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A COMPUTER PROGRAM FOR THE THREE-DIMENSIONAL DYNAMIC ANALYSIS OF EARTH DAMS

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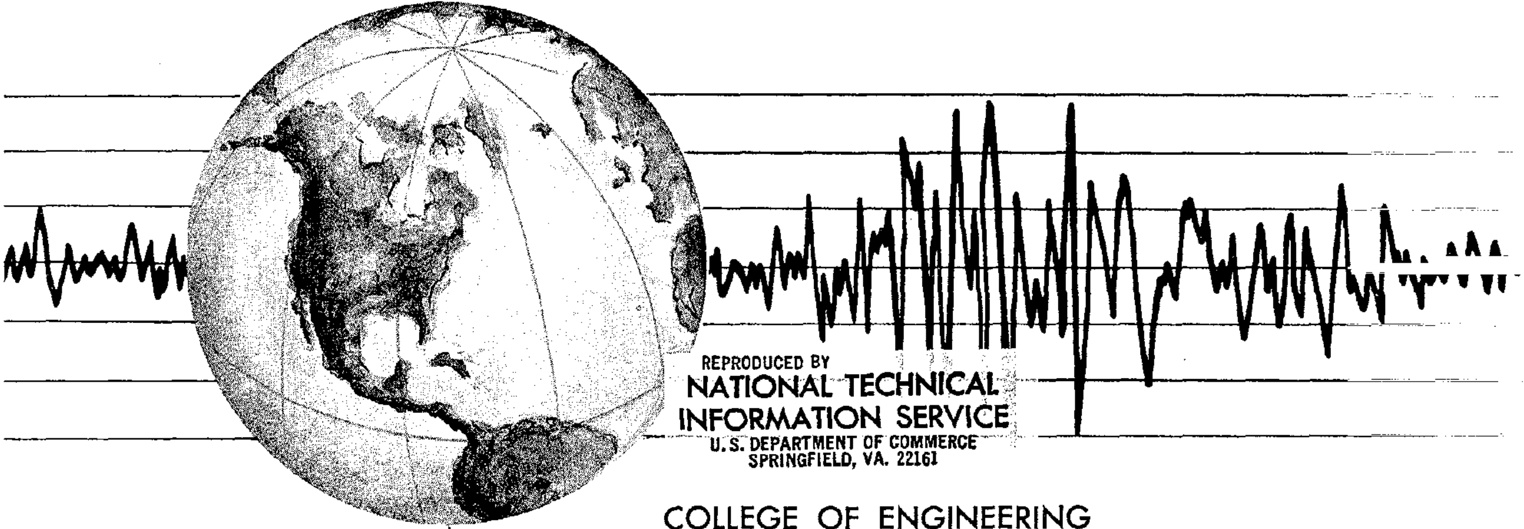

COLLEGE OF ENGINEERING

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4. COMMENTS ON INPUT (Contd.)

1. INTRODUCTION

Significant progress has been made over the past two decades in the development of analytical procedures for evaluating the response and stability of earth dams subjected to seismic loads. Current methods of stability analysis involve procedures such as that proposed by Seed et al., (1973) which consists of the following steps:

1. Determination of the initial stresses existing throughout the dam and the foundation before the earthquake.
2. Determination of the characteristics of the earthquake motions that are likely to affect the dam.
3. Computation of the response of the embankment and foundation to the selected earthquake motions.
4. Determination in the laboratory or by means of empirical correlations of the response to the induced dynamic stresses of representative samples of the embankment and foundation materials.
5. Evaluation of the overall deformations and stability of the embankment dam.

Due to the fact that the finite element method can easily handle geometrical irregularities, complex material behavior and arbitrary boundary conditions it is perhaps the most flexible tool currently available to perform the dynamic response analysis of an earth dam.

Limitations of computer speed and storage capacity have restricted until recently the use of the finite element method to two-dimensional problems. Although many earth dams fall within this category, there are also many cases in which the assumption of plane strain behavior gives

only approximate results and therefore a full three-dimensional analysis is warranted. Thus, the availability of a numerical procedure for the dynamic analysis of earth dams in three-dimensions seems desirable.

Two-dimensional finite element techniques which use the complex response method and therefore permit variations in modulus and damping in different elements of a soil structure, were developed by Lysmer et al., (1974,1975). These procedures were extended to three dimensions, with a constraint on the possible deformations of the finite element model, by Kagawa (1977). The present version of the computer program TLUSH constitutes a further development of these procedures (Mejia, 1981) and incorporates additional features among which are the following: 1) Complete freedom for the selection of the direction of the earthquake motions, 2) Complete freedom in the deformational modes of the model, 3) A new interpolation scheme, 4) A nodal point and element data generation routine, 5) More efficient element stiffness generation routines and 6) A more efficient program structure that has lower memory requirements.

The program TLUSH can take into account the strong nonlinear effects characteristic of soil masses subjected to strong earthquake motions. This is achieved by a combination of the equivalent linear method (Seed and Idriss, 1969) and the complex response method. Typical relationships between stiffness, damping and effective shear strains for sand and clay are provided within the program. Special options that permit creation of a permanent record of both input and basic information on the complete solution, and recovery of this information for iteration and output purposes are available within the program.

2. ANALYTICAL PROCEDURE

Within the framework of the finite element techniques employed by the computer program TLUSH a typical earth dam will be modeled by an assemblage of elements as shown in Fig. 1. Eight node isoparametric brick elements with three degrees of freedom per node and linear interpolation on the displacement field are used in the model. Nodal points are defined only at the intersection of three of the planes defining an element. It is assumed that the walls of the valley in which the dam is located are rigid and therefore all points on these boundaries move in phase and with the same displacement amplitudes. Interaction between the dam and its abutments and between the dam and the reservoir is neglected. Material behavior is assumed to be characterized by an equivalent linear elastic shear modulus and an equivalent fraction of damping.

2.1 Equation of Motion

Considerations of dynamic equilibrium of the model shown in Fig. 1 lead to the following equations of motion:

$$[M]\{\ddot{u}\} + [K]\{u\} = -[M]\{r\}\ddot{y}(t) \tag{1}$$

where: $\{u\}$ = the nodal point displacements relative to the rigid boundary,

$\{\ddot{u}\}$ = the corresponding accelerations

$[K]$ = the complex stiffness matrix

$[M]$ = the mass matrix

$\ddot{y}(t)$ = the input rigid boundary acceleration

$\{r\}$ = the load vector that gives the direction of the input motion.

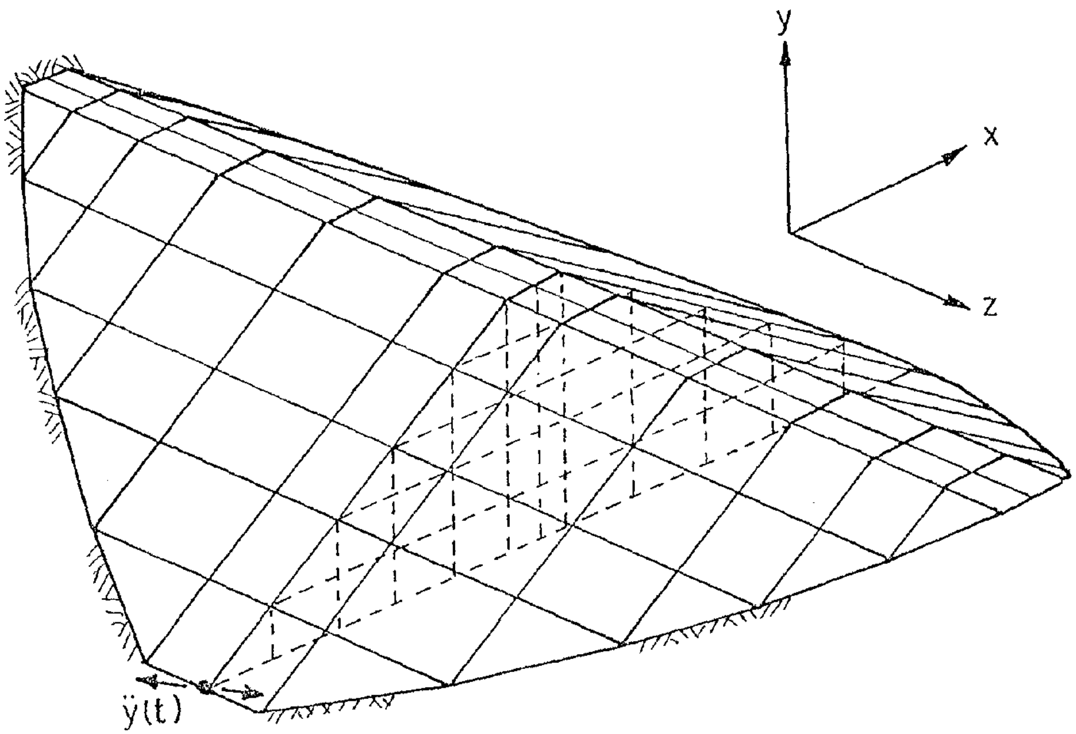


FIG. 1 TYPICAL 3-D FINITE ELEMENT MODEL OF AN EARTH DAM

The load vector $\{r\}$ is given by:

