ITERATION
C
 1000 NEIG = NEIG + 1
      E1 = 0.
      SHIFT = 0.
      NS = 0
      KKK = 2
      CALL BANSOL (NR,MP,NN,V,B,0)
      DO 170  I = NR,NN
  170 B(I) = 0.
      DO 180  I = 1,NR
  180 B(I) = 1.
      IF (NBC.LE.0)  GO TO 200
      DO 190  N = 1,NBC
      I = NBDC(N)
  190 B(I) = 0.
  200 NS = NS + 1
      CALL BANSOL (NR,MM,NN,V,B,KKK)
      KKK = 1
      E = 0.
      DO 220  I = 1,NR
      IF (ABS(B(I)).GT.ABS(E))  E = B(I)
  220 CONTINUE
      E = 1./E
      EPS = (E-E1)/E*100.
      DO 230  I = 1,NR
  230 B(I) = B(I)*E
      E1 = E
      IF (ABS(EPS).GT.1..AND.NS.LT.15)  GO TO 200
      NL = NLOOP - 3
  250 DO 260  I = 1,NR
  260 R(I) = B(I)
      NS = NS + 1
      CALL BANSOL (NR,MM,NN,V,B,1)
      E = 0.
      DO 300  I = 1,NR
      IF (ABS(B(I)).GT.ABS(E))  E = B(I)
  300 CONTINUE
      DMAX = 0.
      SUMD = 0.
      DO 320  I = 1,NR
      B(I) = B(I)/E
      D = ABS(B(I)-R(I))
      IF (D.GT.DMAX)  DMAX = D
  320 SUMD = SUMD + D**2
      IF (DMAX.LE.TOL.OR.NS.GE.NSMAX)  GO TO 400
      NL = NL + 1
      IF (NL.LT.NLOOP)  GO TO 250
      REWIND 2
      READ(2)  (V(I),I=1,NN)
      NL = 0
      X = 0.
      Y = 0.
      DO 340  I = 1,NR
      X = X + B(I)*R(I)
  340 Y = Y + B(I)*B(I)
      SHIFT = SHIFT + APAX1(1.,-4.*SUMD-0.9)*X/(Y*E)
      DO 350  I = 1,NR
  350 V(I) = V(I) - SHIFT
      CALL BANSOL (NR,MP,NN,V,B,0)
      GO TO 250
  400 X = 0.
      Y = 0.
      DO 420  I = 1,NR
      X = X + B(I)*R(I)
  420 Y = Y + B(I)*B(I)
      SHIFT = SHIFT + X/(Y*E)
      EV(NEIG) = SHIFT + PSHIFT
      SHIFT = SHIFT - TOL
      PSHIFT = EV(NEIG) - TOL
      Y = SQRT(Y)
      DO 430  I = 1,NR
  430 R(I) = B(I)/Y
      IF (NEIG.GE.NEV)  GO TO 650
C
C     DEFLATE BAND MATRIX
C
```

```
      REWIND 2
      READ(2)  (V(I),I=1,MM)
      DO 650  MX = 1,MR
      FB = F(MX)
      IF (FB.NE.0.)  GO TO 400
  650 CONTINUE
  400 DO 500  I = 1,NR
      L = NB + I
      V(I) = V(I) - SHIFT
  500 V(L) = 0.
      NRS = NR - 1
      NR1 = NR + 1
      Q1 = B(1)**2
      S2 = 0.
      C  = 1.
      DO 600  I = 1,NRS
      K = I + 1
      Q = Q1 + B(K)**2
      IF (I.LT.MX)  GO TO 550
      S2 = Q1/Q
      C = B(K)/SQRT(Q)
      IF (FB.LT.0.)  C = -C
  550 S = SQRT(S2)
      C2 = C*C
      SN(I) = S
      CN(I) = C
      Q1 = C
      L = NR + I
      A11 = V(I)
      A22 = V(K)
      A12 = V(L)
      X = 2.*A12*S*C
      V(I) = A11*C2 + A22*S2 - X
      V(K) = A22*C2 + A11*S2 + X
      V(L) = A12*(C2-S2) + (A11-A22)*S*C
      MR = MIN0 (I,MR)
      IF (MR.LE.1)  GO TO 570
      L1 = I
      DO 560  J = 2,MR
      L1 = L1 + NNR
      L2 = L1 + NN
      A1 = V(L1)
      A2 = V(L2)
      V(L1) = A1*C - A2*S
  560 V(L2) = A2*C + A1*S
  570 MR = MIN0 (MM1,NR1-I)
      IF (MR.LT.3)  GO TO 600
      L2 = K
      DO 580  J = 3,MR
      L2 = L2 + NN
      L1 = L2 + NNR
      A1 = V(L1)
      A2 = V(L2)
      V(L1) = A1*C - A2*S
  580 V(L2) = A2*C + A1*S
  600 CONTINUE
C
C     DEFLATED MATRIX, EIGENVECTOR, SINES AND COSINES OF
C     JACOBI ROTATION MATRICES ARE STORED ON TAPE
C
      REWIND 2
      WRITE (2) (V(I),I=1,MM)
      WRITE (1) (R(I),SN(I),CN(I),I=1,NN)
      NR = NR - 1
      IF (NEC.LE.0)  GO TO 1000
      DO 620  N = 1,NEC
      I = NEC(N)
      IF (I.GE.NX)  NEC(N) = I - 1
  620 CONTINUE
      GO TO 1000
C
C     RECOVER EIGENVECTORS OF ORIGINAL MATRIX
C     AND CHECK EIGENVALUE ARRANGEMENT
C
  650 DO 700  I = 1,NN
  700 A(I,NEV) = R(I)
      IF (NEV.LE.1)  GO TO 900
      LL = NEV - 1
      DO 800  N = 1,LL
      P = NEV - N
      NRS = NN - P
      NR = NRS + 1
      BACKSPACE 1
      READ  (1)(A(I,P),SN(I),CN(I), I=1,NN)
      BACKSPACE 1
      KK = P + 1
      DO 800  L = 1,NRS
      I = NR - L
      K = I + 1
      DO 800  J = KK,NEV
      A1 = A(I,J)
      A2 = A(K,J)
      A(I,J) = A1*CN(I) + A2*SN(I)
  800 A(K,J) = A2*CN(I) - A1*SN(I)
      DO 830  K = 1,LL
      M = LL - K + 1
      DO 830  J = 1,M
      E1 = EV(J)
      E2 = EV(J+1)
      IF (E1.LT.E2)  GO TO 830
      EV(J+1) = E1
      EV(J)   = E2
      DO 820  I = 1,NN
      TEMP = A(I,J)
      A(I,J) = A(I,J+1)
  820 A(I,J+1) = TEMP
  830 CONTINUE
  900 DO 920  I = 1,NN
      X = SMASS(I)
      SMASS(I) = 1./X**2
      DO 920  J = 1,NEV
  920 A(I,J) = A(I,J)*X
      RETURN
      END
      SUBROUTINE BANSOL (NN,MM,NDIF,A,B,KKK)
C
C     ****************************************************************
C     IN CORE LINEAR EQUATION SOLVER FOR SYMMETRIC BAND MATRICES
C      KKK = 0  TRIANGULARIZES BAND MATRIX A
C      KKK = 1  REDUCES AND BACKSUBSTITUTES VECTOR B
C      KKK = 2  BACKSUBSTITUTES VECTOR B
C     ****************************************************************
C
      DIMENSION A(NDIF,1), B(1)
```

```
      MA = NN - 1                                                        BANSOL.12
      IF (NN-1)  100,300,400                                             BANSOL.13
  100 DO 200  N = 1,MA                                                   BANSOL.14
      N = N - 1                                                          BANSOL.15
      IF (A(N,1).EQ.0.)   A(N,1)  = 1.0E-36                              BANSOL.16
      PIVOT = A(N,1)                                                     BANSOL.17
      MR = MINO (MM,NN-N)                                                BANSOL.18
      DO 200  L = 2,MR                                                   BANSOL.19
      C = A(N,L)/PIVOT                                                   BANSOL.20
      IF (C.EQ.0.)  GO TO 200                                            BANSOL.21
      I = N + L                                                          BANSOL.22
      J = 0                                                              BANSOL.23
      DO 100  K = L,MR                                                   BANSOL.24
      J = J + 1                                                          BANSOL.25
  100 A(I,J) = A(I,J) - C*A(N,K)                                         BANSOL.26
      A(N,L) = C                                                         BANSOL.27
  200 CONTINUE                                                           BANSOL.28
      IF (A(NN,1).EQ.0.)  A(NN,1) = 1.0E-16                              BANSOL.29
      GO TO 500                                                          BANSOL.30
  300 DO 350  N = 1,NN                                                   BANSOL.31
      M = N - 1                                                          BANSOL.32
      MR = MINO (MM,NN-M)                                                BANSOL.33
      C = B(N)                                                           BANSOL.34
      B(N) = C/A(N,1)                                                    BANSOL.35
      DO 350  L = 2,MR                                                   BANSOL.36
      I = M + L                                                          BANSOL.37
  350 B(I) = B(I) - A(N,L)*C                                             BANSOL.38
  400 B(NN) = B(NN)/A(NN,1)                                              BANSOL.39
      DO 450  K = 2,NN                                                   BANSOL.40
      M = NA - K                                                         BANSOL.41
      N = M + 1                                                          BANSOL.42
      MR = MINO (MM,K)                                                   BANSOL.43
      DO 450  L = 2,MR                                                   BANSOL.44
      I = M + L                                                          BANSOL.45
  450 B(N) = B(N) - A(N,L)*B(I)                                          BANSOL.46
  500 RETURN                                                             BANSOL.47
      END                                                                BANSOL.48
      SUBROUTINE CINTER (T,X,NX,N,DT,C)                                  CINTER.2
C                                                                        CINTER.3
C     ******************************************************************CINTER.4
C     INTERPOLATE T AND X INTO C AT DT INTERVALS                         CINTER.5
C     ******************************************************************CINTER.6
C                                                                        CINTER.7
      DIMENSION T(1),X(1),C(1)                                           CINTER.8
C                                                                        CINTER.9
      C(1)=X(1)                                                          CINTER.10
      I=0                                                                CINTER.11
      T1=T(1)                                                            CINTER.12
C                                                                        CINTER.13
      DO 10 J=2,N                                                        CINTER.14
      TJ=FLOAT(J-1)*DT                                                   CINTER.15
    5 IF (TJ.LE.T(I+1)-T1) GO TO 10                                      CINTER.16
      I=I+1                                                              CINTER.17
      IF (I.GE.NX) RETURN                                                CINTER.18
      SCALE=(X(I+1)-X(I))/(T(I+1)-T(I))                                  CINTER.19
      GO TO 5                                                            CINTER.20
   10 C(J)=X(I)+SCALE*(TJ-T(I)+T1)                                       CINTER.21
      RETURN                                                             CINTER.22
      END                                                                CINTER.23
      SUBROUTINE CSYMEQ(A,B,NN,LL)                                       CSYMEQ.2
C                                                                        CSYMEQ.3
C     ******************************************************************CSYMEQ.4
```

```
C     SOLVE SYMMETRIC SYSTEM OF COMPLEX LINEAR EQUATIONS                 CSYMEQ.5
C     ******************************************************************CSYMEQ.6
C                                                                        CSYMEQ.7
      COMPLEX A(NN,1),B(NN,1),DUM                                        CSYMEQ.8
C                                                                        CSYMEQ.9
      DO 475 N=1,NN                                                      CSYMEQ.10
      N1=N+1                                                             CSYMEQ.11
      DUM=1.0/A(N,N)                                                     CSYMEQ.12
C                                                                        CSYMEQ.13
      DO 150 L=1,LL                                                      CSYMEQ.14
  150 B(N,L)=B(N,L)*DUM                                                  CSYMEQ.15
C                                                                        CSYMEQ.16
      IF (N-NN) 200,500,200                                              CSYMEQ.17
  200 DO 450 J=N1,NN                                                     CSYMEQ.18
      IF (CABS(A(N,J))) 250,450,250                                      CSYMEQ.19
  250 A(N,J)=A(N,J)*DUM                                                  CSYMEQ.20
C                                                                        CSYMEQ.21
      DO 300 I=J,NN                                                      CSYMEQ.22
      A(I,J)=A(I,J)-A(I,N)*A(N,J)                                        CSYMEQ.23
  300 A(J,I)=A(I,J)                                                      CSYMEQ.24
C                                                                        CSYMEQ.25
      DO 400 L=1,LL                                                      CSYMEQ.26
  400 B(J,L)=B(J,L)-A(J,N)*B(N,L)                                        CSYMEQ.27
  450 CONTINUE                                                           CSYMEQ.28
  475 CONTINUE                                                           CSYMEQ.29
C                                                                        CSYMEQ.30
C     BACK-SUBSTITUTION                                                  CSYMEQ.31
C                                                                        CSYMEQ.32
  500 N1=N                                                               CSYMEQ.33
      N=N-1                                                              CSYMEQ.34
      IF (N) 700,700,550                                                 CSYMEQ.35
  550 DO 600 L=1,LL                                                      CSYMEQ.36
      DO 600 J=N1,NN                                                     CSYMEQ.37
  600 B(N,L)=B(N,L)-A(N,J)*B(J,L)                                        CSYMEQ.38
      GO TO 500                                                          CSYMEQ.39
C                                                                        CSYMEQ.40
  700 RETURN                                                             CSYMEQ.41
      END                                                                CSYMEQ.42
      SUBROUTINE EIGEN (NEBC,SMASS,EV,AKFO,IBASE,A,W1,W2,W3,W4,CC,       EIGEN.2
     1                  ESCALE,NB2,NEQ,NEV,MBAND)                        EIGEN.3
C                                                                        EIGEN.4
C     ******************************************************************EIGEN.5
C     COMPUTE MODE SHAPES AND FREQUENCIES                                EIGEN.6
C     MAXIMUM NUMBER OF MODES = MBAND+1                                  EIGEN.7
C     ******************************************************************EIGEN.8
C                                                                        EIGEN.9
      COMMON /CNTRL1/ NUMNP,MBAND,NUMEL,NBC,IGRAV,NPP,ML,TRACE,IOPR,     EIGEN.10
     .                ICPP,NBASE,IRIG,KJUNK(12)                          EIGEN.11
      COMMON /LABEL/  HED(18)                                            EIGEN.12
      DIMENSION NEBC(1),SMASS(1),A(NEQ,MBAND 1,EV(1),W1(1),W2(1),W3(1),  EIGEN.13
     .          W4(1),CC(NEV,1),IBASE(1)                                 EIGEN.14
      COMPLEX AKFO(NB2,NB2)                                              EIGEN.15
C                                                                        EIGEN.16
      IF (IRIG.NE.0) GO TO 125                                           EIGEN.17
      REWIND 90                                                          EIGEN.18
      READ (90)                                                          EIGEN.19
      READ (90)                                                          EIGEN.20
      READ (90) AKFO                                                     EIGEN.21
      REWIND 90                                                          EIGEN.22
      DO 110 I=1,NB2                                                     EIGEN.23
      DO 110 J=1,NB2                                                     EIGEN.24
      AKFO(I,J)=AKFO(I,J)*ESCALE                                         EIGEN.25
```

```
  110 AKPO(J,I)=AKPO(I,J)                                               EIGEN.26
C                                                                       EIGEN.27
  125 IF (ICPR.NE.0) GO TO 220                                          EIGEN.28
      IF (IGRAV.NE.0) BACKSPACE 1                                       EIGEN.29
      BACKSPACE 1                                                       EIGEN.30
      READ (1) A                                                        EIGEN.31
      IF (IGRAV.NE.0) READ (1)                                          EIGEN.32
      IF (IDIG.NE.0) GO TO 135                                          EIGEN.33
C                                                                       EIGEN.34
      DO 130 I=1,ND2                                                    EIGEN.35
      L=IBASE(I)                                                        EIGEN.36
      DO 130 J=1,ND2                                                    EIGEN.37
      K=IBASE(J)-L+1                                                    EIGEN.38
      IF ((K.LE.0).OR.(K.GT.MBAND)) GO TO 130                           EIGEN.39
      A(L,K)=A(L,K)+REAL(AKPO(I,J))                                     EIGEN.40
  130 CONTINUE                                                          EIGEN.41
C                                                                       EIGEN.42
C     SOLVE FOR EIGENVALUES AND EIGENVECTORS                            EIGEN.43
C                                                                       EIGEN.44
  135 CALL BANEIG(NEC,MBAND,NEV,NAC,EV,NEGC,SMASS,A,W1,A,W2,W3,W4,TRACE)EIGEN.45
C                                                                       EIGEN.46
C     OUTPUT EIGENVALUES AND EIGENVECTORS                               EIGEN.47
C                                                                       EIGEN.48
      WRITE (6,2006) NEQ                                                EIGEN.49
      DO 140 I=1,NEV                                                    EIGEN.50
      EV(I)=SQRT(EV(I))                                                 EIGEN.51
  140 WRITE (6,2005) I,EV(I)                                            EIGEN.52
      WRITE (6,2007)                                                    EIGEN.53
      CALL MPRINT (A,NEC,NEV)                                           EIGEN.54
      WRITE (6,2008)                                                    EIGEN.55
      DO 190 I=1,NEV                                                    EIGEN.56
      DO 160 J=1,NEV                                                    EIGEN.57
      SUM=0.0                                                           EIGEN.58
      DO 150 K=1,NEQ                                                    EIGEN.59