$$\{r\} = C_x \begin{Bmatrix} 1 \\ 0 \\ 0 \\ 1 \\ 0 \\ 0 \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ 1 \\ 0 \\ 0 \end{Bmatrix} + C_y \begin{Bmatrix} 0 \\ 1 \\ 0 \\ 0 \\ 1 \\ 0 \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ 0 \\ 1 \\ 0 \end{Bmatrix} + C_z \begin{Bmatrix} 0 \\ 0 \\ 1 \\ 0 \\ 0 \\ 1 \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ 0 \\ 0 \\ 1 \end{Bmatrix} \tag{2}$$

where C_x, C_y and C_z are scalar constants that determine the magnitude of the components of the input motion in the x, y and z directions respectively.

The global mass and stiffness matrices are assembled from the corresponding element matrices following standard finite element procedures and the direct stiffness method (Zienkiewicz, 1977). Viscous damping is introduced by the use of complex shear moduli in forming the element stiffness matrices:

$$G^* = G(1 - 2\beta^2 + 2i\beta\sqrt{1 - \beta^2}) \tag{3}$$

where: G = the element shear modulus

β = the element fraction of damping

and therefore, the stiffness matrix for the system will have complex coefficients.

2.2 The Method of Complex Response

Use of the complex response method is made in order to solve the equations of motion for the system (equation (1)). In this method it is assumed that the system is linear and that the input motion is periodic.

As a consequence the principle of superposition is applicable and the input accelerations can be expressed as a sum of harmonics:

$$\ddot{y}(t) = R_e \sum_{s=0}^{N/2} \ddot{Y}_s \exp(i\omega_s t) \tag{4}$$

where: N = the number of digitized points in the input motion.

$$\omega_s = \frac{2\pi s}{N\Delta t} \tag{5}$$

Δt = the time step of digitization

$\ddot{Y}_s$ = the complex Fourier amplitudes which are given by:

$$\left.\begin{aligned} \ddot{Y}_s &= \frac{1}{N} \sum_{K=0}^{N-1} \ddot{y}_k \exp(-i\omega_s k\Delta t) \quad \text{for } s=0,\ s=N/2 \\ \ddot{Y}_s &= \frac{2}{N} \sum_{K=0}^{N-1} \ddot{y}_k \exp(-i\omega_s k\Delta t) \quad \text{for } 1 \le s \le N/2 \end{aligned}\right\} \tag{6}$$

The complex Fourier amplitudes, $\ddot{Y}_s$, can be computed efficiently using the Fast Fourier Transform algorithm developed by Cooley and Tukey (1965) which requires that N be a power of 2. This requirement is generally not a drawback since trailing zeroes usually need to be added at the end of the earthquake excitation to provide for an adequate quiet zone that allows the decay of free vibrations of the model.

Substitution of equation (4) into equation (1) leads to:

$$[M]\{\ddot{u}\} + [K]\{u\} = -[M]\{r\}R_e\left(\sum_{s=0}^{N/2} \ddot{Y}_s \exp(i\omega_s t)\right) \tag{7}$$

The steady-state solution of this equation can also be expressed as a sum of harmonics. That is:

$$\{u\} = R_e \sum_{s=0}^{N/2} \{U_s\} \exp(i\omega_s t) \tag{8}$$

The complex displacement amplitudes $\{U_s\}$ can be obtained by substituting equation (8) into equation (7). Since the principle of superposition is applicable this leads to the following matrix equation for each frequency ω_s:

$$([K] \cdot \omega_s^2 [M])\{U_s\} = -[M]\{r\}\ddot{Y}_s \tag{9}$$

This is a system of linear algebraic equations with complex coefficients that can be solved by gauss elimination. Solution of equation (9) for each frequency ω_s constitutes a formidable task since it is not uncommon for an input record to have 2048 digitized points and therefore 1025 frequency points in its Fourier spectrum. In order to simplify the computational effort a cut-off frequency is usually selected. This frequency is chosen at a value such that the response of the dam to higher frequencies is small and does not need to be computed. Additionally, the following equation:

$$([K] - \omega_s^2 [M])\{A_s\} = -[M]\{r\} \tag{10}$$

is solved instead of equation (9). A limited number of frequencies is selected for solution of equation (10) and a special interpolation technique is used to compute intermediate values of $\{A_s\}$. The complex displacement amplitudes can then be obtained from the following expression:

$$\{U_s\} = \{A_s\}\ddot{Y}_s \tag{11}$$

2.3 Interpolation in the Frequency Domain

Linear interpolation on the inverse of the amplification functions has been used in the past as the technique to obtain intermediate values of $\{A_s\}$ (Lysmer et al., 1974,1975). However, this interpolation scheme does not perform well when there is a close spacing between natural frequencies which seems to be the case of three-dimensional systems.

A sophisticated technique that makes use of the transfer function for a two-degree-of-freedom system to interpolate between the amplification function values $\{A_s\}$ has been developed by Tajirian (1981) and has been incorporated to the computer program TLUSH. The transfer function for a two-degree-of-freedom system has typically two frequency peaks and is given by an expression of the form:

$$A(\omega) = \frac{C_1\omega^4 + C_2\omega^2 + C_3}{\omega^4 + C_4\omega^2 + C_5} \tag{12}$$

where: ω = angular frequency

C_1, C_2, C_3, C_4, C_5 = complex constants.

The values of the amplification function $\{A_s\}$ at five particular frequencies spanning the range where interpolation is to be performed are necessary to determine the five constants that define the transfer function (equation 12), which is then used to compute the intermediate values of $\{A_s\}$.

The nodal displacements $\{u\}$, which completely define the response of the dam, can be computed from equations (11) and (8). Velocities, accelerations and strains can be directly computed in the frequency domain from the displacement amplitudes $\{U_s\}$ and can then be transformed into the time domain.

2.4 The Equivalent Linear Method

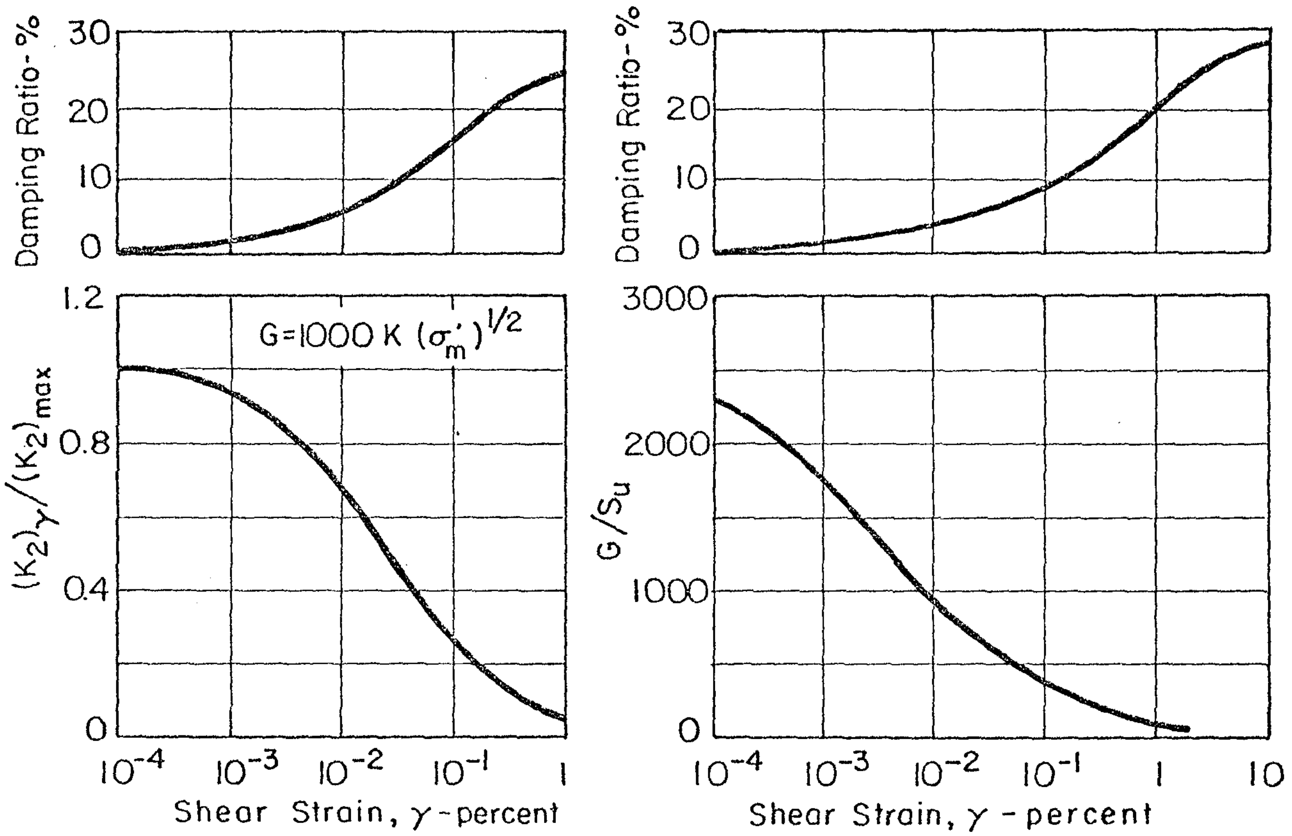
Due to the extensive use of superposition, the procedures previously outlined are only applicable to linear systems. However, the response of soils to dynamic loading is highly non-linear in nature and must be accounted for in order to obtain meaningful results from the dynamic analysis of soil structures.

The approximate method proposed by Seed and Idriss (1969) to take into account the non-linear behavior of soils is used in TLUSH. According to this method the non-linear response of a soil structure can be approximated by a linear analysis for which the stiffness and damping are compatible with the induced strains at every point of the system.

An extensive summary of data on strain compatible moduli and damping for clays and sands was presented by Seed and Idriss (1970) from which the curves shown in Fig. 2 were developed. Starting from selected initial moduli and damping values for each element in the model, these curves can be used iteratively to reach compatibility between the properties used in the analysis and the computed strains.

The relationships between stiffness, damping and effective shear strains for sands and clays proposed by Seed and Idriss (1970) have been provided within the program but other modulus attenuation curves can readily be read into the program. The following procedure is employed to obtain an approximate non-linear solution:

1. Read in initial assumed values of shear modulus and damping for all elements.
2. Solve equation (1) and use equation (11) to obtain the complex displacement amplitudes.
3. Compute strain amplitudes for all elements.



(a) Cohesionless Soils

(b) Saturated Clays

FIG. 2 AVERAGE SHEAR MODULI AND DAMPING CHARACTERISTICS OF SOILS

(After Seed and Idriss, 1970)

4. Compute the effective shear strains for all elements.
5. Determine new strain compatible values of shear modulus and damping by using the built in relationships of Fig. 2 or others supplied externally.
6. Repeat steps 2 through 5 until compatibility between the material properties used in the analysis and the computed shear strains is reached.

2.5 Effective Shear Strain

The three-dimensional strain state at a point can be described by a second order strain tensor with 6 independent terms which in a Cartesian coordinate system can be written as:

$$\underset{\sim}{\varepsilon} = \begin{bmatrix} \varepsilon_{xx} & \varepsilon_{xy} & \varepsilon_{xz} \\ \varepsilon_{yx} & \varepsilon_{yy} & \varepsilon_{yz} \\ \varepsilon_{zx} & \varepsilon_{zy} & \varepsilon_{zz} \end{bmatrix} \qquad (13)$$

During the seismic response of a dam the strain state varies with time at each point and therefore the selection of a single value to represent both the directional and time variation of strain level is difficult.

Soils are materials with a complex constitutive behavior which, strictly speaking, depends on all terms in expression (13). However, the state of present knowledge on constitutive laws for soils does not permit a complete characterization of material behavior. The method proposed by Seed and Idriss (1970) which consists of using the maximum shear strain as the parameter indicative of strain level is used in the computer program TLUSH. As a consequence the strain level will be given by an effective shear strain defined as:

$$\gamma_{eff} = 0.65 \cdot \max_{t} |\gamma_{max}| \qquad (14)$$

Time variation in the strain level is taken into account by the factor 0.65 which is purely empirical but is assumed to be representative of an average time value of the maximum shear strain. The value of this factor is not critical in view of the fact that the computed motions are not very sensitive to moderate variations in the magnitude of the effective shear strain.

The peak maximum shear strain used in equation (14) can be computed by either of two methods available as two options of the computer program TLUSH. The first method consists of obtaining the maximum and minimum principal strains from a solution to the following equation for each time step.

$$\begin{vmatrix} \varepsilon_{xx}-\varepsilon & \varepsilon_{xy} & \varepsilon_{xz} \\ \varepsilon_{yx} & \varepsilon_{yy}-\varepsilon & \varepsilon_{yz} \\ \varepsilon_{zx} & \varepsilon_{zy} & \varepsilon_{zz}-\varepsilon \end{vmatrix} = 0 \qquad (15)$$

Once the principal strains have been determined at each time step the peak maximum shear strain can easily be found. The second method makes use of the fact that the peak maximum shear strain can be estimated from the root-mean-square value of the maximum shear strain as follows:

$$\max_t |\gamma_{max}| \simeq C \cdot \mathrm{RMS}\ (\gamma_{max}) \qquad (16)$$

where C is a constant approximately given by:

$$C = \max_t |\ddot{y}| \Big/ \mathrm{RMS}(\ddot{y}) \qquad (17)$$

The root-mean-square values of γ_{max} and $\ddot{y}$ can be conveniently evaluated by making use of Parseval's identity which for an arbitrary function f(t) is given by:

$$\mathrm{RMS}^2(f) = \frac{1}{2} \sum_{s=0}^{N/2} |F_s|^2 \tag{18}$$

where F_s, s=0,1,2, N/2 are the complex Fourier amplitudes of the function f(t), that is

$$f(t) = R_e \sum_{s=0}^{N/2} F_s \exp(i\omega_s t) \tag{19}$$

This method is substantially faster than the first one since equation (15) can be solved in terms of the strain amplitudes for each frequency and all computations can be performed in the frequency domain without the need for numerous Fourier transforms.

3. PROGRAM DESCRIPTION

3.1 Program Structure

The computer program TLUSH is written in standard FORTRAN IV language and the CDC 7600 version consists of a main program TLUSH and 42 subroutines which will be described under the next subheading. The program is easily convertible to most modern computer systems that have more than 100K words of high speed storage. It has been designed so that it can operate in any of three modes all of which produce a listing of the relevant input data. The type of mode to be used in a particular run can be specified by the value of the variable NOPT on the first input data card.