  150 SUM=SUM+A(K,I)*SMASS(K)*A(K,J)                                    EIGEN.60
  160 CC(I,J)=SUM                                                       EIGEN.61
      II=I-1                                                            EIGEN.62
      IF (II) 190,190,170                                               EIGEN.63
  170 DO 180 L=1,II                                                     EIGEN.64
  180 CC(I,L)=CC(L,I)                                                   EIGEN.65
  190 CONTINUE                                                          EIGEN.66
      CALL PPRINT (CC,NEV,NEV)                                          EIGEN.67
C                                                                       EIGEN.68
      IF (ICPP.EQ.0) RETURN                                             EIGEN.69
      DO 200 N=1,NEV                                                    EIGEN.70
  200 PUNCH 2009,N,EV(N)                                                EIGEN.71
      DO 210 N=1,NEV                                                    EIGEN.72
      DO 210 M=1,NUPNP                                                  EIGEN.73
      L=M+M-1                                                           EIGEN.74
  210 PUNCH 1020,M,A(L,N),A(L+1,N)                                      EIGEN.75
      RETURN                                                            EIGEN.76
C                                                                       EIGEN.77
C     READ FREQUENCIES AND MODESHAPES                                   EIGEN.78
C                                                                       EIGEN.79
  220 READ  (5,1010) (EV(N),N=1,NEV)                                    EIGEN.80
      DO 230 N=1,NEV                                                    EIGEN.81
      DO 230 M=1,NUPNP                                                  EIGEN.82
      L=M+M-1                                                           EIGEN.83
  230 READ  (5,1020) MM,A(L,N),A(L+1,N)                                 EIGEN.84
      WRITE (6,2006) NEC                                                EIGEN.85
      DO 240 I=1,NEV                                                    EIGEN.86
  240 WRITE (6,2005) I,EV(I)                                            EIGEN.87
      WRITE (6,2007)                                                    EIGEN.88
      CALL PPRINT (A,NEC,NEV)                                           EIGEN.89
      RETURN                                                            EIGEN.90
C                                                                       EIGEN.91
 1010 FORMAT (12X,F15.8)                                                EIGEN.92
 1020 FORMAT (1I12,2E15.6)                                              EIGEN.93
 2005 FORMAT (2H0W,I3,1H=,1PE15.5)                                      EIGEN.94
 2006 FORMAT (1H1,20X,8A10//                                            EIGEN.95
     . 1X,27(1H*)/28H FREQUENCIES AND MODE SHAPES/1X,27(1H*)///         EIGEN.96
     . 50H FREQUENCIES (RAD/SEC) OF DAM WITH RESERVOIR EMPTY  /         EIGEN.97
     . 50H ------------------------------------------------- //)        EIGEN.98
 2007 FORMAT (68H1 EIGENVECTORS (NORMALIZED WITH RESPECT TO THE MASS MATEIGEN.99
     1RIX)-MATRIX A)                                                    EIGEN.100
 2008 FORMAT (49H1 VERIFICATION OF ORTHOGONALITY RELATION-ATMA=I)       EIGEN.101
 2009 FORMAT (1I12,F15.8)                                               EIGEN.102
      END                                                               EIGEN.103
      SUBROUTINE INNCTR(F,A,B,C,D,NW,NBASE,NJ2,NJ,NREC,RNU)             INNCTR.2
C                                                                       INNCTR.3
C     ************************************************************      INNCTR.4
C     CONTROL GENERATION OF DYNAMIC STIFFNESS MATRIX FROM THE           INNCTR.5
C     COMPLIANCE DATA STORED ON TAPE80                                  INNCTR.6
C     ************************************************************      INNCTR.7
C                                                                       INNCTR.8
      COMPLEX F(NW,3,NBASE),A(NJ2,NJ2),B(NJ2,NJ2),C(NJ2,NJ2),D(NJ2,NJ2) INNCTR.9
C                                                                       INNCTR.10
      NEL=NBASE-1                                                       INNCTR.11
      NEL2=NEL+NEL                                                      INNCTR.12
      NN=NBASE                                                          INNCTR.13
      IF (NBASE.GT.NJ) NN=NJ                                            INNCTR.14
C                                                                       INNCTR.15
C     SKIP AND READ COMPLIANCE DATA                                     INNCTR.16
C                                                                       INNCTR.17
      IF (NREC.EQ.0) GO TO 20                                           INNCTR.18
      DO 10 I=1,NREC                                                    INNCTR.19
   10 READ (80,99)                                                      INNCTR.20
   20 READ (80,99) (((F(I,J,K),I=1,NW),J=1,3),K=1,NN)                   INNCTR.21
C                                                                       INNCTR.22
      IF (NBASE.LE.NJ) GO TO 40                                         INNCTR.23
      NN=NJ+1                                                           INNCTR.24
      DO 30 K=NN,NBASE                                                  INNCTR.25
      DO 30 J=1,3                                                       INNCTR.26
      DO 30 I=1,NW                                                      INNCTR.27
   30 F(I,J,K)=0.0                                                      INNCTR.28
C                                                                       INNCTR.29
   40 CALL INFORK (F,A,B,C,D,NW,NBASE,NJ2,NEL,NEL2,RNU)                 INNCTR.30
      RETURN                                                            INNCTR.31
   99 FORMAT (4F18.14)                                                  INNCTR.32
      END                                                               INNCTR.33
      SUBROUTINE INFOR4 (F,NW,INW,NJ,NJ2,NEL,NEL1,NEL2,H)               INFOR4.2
C                                                                       INFOR4.3
C     ************************************************************      INFOR4.4
C     FORM TRANFORMATION MATRICES                                       INFOR4.5
C     ************************************************************      INFOR4.6
C                                                                       INFOR4.7
      COMPLEX F(NW,3,NJ),H(NJ2,NEL2)                                    INFOR4.8
C                                                                       INFOR4.9
      ISTART=-1                                                         INFOR4.10
      DO 1 I=1,NEL                                                      INFOR4.11
      ISTART=ISTART+2                                                   INFOR4.12
      J=0                                                               INFOR4.13
      ICOL=ISTART                                                       INFOR4.14
      DO 1 IROW=ISTART,NJ2,2                                            INFOR4.15
```

```
      J=J+1                                                              INFOR4.16
      H (IROW,ICOL)=F(INW,1,J)                                           INFOR4.17
      H (IROW+1,ICOL)=-F(INW,3,J)                                        INFOR4.18
      H (IROW,ICOL+1)=F(INW,3,J)                                         INFOR4.19
1     H (IROW+1,ICOL+1)=F(INW,2,J)                                       INFOR4.20
      ISTART=-1                                                          INFOR4.21
      DO 2 I=1,NEL1                                                      INFOR4.22
      ISTART=ISTART+2                                                    INFOR4.23
      IROW=ISTART                                                        INFOR4.24
      ISTART2=ISTART+2                                                   INFOR4.25
      DO 2 ICOL=ISTART2,NEL2,2                                           INFOR4.26
      H (IROW,ICOL)=H (ICOL+2,IROW)                                      INFOR4.27
      H (IROW+1,ICOL)=H (ICOL+2,IROW+1)                                  INFOR4.28
      H (IROW,ICOL+1)=H (ICOL+3,IROW)                                    INFOR4.29
2     H (IROW+1,ICOL+1)=H (ICOL+3,IROW+1)                                INFOR4.30
      RETURN                                                             INFOR4.31
      END                                                                INFOR4.32
      SUBROUTINE INFORK (F,A,B,C,D,NW,NJ,NJ2,NEL,NEL2,ENU)               INFORK.2
C                                                                        INFORK.3
C     ****************************************************************** INFORK.4
C     GENERATE DYNAMIC STIFFNESS MATRIX                                  INFORK.5
C     ****************************************************************** INFORK.6
C                                                                        INFORK.7
      COMPLEX F(NW,3,NJ),B(NJ2,NJ2),C(NEL2,NEL2),D(NEL2,NEL2),           INFORK.8
     1        A(NJ2,NEL2)                                                INFORK.9
      DATA E/1.0/                                                        INFORK.10
C                                                                        INFORK.11
      GMUS=.125*E/(1.+ENU)                                               INFORK.12
      NEL1=NEL-1                                                         INFORK.13
      NI=NJ2-1                                                           INFORK.14
      NELO=NEL2+1                                                        INFORK.15
C                                                                        INFORK.16
      DO 10 INW=1,NW                                                     INFORK.17
      CALL INFOR4 (F,NW,INW,NJ,NJ2,NEL,NEL1,NEL2,A)                      INFORK.18
      DO 1 I=1,NEL2                                                      INFORK.19
      DO 1 J=1,NEL2                                                      INFORK.20
1     C(I,J)=.5*(A(I,J)+A(I+2,J))                                        INFORK.21
      DO 2 I=1,NEL2                                                      INFORK.22
      DO 3 J=1,NEL2                                                      INFORK.23
3     D(I,J)=(0.,0.)                                                     INFORK.24
2     D(I,I)=(1.,0.)                                                     INFORK.25
      CALL CSYMEQ (C,D,NEL2,NEL2)                                        INFORK.26
      B(1,1)=GMUS*D(1,1)                                                 INFORK.27
      B(2,2)=GMUS*D(2,2)                                                 INFORK.28
      B(2,1)=GMUS*D(2,1)                                                 INFORK.29
      DO 4 I=3,NEL2                                                      INFORK.30
      DO 4 J=1,2                                                         INFORK.31
4     B(I,J)=GMUS*(D(I-2,J)+D(I,J))                                      INFORK.32
      DO 5 I=3,NEL2                                                      INFORK.33
      DO 5 J=3,I                                                         INFORK.34
5     B(I,J)=GMUS*(D(I-2,J-2)+D(I-2,J)+D(I,J-2)+D(I,J))                  INFORK.35
      DO 7 I=NELO,NJ2                                                    INFORK.36
      DO 7 J=NELO,I                                                      INFORK.37
7     B(I,J)=GMUS*D(I-2,J-2)                                             INFORK.38
      DO 8 I=NELO,NJ2                                                    INFORK.39
      DO 8 J=1,2                                                         INFORK.40
8     B(I,J)=GMUS*(D(I-2,J))                                             INFORK.41
      DO 9 I=NELO,NJ2                                                    INFORK.42
      DO 9 J=3,NEL2                                                      INFORK.43
9     B(I,J)=GMUS*(D(I-2,J)+D(I-2,J-2))                                  INFORK.44
      DO 6 I=1,NI                                                        INFORK.45
      I1=I+1                                                             INFORK.46
      DO 6 J=I1,NJ2                                                      INFORK.47
6     B(I,J)=B(J,I)                                                      INFORK.48
C                                                                        INFORK.49
      WRITE (90) B                                                       INFORK.50
      IF (INW.EQ.1) WRITE (90) B                                         INFORK.51
10    CONTINUE                                                           INFORK.52
C                                                                        INFORK.53
      RETURN                                                             INFORK.54
      END                                                                INFORK.55
      SUBROUTINE FORMK (AKF,EIG,IBASE,DUMMY,AKFI,NEV,NB2,NEQ)            FORMK.2
C                                                                        FORMK.3
C     ****************************************************************** FORMK.4
C     TRANSFORM FOUNDATION IMPEDANCE MATRIX USING RITZ VECTORS           FORMK.5
C     ****************************************************************** FORMK.6
C                                                                        FORMK.7
      COMPLEX AKF(NB2,1),DUMMY(NB2),AKFI(NEV,1),SUM                      FORMK.8
      DIMENSION EIG(NEQ,1),IBASE(1)                                      FORMK.9
C                                                                        FORMK.10
      DO 130 I=1,NEV                                                     FORMK.11
      DO 110 J=1,NB2                                                     FORMK.12
      DUMMY(J)=0.0                                                       FORMK.13
      DO 110 K=1,NB2                                                     FORMK.14
      L=IBASE(K)                                                         FORMK.15
  110 DUMMY(J)=DUMMY(J)+EIG(L,I)*AKF(K,J)                                FORMK.16
C                                                                        FORMK.17
      DO 130 K=I,NEV                                                     FORMK.18
      SUM=0.0                                                            FORMK.19
      DO 120 J=1,NB2                                                     FORMK.20
      L=IBASE(J)                                                         FORMK.21
  120 SUM=SUM+DUMMY(J)*EIG(L,K)                                          FORMK.22
      AKFI(K,I)=SUM                                                      FORMK.23
  130 AKFI(I,K)=SUM                                                      FORMK.24
C                                                                        FORMK.25
      RETURN                                                             FORMK.26
      END                                                                FORMK.27
      SUBROUTINE FOUND (AKF1,AKF2,AKF,IBASE,A,DUMMY,S,W,ESCALE,NTEMP,    FOUND.2
     1                  NB2,NEV,NEQ)                                     FOUND.3
C                                                                        FOUND.4
C     ****************************************************************** FOUND.5
C     COMPUTE FOUNDATION IMPEDANCE MATRIX TO S                           FOUND.6
C     ****************************************************************** FOUND.7
C                                                                        FOUND.8
      COMMON /AFOUND/ NW,NDAMP,AOCSB(91),DMP(4)                          FOUND.9
      COMPLEX AKF1(NEV,1),AKF2(NEV,1),AKF(NB2,NB2),DUMMY(1),S(NEV,1)     FOUND.10
      DIMENSION A(NEQ,1),IBASE(1)                                        FOUND.11
C                                                                        FOUND.12
      J = 0                                                              FOUND.13
   10 IF (W.LE.AOCSB(NTEMP+1)) GO TO 20                                  FOUND.14
      J = J + 1                                                          FOUND.15
      NTEMP = NTEMP + 1                                                  FOUND.16
      IF (NTEMP.GE.NW) GO TO 90                                          FOUND.17
      GO TO 10                                                           FOUND.18
   20 IF (J.EQ.0) GO TO 60                                               FOUND.19
C                                                                        FOUND.20
      IF (J.EQ.1) GO TO 40                                               FOUND.21
      J = J - 1                                                          FOUND.22
      DO 30 K=1,J                                                        FOUND.23
   30 READ (90) AKF                                                      FOUND.24
      CALL FORMK (AKF,A,IBASE,DUMMY,AKF2,NEV,NB2,NEQ)                    FOUND.25
   40 DO 50 I=1,NEV                                                      FOUND.26
      DO 50 K=1,NEV                                                      FOUND.27
   50 AKF1(K,I) = AKF2(K,I)                                              FOUND.28
```

```
      READ (90) AKF                                                     FOUND.29
      CALL FORMK (AKF,A,IBASE,DUMMY,AKF2,NEV,NB2,NEQ)                   FOUND.30