MODE1 - The Initiation Mode

MODE1 is the mode to be specified when running the program for the first time on a particular problem. In this mode all input comes from cards; the program will set up the equations of motion and solve them for

a specified number of iterations using in each iteration after the first, material properties compatible with the strains computed in the previous iteration. After the last iteration any output desired will be generated. A special option permits the creation of a permanent record on a magnetic tape, TAPE1, of all input data and of the complete solution. This information can subsequently be easily recovered in MODE2 or MODE3 runs. An additional option permits the storage of the element mass matrices, the normalized element stiffness matrices and the load vector on a magnetic tape, TAPE5, in this way making it possible to avoid their generation in subsequent MODE1 or MODE2 runs.

MODE2 - The Iteration Mode

In order to monitor the convergence of strain compatible properties in real size jobs it is convenient to perform the iterations on soil properties one at a time. In this way it is possible to speed up the rate of convergence of the solution and to make more efficient use of the program. MODE2 provides the re-start capability required to perform further iterations if necessary. In this mode the contents of TAPE1 are read and copied onto TAPE2, the equations of motion are set up and solved using the improved soil properties computed in the previous iteration, additional iterations can be performed, and any desired output can be generated. Just as in MODE1 a permanent record of the complete solution can be stored on TAPE1 for further reference. TAPE2 serves as a back-up in case the contents of the original TAPE1 need to be preserved.

MODE3 - The Extraction Mode

This mode is useful for the extraction of additional information on the solution to a certain problem which has been stored on TAPE1. In this

mode, the program will read the TAPE1 generated in previous MODE1 or MODE2 runs and produce the additional output specified, without performing any finite element computations. Hence, the contents of TAPE1 are unaltered in this mode.

Data Check Run

An additional mode is provided to permit the revision of the input data for MODE1. All input data is read from cards, just as in MODE1, and this information is printed out.

From the previous discussion it follows that the main difference between MODE1 and MODE2 is the form in which the input data is read in. Both modes follow approximately the same numerical procedure which can be summarized in the following steps:

1. Read in control data and set up dynamic storage allocation.
2. Read in finite element model data and generate missing information.
    a. Element data.
    b. Nodal point data.
3. Read in earthquake motion, transform to frequency domain and apply base line correction.
4. Print out all input data.
5. Form element mass matrices, normalized element stiffness matrices and load vector.
6. Compute element stiffness matrices.
7. Set up blocks and profile for equation solution.
8. Form total mass and stiffness matrices by blocks.
9. Solve equation of motion (Eq. 10) for selected frequencies and store amplification functions.

10. Compute strain amplification functions for all elements.
11. Determine effective shear strains and strain compatible soil properties for all elements.
12. Repeat from step 6, using the improved soil properties, for the number of iterations specified.
13. Generate all nodal point and stress output.
14. Stop.

The above numerical procedure is schematically illustrated in Fig. 3 which shows a simplified flowchart of the program.

3.2 Description of Routines

The CDC 7600 version of TLUSH consists of a main program and 42 subroutines which carry out the numerical procedure previously described. Additionally there are three CDC system routines, LOCF, SECOND and SETFLS, which are called by the program subroutines, LOC, TIME and MCORE respectively. The calling sequence for the program subroutines along with the tapes referenced by each routine is given in Table 1. A brief description of each routine follows:

TLUSH	This is the main program. It consists mostly of comment cards that describe the input data and it calls the initiation subroutine INPT.
ADJUST	This subroutine applies base line correction in the frequency domain to the input acceleration time history.
ARRNG	It establishes the order in which the element mass and stiffness matrices will be generated.

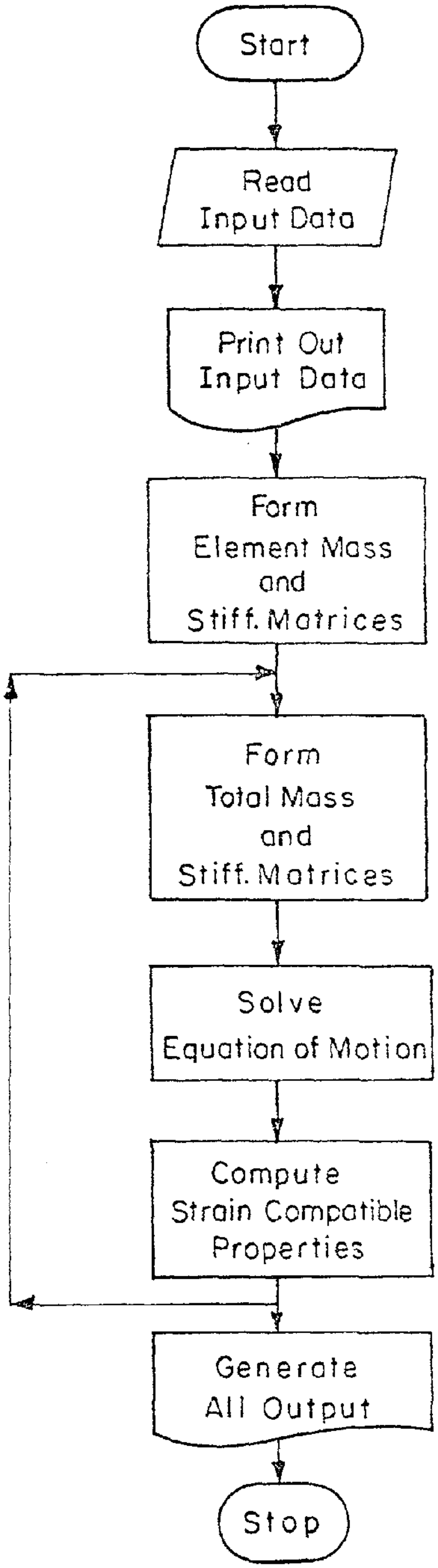


FIG. 3 · SIMPLIFIED FLOWCHART FOR TLUSH

Table 1. Calling Sequence for Subroutines and Tapes

Program	Calls	Called by	Tapes Referenced
TLUSH	INPT,SECOND	This is the main program	
ADJUST		VEDDA	
ARRNG		VEDDA	
BLOCK	RDSTF	GSTIF	6,7,8
CALBN	RDSTF	FRMSTF	5
CMPMAX		DRCTSP	
CNSTNTS	CSOLVE	INSET	
CSOLVE		CNSTNTS	
CURV52		STRAIN	
DRCTSP	CMPMAX,PLOT	MOTION	
ELSTRN		STRNAP	
EXPND		INSET	
FCONTL		INPT	
FFT		RFFT,RFSN	
FORM	LUMP	FRMSTF	
FRMSTF	CALBN,FORM,RDSTF	SOLVEB	5,6,10
FSET		MOTION	
GSTIF	BLOCK, TOTSTF	SOLVEB	
INPT	FCONTL,MCORE,VEDDA	TLUSH	1,2
INSET	CNSTNTS,EXPND	INTPL	
INTPL	INSET	MOTION,STRAIN	
LOC	LOCF	MCORE	
LUMP	VOLUME	FORM	

Table 1. (continued)

Program	Calls	Called by	Tapes Referenced
MCORE	LOC,SETFLS	INPT,SOLVEB,VEDDA	
MOTION	DRCTSP,FSET,INTPL PLOT,PROUT,RFSN TIME	VEDDA	3
PLOT		DRCTSP,MOTION,STRESS	
PRINT		VEDDA	
PROUT		MOTION	
RDSTF		BLOCK,CALBN,FRMSTF TOTSTF	
RFFT	FFT	VEDDA	
RFSN	FFT	MOTION,STRAIN,VEDDA	
ROOTME		STRNAP	
RW		SLOWR,SOLVEB,STRNAP TOTSTF,VEDDA	
SHMAX		STRAIN	
SLOWR	RW	SOLVEB	7,9,11,13,14 15,19,20,21,22
SOLVEB	FRMSTF,GSTIF,MCORE RW,SLOWR,TIME	VEDDA	1,12,9
STRAIN	CURV52,INTPL,RFSN SHMAX,TIME	VEDDA	4,17,18
STRESS	PLOT,TIME	VEDDA	17
STRNAP	ELSTRN,ROOTME,RW	VEDDA	1,3,4,18,19
TIME	SECOND	MOTION,SOLVEB,STRAIN STRESS,VEDDA	