C                                                                       FOUND.31
   60 ZINTA = (AOCSB(NTEMP+1) - W)/(AOCSB(NTEMP+1) - AOCSB(NTEMP))      FOUND.32
      ZINTB = ESCALE*(1.0 - ZINTA)                                      FOUND.33
      ZINTA = ESCALE*ZINTA                                              FOUND.34
      DO 70 I=1,NEV                                                     FOUND.35
      DO 70 K=I,NEV                                                     FOUND.36
      S(K,I) = S(K,I) + ZINTA*AKF1(K,I) + ZINTB*AKF2(K,I)               FOUND.37
   70 S(I,K) = S(K,I)                                                   FOUND.38
C                                                                       FOUND.39
      RETURN                                                            FOUND.40
C                                                                       FOUND.41
   90 WRITE (6,98) W                                                    FOUND.42
      STOP                                                              FOUND.43
C                                                                       FOUND.44
   98 FORMAT ( 7H0OMEGA=,F8.4,59H IS GREATER THAN MAXIMUM FOUNDATION IMPFOUND.45
     1EDANCE FREQUENCY           )                                      FOUND.46
      END                                                               FOUND.47
      SUBROUTINE JOBLOG (MSTOR,NBCOM,T1,T2,T3,T4,T5,T6)                 JOBLOG.2
C                                                                       JOBLOG.3
C     ******************************************************************JOBLOG.4
C     BLANK COMMON STORAGE AND EXECUTION TIME                           JOBLOG.5
C     ******************************************************************JOBLOG.6
C                                                                       JOBLOG.7
      COMMON /LABEL/ HED(8)                                             JOBLOG.8
C                                                                       JOBLOG.9
      T1=AMAX1(0.0,T2-T1)                                               JOBLOG.10
      T2=AMAX1(0.0,T3-T2)                                               JOBLOG.11
      T3=AMAX1(0.0,T4-T3)                                               JOBLOG.12
      T4=AMAX1(0.0,T5-T4)                                               JOBLOG.13
      T5=AMAX1(0.0,T6-T5)                                               JOBLOG.14
      T6=T1+T2+T3+T4+T5                                                 JOBLOG.15
      WRITE (6,2000) HED,MSTOR,NBCOM,T1,T2,T3,T4,T5,T6                  JOBLOG.16
      RETURN                                                            JOBLOG.17
C                                                                       JOBLOG.18
 2000 FORMAT (1H1,20X,8A10//26X,11(1H*)/                                JOBLOG.19
     .          26X,11HJ O B L O G /26X,11(1H*)//                       JOBLOG.20
     .           7X,49H***  BLANK COMMON STORAGE AND EXECUTION TIME  ***//JOBLOG.21
     .           5X,44HBLANK COMMON STORAGE AVAILABLE              =,I8/   JOBLOG.22
     .           5X,44HBLANK COMMON STORAGE REQUIRED               =,I8//  JOBLOG.23
     .           5X,14HEXECUTION TIME //                                JOBLOG.24
     .          10X,44HFORM FOUNDATION DYNAMIC IMPEDANCE MATRIX  =,F8.3/ JOBLOG.25
     .          10X,44HFORM STIFFNESS AND SOLVE FOR STATIC LOADS =,F8.3/ JOBLOG.26
     .          10X,44HCOMPUTE FREQUENCIES AND MODE SHAPES       =,F8.3/ JOBLOG.27
     .          10X,44HCOMPLEX FREQUENCY RESPONSE FUNCTIONS      =,F8.3/ JOBLOG.28
     .          10X,44HEARTHQUAKE RESPONSE                       =,F8.3/ JOBLOG.29
     .          10X,44HTOTAL EXECUTION TIME                      =,F8.3) JOBLOG.30
      END                                                               JOBLOG.31
      SUBROUTINE KOMPLX (Z,IJBC,SMASS,EV,AKFO,IBASE,A,AKF1,AKF2,AKF,    KOMPLX.2
     .    DUMMY,HY,S,TEPP,SFO,A2,Q,LAM1,LAM2,EI1,EI2,TERM,COM1,COM2,    KOMPLX.3
     .    RSUM1,EID,YBUF,ALPHA,DFAC1,SGN,NEV,NEV1,NEQ,NTERM,NBU,        KOMPLX.4
     .    ESCALE,NB2)                                                   KOMPLX.5
C                                                                       KOMPLX.6
C     ******************************************************************KOMPLX.7
C     COMPUTE COMPLEX-VALUED FREQUENCY RESPONSE FUNCTIONS FOR THE       KOMPLX.8
C     GENERALIZED COORDINATES                                           KOMPLX.9
C     ******************************************************************KOMPLX.10
C                                                                       KOMPLX.11
      COMMON /CNTRL1/ NUMNP,NBAND,NUMEL,NBC,IGRAV,NPP,WL,TRACE,IOPR,    KOMPLX.12
     .                ICPP,NBASE,IRIG,XJUNK(12)                         KOMPLX.13
      COMMON /CNTRL2/ NCATA,NNR,DT,NREST,NBUF,NBLOCK,IHV,NCOMP,YJUNK(4) KOMPLX.14
      COMMON /LABEL/  HED(8)                                            KOMPLX.15
C                                                                       KOMPLX.16
      DIMENSION Z(1),IJBC(1),SMASS(1),EV(1),A(NEQ,NEV1),A2(1),U(NEV,1), KOMPLX.17
     .            RSUM1(1),NACC(6,2),FMT(6),IBASE(1)                    KOMPLX.18
C                                                                       KOMPLX.19
      COMPLEX HY(NEV,1),S(NEV,1),TERM2,YBUF(NBU,1),AKFO(NB2,1),         KOMPLX.20
     .          AKF(NB2,NB2),AKF1(NEV,1),AKF2(NEV,1),DUMMY(1),          KOMPLX.21
     .          SFO(NEV,1),LAM1(1),LAM2(1),EI1(NEV1,1),EI2(NEV1,1),     KOMPLX.22
     .          TEMP(1),TERM(1),COM1(1),COM2(1),EID(1),FACV,DUM,BM1     KOMPLX.23
      LOGICAL RIGBOT,LIHV                                               KOMPLX.24
C                                                                       KOMPLX.25
      DATA PI/3.14159265358979/,CC/4720.0/,DELFAC/0.25/                 KOMPLX.26
C                                                                       KOMPLX.27
      BM1=CMPLX(1.0,DFAC1)                                              KOMPLX.28
      DO 50 I=1,NEV                                                     KOMPLX.29
      DO 50 J=1,NEV                                                     KOMPLX.30
   50 SFO(I,J)=0.                                                       KOMPLX.31
      RIGBOT=.TRUE.                                                     KOMPLX.32
C                                                                       KOMPLX.33
C     GENERALIZED CONSTANTS AND VECTOR Q                                KOMPLX.34
C                                                                       KOMPLX.35
      DO 260 M=1,NEV                                                    KOMPLX.36
      A2(M)=EV(M)*EV(M)                                                 KOMPLX.37
      SUM1=0.                                                           KOMPLX.38
      SUM2=0.                                                           KOMPLX.39
      DO 255 J=1,NUMNP                                                  KOMPLX.40
      JJ=J+J                                                            KOMPLX.41
      L=JJ-1                                                            KOMPLX.42
      SUM1=SUM1+A(L ,M)*SMASS(L )                                       KOMPLX.43
  255 SUM2=SUM2+A(JJ,M)*SMASS(JJ)                                       KOMPLX.44
      IF (IHV-1) 258,255,257                                            KOMPLX.45
  257 Q(M,2)=-SUM2                                                      KOMPLX.46
  258 Q(M,1)=-SUM1                                                      KOMPLX.47
      GO TO 260                                                         KOMPLX.48
  259 Q(M,1)=-SUM2                                                      KOMPLX.49
  260 CONTINUE                                                          KOMPLX.51
C                                                                       KOMPLX.52
C     SET IMAGINARY PART OF AKFO TO BE ZERO                             KOMPLX.53
C     IN SUBSEQUENT COMPUTATIONS THE SAME STORAGE IS USED AS COMPLEX    KOMPLX.54
C                                                                       KOMPLX.55
      IF(IRIG.NE.0) GO TO 261                                           KOMPLX.56
      DO 1 II=1,NB2                                                     KOMPLX.57
      DO 1 JJ=II,NB2                                                    KOMPLX.58
      AKFO(II,JJ)=CMPLX(REAL(AKFO(II,JJ)),0.0)                          KOMPLX.59
    1 AKFO(JJ,II)=AKFO(II,JJ)                                           KOMPLX.60
      CALL FORMK(AKFO,A,IBASE,DUMMY,SFO,NEV,NB2,NEQ)                    KOMPLX.61
C                                                                       KOMPLX.62
C     POSITION TAPE90                                                   KOMPLX.63
C                                                                       KOMPLX.64
      READ(90)                                                          KOMPLX.65
      READ(90)                                                          KOMPLX.66
      READ (90) AKF                                                     KOMPLX.67
      CALL FORMK (AKF,A,IBASE,DUMMY,AKF1,NEV,NB2,NEQ)                   KOMPLX.68
      READ (90) AKF                                                     KOMPLX.69
      CALL FORMK (AKF,A,IBASE,DUMMY,AKF2,NEV,NB2,NEQ)                   KOMPLX.70
      NTEMP=1                                                           KOMPLX.71
C                                                                       KOMPLX.72
C     WRITE MODE SHAPE ARRAY ON TAPE                                    KOMPLX.73
C                                                                       KOMPLX.74
  261 WRITE (1) A                                                       KOMPLX.75
      IF (NPP.EQ.0) GO TO 290                                           KOMPLX.76
C
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C     COMPUTE PARAMETERS FOR IMPOUNDED WATER                       KOMPLX.77
C                                                                  KOMPLX.78
      RHO=.0624/32.2                                               KOMPLX.79
      CONST=SCW*RHO                                                KOMPLX.80
      RHO2=2.0*RHO                                                 KOMPLX.81
      QC=(1.0-ALPHA)/(1.0+ALPHA)                                   KOMPLX.82
      IF (ALPHA.LT.1.0) RIGBOT =.FALSE.                            KOMPLX.83
      LT=IJBC(NPP)                                                 KOMPLX.84
      H=WL-Z(LT)                                                   KOMPLX.85
      QCH=QC*H/CC                                                  KOMPLX.86
      HHCC=H*H/(CC*CC)                                             KOMPLX.87
      DELONG=1.0                                                   KOMPLX.88
      IF (.NOT.RIGBOT) DELONG = 0.50*PI*DELFAC/QCH                 KOMPLX.89
C                                                                  KOMPLX.90
C     MODIFY VALUE OF A AT FIRST UPSTREAM NODAL POINT              KOMPLX.91
C                                                                  KOMPLX.92
      I=IJBC(1)                                                    KOMPLX.93
      J=IJBC(2)                                                    KOMPLX.94
      II=I+I-1                                                     KOMPLX.95
      JJ=J+J-1                                                     KOMPLX.96
      WLIJ=(WL-Z(J))/(Z(I)-Z(J))                                   KOMPLX.97
      DO 100 K=1,NEV                                               KOMPLX.98
  100 A(II,K)=A(JJ,K)+(A(II,K)-A(JJ,K))*WLIJ                       KOMPLX.99
      Z(I)=WL                                                      KOMPLX.100
C                                                                  KOMPLX.101
C     COMPUTE EIGENPROPERTIES OF IMPOUNDED WATER FOR               KOMPLX.102
C     ZERO FREQUENCY                                               KOMPLX.103
C                                                                  KOMPLX.104
      DO 110 N=1,NTERM                                             KOMPLX.105
110   LAM2(N)=FLOAT(2*N-1)*PI/2.0                                  KOMPLX.106
      CALL KPEIGN (LAM2,EI2,A,Z,IJBC,COM1,COM2,NTERM,NTERM,NEV,NEVI, KOMPLX.107
     *             NEQ,NPP,0,0,H)                                  KOMPLX.108
C                                                                  KOMPLX.109
C     SET UP FREQUENCY INCREMENTS FOR FREQUENCY RESPONSES          KOMPLX.110
C                                                                  KOMPLX.111
  290 DOM = PI/(FLOAT(NDATA)*DT)                                   KOMPLX.112
      WRITE (6,2010) NED                                           KOMPLX.113
      MNEV=NEV                                                     KOMPLX.114
      IF (NEV.GT.6) MNEV=6                                         KOMPLX.115
      IBLANK=(MNEV-1)*10                                           KOMPLX.116
      ENCODE (60,2020,FMT) IBLANK                                  KOMPLX.117
      WRITE (6,FMT) ((J,J=1,MNEV),I=1,NCOMP)                       KOMPLX.118
C                                                                  KOMPLX.119
      LL    =0                                                     KOMPLX.120
      MM    =0                                                     KOMPLX.121
      NBLOCK=3                                                     KOMPLX.122
      NB=2*NDUP                                                    KOMPLX.123
      NFR=NDATA+1                                                  KOMPLX.124
      NEV2=(NEV*NEV1)/2                                            KOMPLX.125
      OMEGA=0.                                                     KOMPLX.126
      OMEGA2=0.0                                                   KOMPLX.127
      LIMV=.TRUE.                                                  KOMPLX.128
      IF (IMV.EQ.1) LIMV=.FALSE.                                   KOMPLX.129
      REWIND 2                                                     KOMPLX.130
      REWIND 3                                                     KOMPLX.131
C                                                                  KOMPLX.132
C     COMPUTE RESPONSE FUNCTION(S) FOR EACH EXCITATION FREQUENCY   KOMPLX.133
C                                                                  KOMPLX.134
      DO 570 KKK=1,NFR                                             KOMPLX.135
      OM2=OMEGA**2                                                 KOMPLX.136
C                                                                  KOMPLX.137
C     INITIALIZE S(OMEGA) AND LOAD VECTOR                          KOMPLX.138
C                                                                  KOMPLX.139
      DO 320 M=1,NEV                                               KOMPLX.140
      DO 305 I=1,NCCPP                                             KOMPLX.141
  305 HY(M,I)=CMPLX(C(M,I),0.)                                     KOMPLX.142
      S(M,M)=-OM2*(A2(M)-SFO(M,M))*OM1                             KOMPLX.143
      IF (M.GE.NEV) GO TO 320                                      KOMPLX.144
      M1=M+1                                                       KOMPLX.145
      DO 310 N=M1,NEV                                              KOMPLX.146
      S(M,N)=-SFO(M,N)*OM1                                         KOMPLX.147
310   S(N,M)=S(M,N)                                                KOMPLX.148
320   CONTINUE                                                     KOMPLX.149
C                                                                  KOMPLX.150
      IF (NPP.EQ.0) GO TO 500                                      KOMPLX.151
      IF (IPV.EQ.0) GO TO 450                                      KOMPLX.152
      OMC=OMEGA/CC                                                 KOMPLX.153
      CALL KPVEAT (RSUM1,A,Z,IJBC,NEV,NEQ,NPP,OMC,H)               KOMPLX.154
      I=1                                                          KOMPLX.155
      IF (IPV.EQ.2) I=2                                            KOMPLX.156
      ARG = OMC*H                                                  KOMPLX.157
      IF (OMEGA.EQ.0.0) FACV=0.50*CONST                            KOMPLX.158
      IF (OMEGA.GT.0.0) FACV=(CONST/(OMC*OMC))/                    KOMPLX.159
     1   CMPLX(COS(ARG),QC*SIN(ARG))                               KOMPLX.160
      DO 420 M=1,NEV                                               KOMPLX.161
420   HY(M,1) = HY(M,I)+FACV*RSUM1(M)                              KOMPLX.162
C                                                                  KOMPLX.163
C     COMPUTE EIGENPROPERTIES FOR NEXT FREQUENCY INTERVAL          KOMPLX.164
C     IF NECESSARY                                                 KOMPLX.165
C                                                                  KOMPLX.166
450   IF(OMEGA.LT.OMEGA2.OR.RIGBOT) GO TO 444                      KOMPLX.167
      OMEGA2=OMEGA2+DELONG                                         KOMPLX.168
      DO 442 N=1,NTERM                                             KOMPLX.169
      LAM1(N)=LAM2(N)                                              KOMPLX.170
      DO 442 M=1,NEVI                                              KOMPLX.171
442   EI1(M,N)=EI2(M,N)                                            KOMPLX.172
      CALL KPEIGN (LAM2,EI2,A,Z,IJBC,COM1,COM2,NTERM,NTERM,NEV,NEVI, KOMPLX.173
     *             NEQ,NPP,OMEGA2*QCH,H)                           KOMPLX.174
C                                                                  KOMPLX.175
C     INTERPOLATE EIGENVALUES AND COMPUTE TERMS                    KOMPLX.176
C                                                                  KOMPLX.177
444   ZINTA=(OMEGA2-OMEGA)/DELONG                                  KOMPLX.178
      ZINTB=1.0-ZINTA                                              KOMPLX.179
      DO 445 M=1,NEV2                                              KOMPLX.180
445   TEMP(M)=0.0                                                  KOMPLX.181
      OMHC2=OM2*HHCC                                               KOMPLX.182
      IF (RIGBOT) GO TO 447                                        KOMPLX.183
      OMQH=OMEGA*QCH                                               KOMPLX.184
      OMQH2=OMQH*QCH                                               KOMPLX.185
      DO 446 N=1,NTERM                                             KOMPLX.186
      DUM=ZINTA*LAM1(N)+ZINTB*LAM2(N)                              KOMPLX.187
      DUM=DUM*DUM                                                  KOMPLX.188
446   TERM(N)=RHO2*DUM/((DUM*CMPLX(-OMQH2,OMQH))*CSQRT(DUM-OMHC2)) KOMPLX.189
      GO TO 449                                                    KOMPLX.190
447   DO 448 N=1,NTERM                                             KOMPLX.191
      RDUM=REAL(LAM2(N))                                           KOMPLX.192
448   TERM(N)=RHO2/CSQRT(CMPLX(RDUM*RDUM-OMHC2,0.0))               KOMPLX.193
C                                                                  KOMPLX.194
C     COMPUTE HYDRODYNAMIC TERMS                                   KOMPLX.195
C                                                                  KOMPLX.196
449   DO 460 N=1,NTERM                                             KOMPLX.197
      IF (RIGBOT) GO TO 453                                        KOMPLX.198
      DO 452 M=1,NEVI                                              KOMPLX.199
452   EIO(M)=ZINTA*EI1(M,N)+ZINTB*EI2(M,N)                         KOMPLX.200
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      GO TO 454
453   DO 454 M=1,NEV1
454   EI(M)=EI2(M,M)
456   KPT=0
      DO 446 M=1,NEV
      DUM=EI(M+1)*TERM(M)
      IF (LINV) HY(M,1)=HY(M,1)-DUM*EI(2)
      DO 440 K=M,NEV
      KPT=KPT+1
440   TEMP(KPT)=TEMP(KPT)+DUM*EI(K+1)
C
C     ADD HYDRODYNAMIC TERMS TO S
C
      KPT=0
      DO 448 M=1,NEV
      DO 448 K=M,NEV
      KPT=KPT+1
      S(M,K)=S(M,K)-OM2*TEMP(KPT)
448   S(K,M)=S(M,K)
C
C     ADD CONTRIBUTION DUE TO FOUNDATION FLEXIBILITY
C
  500 IF (IRIG.EQ.0) CALL FOUND (AKF1,AKF2,AKF,IBASE,A,DUMMY,S,OMEGA,
     1                ESCALE,NTEMP,NB2,NEV,NEQ)
C
C     SOLVE FOR GENERALIZED DISPLACEMENTS
C
      CALL CSYMEQ(S,HY,NEV,NCOMP)
C
      DO 505 I=1,NCOMP
      DO 505 M=1,MNEV
  505 HACC(M,I)=OM2*CABS(HY(M,I))
      WRITE (6,2040) OMEGA,((HACC(M,I),M=1,MNEV),I=1,NCOMP)
C
      LL=LL+1
      DO 520 KK=1,NEV
      MM=MM+1
      DO 520 I=1,NCOMP
  520 YBUF(MM,I)=HY(KK,I)
      IF (LL.NE.NWR) GO TO 530
C
C     WRITE FREQUENCY RESPONSES ON TAPE
C
      DO 525 I=1,NCOMP
      IF (I.EQ.1) ITAPE=2
      IF (I.EQ.2) ITAPE=3
  525 CALL WRITEY(YBUF(1,I),NB,ITAPE)
      NBLOCK=NBLOCK+1
      LL=0
      MM=0
  530 OMEGA=OMEGA+DOP
  570 CONTINUE
 
      NREST=NPB-NWR*NBLOCK
      IF (NREST.EQ.0) RETURN
      NR=2*NREST*NEV
      DO 590 I=1,NCOMP
      IF (I.EQ.1) ITAPE=2
      IF (I.EQ.2) ITAPE=3
  590 CALL WRITEY(YBUF(1,I),NR,ITAPE)
C
      RETURN
C
 2010 FORMAT (1H1,
     * 20X,6A10// 80H ABSOLUTE VALUE OF FREQUENCY RESPONSES FOR GENERALI
     *ZED ACCELERATIONS OF THE DAM    /
     *              80H ----------------------------------------------
     *------------------------------    // )
 2020 FORMAT (19H1(10X,10HHORZ.EXCIT.1),37HX,10HVERT.EXCIT//,5X,5HOMEGA,
     *12I10/)  )
 2040 FORMAT (13(1X,F5.4))
      END
      SUBROUTINE KPEIGN (LAM2,EI2,A,Z,IJBC,SUM1,SUM2,NTERM,NTERM1,NEV,
     1                   NEV1,NEQ,NPP,OMOM,N)
C
C     ****************************************************************
C     COMPUTE EIGENVALUES AND PARTICIPATION FACTORS OF THE IMPOUNDED
C     WATER IN THE RESERVOIR
C     ****************************************************************
C
      DIMENSION LAM2(1),EI2(NEV1,1),A(NEQ,1),Z(1),IJBC(1),SUM1(1),
     1          SUM2(1)
      COMPLEX LAM2,EI2,SUM1,SUM2,X0,X1,X2,X3,LNL,WP,WN,S1,C1,E,EP,EN,
     1        S2,C2,C221,D1,D2,TWO,I
      EQUIVALENCE (X0,WP),(X1,WP1,(X2,EP),(X3,EN)
      DATA NMAX/20/,TOL/1.0E-7/,TWO/(0.0,2.0)/,I/(0.0,1.0)/
C
C     COMPUTE EIGENVALUES USING NEWTON-RAPHSON METHOD
C
      DO 30 L=1,NTERM
      X0 = LAM2(L)
      X2 = CEXP(TWO*X0)
      C1 = X0 + OPOM
      X3 = X2 + (X0-OMOM)/C1
      DO 10 N=1,NMAX
      X1 = X0 - 0.50*X3/(I*X2+OMOM/(C1*C1))
      X2 = CEXP(TWO*X1)
      C1 = X1 + OPOM
      X3 = X2 + (X1-OMOM)/C1
      IF (CABS(X1-X0).LT.TOL.AND.CABS(X3).LT.TOL) GO TO 20
      X0 = X1
   10 CONTINUE
      WRITE (6,99) L, OPOM
   20 LAM2(L) = X1
   30 CONTINUE
C
C     COMPUTE PARTICIPATION FACTORS (N,L)
C
      NELMNT = NPP - 1
      LT = IJBC(NPP)
      Z0 = Z(LT)
      DO 80 L=1,NTERM1
      DO 40 N=1,NEV
      SUM1(N) = 0.0
   40 SUM2(N) = 0.0
      LNL = LAM2(L)
      WP = LNL + OMOM
      WN = LNL - OMOM
      S1 = 2.0*OMOM
      C1 = 2.0*LNL
      DO 60 K=1,NELMNT
      I1 = IJBC(NPP-K+1)
      J1 = IJBC(NPP-K  )
      I2 = I1 + I1 - 1
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      J2 = J1 + J1 - 1                                                   KPEIGN.54
      E = CEXP(I*LNL*((Z(J1)-Z0)/H))                                     KPEIGN.55
      EP = W*E                                                           KPEIGN.56
      EN = W/E                                                           KPEIGN.57
      S2 = EP - EN                                                       KPEIGN.58
      C2 = EP + EN                                                       KPEIGN.59
      CZ21 = (C2-C1)/(Z(J1)-Z(I1))                                       KPEIGN.60
      DO 50 N=1,NEV                                                      KPEIGN.61
      SUM1(N) = SUM1(N) + A(J2,N)*S2 - A(I2,N)*S1                        KPEIGN.62
   50 SUM2(N) = SUM2(N) + CZ21*(A(J2,N)-A(I2,N))                         KPEIGN.63
      S1 = S2                                                            KPEIGN.64
   60 C1 = C2                                                            KPEIGN.65
      D2 = (I*H)/LNL                                                     KPEIGN.66
      D1 = -0.50*D2/LNL                                                  KPEIGN.67
      DO 70 N=1,NEV                                                      KPEIGN.68
   70 EI2(N+1,L) = D1*(SUM1(N)+D2*SUM2(N))                               KPEIGN.69
   80 EI2(   1,L) = D1*(S2-2.0*OMEM)                                     KPEIGN.70
      RETURN                                                             KPEIGN.71
C                                                                        KPEIGN.72
   99 FORMAT (1H0,60H***** EIGENVALUE DID NOT CONVERGE, COMPUTATION PROCKPEIGN.73
     1EDING (N= ,I3,6H CROM=,F12.6,7H) ***** )                           KPEIGN.74
      END                                                                KPEIGN.75
      SUBROUTINE KPVERT (SUM1,A,Z,IJBC,NEV,NEQ,NPP,OMC,H)                KPVERT.2
C                                                                        KPVERT.3
C     *******************************************************************KPVERT.4
C     COMPUTE HYDRODYNAMIC FORCE DUE TO VERTICAL GROUND MOTION           KPVERT.5
C     *******************************************************************KPVERT.6
C                                                                        KPVERT.7
      DIMENSION SUM1(1),A(NEQ,1),Z(1),IJBC(1)                            KPVERT.8
      EQUIVALENCE (C1,Z1),(C2,Z2),(SZ21,Z21P),(ARG,Z21M),(LT,Z213)      KPVERT.9
C                                                                        KPVERT.10
      NELMNT = NPP - 1                                                   KPVERT.11
      LT = IJBC(NPP)                                                     KPVERT.12
      Z0 = Z(LT)                                                         KPVERT.13
      DO 10 N=1,NEV                                                      KPVERT.14
   10 SUM1(N) = 0.0                                                      KPVERT.15
      IF (OMC.EQ.0.0) GO TO 40                                           KPVERT.16
C                                                                        KPVERT.17
      ARG = OMC*H                                                        KPVERT.18
      C1 = COS(ARG)                                                      KPVERT.19
      S1 = SIN(ARG)                                                      KPVERT.20
      DO 30 K=1,NELMNT                                                   KPVERT.21
      I1 = IJBC(NPP-K+1)                                                 KPVERT.22
      J1 = IJBC(NPP-K  )                                                 KPVERT.23
      I2 = I1 + I1 - 1                                                   KPVERT.24
      J2 = J1 + J1 - 1                                                   KPVERT.25
      ARG = OMC*(H-Z(J1)+Z0)                                             KPVERT.26
      C2 = COS(ARG)                                                      KPVERT.27
      S2 = SIN(ARG)                                                      KPVERT.28
      SZ21 = (S2-S1)/(OMC*(Z(J1)-Z(I1)))                                 KPVERT.29
      DO 20 N=1,NEV                                                      KPVERT.30
   20 SUM1(N) = SUM1(N) + (A(J2,N)*C2-A(I2,N)*C1)                        KPVERT.31
     1                  + SZ21*(A(J2,N)-A(I2,N))                         KPVERT.32
      C1 = C2                                                            KPVERT.33
   30 S1 = S2                                                            KPVERT.34
      RETURN                                                             KPVERT.35
C                                                                        KPVERT.36
   40 Z1 = 0.0                                                           KPVERT.37
      TT = 2.0/3.0                                                       KPVERT.38
      DO 60 K=1,NELMNT                                                   KPVERT.39
      I1 = IJBC(NPP-K+1)                                                 KPVERT.40
      J1 = IJBC(NPP-K  )                                                 KPVERT.41
      I2 = I1 + I1 - 1                                                   KPVERT.42
      J2 = J1 + J1 - 1                                                   KPVERT.43
      Z2 = Z(J1) - Z0                                                    KPVERT.44
      Z21P = Z2 + Z1                                                     KPVERT.45
      Z21M = (Z2-Z1)*H                                                   KPVERT.46
      Z213 = (Z2*Z2+Z2*Z1+Z1*Z1)*TT                                      KPVERT.47
      DO 50 N=1,NEV                                                      KPVERT.48
   50 SUM1(N) = SUM1(N) + (A(J2,N)+A(I2,N))*Z21M                         KPVERT.49
     1                  - (A(I2,N)*Z2-A(J2,N)*Z1)*Z21P                   KPVERT.50
     2                  - (A(J2,N)-A(I2,N))*Z213                         KPVERT.51
   60 Z1 = Z2                                                            KPVERT.52
      RETURN                                                             KPVERT.53
      END                                                                KPVERT.54
      SUBROUTINE MPRINT (A,NR,NC)                                        MPRINT.2
C                                                                        MPRINT.3
C     *******************************************************************MPRINT.4
C     SUBROUTINE TO PRINT MATRICES                                       MPRINT.5
C     *******************************************************************MPRINT.6
C                                                                        MPRINT.7
      DIMENSION A( NR,1)                                                 MPRINT.8
      DO 100 J=1,NC,8                                                    MPRINT.9
      JM=J+7                                                             MPRINT.10
      IF(JM-NC) 75,75,50                                                 MPRINT.11
   50 JM=NC                                                              MPRINT.12
   75 WRITE (6,1000) (K,K=J,JM)                                          MPRINT.13
      DO 100 I=1,NR                                                      MPRINT.14
  100 WRITE (6,1001) I,(A(I,K),K=J,JM)                                   MPRINT.15
      RETURN                                                             MPRINT.16
C                                                                        MPRINT.17
 1000 FORMAT (/// 8X, 8I14)                                              MPRINT.18
 1001 FORMAT (1X,I4,3X,8E14.7)                                           MPRINT.19
      END                                                                MPRINT.20
      SUBROUTINE QUAD (R1,R2,R3,R4,Z1,Z2,Z3,Z4,RM,ZM,ELMASS,D,QK,QC,Q,   QUAD.2
     *                 RHC,IGRAV)                                        QUAD.3
C                                                                        QUAD.4
C     *******************************************************************QUAD.5
C     FORMS STIFFNESS MATRIX QK, CENTROIDAL STRESS MATRIX QC             QUAD.6
C     AND LOAD VECTOR FOR AN INCOMPATIBLE ISOPARAMETRIC                  QUAD.7
C     QUADRILATERAL ELEMENT USING A FOUR POINT INTEGRATION FORMULA       QUAD.8
C     *******************************************************************QUAD.9
C                                                                        QUAD.10
      DIMENSION QK(8,8),QC(3,8),D(3,3),TT(4),B(3,12),SS(4),GQ(12,12),    QUAD.11
     *          P(12),Q(8),ELMASS(4)                                     QUAD.12
      LOGICAL  TRIANG                                                    QUAD.13
      DATA SS/-1.,1.,1.,-1./,TT/-1.,-1.,1.,1. /                          QUAD.14
C                                                                        QUAD.15
      FZ=-RHC*32.2                                                       QUAD.16
C                                                                        QUAD.17
C     INITIALIZE                                                         QUAD.18
C                                                                        QUAD.19
      DO 15 J=1,12                                                       QUAD.20
      P(J)=0.0                                                           QUAD.21
      DO 10 I=1,3                                                        QUAD.22
   10 B(I,J)=0.0                                                         QUAD.23
      DO 15 I=1,12                                                       QUAD.24
   15 GQ(I,J)=0.0                                                        QUAD.25
C                                                                        QUAD.26
      R12=R1-R2                                                          QUAD.27
      R13=R1-R3                                                          QUAD.28
      R14=R1-R4                                                          QUAD.29
      R23=R2-R3                                                          QUAD.30
      R24=R2-R4                                                          QUAD.31
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      R34=R3-R4
      Z12=Z1-Z2
      Z13=Z1-Z3
      Z14=Z1-Z4
      Z23=Z2-Z3
      Z24=Z2-Z4
      Z34=Z3-Z4
      VOL=R13*Z24-R24*Z13
      RM=(R1+R2+R3+R4)/4.0
      ZM=(Z1+Z2+Z3+Z4)/4.0
      PZTO=-(Z14+Z23)
      PRTO=-(R14+R23)
      PZSO=-(Z12-Z34)
      PRSO=-(R12-R34)
C
C     CHECK IF ELEMENT IS TRIANGULAR
C
      TRIANG=.FALSE.
      IF (R14.EQ.0.0.AND.Z14.EQ.0.0) TRIANG=.TRUE.
C
C     LOOP OVER 2X2 GAUSS QUADRATURE POINTS
C
      DO 500 II=1,4
      S=SS(II)*0.57735026918962
      T=TT(II)*0.57735026918962
      SM=1.0-S
      SP=1.0+S
      TM=1.0-T
      TP=1.0+T
      H1=SM*TM
      H2=SP*TM
      H3=SP*TP
      H4=SM*TP
C
      PZT=-(SM*Z14+SP*Z23)/4.0
      PRT=-(SM*R14+SP*R23)/4.0
      PZS=-(TM*Z12-TP*Z34)/4.0
      PRS=-(TM*R12-TP*R34)/4.
      XJ=PRS*PZT-PRT*PZS
      X1=PZT/XJ
      X2=-PZS/XJ
      X3=-PRT/XJ
      X4=PRS/XJ
C
C     STRAIN DISPLACEMENT TRANSFORMATION
C
      B(1,1)=-TM*X1-SM*X2
      B(1,3)= TM*X1-SP*X2
      B(1,5)= TP*X1+SP*X2
      B(1,7)=-TP*X1+SM*X2
      B(2,2)=-TM*X3-SM*X4
      B(2,4)= TM*X3-SP*X4
      B(2,6)= TP*X3+SP*X4
      B(2,8)=-TP*X3+SM*X4
      B(3,1)=B(2,2)
      B(3,3)=B(2,4)
      B(3,5)=B(2,6)
      B(3,7)=B(2,8)
      B(3,2)=B(1,1)
      B(3,4)=B(1,3)
      B(3,6)=B(1,5)
      B(3,8)=B(1,7)
      IF (TRIANG) GO TO 300
C
C     INCLUDE INCOMPATIBLE MODES
C
      SS2=-(S+S)/XJ
      TT2=-(T+T)/XJ
      B(1, 9)= PZTO*SS2
      B(1,10)=-PZSO*TT2
      B(2,11)=-PRTO*SS2
      B(2,12)= PRSO*TT2
      B(3, 9)= B(2,11)
      B(3,10)= B(2,12)
      B(3,11)= B(1, 9)
      B(3,12)= B(1,10)
  300 CONTINUE
C
C     THE ENLARGED STIFFNESS MATRIX
C
      FAC=XJ/16.0
      DO 400 J=1,12
      D1=(D(1,1)*B(1,J)+D(1,2)*B(2,J)+D(1,3)*B(3,J))*FAC
      D2=(D(2,1)*B(1,J)+D(2,2)*B(2,J)+D(2,3)*B(3,J))*FAC
      D3=(D(3,1)*B(1,J)+D(3,2)*B(2,J)+D(3,3)*B(3,J))*FAC
      DO 400 I=J,12
      QQ(I,J)=QQ(I,J)+B(1,I)*D1+B(2,I)*D2+B(3,I)*D3
  400 QQ(J,I)=QQ(I,J)
C
C     FORM EQUIVALENT BODY FORCE VECTOR
C
      IF (IGRAV.EQ.0) GO TO 500
      BZ=FZ*XJ
      P(2)=P(2)+BZ*H1/4.
      P(4)=P(4)+BZ*H2/4.
      P(6)=P(6)+BZ*H3/4.
      P(8)=P(8)+BZ*H4/4.