Table 1. (continued)

Program	Calls	Called by	Tapes Referenced
TOTSTF	RDSTF,RW	GSTIF	6,7,8,9 10,11
VEDDA	ADJUST,ARRNG,MCORE MOTION,PRINT,RFFT RFSN,RW,SOLVEB STRAIN,STRESS,STRNAP, TIME	INPT	1,2,3 12,16
VOLUME		LUMP	

BLOCK	Sets up the equation profile and the blocking of the global mass and stiffness matrices for the out-of-core solver.
CALBN	Reorders the rows and columns in the element mass and stiffness matrices.
CMPMAX	Determines the maximum values in the computation of response spectra.
CNSTNTS	Sets up the five equations necessary for the determination of the constants in the interpolation function.
CSOLVE	Determines the five constants in the interpolation function by solving a system of simultaneous equations.
CURV52	Computes updated strain-compatible soil properties from material curves.
DRCTSP	Computes and plots acceleration and velocity response spectra.
ELSTRN	Computes strain application functions at the centroid of an element.
EXPND	Determines intermediate values in the amplification functions by interpolation.
FCONTL	Determines the frequencies for which the equations of motion are to be solved.
FFT	This is a standard routine for complex Fast Fourier Transform.
FORM	Forms the mass and normalized stiffness matrices for an element.

FRMSTF	Generates the element mass and stiffness matrices and the load vector.
FSET	Determines the frequencies at which response spectral values are to be computed and sets the time array for plotting.
GSTIF	Drives the routines that set up the equation profile, calculate blocking information and assemble the global mass and stiffness matrices.
INPT	Reads control data from cards or TAPE1, writes this information on TAPE1 or TAPE2 and sets up field lengths and dynamic storage allocation.
INSET	Drives the interpolation routines which compute the interpolation function and expand the amplification function.
INTPL	Prepares amplification functions for interpolation and controls interpolation procedure.
LOC	Calls the system routine LOCF to find out the address of a certain variable.
LUMP	Computes the lumped mass matrix for an element.
MCORE	Calls the system routine SETFLS which sets the core memory field length.
MOTION	Controls the output at specified nodal points. Computes and plots amplification functions, response spectra and acceleration time histories.

PLOT	Performs printer plotting of amplification functions, response spectra,acceleration time histories and stress time histories.
PRINT	Prints out all input data.
PROUT	Prints out the peak accelerations at specified nodal points.
RDSTF	Controls reading and writing of element mass and stiffness matrices.
RFFT	This is a standard routine for Fast Fourier Transform from the time domain into the frequency domain.
RFSN	This is a standard routine for Fast Fourier Transform from the frequency domain into the time domain.
ROOTME	Computes the square of the root-mean-square of the maximum shear strain for an element in the frequency domain.
RW	Controls the reading, writing, rewinding and back-spacing of tapes.
SHMAX	Computes the maximum shear strain at the centroid on an element in the time domain.
SLOWR	This is an out-of-core equation solver for symmetric linear algebraic equations in complex variables. It uses the active column method of gaussian elimination.
SOLVEB	Drives the routines that set up the equations of motion and solve them.

STRAIN	Determines effective shear strains and updated strain-compatible soil properties for all elements and computes stress time histories at specified points.
STRESS	Controls the output of element stress time histories.
STRNAP	Computes and writes strain amplification functions on tape and sets up amplification functions for subroutine MOTION.
TIME	Calls the system routine SECOND which gives the time since the start of execution.
TOTSTF	Assembles in blocks the global mass and stiffness matrices.
VEDDA	This is the main subroutine which controls the flow of the program. It reads the finite element input data, reads and modifies the control motion, generates most of TAPE1 and TAPE2, controls the solution of the equations of motion and the iteration on soil properties, and controls output from the program.
VOLUME	Computes the volume of a tetrahedron.

3.3 Tape Usage

The computer program TLUSH uses a total of 22 tapes of which, three may need to be specified as physical tapes depending on the options used in the program. TAPE1 should be specified as a physical tape in MODE1 and MODE3. TAPE1 and TAPE2 should be specified as physical tapes in MODE2. TAPE5 needs to be specified as a physical tape if permanent storage of the element matrices is required. All other tapes are usually simulated on

magnetic discs or drums. The following is a description of the contents of the tapes as used by the program.

TAPE1	This is the principal input tape for MODE2 and MODE3. It contains all input data, estimated and current soil properties, and the computed amplification functions.
TAPE2	This is a copy of TAPE1 produced in the initial stages of MODE2.
TAPE3	Stores the computed amplification functions for nodal points where output is required.
TAPE4	Stores the computed strain amplification functions for all elements.
TAPE5	Is used to store element mass and normalized stiffness matrices and the load vector.
TAPE6	Stores element mass and stiffness matrices and boundary conditions.
TAPE7	Is used to store information necessary for block generation.
TAPE8	Is used to store information on equation blocking.
TAPE9	Is used to store information on equation blocking.
TAPE10	Stores the load vector.
TAPE11	Is used to store global mass and stiffness matrices in blocks.

TAPE12	Is used as temporary storage of the permanent data of the blank common.
TAPE13	Is used as a scratch file by the out-of-core equation solver.
TAPE14	Is used as a scratch file by the out-of-core equation solver.
TAPE15	Is used as a scratch file by the out-of-core equation solver.
TAPE16	Stores the updated material properties and the root-mean-square values of the maximum shear strain for all elements.
TAPE17	Is used to store element stress time histories to be output.
TAPE18	Stores strain amplification functions for elements where stress time histories are required.
TAPE19	Is used to store the displacement amplification functions for the frequencies used in the solution of the equations of motion.
TAPE20	Is used as a scratch file by the out-of-core equation solver.
TAPE21	Is used as a scratch file by the out-of-core equation solver.
TAPE22	Is used as a scratch file by the out-of-core equation solver.

3.4 Error Messages

TLUSH has the capability of detecting some errors in the input data. Once an error is detected the program will stop execution and issue an error message. A description of the errors which can be detected by TLUSH follows:

ERROR NO. 1	The number of points in the input acceleration time history, N3, exceeds the number of points specified for the Fast Fourier Transform, KGMAX.
ERROR NO. 2	The specified small core length, NSCM, is too short for the blank common required in the initial stages of the program.
ERROR NO. 3	The specified small core length, NSCM, is too short for the blank common required by subroutine STRAIN.
ERROR NO. 4	The specified small core length, NSCM, is too short for the buffer used in subroutine STRAIN.
ERROR NO. 5	The specified small core length, NSCM, is too short for the blank common required by subroutine MOTION.
ERROR NO. 6	The specified small core length, NSCM, is too short for the buffer used in subroutine MOTION.
ERROR NO. 7	The number of additional displacement boundary conditions, NBP, does not agree with the total number of boundary conditions specified on the nodal point cards.
ERROR NO. 8	The computed volume of a finite element is less than or equal to zero.
ERROR NO. 9	There is an equation number for which all the corresponding matrix coefficients are zeroes.
ERROR NO. 10	There is an equation number for which the diagonal element of the global stiffness matrix is zero.

3.5 Core Memory

TLUSH requires about 110000 (octal) words of memory to load and about 76000 (octal) words plus the length of blank common in words to execute on a CDC 7600 computer using the FTN4 compiler. The program uses dynamic storage allocation and therefore it automatically assigns the required dimension or length for each variable used. Three lengths of blank common which are used by the three main subroutines, VEDDA, STRAIN and MOTION, are computed internally and printed out by the program. The largest of these three, determines the minimum field length required to run the program. As mentioned above, the minimum field length for execution is obtained by adding the blank common length to the core memory occupied by the program (76000 octal words on a CDC 7600 system). This length should be shorter than the maximum field length available on the system, which in the case of the BKY CDC 7600 computer is 170000 (octal) words.