  500 CONTINUE
C
C     ELIMINATE AUXILIARY DEGREES OF FREEDOM
C
      IF((D(3,3).LT.D(1,1)/1000000.).OR.TRIANG) GO TO 80
      DO 50 N=1,4
      L=12-N
      M=L+1
      DO 50 I=1,L
      C=QQ(I,M)/QQ(M,M)
      DO 50 J=1,L
   50 QQ(I,J)=QQ(I,J)-C*QQ(M,J)
C
C     RELOCATE THE STIFFNESS MATRIX AND LOAD VECTOR
C
   80 DO 70 I=1,8
      Q(I)=P(I)
      DO 70 J=1,8
   70 QK(I,J)=QQ(I,J)
C
C     FORM STRESS MATRIX QS AT CENTROID (RM,ZM) OF THE ELEMENT
C
      DO 40 I=1,3
      D1=D(I,1)
      D2=D(I,2)
      D3=D(I,3)
      T1=( D1*Z24-D3*R24)/VOL
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      T2=(-C1*Z13+D3*R13)/VOL                                           QUAD.156
      T3=(-C2*R24+D3*Z24)/VOL                                           QUAD.157
      T4=( C2*R13-D3*Z13)/VOL                                           QUAD.158
      QC(I,1)=   T1                                                     QUAD.159
      QC(I,3)=   T2                                                     QUAD.160
      QC(I,5)=  -T1                                                     QUAD.161
      QC(I,7)=  -T2                                                     QUAD.162
      QC(I,2)= T3                                                       QUAD.163
      QC(I,4)= T4                                                       QUAD.164
      QC(I,6)=-T3                                                       QUAD.165
      QC(I,8)=-T4                                                       QUAD.166
   40 CONTINUE                                                          QUAD.167
C                                                                       QUAD.168
C     COMPUTE LUMPED MASSES                                             QUAD.169
C                                                                       QUAD.170
      RM1=R1-RM                                                         QUAD.171
      RM2=R2-RM                                                         QUAD.172
      RM3=R3-RM                                                         QUAD.173
      RM4=R4-RM                                                         QUAD.174
      ZM1=Z1-ZM                                                         QUAD.175
      ZM2=Z2-ZM                                                         QUAD.176
      ZM3=Z3-ZM                                                         QUAD.177
      ZM4=Z4-ZM                                                         QUAD.178
      ELMASS(1)=RHO*( RM1*Z24-ZM1*R24)/4.                               QUAD.179
      ELMASS(2)=RHO*(-RM2*Z13+ZM2*R13)/4.                               QUAD.180
      ELMASS(3)=RHO*(-RM3*Z24+ZM3*R24)/4.                               QUAD.181
      ELMASS(4)=RHO*( RM4*Z13-ZM4*R13)/4.                               QUAD.182
C                                                                       QUAD.183
      RETURN                                                            QUAD.184
      END                                                               QUAD.185
      SUBROUTINE  READB (A,LA,N,NUMEL)                                  READB.2
C                                                                       READB.3
C     ******************************************************************READB.4
C     READ ELEMENT DATA FROM TAPE                                       READB.5
C     ******************************************************************READB.6
C                                                                       READB.7
      COMMON /BUF/ B(2220)                                              READB.8
      DIMENSION A(LA)                                                   READB.9
C                                                                       READB.10
      LB=2220                                                           READB.11
      IF ( N .NE. 1 ) GO TO 100                                         READB.12
      REWIND 1                                                          READB.13
      M=0                                                               READB.14
      READ (1) B                                                        READB.15
  100 MM=M+LA                                                           READB.16
      DO 200 I=1,LA                                                     READB.17
      II=I+M                                                            READB.18
  200 A(I)=B(II)                                                        READB.19
      M=MM                                                              READB.20
      IF ( N .EQ. NUMEL ) GO TO 400                                     READB.21
      IF ( (M+LA) .LE. LB ) GO TO 400                                   READB.22
      READ (1) B                                                        READB.23
      M=0                                                               READB.24
  400 RETURN                                                            READB.25
      END                                                               READB.26
      SUBROUTINE READSS (SST,XY,LLM,NUMEL)                              READSS.2
C                                                                       READSS.3
C     ******************************************************************READSS.4
C     SUBROUTINE TO READ ELEMENT STRESS TRANSFORMATION MATRICES,        READSS.5
C     CENTROIDAL COORDINATES AND LM ARRAY FROM TAPE 1 AND STORE         READSS.6
C     THEM IN CORE AS ONE-DIMENSION ARRAYS                              READSS.7
C     ******************************************************************READSS.8
C                                                                       READSS.9
      DIMENSION SST(1),XY(1),LLM(1)                                     READSS.10
      COMMON /ELDATA/ LM(8),SS(3,8),XC,YC,ELMASS(4),S(8,8),MTYPE,Q(8),  READSS.11
     1                C(3,3)                                            READSS.12
C                                                                       READSS.13
      REWIND 1                                                          READSS.14
      K=0                                                               READSS.15
      M=0                                                               READSS.16
C                                                                       READSS.17
      DO 120 N=1,NUMEL                                                  READSS.18
      CALL READB(LM,111,N,NUMEL)                                        READSS.19
      DO 100 I=1,3                                                      READSS.20
      DO 100 J=1,8                                                      READSS.21
      K=K+1                                                             READSS.22
  100 SST(K)=SS(I,J)                                                    READSS.23
      N2=N+N                                                            READSS.24
      XY(N2-1)=XC                                                       READSS.25
      XY(N2  )=YC                                                       READSS.26
      DO 110 J=1,8                                                      READSS.27
      M=M+1                                                             READSS.28
  110 LLM(M)=LM(J)                                                      READSS.29
  120 CONTINUE                                                          READSS.30
      RETURN                                                            READSS.31
      END                                                               READSS.32
      SUBROUTINE READY(Y,LH,ITAPE)                                      READY.2
C                                                                       READY.3
C     ******************************************************************READY.4
C     READ RESPONSE DATA FROM TAPE                                      READY.5
C     ******************************************************************READY.6
C                                                                       READY.7
      DIMENSION Y(LH)                                                   READY.8
C                                                                       READY.9
      READ (ITAPE) Y                                                    READY.10
      RETURN                                                            READY.11
      END                                                               READY.12
      SUBROUTINE REALY(Y,YREAL,NC2,NEV,ITAPE)                           REALY.2
C                                                                       REALY.3
C     ******************************************************************REALY.4
C     WRITE RESPONSE OF GENERALIZED COORDINATES ON TAPE IN BLOCKS       REALY.5
C     ******************************************************************REALY.6
C                                                                       REALY.7
      COMMON /CNTRL2/ NDATA,NNR,DT,NREST,NBUF,NBLOCK,INV,NCMP,ISEL,     REALY.8
     *                ICCPB,NPRINT,ND                                   REALY.9
      DIMENSION YREAL(1),Y(NC2,1)                                       REALY.10
C                                                                       REALY.11
      REWIND ITAPE                                                      REALY.12
      NROW= 2*NNR                                                       REALY.13
      NBLOCK=ND   /NROW                                                 REALY.14
      IF (NBLOCK.EQ.0) NROW=ND                                          REALY.15
      NB=NROW*NEV                                                       REALY.16
      NREST=ND   -NBLOCK*NROW                                           REALY.17
      JJ=0                                                              REALY.18
      IBLOCK=0                                                          REALY.19
C                                                                       REALY.20
  190 IBLOCK=IBLOCK+1                                                   REALY.21
      MM=0                                                              REALY.22
      DO 230 I=1,NROW                                                   REALY.23
      JJ=JJ+1                                                           REALY.24
      DO 220 KK=1,NEV                                                   REALY.25
      MM=MM+1                                                           REALY.26
  220 YREAL(MM)=Y(JJ,KK)                                                REALY.27
  230 CONTINUE                                                          REALY.28
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C                                                                       REALY.29
      CALL WRITEV(YREAL,NG,ITAPE)                                       REALY.30
C                                                                       REALY.31
      IF (IBLOCK.LT.NBLOCK) GO TO 100                                   REALY.32
C                                                                       REALY.33
      NROW=NREST                                                        REALY.34
      NB=NREST*NEV                                                      REALY.35
      IF (IBLOCK.GT.NBLOCK) RETURN                                      REALY.36
      IF (NREST.GT.0) GO TO 100                                         REALY.37
      RETURN                                                            REALY.38
C                                                                       REALY.39
      END                                                               REALY.40
      SUBROUTINE RESPNS (X,XS,A,Y,YBUF,SIGMAX,TMAX,SIGMIN,TMIN,NODE,NELM,RESPNS.2
     *                   STRES,SST,XY,LLM,NNODE,NNELM,NEQ,NEV,NUME,NUM) RESPNS.3
C                                                                       RESPNS.4
C     ******************************************************************RESPNS.5
C     SUPERPOSITION OF MODES AND TIME RESPONSES OF DISPLACEMENTS        RESPNS.6
C     AND STRESSES                                                      RESPNS.7
C     ******************************************************************RESPNS.8
C                                                                       RESPNS.9
      COMMON /CNTRL1/ NUMNP,NBAND,NUMEL,NOC,IGRAV,                      RESPNS.10
     *                XJUNK(19)                                         RESPNS.11
      COMMON /CNTRL2/ NCATA,NWR,DT,NREST,NBUF,NBLOCK,IW,NCCMP,ISEL,     RESPNS.12
     *                ICOMB,NPRINT,NB                                   RESPNS.13
      COMMON /LABEL/  HED(8)                                            RESPNS.14
      DIMENSION X(NEQ),XS(NEQ),A(NEQ,NEV),Y(NEV),YBUF(1),SIGMAX(NUME),  RESPNS.15
     *          TMAX(1),SIGMIN(NUME),TMIN(1),NODE(1),NELM(1),STRES(NUM),RESPNS.16
     *          SST(1),XY(2),LLM(1)                                     RESPNS.17
C                                                                       RESPNS.18
      IF (IGRAV.EQ.0.OR.ICOMB.EQ.0) GO TO 100                           RESPNS.19
C                                                                       RESPNS.20
C     READ STATIC DISPLACEMENTS AND STRESSES FROM TAPE                  RESPNS.21
C                                                                       RESPNS.22
      BACKSPACE 1                                                       RESPNS.23
      BACKSPACE 1                                                       RESPNS.24
      READ (1) XS,SIGMAX,SIGMIN                                         RESPNS.25
      GO TO 130                                                         RESPNS.26
C                                                                       RESPNS.27
C     INITIALIZE DISPLACEMENTS AND STRESSES                             RESPNS.28
C                                                                       RESPNS.29
  100 DO 110 I=1,NEQ                                                    RESPNS.30
  110 XS(I)=0.                                                          RESPNS.31
      DO 120 I=1,NUMEL                                                  RESPNS.32
      SIGMAX(I)=0.                                                      RESPNS.33
  120 SIGMIN(I)=0.                                                      RESPNS.34
      BACKSPACE 1                                                       RESPNS.35
  130 DO 140 I=1,NUMEL                                                  RESPNS.36
      TMAX(I)=0.                                                        RESPNS.37
  140 TMIN(I)=0.                                                        RESPNS.38
C                                                                       RESPNS.39
C     READ MODE SHAPE MATRIX FROM TAPE                                  RESPNS.40
C                                                                       RESPNS.41
      READ (1) A                                                        RESPNS.42
C                                                                       RESPNS.43
C     READ ELEMENT STRESS TRANSFORMATION MATRICES                       RESPNS.44
C                                                                       RESPNS.45
      CALL READSS(SST,XY,LLM,NUMEL)                                     RESPNS.46
C                                                                       RESPNS.47
      IF (ISEL.EQ.0) GO TO 150                                          RESPNS.48
C                                                                       RESPNS.49
C     READ SELECTED NODAL POINT AND ELEMENT NUMBERS FOR WHICH           RESPNS.50
C     RESPONSES ARE TO BE PRINTED                                       RESPNS.51
C                                                                       RESPNS.52
      IF (NNODE.EQ.0) GO TO 145                                         RESPNS.53
      READ (5,1000) (NODE(I),I=1,NNODE)                                 RESPNS.54
  145 IF (NNELM.EQ.0) GO TO 160                                         RESPNS.55
      READ (5,1000) (NELM(I),I=1,NNELM)                                 RESPNS.56
      GO TO 160                                                         RESPNS.57
  150 NNODE=NUMNP                                                       RESPNS.58
      NNELM=NUMEL                                                       RESPNS.59
C                                                                       RESPNS.60
  160 REWIND 2                                                          RESPNS.61
      REWIND 3                                                          RESPNS.62
      WRITE (3) NUMNP,NUMEL,NEV,ND,DT                                   RESPNS.63
      NROW=2*NWR                                                        RESPNS.64
      IF (NBLOCK.EQ.0) NROW=ND                                          RESPNS.65
      NB=NROW*NEV                                                       RESPNS.66
      T=0.                                                              RESPNS.67
      IBLOCK=0                                                          RESPNS.68
      IPRINT=NPRINT-1                                                   RESPNS.69
      IF ((NNODE.LE.0).AND.(NNELM.LE.0)) GO TO 170                      RESPNS.70
      IF (ICOMB.EQ.0) WRITE (6,2000) HED                                RESPNS.71
      IF (ICOMB.NE.0) WRITE (6,2001) HED                                RESPNS.72
C                                                                       RESPNS.73
  170 IBLOCK=IBLOCK+1                                                   RESPNS.74
      M=0                                                               RESPNS.75
C                                                                       RESPNS.76
C     READ MODAL RESPONSES                                              RESPNS.77
C                                                                       RESPNS.78
      CALL READY(YBUF,NB,2)                                             RESPNS.79
      DO 235 NT=1,NROW                                                  RESPNS.80
      DO 180 K=1,NEV                                                    RESPNS.81
      M=M+1                                                             RESPNS.82
  180 Y(K)=YBUF(M)                                                      RESPNS.83
C                                                                       RESPNS.84
C     SUPERPOSITION OF MODES                                            RESPNS.85
C                                                                       RESPNS.86
      DO 200 N=1,NUMNP                                                  RESPNS.87
      J=N+N                                                             RESPNS.88
      I=J-1                                                             RESPNS.89
      SUM1=0.                                                           RESPNS.90
      SUM2=0.                                                           RESPNS.91
      DO 190 K=1,NEV                                                    RESPNS.92
      SUM1=SUM1+Y(K)*A(I,K)                                             RESPNS.93
  190 SUM2=SUM2+Y(K)*A(J,K)                                             RESPNS.94
      X(I)=SUM1+XS(I)                                                   RESPNS.95
  200 X(J)=SUM2+XS(J)                                                   RESPNS.96
C                                                                       RESPNS.97
C     WRITE DISPLACEMENTS ON TAPE                                       RESPNS.98
C                                                                       RESPNS.99
      WRITE (3) X                                                       RESPNS.100
C                                                                       RESPNS.101
C     PRINT NODAL DISPLACEMENTS                                         RESPNS.102
C                                                                       RESPNS.103
      IPRINT=IPRINT+1                                                   RESPNS.104
      IF (IPRINT.NE.NPRINT) GO TO 220                                   RESPNS.105
      IF ((NNODE.LE.0).AND.(NNELM.LE.0)) GO TO 205                      RESPNS.106
      WRITE (6,2010) T                                                  RESPNS.107
  205 IPRINT=0                                                          RESPNS.108
      INDEX=0                                                           RESPNS.109
      IF (NNODE.LE.0) GO TO 230                                         RESPNS.110
      DO 210 I=1,NNODE                                                  RESPNS.111
      IF (ISEL.EQ.0) N=I                                                RESPNS.112
      IF (ISEL.NE.0) N=NODE(I)                                          RESPNS.113
```

```
  210 WRITE (6,2020) N,X(N+N-1),X(N+N)                                   RESPNS.114
      GO TO 230                                                          RESPNS.115
  220 INDEX=1                                                            RESPNS.116
C                                                                        RESPNS.117
C     COMPUTE ELEMENT STRESSES AND PRINT                                 RESPNS.118
C                                                                        RESPNS.119
  230 CALL STRESS (X,SST,XY,LLM,SIGMAX,TMAX,SIGMIN,TMIN,STRES,T,NELM,    RESPNS.120
     .               NNELP,ISEL,NUM,INDEX)                               RESPNS.121
  235 T=T+DT                                                             RESPNS.122
C                                                                        RESPNS.123
      IF (IBLOCK.LT.NBLOCK) GO TO 170                                    RESPNS.124
      NROW=NREST                                                         RESPNS.125
      NB=NREST+NEV                                                       RESPNS.126
      IF (IBLOCK.GT.NBLOCK) GO TO 240                                    RESPNS.127
      IF (NREST.GT.0) GO TO 170                                          RESPNS.128
C                                                                        RESPNS.129
C     PRINT STRESS ENVELOPS                                              RESPNS.130
C                                                                        RESPNS.131
  240 WRITE (6,2030)                                                     RESPNS.132
      WRITE (6,2040) (I,TMAX(I),SIGMAX(I),TMIN(I),SIGMIN(I),I=1,NUMEL)   RESPNS.133
C                                                                        RESPNS.134
      RETURN                                                             RESPNS.135
C                                                                        RESPNS.136
 1000 FORMAT (16I5)                                                      RESPNS.137
 2000 FORMAT (1H1,20X,8A10//                                             RESPNS.138
     .               95H TIME RESPONSE OF NODAL DISPLACEMENTS AND ELEMENT RESPNS.139
     .STRESSES...NOT INCLUDING STATIC EFFECTS....../1X,94(1H-)//)         RESPNS.140
 2001 FORMAT (1H1,20X,8A10//                                             RESPNS.141
     .               95H TIME RESPONSE OF NODAL DISPLACEMENTS AND ELEMENT RESPNS.142
     .STRESSES...... INCLUDING STATIC EFFECTS....../1X,94(1H-)//)         RESPNS.143
 2010  FORMAT (///8H TIME T=,F10.6,5H SEC./1X,22(1H-)//                  RESPNS.144
     . 53H NODAL POINT  X-DISPLACEMENT  Y-DISPLACEMENT (IN FT.)/)        RESPNS.145
 2020 FORMAT (I9,3X,2E16.6)                                              RESPNS.146
 2030 FORMAT (93H1 MAX. AND MIN. STRESS(PSI) IN EACH INDIVIDUAL ELEMENT  RESPNS.147
     .AND THEIR TIMES(SEC) OF OCCURRENCE //                              RESPNS.148
     . 59H0  ELEMENT        TIME  MAX.STRESS        TIME  MIN.STRESS //) RESPNS.149
 2040 FORMAT (I10,4E12.4)                                                RESPNS.150
      END                                                                RESPNS.151
      SUBROUTINE RIGID (R,Z,XS,IBASE,AKFO,B,AB,XCG,YCG,BL,NUMNP,NBASE,   RIGID.2
     .                  NB2)                                             RIGID.3
C                                                                        RIGID.4
C     ******************************************************************RIGID.5
C     CALCULATE FORCES CORRESPONDING TO RIGID BODY DISPLACEMENT OF       RIGID.6
C     THE BASE                                                           RIGID.7
C     ******************************************************************RIGID.8
C                                                                        RIGID.9
      DIMENSION U(3),AKR(3,3),R(1),Z(1),XS(1),B(NB2,3),IBASE(1),         RIGID.10
     .          AB(NB2,3)                                                RIGID.11
      COMPLEX AKFO(NB2,1)                                                RIGID.12
C                                                                        RIGID.13
C     RESULTANT FORCES ON THE FOUNDATION ROCK                            RIGID.14
C                                                                        RIGID.15
      DO 100 I=1,3                                                       RIGID.16
  100 U(I)=0.                                                            RIGID.17
      DO 110 I=1,NUMNP                                                   RIGID.18
      IY=I+I                                                             RIGID.19
      IX=IY-1                                                            RIGID.20
      U(1)=U(1)+XS(IX)                                                   RIGID.21
      U(2)=U(2)+XS(IY)                                                   RIGID.22
  110 U(3)=U(3)-XS(IX)*(Z(I)-YCG)+XS(IY)*(R(I)-XCG)                      RIGID.23
C                                                                        RIGID.24
C     DISPLACEMENT TRANSFORMATION MATRIX B                               RIGID.25
C                                                                        RIGID.26
      DO 120 I=1,NBASE                                                   RIGID.27
      IY=I+I                                                             RIGID.28
      IX=IY-1                                                            RIGID.29
      II=IBASE(IY)/2                                                     RIGID.30
      B(IX,1)=1.                                                         RIGID.31
      B(IY,1)=0.                                                         RIGID.32
      B(IX,2)=0.                                                         RIGID.33
      B(IY,2)=1.                                                         RIGID.34
      B(IX,3)=0.                                                         RIGID.35
      B(IY,3)=(R(II)-XCG)                                                RIGID.36
  120 CONTINUE                                                           RIGID.37
C                                                                        RIGID.38
C     CALCULATE RIGID BODY STIFFNESS MATRIX AND STORE ONLY THE UPPER     RIGID.39
C     TRIANGLE                                                           RIGID.40
C                                                                        RIGID.41
      DO 140 I=1,NB2                                                     RIGID.42
      DO 140 J=1,3                                                       RIGID.43
      AB(I,J)=0.                                                         RIGID.44
      DO 130 K=1,NB2                                                     RIGID.45
  130 AB(I,J)=AB(I,J)+REAL(AKFO(I,K))*B(K,J)                             RIGID.46
  140 CONTINUE                                                           RIGID.47
C                                                                        RIGID.48
      DO 150 I=1,3                                                       RIGID.49
      DO 150 J=1,3                                                       RIGID.50
  150 AKR(I,J)=0.                                                        RIGID.51
      DO 170 I=1,3                                                       RIGID.52
      DO 170 J=I,3                                                       RIGID.53
      L=J-I+1                                                            RIGID.54
      DO 160 K=1,NB2                                                     RIGID.55
  160 AKR(I,L)=AKR(I,L)+B(K,I)*AB(K,J)                                   RIGID.56
  170 CONTINUE                                                           RIGID.57
C                                                                        RIGID.58
C     SOLVE FOR RIGID BODY DISPLACEMENTS                                 RIGID.59
C                                                                        RIGID.60
      CALL BANSOL (3,3,3,AKR,U,0)                                        RIGID.61
      CALL BANSOL (3,3,3,AKR,U,1)                                        RIGID.62
C                                                                        RIGID.63
C     CALCULATE RO AND ADD TO LOAD VECTOR                                RIGID.64
C                                                                        RIGID.65
      DO 190 I=1,NB2                                                     RIGID.66
      RO=0.                                                              RIGID.67
      L=IBASE(I)                                                         RIGID.68
      DO 180 J=1,3                                                       RIGID.69
  180 RO=RO+AB(I,J)*U(J)                                                 RIGID.70
  190 XS(L)=XS(L)-RO                                                     RIGID.71
C                                                                        RIGID.72
      RETURN                                                             RIGID.73
      END                                                                RIGID.74
      SUBROUTINE STATIC (NEBC,XS,A,SIGMAX,TMAX,SIGMIN,TMIN,STRES,        STATIC.2
     .                   SST,XY,LLM,NEQ,MBAN,NUM,NUME)                   STATIC.3
C                                                                        STATIC.4
C     ******************************************************************STATIC.5
C     COMPUTE STATIC RESPONSE                                            STATIC.6
C     ******************************************************************STATIC.7
C                                                                        STATIC.8
      COMMON /CNTRL1/ NUMNP,NBAND,NUMEL,NBC,XJUNK(20)                    STATIC.9
      COMMON /LABEL/  HED(8)                                             STATIC.10
      DIMENSION NEBC(1),XS(NEQ),A(NEQ,MBAN ),SIGMAX(NUME),TMAX(1),       STATIC.11
     .          SIGMIN(NUME),TMIN(1),STRES(1),SST(1),XY(1),LLM(1)        STATIC.12
C                                                                        STATIC.13
      CALL BANSOL(NEC,NBAND,NEQ,A,XS,0)                                  STATIC.14
```

```
      CALL BANSOL(NEQ,MBAND,NEQ,A,XS,1)
C
      WRITE (6,2000) HED
      WRITE (6,2010) (N,XS(2*N-1),XS(2*N),N=1,NUMNP)
      TT=0.0
      DO 100 N=1,NUMEL
      SIGMAX(N)=-99999.
      TMAX(N)=0.
      SIGMIN(N)=99999.
  100 TMIN(N) =0.
C
      CALL READSS(SST,XY,LLM,NUMEL)
C
      WRITE (6,2020) HED
      CALL STRESS (XS,SST,XY,LLM,SIGMAX,TMAX,SIGMIN,TMIN,STRES,TT,NELM,
     *             NUMEL,0,NUM,0)
C
      READ (1)
      WRITE (1) XS,SIGMAX,SIGMIN
      RETURN
C
 2000 FORMAT (1H1,
     * 20X,8A10//1X,23(1H*)/24H STATIC ANALYSIS RESULTS/1X,23(1H*)///
     * 42H DISPLACEMENTS DUE TO STATIC LOADS...IN FT  /
     * 42H ------------------------------------------ //
     * 42H NODAL PT  X-DISPLACEMENT  Y-DISPLACEMENT  )
 2010 FORMAT(I9,2E16.4)
 2020 FORMAT (1H1,20X,8A10)
      END
      SUBROUTINE STIFF (R,Z,NEBC,CODE,YMOD,ENU,RO,NUMMAT,PSP)
C
C     ****************************************************************
C     GEOMETRY OF THE STRUCTURE AND MATERIAL PROPERTIES ARE READ IN.
C     NODAL POINTS CAN BE GENERATED AT EQUAL INTERVALS OR IN LAYERS.
C     ELEMENT STIFFNESS,MASS ETC. ARE WRITTEN ON TAPE 1 ELEMENT
C     BY ELEMENT.
C     ****************************************************************
C
      COMMON /CNTRL1/ NUMNP,MBAND,NUMEL,NBC,IGRAV,XJUNK(19)
      COMMON /ELDATA/ LM(8),SS(3,8),XC,YC,ELMASS(4),S(8,8),MTYPE,Q(8),
     *                C(3,3)
      COMMON /LABEL/  HED(8)
      DIMENSION R(1),Z(1),NEBC(1),CODE(1),IX(4),IE(5),YMOD(1),ENU(1),
     *          RO(1)
C
C     READ AND PRINT MATERIAL PROPERTIES
C
      WRITE (6,2000) HED
      DO 110 M=1,NUMMAT
      READ  (5,1001) MTYPE,YMOD(MTYPE),ENU(MTYPE),RO(MTYPE)
      WRITE (6,2000) MTYPE,YMOD(MTYPE),ENU(MTYPE),RO(MTYPE)
      IF (ENU(MTYPE).LT.0.4999) GO TO 105
      ENU(MTYPE)=1.
      F=YMOD(MTYPE)
      GO TO 110
  105 IF (PSP.EQ.0.0) GO TO 110
      YMOD(MTYPE)=YMOD(MTYPE)/(1.-ENU(MTYPE)**2)
      ENU(MTYPE) =ENU(MTYPE)/(1.-ENU(MTYPE))
  110 CONTINUE
C
C     READ AND PRINT OF NODAL POINT DATA
C
      WRITE (6,2004) HED
      L=0
      NBC=0
  120 READ  (5,1002) N,CODE(N),R(N),Z(N),MOD,NLIM,FACR,FACZ
      L1=L+1
      IF (N-L1) 190,170,130
  130 IF (L.LE.0) GO TO 180
      DIV=N-L
      DR=(R(N)-R(L))/DIV
      DZ=(Z(N)-Z(L))/DIV
      M=N-1
      DO 140 K=L1,M
      CODE(K)=0.0
      R(K)=R(K-1)+DR
  140 Z(K)=Z(K-1)+DZ
      GO TO 170
  150 L1=N+1
      IF (FACR.LE.0.0) FACR=1.0
      IF (FACZ.LE.0.0) FACZ=1.0
      WRITE (6,2100) MOD,NLIM,FACR,FACZ
  160 N=N+1
      N1=N-MOD
      N2=N1-MOD
      IF (N1.LE.0.OR.N2.LE.0) GO TO 200
      CODE(N)=0.0
      R(N)=R(N1)+FACR*(R(N1)-R(N2))
      Z(N)=Z(N1)+FACZ*(Z(N1)-Z(N2))
      IF (N.LT.NLIM) GO TO 160
      MOD=0
  170 L=N
      WRITE (6,2002)(K,CODE(K),R(K),Z(K),K=L1,N)
      COD=CODE(N)
      IF ((COD.EQ.1.0).OR.(COD.EQ.3.0)) GO TO 171
      GO TO 172
  171 NBC=NBC+1
      NEBC(NBC)=2*N-1
  172 IF ((COD.EQ.2.0).OR.(COD.EQ.3.0)) GO TO 173
      GO TO 175
  173 NBC=NBC+1
      NEBC(NBC)=2*N
  175 IF (MOD.GT.0) GO TO 150
      IF (N-NUMNP) 120,220,210
  180 WRITE (6,2130)
      STOP
  190 WRITE (6,2140) N
      STOP
  200 WRITE (6,2150)
      STOP
  210 WRITE (6,2160) N,NUMNP
      STOP
  220 CONTINUE
C
C     READ AND PRINT ELEMENT PROPERTIES
C
      WRITE (6,2001) HED
      N=0
      MBAND=0
  230 READ(5,1003) M,(IE(I),I=1,5)
  240 N=N+1
      IF(M.EQ.N) GO TO 260
      DO 250 I=1,4
  250 IX(I)=IX(I)+1
```

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      GO TO 200                                                          STIFF.97
  260 DO 270 I=1,4                                                       STIFF.98
  270 IX(I)=IE(I)                                                        STIFF.99
      MTYPE=IE(5)                                                        STIFF.100
C                                                                        STIFF.101
C     DETERMINE BAND WIDTH                                               STIFF.102
C                                                                        STIFF.103
  200 MB=0                                                               STIFF.104
      DO 290 I=1,4                                                       STIFF.105
      DO 290 J=1,4                                                       STIFF.106
      MM=IABS(IX(I)-IX(J))                                               STIFF.107
      IF(MM.GT.MB) MB=MM                                                 STIFF.100
  290 CONTINUE                                                           STIFF.109
      MB=2*MB+2                                                          STIFF.110
      IF(MB.GT.MBAND) MBAND=MB                                           STIFF.111
      WRITE (6,2003) N,(IX(I),I=1,4),MTYPE                               STIFF.112
C                                                                        STIFF.113
C     STRESS-STRAIN TRANSFORMATION MATRIX                                STIFF.114
C                                                                        STIFF.115
      IF (ENU(MTYPE).LE.0.999) GO TO 300                                 STIFF.116
      GO TO 305                                                          STIFF.117
  300 F=YMOD(MTYPE)/(1.-ENU(MTYPE)**2)                                   STIFF.118
  305 C(1,1)=F                                                           STIFF.119
      C(1,2)=F*ENU(MTYPE)                                                STIFF.120
      C(1,3)=0.0                                                         STIFF.121
      C(2,1)=C(1,2)                                                      STIFF.122
      C(2,2)=C(1,1)                                                      STIFF.123
      C(2,3)=0.0                                                         STIFF.124
      C(3,1)=0.0                                                         STIFF.125
      C(3,2)=0.0                                                         STIFF.126
      C(3,3)=0.5*F*(1.-ENU(MTYPE))                                       STIFF.127
C                                                                        STIFF.120
C     FORM ELEMENT STIFFNESS MATRICES                                    STIFF.129
C                                                                        STIFF.130
      I=IX(1)                                                            STIFF.131
      J=IX(2)                                                            STIFF.132
      K=IX(3)                                                            STIFF.133
      L=IX(4)                                                            STIFF.134
      RHO=RO(MTYPE)                                                      STIFF.135
      CALL QUAD (R(I),R(J),R(K),R(L),Z(I),Z(J),Z(K),Z(L),XC,YC,ELMASS,   STIFF.136
     .          C,S,SS,C,RHO,IGRAV)                                      STIFF.137
C                                                                        STIFF.130
      DO 310 I=1,4                                                       STIFF.139
      IK=I+I                                                             STIFF.140
      II=IX(I)                                                           STIFF.141
      IJ=II+II                                                           STIFF.142
      LM(IK)=IJ                                                          STIFF.143
      LM(IK-1)=IJ-1                                                      STIFF.144
  310 CONTINUE                                                           STIFF.145
C                                                                        STIFF.146
C     STORE ELEMENT INFORMATION ON TAPE                                  STIFF.147
C                                                                        STIFF.140
      CALL WRITEB(LM,II,N,NUMEL)                                         STIFF.149
      IF(N.EQ.NUMEL) GO TO 320                                           STIFF.150
      IF(N.EQ.M) GO TO 230                                               STIFF.151
      GO TO 240                                                          STIFF.152
  320 RETURN                                                             STIFF.153
C                                                                        STIFF.154
 1001 FORMAT (I5,3F10.0)                                                 STIFF.155
 1002 FORMAT (I5,F5.0,2F10.0,2I5,2F10.0)                                 STIFF.156
 1003 FORMAT (6I5)                                                       STIFF.157
 2000 FORMAT (1H1,                                                       STIFF.158
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     . 20X,8A10//1X,20(1H*)/21H MATERIAL INFORMATION/1X,20(1H*)/)        STIFF.159
 2001 FORMAT (1H1,                                                       STIFF.160
     . 20X,8A10//1X,21(1H*)/22H ELEMENT SPECIFICATION/1X,21(1H*)//       STIFF.161
     . 54H ELEMENT NO.      I      J      K      L        MATERIAL ///)  STIFF.162
 2002 FORMAT (I7, F10.2,2F10.3)                                          STIFF.163
 2003 FORMAT (I11,2X,4I6,I12)                                            STIFF.164
 2004 FORMAT (1H1,                                                       STIFF.165
     . 20X,8A10// 1X,25(1H*)/26H NODAL POINT SPECIFICATION/1X,25(1H*)/// STIFF.166
     . 37H   NODE      CODE      X-ORD      Y-ORD  //)                   STIFF.167
 2006 FORMAT (16H0MATERIAL NUMBER I3/                                    STIFF.160
     . 4H0 E= F16.4,7H K/SFT./                                           STIFF.169
     . 4H0NU= F16.6/                                                     STIFF.170
     . 4H0RO= F16.4,16H K-SEC**2/FT.**4/)                                STIFF.171
 2100 FORMAT (21H GENERATION WITH NOD=I3,3X,6H NLIN=I4,3X,6H FACR=F10.5,STIFF.172
     . 3X,6H FACZ=F10.5)                                                 STIFF.173
 2130 FORMAT (28H0FIRST JOINT CARD IS MISSING)                           STIFF.174
 2140 FORMAT (31H0COORDINATE CARD FOR JOINT NO. I5,16H NOT IN SEQUENCE) STIFF.175
 2150 FORMAT (42H0INSUFFICIENT INFORMATION TO GENERATE MESH)             STIFF.176
 2160 FORMAT (16H0JOINT NUMBER I5,21H EXCEEDS GIVEN NUMNP=I5)            STIFF.177
      END                                                                STIFF.170
      SUBROUTINE STRESS (XO,SST,XY,LLM,SIGMAX,TMAX,SIGMIN,TMIN,STRES,TT,STRESS.2
     .                   NELM,NNELM,ISEL,NUM,INDEX)                      STRESS.3
C                                                                        STRESS.4
C     ****************************************************************STRESS.5
C     COMPUTE ELEMENT STRESSES AND STRESS ENVELOPES                      STRESS.6
C     ****************************************************************STRESS.7
C                                                                        STRESS.8
      COMMON /CNTRL1/ NUMNP,MBAND,NUMEL,RJUNK(21)                        STRESS.9
      DIMENSION XO(1),SIG(6),SIGMAX(1),TMAX(1),SIGMIN(1),TMIN(1),        STRESS.10
     .          NELM(1),STRES(NUM),SST(1),XY(1),LLM(1)                   STRESS.11
C                                                                        STRESS.12
C     COMPUTE ELEMENT STRESSES                                           STRESS.13
C                                                                        STRESS.14
      IF ((INDEX.EQ.0).AND.(NNELM.GT.0)) WRITE (6,2000)                  STRESS.15
      K=1                                                                STRESS.16
      II=0                                                               STRESS.17
C                                                                        STRESS.19
      DO 300 N=1,NUMEL                                                   STRESS.19
      N2=N+N                                                             STRESS.20
      NB=(N-1)*8                                                         STRESS.21
C                                                                        STRESS.22
      DO 180 I=1,3                                                       STRESS.23
      SIG(I)=0.0                                                         STRESS.24
      DO 180 J=1,8                                                       STRESS.25
      II=II+1                                                            STRESS.26
      M=NB+J                                                             STRESS.27
      JJ=LLM(M)                                                          STRESS.28
  180 SIG(I)=SIG(I)+SST(II)*XO(JJ)                                       STRESS.29
      DO 190 J=1,3                                                       STRESS.30
  190 SIG(J)=6.94444*SIG(J)                                              STRESS.31
      NN=3*N                                                             STRESS.32
      STRES(NN-2)=SIG(1)                                                 STRESS.33
      STRES(NN-1)=SIG(2)                                                 STRESS.34
      STRES(NN)  =SIG(3)                                                 STRESS.35
C                                                                        STRESS.36
      XC=XY(N2-1)                                                        STRESS.37
      YC=XY(N2  )                                                        STRESS.38
C                                                                        STRESS.39
C     CALCULATE PRINCIPAL STRESSES                                       STRESS.40
C                                                                        STRESS.41
      CC=(SIG(1)+SIG(2))/2.0                                             STRESS.42
      BB=(SIG(1)-SIG(2))/2.                                              STRESS.43
```

```
      CR=SQRT(BB**2+SIG(3)**2)
      SIG(4)=CC+CR
      SIG(5)=CC-CR
      IF ((BB.EQ.0.0).AND.(SIG(3).EQ.0.0)) GO TO 295
      SIG(6)=28.648*ATAN2(SIG(3),BB)
C
  295 IF ((INDEX.NE.0).OR.(NNELM.EQ.0)) GO TO 330
      IF (ISEL.EQ.0) GO TO 310
      IF (K.GT.NNELP) GC TO 330
      IF (N.NE.MELM(K)) GO TO 330
  310 WRITE (6,2001) N,XC,YC,(SIG(I),I=1,6)
      K=K+1
C
  330 IF (SIGMAX(N)-SIG(4)) 340,350,350
  340 SIGMAX(N)=SIG(4)
      TMAX(N)=TT
  350 IF (SIGMIN(N)-SIG(5)) 300,300,360
  360 SIGMIN(N)=SIG(5)
      TMIN(N)=TT
  300 CONTINUE
      WRITE (3) STRES
      RETURN
C
 2000 FORMAT(/1H0,23HELEMENT STRESSES IN PSI/
     .6H0EL.NO  7X  1HX  7X  1HY  7X  5HSIG-X  7X  5HSIG-Y  6X  6HTAU-XY
     .5X  7HSIG-MAX  5X  7HSIG-MIN  5X  5HANGLE /)
 2001 FORMAT (I5,1X,2F8.2,5E12.4,F10.2)
      END
      SUBROUTINE TOTAL(R,Z,NEBC,IJBC,MASS,AKFD,IBASE,A,XS,B,AB,NEQ,MBAN,
     .                SGN,NB2,ESCALE)
C
C     *******************************************************************
C     TOTAL STIFFNESS AND MASS MATRICES AND LOAD VECTOR ARE FORMED BY
C     READING THE ELEMENT STIFFNESS AND MASS ETC.FROM TAPE 1.NODAL POINT
C     LOADS DUE TO WATER PRESSURE ARE CALCULATED.
C     *******************************************************************
C
      COMMON /CNTRL1/ NUMNP,MBAND,NUMEL,NBC,IGRAV,NPP,WL,TRACE,
     .               ICPR,IOPP,NBASE,IRIG,XJUNK(12)
      COMMON /ELDATA/ LM(8),SS(3,8),XC,YC,ELMASS(4),S(8,8),MTYPE,Q(8),
     .               C(3,3)
      COMMON /LABEL/  HED(8)
      DIMENSION R(1),Z(1),NEBC(1),MASS(1),XS(1),A(NEQ,MBAN),IJBC(1),
     .          IBASE(1),B(NB2,3),AB(NB2,3)
      COMPLEX AKFD (NE2,NE2)
      REAL MASS
C
C     FORM TOTAL MASS AND STIFFNESS MATRICES
C
      DO 100 I=1,NEC
      MASS(I)=0.0
      XS(I)=0.0
      DO 100 J=1,MBAND
  100 A(I,J)=0.0
      DO 140 N=1,NUMEL
C
      CALL READQ(LM,111,N,NUMEL)
C
      DO 120 I=1,8
      II=LM(I)
      XS(II)=XS(II)+Q(I)
      DO 110 J=1,8
      JJ=LM(J)-II+1
      IF (JJ.LT.1) GC TC 110
      A(II,JJ)=A(II,JJ)+S(I,J)
  110 CONTINUE
  120 CONTINUE
      DO 130 I=1,4
      II=LM(2*I)
      MASS(II)=MASS(II)+ELMASS(I)
  130 MASS(II-1)=MASS(II)
  140 CONTINUE
      WRITE (1) A
C
C     PRESSURE BOUNDARY CONDITIONS
C
      IF(NPP.EQ.0) GO TC 160
      READ  (5,1010) LR,(IJBC(K),K=1,NPP)
      IF (LR.EQ.0) WRITE (6,2010)HED
      IF (LR.NE.0) WRITE (6,2011)HED
      WRITE (6,2020)
      I=IJBC(1)
      J=IJBC(2)
      II=I+I
      JJ=J+J
      X=WL-Z(J)
      PJ=0.0624*X
      DZ=Z(I)-Z(J)
      DR=R(I)-R(J)
      SGN=1.