The user must specify in the first control card, the maximum length of blank common to be used by the program, NSCM. This number should be greater than the minimum blank common requirements printed at the beginning of execution of the program. However, it is usually convenient to specify the largest blank common length compatible with the maximum field length available on the system. In this way, the out-of-core solver has the largest possible high-speed storage space to work with. The largest small core length that can be specified on a CDC 7600 computer using the FTN4 compiler, is 30500 (decimal) words. The program adjusts the field length to fit its need at each stage of execution and therefore no idle space is wasted.

Problems may be encountered in satisfying the blank common requirements of large jobs in medium sized computers (CDC 6400). In these cases the following suggestions might prove helpful in reducing the core memory requirements:

1. Select the largest mesh size compatible with accuracy requirements.
2. Keep the maximum frequency of the analysis as low as possible.
3. Do not specify extensive output in MODE1 or MODE2 runs.
4. Use the lowest possible number of points in the Fast Fourier Transform.

4. COMMENTS ON INPUT

4.1 Mesh Size Requirements

Use of the finite element method for the dynamic response analysis of an earth dam requires discretization of the dam by a finite element model. The definition of the model boundaries and the selection of a general mesh layout are the two main ingredients in the design of a model.

Difficulties are encountered in the definition of the model boundaries and in the characterization of the earthquake motions at the boundaries of open systems such as earth dams. The simplifying assumptions that the boundary of the finite element model of an earth dam is rigid, and that the earthquake excitation acts on this rigid boundary, are implicit in the analytical approach used by TLUSH (see Fig. 1). Therefore, it is appropriate to select the boundary for the model of a dam at the physical boundary that best resembles this condition. In many cases this boundary is provided by a rock interface in the valley where the dam is located.

Another aspect of importance in the design of a model for the dynamic analysis of an earth dam is the selection of an adequate mesh layout. Two criteria, which in essence are equivalent, are available to determine an appropriate mesh layout for the dynamic analysis of earth dams. The first criterion requires that the mesh layout be such, that a good approximation of the predominant mode shapes of vibration of the dam can be obtained. The second criterion requires that the element size should not be larger than a certain fraction of the shortest wavelengths to be transmitted through the finite element mesh (Lysmer et al., 1974). The following expression is generally accepted:

$$h_{max} = \frac{1}{5} \frac{V_s}{\nu_{max}} \qquad (20)$$

where h_{max} is the vertical element dimension, V_s is the shear wave velocity in the element, and ν_{max} is the highest frequency of the analysis, TOTFR. Recent studies by Mejia (1981) have shown that, in general, 10 to 15 elements in the cross valley direction of a dam give a good representation, in this direction, of the predominant mode shapes of vibration of dams in triangular canyons subjected to strong shaking.

4.2 Identification of Nodes and Elements

Once the mesh layout for the finite element model of a dam is selected, identification of the nodal points and elements is required. The nodal points of the model should be numbered in such a way that the average bandwidth of the global stiffness matrix is minimized. Additionally nodal points on the rigid boundary have to be numbered last (see Figs. 5 and 6). The user specifies the first nodal point on the rigid boundary,

NB1, and all points with higher numbers are considered by the program to be on this boundary.

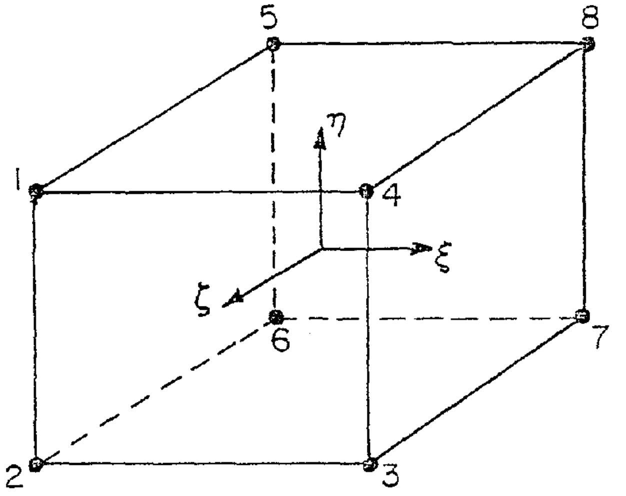
The program is designed to work with eight node brick isoparametric elements. Therefore elements may have any shape with a maximum of 8 nodal points and straight edges between these points. Elements are also numbered and identification of the nodal points defining an element must follow the rules shown in Fig. 4. This figure additionally shows two examples which illustrate element identification. The order of nodal point numbers which define an element should be such that NP1,NP2....NP8 on an element card correspond to the numbers 1,2....8 in Fig. 4(a).

The program has the capability of generating data for nodal points and elements not included in the input data. Nodal point coordinates are generated by interpolation along a straight line connecting the nodes on two successive input data cards. Element data is generated by using the same material properties and incrementing the nodes on the previous element card a specified number, LX.

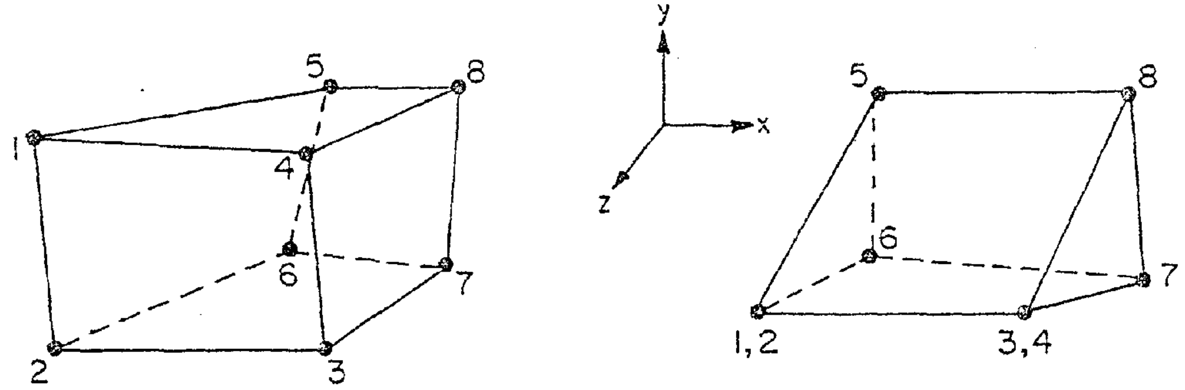
4.3 Element Matrices

The computer program TLUSH generates the element stiffness and mass matrices in two steps. The first step consists of computing normalized matrices. In the second step these matrices are multiplied by the element complex shear moduli and density in order to obtain the element stiffness and mass matrices respectively.

The normalized stiffness matrix for an element is computed following standard finite element procedures and corresponds to the element stiffness matrix for a shear modulus with a value of 1. It depends only on the geometry of the element and the value of Poisson's ratio. The



(a) Element Normalized Coordinate System



(b) Elements in Global Coordinate System

FIG. 4 ELEMENT IDENTIFICATION IN TLUSH

normalized mass matrix also depends only on the geometry of the element since it corresponds to the element mass matrix for a density with a value of 1. This matrix is computed as a combination of the consistent mass matrix and the lumped mass matrices for the element, according to the following expression:

$$[M] = \mathrm{RATIA}*[M]^{c} + (1-\mathrm{RATIA})\,[M]^{l} \tag{21}$$

where the parameter RATIA may range between 0 and 1.0 and is specified by the user. Values of RATIA between 0.5 and 0.75 optimize the ability of the element to transmit high frequencies.

It follows that elements which have the same geometry and value of Poisson's ratio will have identical normalized element matrices. To take advantage of this fact, an option in TLUSH permits normalized matrices to be duplicated for elements that have the same identification number, IDEL(N), different than zero.

The normalized element matrices are multiplied by the complex shear modulus:

$$G^* = G(1 - 2\beta^2 + 2i\beta\sqrt{1 - \beta^2}\,) \tag{22}$$

and the density, ρ, in order to obtain the element stiffness and mass matrices respectively. The parameter β corresponds to the element fraction of damping.