      IF (LR.NE.0) SGN=-SGN
      PJ=PJ*SGN
      X1=WL-Z(I)
      IF (X1.LE.0.) GO TO 200
      PJ=0.0624*X1
      PJ=PJ*SGN
      R1=0.
      R2=0.
      NF=1
      GO TO 210
  200 F=X/DZ
      RI1= PJ*F**2.*DZ/6.
      RI2=-PJ*F**2.*DR/6.
      RJ1= PJ*F*(1-F/3.)*DZ/2.
      RJ2=-PJ*F*(1-F/3.)*DR/2.
      XS(II-1)=XS(II-1)+RI1
      XS(II)=XS(II)+RI2
      XS(JJ-1)=XS(JJ-1)+RJ1
      XS(JJ)=XS(JJ)+RJ2
      R1=RJ1
      R2=RJ2
      WRITE (6,2030) I,RI1,RI2
      NF=2
  210 NN=NPP-1
      DO 150 L=NF,NN
      PI=PJ
      I=IJBC(L)
      J=IJBC(L+1)
      II=I+I
      JJ=J+J
      DR=R(I)-R(J)
      DZ=Z(I)-Z(J)
      PJ=0.0624*(WL-Z(J))
      PJ=PJ*SGN
```

```
      RI1= (2.*PI+PJ)*DZ/6.
      RI2=-(2.*PI+PJ)*DR/6.
      RJ1= (2.*PJ+PI)*DZ/6.
      RJ2=-(2.*PJ+PI)*DR/6.
      XS(II-1)=XS(II-1)+RI1
      XS(II)=XS(II)+RI2
      XS(JJ-1)=XS(JJ-1)+RJ1
      XS(JJ)=XS(JJ)+RJ2
      RI1=RI1+R1
      RI2=RI2+R2
      R1=RJ1
      R2=RJ2
      WRITE (6,2030) (I,RI1,RI2)
  150 CONTINUE
      WRITE (6,2030) (J,R1,R2)
  160 CONTINUE
C
C     ADD STATIC FOUNDATION STIFFNESS AND EQUIVALENT FORCES
C     FOR RIGID BODY MOTION OF FLEXIBLE FOUNDATION ROCK
C
      IF(IRIG.NE.0) GO TO 250
C
C     FORM STATIC FOUNDATION ROCK STIFFNES
C
      REWIND 90
      READ(90)
      READ(90)
      READ(90) AKF0
      REWIND 90
      DO 220 I=1,NB2
      DO 220 J=I,NB2
      AKF0(I,J)=AKF0(I,J)*ESCALE
220   AKF0(J,I)=AKF0(I,J)
C
C     READ BASE NODE NUMBERS
C
C     COORDINATES OF CENTROID OF BASE
C
      READ(5,1010)(IBASE(I),I=1,NB2,2)
      IL=IBASE(1)
      IR=IBASE(NB2-1)
      BL=(R(IR)-R(IL))/2.
      XCG=(R(IR)+R(IL))/2.
      YCG=(Z(IR)+Z(IL))/2.
C
C     EQUATION NUMBERS CORRESPONDING TO BASE DOF.
C
      DO 230 I=1,NBASE
      II=I+I
      J=IBASE(II-1)
      IBASE(II)=2*J
230   IBASE(II-1)=IBASE(II)-1
C
C     ADD FOUNDATION STATIC STIFFNESS TO STRUCTURE STIFFNESS
C
      DO 240 I=1,NB2
      L=IBASE(I)
      DO 240 J=1,NB2
      K=IBASE(J)-L+1
      IF((K.LE.0) .OR. (K.GT.NBAND)) GO TO 240
      A(L,K)=A(L,K)+REAL(AKF0(I,J))
240   CONTINUE
```

```
C
C     COMPUTE RB AND ADD TO XS
C
      CALL RIGID (R,Z,XS,IBASE,AKF0,G,RB,XCG,YCG,BL,NUMNP,NBASE,NB2)
250   CONTINUE
C
C     DISPLACEMENT BOUNDARY CONDITIONS
C
      TRACE=0.
      DO 170 I=1,NEQ
  170 TRACE=TRACE+ABS(A(I,1))
      IF (NBC.LE.0) GO TO 190
      DO 180 K=1,NBC
      I=NBDC(K)
      A(I,1)=1.0
      XS(I)=0.
      DO 180 J=2,MBAND
      A(I,J)=0.
      L=I-J+1
      IF (L.LE.0) GO TO 180
      A(L,J)=0.
  180 CONTINUE
  190 RETURN
C
 1010 FORMAT (16I5)
 2010 FORMAT (1H1,
     . 20X,8A10// 46H POSITIVE X-DIRECTION IS DOWNSTREAM  ---------////)
 2011 FORMAT (1H1,
     . 20X,8A10// 46H POSITIVE X-DIRECTION IS UPSTREAM ------------////)
 2020 FORMAT (52H EQUIVALENT NODAL FORCES DUE TO HYDROSTATIC PRESSURE //
     .32H NODAL POINT     X-LOAD     Y-LOAD/)
 2030 FORMAT (I12,2F10.3)
      END
      SUBROUTINE TRNFRM (Y,UG,YBUF,XT,XUG,NEXP,NC,NEV,TD,NPUGH,NXUGY)
C
C     ******************************************************************
C     TRANSFORM FREQUENCY RESPONSE FUNCTIONS TO TIME DOMAIN WITH FFT
C     FOR SPECIFIED FREE-FIELD GROUND ACCELERATION
C     ******************************************************************
C
      COMMON /CNTRL2/ NDATA,NNP,DT,NREST,NBUF,NBLOCK,IHY,NCOMP,ISEL,
     .                 ICOPB,NPRINT,ND
      COMPLEX YBUF(1),UG(1),Y(NC,1)
      DIMENSION XT(1),XUG(1)
C
      FAC=32.2
      NB=2*NBUF
      NN=2*NDATA
      N2=NN+2
      DELF=1.0/(FLOAT(NN)*DT)
C
C     TRANSFORM RESPONSE TO EACH GROUND MOTION COMPONENT
C
      DO 400 I=1,NCOMP
C
C     READ FREE-FIELD GROUND ACCELERATION DATA
C
      ITAPE=2
      IF (I.EQ.2) GO TO 50
      IF (IHY-1) 40,40,40
   40 READ  (5,1000) (XT(K),XUG(K),K=1,NXUGH)
      WRITE (6,2000) (XT(K),XUG(K),K=1,NXUGH)
```

```
      NE=NELEM                                                  TRNFRM.31
      GO TO 70                                                  TRNFRM.32
   50 ITAPE=3                                                   TRNFRM.33
   60 READ  (5,1000) (XT(K),XUG(K),K=1,NXUGV)                   TRNFRM.34
      WRITE (6,2001) (XT(K),XUG(K),K=1,NXUGV)                   TRNFRM.35
      NX=NXUGV                                                  TRNFRM.36
   70 DO 140 K=1,NX                                             TRNFRM.37
  140 XUG(K)=XUG(K)*FAC                                         TRNFRM.38
C                                                               TRNFRM.39
C     INTERPOLATE GROUND MOTION DATA AT DT STEPS                TRNFRM.40
C                                                               TRNFRM.41
      DO 150 K=1,NDATA                                          TRNFRM.42
  150 UG(K)=0.                                                  TRNFRM.43
      ND=(TD/DT+.5)+1                                           TRNFRM.44
      IF (ND.GT.NDATA) ND=NDATA                                 TRNFRM.45
      CALL CINTER (XT,XUG,NX,ND,DT,UG)                          TRNFRM.46
C                                                               TRNFRM.47
C     FOURIER TRANSFORM OF EARTHQUAKE GROUND MOTION             TRNFRM.48
C                                                               TRNFRM.49
      CALL FFT (UG,NEXP,2,0,0,DT)                               TRNFRM.50
C                                                               TRNFRM.51
C     READ COMPLEX FREQUENCY RESPONSE FROM TAPE AND             TRNFRM.52
C     STORE AS 2-DIMENSIONAL ARRAY                              TRNFRM.53
C                                                               TRNFRM.54
      REWIND ITAPE                                              TRNFRM.55
      JJ=0                                                      TRNFRM.56
      DO 110 N=1,NBLOCK                                         TRNFRM.57
      NN=0                                                      TRNFRM.58
      CALL READY(YBUF,NB,ITAPE)                                 TRNFRM.59
      DO 100 LL=1,NWA                                           TRNFRM.60
      JJ=JJ+1                                                   TRNFRM.61
      DO 100 KK=1,NEV                                           TRNFRM.62
      NN=NN+1                                                   TRNFRM.63
  100 Y(JJ,KK)=YBUF(NN)                                         TRNFRM.64
  110 CONTINUE                                                  TRNFRM.65
      IF (NREST.EQ.0) GC TO 130                                 TRNFRM.66
      NB=2*NREST*NEV                                            TRNFRM.67
      CALL READY(YBUF,NB,ITAPE)                                 TRNFRM.68
      NN=0                                                      TRNFRM.69
      DO 120 LL=1,NREST                                         TRNFRM.70
      JJ=JJ+1                                                   TRNFRM.71
      DO 120 KK=1,NEV                                           TRNFRM.72
      NN=NN+1                                                   TRNFRM.73
  120 Y(JJ,KK)=YBUF(NN)                                         TRNFRM.74
  130 CONTINUE                                                  TRNFRM.75
C                                                               TRNFRM.76
C     FORM Y(W)*UG(W)                                           TRNFRM.77
C                                                               TRNFRM.78
      DO 160 K=1,NEV                                            TRNFRM.79
      Y(1,K)=CMPLX(REAL(Y(1,K))*REAL(UG(1)),                    TRNFRM.80
     *             REAL(Y(NC,K))*AIMAG(UG(1)))                  TRNFRM.81
      DO 16C J=2,NDATA                                          TRNFRM.82
  160 Y(J,K)=Y(J,K)*UG(J)                                       TRNFRM.83
C                                                               TRNFRM.84
C     WRITE ARRAY Y CN TAPE                                     TRNFRM.85
C                                                               TRNFRM.86
      REWINC ITAPE                                              TRNFRM.87
      DO 170 K=1,NEV                                            TRNFRM.88
  170 CALL WRITEY(Y(1,K),N2,ITAPE)                              TRNFRM.89
  400 CONTINUE                                                  TRNFRM.90
C                                                               TRNFRM.91
C     INVERSE FOURIER TRANSFORM TO TIME DOMAIN                  TRNFRM.92
C                                                               TRNFRM.93
      REWIND 2                                                  TRNFRM.94
      REWINC 3                                                  TRNFRM.95
      IEV=0                                                     TRNFRM.96
  190 IEV=IEV+1                                                 TRNFRM.97
      IEV1=IEV+1                                                TRNFRM.98
      CALL READY(Y(1,IEV),N2,2)                                 TRNFRM.99
      IF (IEV.NE.2) GC TC 200                                   TRNFRM.100
      CALL READY(Y(1,IEV1),N2,3)                                TRNFRM.101
      DO 195 J=1,NDATA                                          TRNFRM.102
  195 Y(J,IEV)=Y(J,IEV)+Y(J,IEV1)                               TRNFRM.103
C                                                               TRNFRM.104
  200 CALL FFT (Y(1,IEV),NEXP,2,0,1,DELF)                       TRNFRM.105
      IF (IEV.LT.NEV) GC TO 190                                 TRNFRM.106
      CALL REALY(T,YBUF,2*NC,NEV,2)                             TRNFRM.107
      RETURN                                                    TRNFRM.108
C                                                               TRNFRM.109
 1000 FORMAT (6(F6.3,F6.4))                                     TRNFRM.110
 2000 FORMAT (//27H HORIZONTAL EARTHQUAKE DATA /                TRNFRM.111
     .            27H ---------------------------//             TRNFRM.112
     .108H        TIME  ACCN-G       TIME  ACCN-G       TIME  ACCN-G      TITRNFRM.113
     .ME  ACCN-G       TIME  ACCN-G       TIME  ACCN-G //       TRNFRM.114
     .(6(4X,F6.3,2X,F6.4)))                                     TRNFRM.115
 2001 FORMAT(//27H   VERTICAL EARTHQUAKE DATA /                 TRNFRM.116
     .            27H ---------------------------//             TRNFRM.117
     .108H        TIME  ACCN-G       TIME  ACCN-G       TIME  ACCN-G      TITRNFRM.118
     .ME  ACCN-G       TIME  ACCN-G       TIME  ACCN-G //       TRNFRM.119
     .(6(4X,F6.3,2X,F6.4)))                                     TRNFRM.120
      END                                                       TRNFRM.121
      SUBROUTINE WRITEB (A,LA,N,NUMEL)                          WRITEB.2
C                                                               WRITEB.3
C     ******************************************************************WRITEB.4
C     WRITE ELEMENT DATA ON TAPE                                WRITEB.5
C     ******************************************************************WRITEB.6
C                                                               WRITEB.7
      COMMON /BUF/ B(2220)                                      WRITEB.8
      DIMENSION A(LA)                                           WRITEB.9
C                                                               WRITEB.10
      LB=2220                                                   WRITEB.11
      IF (N.NE.1) GC TO 100                                     WRITEB.12
      N=0                                                       WRITEB.13
      REWINC 1                                                  WRITEB.14
  100 NN=N+LA                                                   WRITEB.15
      DO 200 I=1,LA                                             WRITEB.16
      II=I+N                                                    WRITEB.17
  200 B(II)=A(I)                                                WRITEB.18
      N=NN                                                      WRITEB.19
      IF ( N .EQ. NUMEL ) GO TO 300                             WRITEB.20
      IF ( (N+LA) .LE. LB ) GO TO 400                           WRITEB.21
  300 WRITE (1) B                                               WRITEB.22
      N=0                                                       WRITEB.23
  400 RETURN                                                    WRITEB.24
      END                                                       WRITEB.25
      SUBROUTINE WRITEY(Y,LN,ITAPE)                             WRITEY.2
C                                                               WRITEY.3
C     ******************************************************************WRITEY.4
C     WRITE RESPONSE DATA CN TAPE                               WRITEY.5
C     ******************************************************************WRITEY.6
C                                                               WRITEY.7
      DIMENSION Y(LN)                                           WRITEY.8
C                                                               WRITEY.9
      WRITE (ITAPE) Y                                           WRITEY.10
```

```
      RETURN                                                            WRITEY.11
      END                                                               WRITEY.12
      SUBROUTINE FFT (R,M,L,K,IT,TW)                                    FFT.2
C                                                                       FFT.3
C     ******************************************************************FFT.4
C     COMPUTE FORWARD AND INVERSE FAST FOURIER TRANSFORM (FFT)          FFT.5
C     ******************************************************************FFT.6
C                                                                       FFT.7
      DIMENSION R(1)                                                    FFT.8
      INTEGER V,VF,Z,Z2,Z3,Z4                                           FFT.9
C                                                                       FFT.10
      JE=16                                                             FFT.11
      JI=JE*2                                                           FFT.12
      NK=2**(M-K)*L                                                     FFT.13
      IF(NK.LT.4) STOP                                                  FFT.14
      S2=.7071067811865475244                                           FFT.15
      S3=1.7320508075688772935/(2-IT)                                   FFT.16
      PI=3.14159265358979323846                                         FFT.17
      IF(IT.EQ.1) GO TO 2                                               FFT.18
      IF(L.EQ.2) CALL SCRT2(R,NK,TW)                                    FFT.19
      IF(L.EQ.3) CALL SCRT3(R,M,0,TW)                                   FFT.20
         CALL LPSTOR(L-1,R,0,NK,0,0,S3)                                 FFT.21
    2 IF(M.EQ.1) GO TO 4                                                FFT.22
      MI=M-1                                                            FFT.23
      DO 100 I=1,MI                                                     FFT.24
      IF(IT.EQ.0) INC=2**I*L                                            FFT.25
      IF(IT.EQ.1) INC=2**(M-I)*L                                        FFT.26
      I2=INC-2                                                          FFT.27
      INCD=INC*2                                                        FFT.28
         IF(K.GE.I) CALL LPSTOR(3,R,0,I2,INCD,INC,0.)                   FFT.29
      IF(K.GE.I) GO TO 100                                              FFT.30
      PIO=PI/INCO                                                       FFT.31
      C=COS(2.*PIO)                                                     FFT.32
      S=SIN(2.*PIO)                                                     FFT.33
         CALL LPSTOR(4+IT,R,0,NK,INCD,INC,0.)                           FFT.34
      IF(INC.EQ.4) GO TO 19                                             FFT.35
      JF=INC/2-1                                                        FFT.36
         DO 10 J=3,JF,JI                                                FFT.37
         ANG=(J-3)*PIO                                                  FFT.38
         CC=COS(ANG)                                                    FFT.39
         SS=SIN(ANG)                                                    FFT.40
         VF=MIN0(J+JI-2,JF)                                             FFT.41
         DO 10 V=J,VF,2                                                 FFT.42
         Z3=-I2-V                                                       FFT.43
         CT=CC                                                          FFT.44
         CC=CT*C-SS*S                                                   FFT.45
         SS=SS*C+S*CT                                                   FFT.46
         IF(IT.EQ.1) GO TO 13                                           FFT.47
         DO 12 Z=V,NK,INCD                                              FFT.48
         Z2=Z+1                                                         FFT.49
         Z3=Z3+INCD                                                     FFT.50
         Z4=Z3+1                                                        FFT.51
         A1=R(Z+INC)*CC+R(Z2+INC)*SS                                    FFT.52
         A2=R(Z2+INC)*CC-R(Z+INC)*SS                                    FFT.53
         A3=R(Z3+INC)*SS+R(Z4+INC)*CC                                   FFT.54
         A4=R(Z4+INC)*SS-R(Z3+INC)*CC                                   FFT.55
         R(Z+INC)=R(Z3)-A3                                              FFT.56
         R(Z2+INC)=-R(Z4)+A4                                            FFT.57
         R(Z3+INC)=R(Z)-A1                                              FFT.58
         R(Z4+INC)=-R(Z2)+A2                                            FFT.59
         R(Z)=R(Z)+A1                                                   FFT.60
         R(Z2)=R(Z2)+A2                                                 FFT.61
         R(Z3)=R(Z3)+A3                                                 FFT.62
   12    R(Z4)=R(Z4)+A4                                                 FFT.63
         GO TO 10                                                       FFT.64
   13    DO 14 Z=V,NK,INCD                                              FFT.65
         Z2=Z+1                                                         FFT.66
         Z3=Z3+INCD                                                     FFT.67
         Z4=Z3+1                                                        FFT.68
         A1=R(Z)-R(Z3+INC)                                              FFT.69
         A2=R(Z2)+R(Z4+INC)                                             FFT.70
         A3=R(Z3)-R(Z+INC)                                              FFT.71
         A4=R(Z4)+R(Z2+INC)                                             FFT.72