There are options in TLUSH which permit the storage of element mass and normalized stiffness matrices on TAPE5 and the recovery of these matrices in future runs. Use of these options are likely to be helpful in saving computer time and costs in some systems.

4.4 Material Curves

As mentioned before TLUSH uses the equivalent linear method to arrive at an approximate non-linear solution. In order to perform the successive iterations on soil properties the program uses material curves that describe the relationships between normalized shear modulus and damping, and cyclic maximum shear strain for the types of soil composing the dam. Two options are available in the program for defining the material property curves for a certain problem and any of these options can be selected by appropriately specifying the parameter KMATYP.

One option permits the use of built-in material curves. These curves correspond to those proposed by Seed and Idriss (1970) for clays and sands (see Fig. 2). In the other option any number, MATYP, of such relationships may be read from input data cards. Each set of relationships for modulus and damping must have a sequence number. This material identification number is referenced as element data in the parameter MTYPE(N) for those elements composed of a particular material. Strain independent properties can be assigned to any element by specifying a value of 0 for MTYPE(N).

4.5 Shear Strain Computation

As mentioned before two methods are available within TLUSH for the computation of the peak maximum shear strain. The first method uses a time domain approach. The time histories of the 6 components of strain at the centroid of each element are obtained from the inverse Fast Fourier Transform of the Fourier amplitudes of the strain components. A cubic equation in terms of the 6 components of strain at each time step is solved for the principal strains. From these, the maximum shear

strain is obtained for each time step and the peak value can be determined by direct comparison. The second method uses a frequency domain approach. Using the Fourier complex amplitudes of the 6 strain components at the centroid of each element, a cubic equation is set up for each frequency in the spectrum. From these equations the complex amplitudes of principal strains are obtained from which the amplitudes of the maximum shear strain can be determined. These amplitudes are used to compute the root-mean square value of the maximum shear strain function from which an approximation to the peak value of the function can be obtained.

Although the first method yields the theoretically exact value for the peak maximum shear strain it is much more lengthy than the second method since it involves numerous Fast Fourier Transorms. In addition to using a statistical procedure for determining the peak value, the second method uses a technique which assumes linearity to determine a nonlinear parameter such as the maximum shear strain. For these reasons the peak maximum shear strains computed by this method are different than the exact values. However, the final differences in the strain compatible soil properties computed by the two methods are not likely to be greater than 20%.

By specifying the input parameter KSTRN the user can select any of the following three options: a) No strain computation, b) Strain computation in the time domain and, c) Strain computation in the frequency domain. Additionally, the user must supply the value of the ratio between effective shear strain and peak maximum shear strain, FCT. It must be noted that in order to obtain output for stress time histories, any of the two strain computation options must be specified.

4.6 Frequency Controls

The computer program TLUSH has several frequency controls which permit the user to select the highest frequencies for which the equations of motion are solved. One of these parameters is the cut-off frequency or maximum frequency of the analysis, TOTFR. No computations are performed by the program for frequencies above this value. That is, the displacement amplification functions are assigned a zero value and the complex Fourier amplitudes of displacement, acceleration and strain are assumed to be zero for frequencies above the cut-off frequency.

It follows that the maximum frequency of the analysis, TOTFR, should be higher than the natural frequencies corresponding to the predominant modes of vibration of the structure. That is, the response of the dam to motions at frequencies higher than the cut-off frequency should be negligible. An estimate of an appropriate value for the maximum frequency to be used in the dynamic analysis of an earth dam is given by a number 4 or 5 times higher than the fundamental frequency of vibration of the dam. Typical values for medium sized dams range between 8 and 10 Hz.

In view of the fact that a high degree of accuracy is not required during the first iterations on material properties the use of lower cut-off frequencies in these iterations is justified. TLUSH allows the user to specify a cut-off frequency for each iteration, STEP(I), and this permits the use of low cut-off frequencies in the initial stages of the solution.

4.7 Interpolation

It was mentioned earlier that in order to reduce computational effort

and cost the equations of motion are solved only for a small number of selected frequencies, and a special interpolation scheme is used by the program to obtain intermediate values of the complex amplitudes of the displacement and strain amplification functions. The interpolation technique used by TLUSH has been previously described.

The frequencies for which the equations of motion are solved must be specified by the user. It is desirable to select the minimum number of frequencies that will yield an adequate picture of the displacement and strain amplification functions at all points in the dam. This number of frequencies will depend on the shape of the amplification functions and the distribution or spacing of the frequencies selected. A close spacing betwen solution frequencies should be selected in the frequency ranges where a high degree of accuracy is required and where the amplification functions have a complex shape; that is, a great number of frequency peaks. It is useful to remember that the transfer function for a two-degree-of-freedom system is used to interpolate on the amplification functions and that 5 frequency points are needed to define such function. Thus, normally 5 frequency points are needed in the vicinity of two single frequency peaks to get accurate interpolation of the amplification function values. A greater number of frequency points is needed if there are nearby frequency peaks (Tajirian, 1981). In general, a closer spacing between solution frequencies is needed in the vicinity of the predominant frequencies of vibration of a dam while a lower density may be used in the high frequency range. Also, 30 to 40 points usually suffice to adequately define the amplification functions at most points in a dam. However, the best way to determine an appropriate distribution of solution

frequencies is to carry out the iterations on soil properties one at a time and to have the amplification functions for several points printed out after each iteration.

TLUSH allows the user to specify a maximum number of 5 interpolation ranges. For each range the maximum frequency in that range, FPKINT(I), and the interpolation gap, KINT(I), must be specified. Typical values for KINT(I) vary between 4 and 16.

4.8 Printer Plots

The following printer plots may be obtained from TLUSH:

1. Time histories of nodal point accelerations.
2. Acceleration and velocity response spectra for specified nodal point acceleration time histories.
3. Fourier spectra of acceleration time histories at specified nodal points.
4. Acceleration amplification functions for specified nodal points.
5. Time histories of the 6 components of the stress tensor at the centroid of specified elements.

The user may control the length and degree of refinement of these plots by specifying a value for the parameter NSKIP. The plotting routine will skip the specified number of points in between displayed points. It is important to mention that all accelerations output by the program are absolute accelerations and that the program has the capability of performing baseline correction on the input motions. The effect of baseline correction is small on the computed accelerations; however, it is rather significant on the corresponding velocities and displacements. The use of this option is recommended since it frees the computed motions of

integrated errors in the input motions and does not involve costly calculations.

4.9 Punched Output

The following punched output can be generated by TLUSH:

1. Element data cards with improved strain-compatible soil properties.
2. Acceleration time histories at specified nodal points.
3. Time histories of the stress components at the centroid of specified elements.

It is useful to have the program punch element cards when it is desired to perform a new analysis with a slightly different finite element model. All data on the element cards is punched in the same format as that required for input to the program. The material properties punched are those computed in the last iteration.

Acceleration time histories are punched for the entire duration of the analysis, and at the time interval and with the same format used for the input motions (8F9.6). Stress time histories are punched in psf and with a format (8E9.3).

4.10 Execution Time

It is difficult to estimate a priori the execution time of TLUSH for a given job since this time is a function of many parameters including the speed of the computer used, the available high speed storage capacity, the geometry of the finite element mesh, and the number of output options requested. It is convenient, therefore, to perform a trial run for one or two gaussian eliminations in order to estimate the execution time for a

real size job. This can easily be done since execution time for each gauss elimination is printed out by the program and the total number of eliminations can be estimated a priori. In general, three fifths to four fifths of the total execution time are spent in the solution of the equations of motion.

The following suggestions will prove to be helpful in reducing the execution time of the program:

1. Keep the maximum frequency of the analysis as low as possible.
2. Use interpolation control parameters, KINT(I), as large as possible.
3. Select the largest possible mesh size compatible with accuracy requirements.
4. Use the minimum possible number of points, KGMAX, for the Fast Fourier Transform.
5. Compute maximum shear strains by the RMS procedure.
6. Use option to duplicate element matrices.
7. Compute as few response spectra as possible in MODE1 or MODE2 runs.