         R(Z)=R(Z)+R(Z3+INC)                                            FFT.73
         R(Z2)=R(Z2)-R(Z4+INC)                                          FFT.74
         R(Z3)=R(Z3)+R(Z+INC)                                           FFT.75
         R(Z4)=R(Z4)-R(Z2+INC)                                          FFT.76
         R(Z+INC)=A1*CC-A2*SS                                           FFT.77
         R(Z2+INC)=A2*CC+A1*SS                                          FFT.78
         R(Z3+INC)=A3*SS-A4*CC                                          FFT.79
   14    R(Z4+INC)=A4*SS+A3*CC                                          FFT.80
   10    CONTINUE                                                       FFT.81
      IF(INC.EQ.4) GO TO 100                                            FFT.82
   19 LS=INC/2+1                                                        FFT.83
         CALL LPSTOR(6+IT,R,LS,NK,INCD,INC,S2)                          FFT.84
  100 CONTINUE                                                          FFT.85
    4 IF(IT.EQ.0) RETURN                                                FFT.86
         CALL LPSTOR(4-L,R,0,NK,0,0,S3)                                 FFT.87
      IF(L.EQ.2) CALL SCRT2(R,NK,TW)                                    FFT.88
      IF(L.EQ.3) CALL SCRT3(R,M-K,1,TW)                                 FFT.89
      RETURN                                                            FFT.90
      END                                                               FFT.91
      SUBROUTINE LPSTOR (NS,R,LS,LF,INCD,INC,CC)                        LPSTOR.2
C                                                                       LPSTOR.3
C     ******************************************************************LPSTOR.4
C     STORES DO LOOPS REQUIRED BY SUBROUTINE FFT                        LPSTOR.5
C     ******************************************************************LPSTOR.6
C                                                                       LPSTOR.7
      DIMENSION R(1)                                                    LPSTOR.8
C                                                                       LPSTOR.9
      GO TO (1,2,3,4,5,6,7,8,9), NS                                     LPSTOR.10
    1    DO 11 L=1,LF,4                                                 LPSTOR.11
         R1=R(L)+R(L+1)                                                 LPSTOR.12
         R2=R(L+2)+R(L+3)                                               LPSTOR.13
         R(L+3)=-R(L+2)+R(L+3)                                          LPSTOR.14
         R(L+2)=R(L)-R(L+1)                                             LPSTOR.15
         R(L)=R1+R2                                                     LPSTOR.16
   11    R(L+1)=R1-R2                                                   LPSTOR.17
      RETURN                                                            LPSTOR.18
    2    DO 12 L=1,LF,6                                                 LPSTOR.19
         A1=R(L)+R(L+3)                                                 LPSTOR.20
         A2=R(L)-R(L+3)                                                 LPSTOR.21
         A3=R(L+1)+R(L+2)                                               LPSTOR.22
         A4=R(L+1)-R(L+2)                                               LPSTOR.23
         A5=R(L+4)+R(L+5)                                               LPSTOR.24
         A6=R(L+4)-R(L+5)                                               LPSTOR.25
         R(L)=R1+R3+R5                                                  LPSTOR.26
         R(L+1)=R2+R4+R6                                                LPSTOR.27
         R(L+2)=R2-(R4+R6)*.5                                           LPSTOR.28
         R(L+3)=(-R3+R5)*CC                                             LPSTOR.29
         R(L+4)=R1-(R3+R5)*.5                                           LPSTOR.30
   12    R(L+5)=(R4-R6)*CC                                              LPSTOR.31
      RETURN                                                            LPSTOR.32
    3 R(1)=R(1)+R(2)                                                    LPSTOR.33
```

```
      R(2)=R(INC+1)+R(IAC+1)                                          LPSTOR.34
         DO 13 L=1,LF,2                                               LPSTOR.35
         R(L+2)=R(L+2)+R(INCD-L)                                      LPSTOR.36
 13      R(L+3)=R(L+3)-R(INCD-L+1)                                    LPSTOR.37
      RETURN                                                          LPSTOR.38
  4      DO 14 L=1,LF,INCD                                            LPSTOR.39
         L1=L+INC                                                     LPSTOR.40
         R3=R(L1)                                                     LPSTOR.41
         R(L1)=R(L+1)                                                 LPSTOR.42
         R(L1+1)=-R(L1+1)                                             LPSTOR.43
         R(L+1)=R(L)-R3                                               LPSTOR.44
 14      R(L)=R(L)+R3                                                 LPSTOR.45
      RETURN                                                          LPSTOR.46
  5      DO 15 L=1,LF,INCD                                            LPSTOR.47
         L1=L+INC                                                     LPSTOR.48
         R3=R(L1)                                                     LPSTOR.49
         R(L1)=R(L)-R(L+1)                                            LPSTOR.50
         R(L1+1)=-R(L1+1)-R(L1+1)                                     LPSTOR.51
         R(L)=R(L)+R(L+1)                                             LPSTOR.52
 15      R(L+1)=R3+R3                                                 LPSTOR.53
      RETURN                                                          LPSTOR.54
  6      DO 16 L=LS,LF,INCD                                           LPSTOR.55
         L2=L+1                                                       LPSTOR.56
         R1=(R(L+INC)+R(L2+INC))*CC                                   LPSTOR.57
         R2=(R(L2+INC)-R(L+INC))*CC                                   LPSTOR.58
         R(L+INC)=R(L)-R1                                             LPSTOR.59
         R(L2+INC)=-R(L2)+R2                                          LPSTOR.60
         R(L)=R(L)+R1                                                 LPSTOR.61
 16      R(L2)=R(L2)+R2                                               LPSTOR.62
      RETURN                                                          LPSTOR.63
  7      DO 17 L=LS,LF,INCD                                           LPSTOR.64
         L2=L+1                                                       LPSTOR.65
         R1=R(L)-R(L+INC)                                             LPSTOR.66
         R2=R(L2)+R(L2+INC)                                           LPSTOR.67
         R(L)=R(L)+R(L+INC)                                           LPSTOR.68
         R(L2)=R(L2)-R(L2+INC)                                        LPSTOR.69
         R(L+INC)=(R1-R2)*CC                                          LPSTOR.70
 17      R(L2+INC)=(R1+R2)*CC                                         LPSTOR.71
      RETURN                                                          LPSTOR.72
  8      DO 18 L=1,LF,4                                               LPSTOR.73
         R1=R(L)+R(L+1)                                               LPSTOR.74
         R2=R(L)-R(L+1)                                               LPSTOR.75
         R3=R(L+2)+R(L+2)                                             LPSTOR.76
         R4=R(L+3)+R(L+3)                                             LPSTOR.77
         R(L)=R1+R3                                                   LPSTOR.78
         R(L+1)=R1-R3                                                 LPSTOR.79
         R(L+2)=R2-R4                                                 LPSTOR.80
 18      R(L+3)=R2+R4                                                 LPSTOR.81
      RETURN                                                          LPSTOR.82
  9      DO 19 L=1,LF,6                                               LPSTOR.83
         R1=R(L)+R(L+1)                                               LPSTOR.84
         R2=R(L)-R(L+1)                                               LPSTOR.85
         R3=R(L+2)+R(L+4)                                             LPSTOR.86
         R4=R(L+2)-R(L+4)                                             LPSTOR.87
         R5=(R(L+3)+R(L+5))*CC                                        LPSTOR.88
         R6=(R(L+3)-R(L+5))*CC                                        LPSTOR.89
         R(L)=R1+R3+R3                                                LPSTOR.90
         R(L+1)=R1-R3-R4                                              LPSTOR.91
         R(L+4)=R1-R3+R4                                              LPSTOR.92
         R(L+2)=R2+R6-R5                                              LPSTOR.93
         R(L+3)=R2-R6-R4                                              LPSTOR.94
 19      R(L+5)=R2+R6+R5                                              LPSTOR.95
      RETURN                                                          LPSTOR.96
      END                                                             LPSTOR.97
      SUBROUTINE SORT2 (R,NK,TW)                                      SORT2.2
C                                                                     SORT2.3
C     ****************************************************************SORT2.4
C     SHUFFLES OR UNSHUFFLES THE NK REAL TERMS OF R AND MULTIPLIES BY TWSORT2.5
C     ****************************************************************SORT2.6
C                                                                     SORT2.7
      DIMENSION R(1),NVEC(8)                                          SORT2.8
      DATA NVEC/4,2,6,1,5,3,7,8/                                      SORT2.9
C                                                                     SORT2.10
      NF=1                                                            SORT2.11
      NK2=NK/2                                                        SORT2.12
      NK8=NK/8                                                        SORT2.13
      IF(NK.LT.32) NK8=NK-1                                           SORT2.14
         DO 10 I=1,NK8                                                SORT2.15
         IC=0                                                         SORT2.16
         NT=NF                                                        SORT2.17
         DO 12 J=1,NK,NK8                                             SORT2.18
         IF(NT.LE.J) GO TO 2                                          SORT2.19
         STOR=R(NT)                                                   SORT2.20
         R(NT)=R(J)                                                   SORT2.21
         R(J)=STOR                                                    SORT2.22
         IC=IC+1                                                      SORT2.23
 12      NT=NF+NVEC(IC)                                               SORT2.24
  2      NSUB=NK2                                                     SORT2.25
  4      IF(NSUB.GE.NF) GO TO 10                                      SORT2.26
         NF=NF-NSUB                                                   SORT2.27
         NSUB=NSUB/2                                                  SORT2.28
         GO TO 4                                                      SORT2.29
 10      NF=NF+NSUB                                                   SORT2.30
         DO 20 I=1,NK                                                 SORT2.31
 20      R(I)=R(I)*TW                                                 SORT2.32
      RETURN                                                          SORT2.33
      END                                                             SORT2.34
      SUBROUTINE SORT3 (R,NK,ISRT,TW)                                 SORT3.2
C                                                                     SORT3.3
C     ****************************************************************SORT3.4
C     SHUFFLES (ISRT=0) OR UNSHUFFLES (ISRT=1) THE  NK=(2**MK)*3 REAL   SORT3.5
C     TERMS OF R.  SUBROUTINE SORT2 IS CALLED.                        SORT3.6
C     ****************************************************************SORT3.7
C                                                                     SORT3.8
      DIMENSION R(1)                                                  SORT3.9
C                                                                     SORT3.10
      NK=2**MK*3                                                      SORT3.11
      NL=1+2*NK/3                                                     SORT3.12
      IF(ISRT.EQ.0) CALL SORT2(R,2*NK/3,TW)                           SORT3.13
      IF(ISRT.EQ.0) CALL SORT2(R(NL),NK/3,TW)                         SORT3.14
         DO 70 I=1,MK                                                 SORT3.15
         L=I                                                          SORT3.16
         IF(ISRT.EQ.0) L=MK-I+1                                       SORT3.17
         IF(L.EQ.1) GO TO 18                                          SORT3.18
         I2=2**(L-1)                                                  SORT3.19
         I21=I2-1                                                     SORT3.20
         JS=2*I2+1                                                    SORT3.21
         JI=6*I2                                                      SORT3.22
         IF(ISRT.EQ.0) I2=I2*2                                        SORT3.23
         I3=JI/2-I2                                                   SORT3.24
         DO 12 J=JS,NK,JI                                             SORT3.25
         KF=J+I21                                                     SORT3.26
         DO 12 K=J,KF                                                 SORT3.27
         RS1=R(K)                                                     SORT3.28
```

```
      A(K)=B(K+I2)                                                  SORT3.29
      A(K+I2)=B(K+I3)                                               SORT3.30
12    A(K+I3)=BST                                                   SORT3.31
13    CONTINUE                                                      SORT3.32
   IF(ISRT.EQ.1) CALL SORT2(A,2*NK/3,TW)                            SORT3.33
   IF(ISRT.EQ.1) CALL SORT2(A(NL),NK/3,TW)                          SORT3.34
   RETURN                                                           SORT3.35
   END                                                              SORT3.36
```

APPENDIX B: COMPLIANCE DATA FOR VISCOELASTIC HALF-PLANE

```
0 1.0000000  .3333333    9    90    4    .0100    .1000    .2500    .5000     DATA
  .0250   .0500   .0750   .1000   .1250   .1500   .1750   .2000   .2250   .2500   DATA
  .2750   .3000   .3250   .3500   .3750   .4000   .4250   .4500   .4750   .5000   DATA
  .5250   .5500   .5750   .6000   .6250   .6500   .6750   .7000   .7250   .7500   DATA
  .7750   .8000   .8250   .8500   .8750   .9000   .9250   .9500   .9750 1.0000    DATA
1.0500 1.1000 1.1500 1.2000 1.2500 1.3000 1.3500 1.4000 1.4500 1.5000    DATA
1.5500 1.6000 1.6500 1.7000 1.7500 1.8000 1.8500 1.9000 1.9500 2.0000    DATA
2.1000 2.2000 2.3000 2.4000 2.5000 2.6000 2.7000 2.8000 2.9000 3.0000    DATA
3.1000 3.2000 3.3000 3.4000 3.5000 3.6000 3.7000 3.8000 3.9000 4.0000    DATA
4.1000 4.2000 4.3000 4.4000 4.5000 4.6000 4.7000 4.8000 4.9000 5.0000    DATA
  1.05391693525772   -.28478141497583   1.02698894723741   -.35342201775650DATA
   .83632722478819   -.32747564333698    .78774153872156   -.32028068073414DATA
   .73974010518928   -.37308585038607    .71253082408208   -.32777112372056DATA
   .67348316930836   -.33292673322707    .63430050752029   -.34377025179460DATA
   .62657323638643   -.33807541527226    .59633025407932   -.33373579775539DATA
   .57100203436291   -.33616074738805    .55866515171747   -.33954734458013DATA
   .54050601565207   -.33367676091732    .52136850599747   -.33381482076400DATA
   .50751427604630   -.33646590136779    .49517515080557   -.33373901824905DATA
   .48009640189415   -.33252306438967    .46711154501813   -.33355780751949DATA
   .45656391338772   -.33278092287490    .44664517223115   -.33125536098450DATA
   .43316432843710   -.33119636333282    .42341210842182   -.33093657584365DATA
   .41357289579104   -.32972979816306    .40357972267097   -.32911537646934DATA
   .39452559387464   -.32678385307975    .38589852190442   -.32789508773290DATA
   .37715103187278   -.32705352478277    .36883940088299   -.32649929317252DATA
   .36100770168851   -.32573682144175    .35323210394512   -.32484419083223DATA
   .34565333900557   -.32411016752133    .33843946275676   -.32334778822674DATA
   .33138853030507   -.32245810816559    .32446009404722   -.32160933589584DATA
   .31777507508857   -.32078302601384    .31129073769461   -.31987926607116DATA
   .30492088228416   -.31895811405571    .29872227566350   -.31805630949339DATA
   .29270007586537   -.31711901562087    .28680136207578   -.31614949382483DATA
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-.00357153844555    .00498793277130  -.00214148016757    .00448643205364DATA4851
-.00120910536498    .00380325120196  -.00071031469018    .00313516217949DATA4852
-.00052883889736    .00261837602679  -.00052571514454    .00232195473837DATA4853
-.00056601985849    .00225212532645  -.00053968777402    .00236482176900DATA4854
-.00037463597113    .00258315640921  -.00004178863517    .00281645602308DATA4855
 .00104802155719    .00299850883337   .00231437219887    .00247937783065DATA4856
 .00320299628040    .00127644046815   .00335223176748  -.00023219895103DATA4857
 .00274321458751  -.00155632413375   .00164809963430  -.00233585345332DATA4858
 .00045793958406  -.00246403314950  -.00049661946552  -.00206890227477DATA4859
-.00104992126220  -.00140252883314  -.00120843284912  -.00071392395772DATA4860
-.00108836262090  -.00016474613218  -.00083317996392   .00019125088094DATA4861
-.00055256560717    .00037904008412  -.00030043418231   .00045427653199DATA4862
-.00008610410062    .00046441350893   .00009991123239   .00043252115206DATA4863
 .0002636 720847    .00036187616447   .00039885657345   .00025038469241DATA4864
 .00049039592359    .00010324652723   .00052466608497  -.00006267004832DATA4865
 .00049808671821  -.00022286792070   .00042022219773  -.00035352178634DATA4866
 .00031055281526  -.00043900710484   .00019214223391  -.00047539667260DATA4867
 .00008466267173  -.00046937251421   .00000069770631  -.00043409642089DATA4868
-.00005534061051  -.00038433597695  -.00008556008291  -.00033258703231DATA4869
-.00009586136083  -.00028769302588  -.00009334687131  -.00025369105058DATA4870
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