5. LISTING OF MAIN PROGRAM

```
      PROGRAM TLUSH (INPUT,OUTPUT,PUNCH,TAPE1,TAPE2,TAPE3,TAPE4,TAPE5,
     1  TAPE6,TAPE7,TAPE8,TAPE9,TAPE10,TAPE11,TAPE12,TAPE13,TAPE14,
     2  TAPE15,TAPE16,TAPE17,TAPE18,TAPE19,TAPE20,TAPE21,TAPE22)
C-----------------------------------------------------------------------
C     A COMPUTER PROGRAM FOR THE COMPLEX RESPONSE ANALYSIS OF
C  THREE DIMENSIONAL EARTH DAMS BY THE FINITE ELEMENT METHOD.
C  STRAIN-COMPATIBLE SOIL PROPERTIES BY THE EQUIVALENT LINEAR METHOD.
C  ANY COMBINATION OF LUMPED AND CONSISTENT MASS MATRIX.
C  INPUT ACCELERATION AT RIGID BOUNDARY OF FINITE ELEMENT MODEL.
C-----------------------------------------------------------------------
C  OPERATION MODES - THE PROGRAM CAN OPERATE IN THREE MODES
C      MODE1 - IN THIS MODE, ALL INPUT DATA IS FROM CARDS.  THE PROGRAM
C              WILL COMPUTE THE COMPLETE RESPONSE.  IT WILL ITERATE A
C              SPECIFIED NUMBER OF TIMES TO OBTAIN STRAIN-COMPATIBLE
C              SOIL PROPERTIES.  ANY OUTPUT CAN BE SPECIFIED IN THIS
C              MODE.  DURING EXECUTION, ALL INPUT DATA AND THE FINAL
C              RESPONSE IN THE FREQUENCY DOMAIN OF ALL NODAL POINTS IS
C              WRITTEN ON TAPE 1 WHICH IS THEREFORE A COMPLETE PERMANENT
C              RECORD OF PROBLEM AND SOLUTION.
C      MODE2 - IN THIS MODE, THE CONTENT OF TAPE 1 WILL BE COPIED ONTO
C              TAPE 2 AND THE ADDITIONAL ITERATIONS ON SOIL PROPERTIES
C              CAN BE PERFORMED.  THE CONTENT OF TAPE 1 WILL BE UPDATED
C              FOR THE FOLLOWING ITERATIONS.
C      MODE3 - IN THIS MODE THE INFORMATION ON TAPE 1 CAN BE RECOVERED
C              TO GENERATE ADDITIONAL OUTPUT WITHOUT REPEATING THE COSTLY
C              FINITE ELEMENT PROCEDURE USED IN MODE1 OR MODE2.
C-----------------------------------------------------------------------
C    INPUT DATA
C
C    0. OPERATION MODE CARD (I5,I10)
C       1- 5 NOPT          IF 0 STOP ( LAST DATA CARD )
C                          IF 1 MODE1
C                          IF 2 MODE2
C                          IF 3 MODE3
C                          IF 4 DATA CHECK RUN
C       6-15 NSCM          AVAILABLE SMALL CORE LENGTH IN DECIMAL
C-----------------------------------------------------------------------
C INPUT DATA FOR MODE1
C-----------------------------------------------------------------------
C    1. JOB IDENTIFICATION CARD (12A6, I8)
C       1-72 TITLE (12)    JOB IDENTIFICATION
C      73-80 ITER          RUN NUMBER - IDENTIFICATION ONLY
C
C    2. CONTROL CARD FOR JOB SIZE OF SYSTEM (8I5)
C       1- 5 NELM          TOTAL NUMBER OF ELEMENTS
C       6-10 NOPT          TOTAL NUMBER OF NODAL POINTS
C      11-15 NB1           FIRST NODAL POINT NUMBER ON RIGID BOUNDARY
C                          I.E. ALL NODAL POINTS WITH HIGHER NUMBERS ARE
C                          ASSUMED TO BE ON RIGID BOUNDARY
C      16-20 NBP           NUMBER OF ADDITIONAL DISPLACEMENT BOUNDARY
C                          CONDITIONS.
C                          NOTE***EVERY DEGREE OF FREEDOM SUPRESSED
C                          COUNTS ONE
C      21-25 NUMBER        NUMBER OF ITERATIONS ON SOIL PROPERTIES
C                          ( INITIAL SOLUTION COUNTS ONE )
C      26-30 MATYP         TOTAL NUMBER OF STRAIN-DEPENDENT MATERIALS
C      31-35 KMATYP        =0 READ MATERIAL CURVES FROM CARDS
C                          =1 USE STANDARD BUILT IN MATERIAL CURVES
C      36-40 NFORM         0 -- FORM MATRICES AND LOAD VECTOR
C                          1 -- FORM MATRICES AND LOAD VECTOR
C                                WRITE ON TAPE 5
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C                       2 -- READ MATRICES AND LOAD VECTOR FROM TAPE 5  TLUS  62
C                       WHEN NFORM=1 OR 2, TAPE5 SHOULD BE A PHYSICAL   TLUS  63
C                       TAPE                                            TLUS  64
C                                                                       TLUS  65
C   3. CONTROL CARD FOR INPUT MOTION (2I5,3F10.4,I5)                    TLUS  66
C     1- 5 KGMAX        TOTAL NUMBER OF POINTS USED IN FAST FOURIER     TLUS  67
C                       TRANSFORMS, MUST BE A POWER OF TWO.             TLUS  68
C     6-10 N3           LAST POINT OF EARTHQUAKE RECORD USED IN ANALYSISTLUS  69
C    11-20 DT           TIME STEP OF DIGITIZED EARTHQUAKE RECORD. -SEC. TLUS  70
C    21-30 EQMUL        EARTHQUAKE MULTIPLICATION FACTOR.  IF RECORD IS TLUS  71
C                       CONTROLED BY UGMAX, LEAVE BLANK.                TLUS  72
C    31-40 UGMAX        MAX. INPUT ACCELERATION USED IN ANALYSIS. -G    TLUS  73
C                       IF EQMUL IS NOT ZERO, LEAVE BLANK.              TLUS  74
C    41-45 KBLINE       =1 APPLY BASELINE CORRECTION TO INPUT MOTION    TLUS  75
C                       =0 DO NOT APPLY BASELINE CORRECTION             TLUS  76
C                                                                       TLUS  77
C   4. CONTROL CARD FOR DIRECTION OF INPUT MOTION (3F10.4)              TLUS  78
C                       THE ABOVE INPUT ACCELERATION ON THE RIGID BASE  TLUS  79
C                       CAN BE SPECIFIED TO ACT IN ANY DIRECTION        TLUS  80
C                       ACCORDING TO THE RULE                           TLUS  81
C                       X COMPONENT = HORX * ABOVE MOTION               TLUS  82
C                       Y COMPONENT = VERT * ABOVE MOTION               TLUS  83
C                       Z COMPONENT = HORZ * ABOVE MOTION               TLUS  84
C                       HORX,VERT AND HORZ ARE ENTERED AS FOLLOWS       TLUS  85
C     1-10 HORX         FACTOR FOR X MOTION                             TLUS  86
C    11-20 VERT         FACTOR FOR Y MOTION                             TLUS  87
C    21-30 HORZ         FACTOR FOR Z MOTION                             TLUS  88
C                                                                       TLUS  89
C   5. CONTROL CARDS FOR FREQUENCY OF ANALYSIS.                         TLUS  90
C     5A.  MASTER CONTROL (F10.4, I5)                                   TLUS  91
C     1-10 TOTFR        HIGHEST FREQUENCY TO BE CONSIDERED IN ANALYSIS. TLUS  92
C                       -HZ ( USED FOR DIMENSIONING ONLY, THE ACTUAL    TLUS  93
C                       FREQUENCIES USED ARE SET BY THE VARIABLE        TLUS  94
C                       STEP(I), SEE PT. 9 BELOW )                      TLUS  95
C    11-15 KINTS        NUMBER OF VARIABLE INTERPOLATION RANGES(MAX=5)  TLUS  96
C     5B.  (KINTS) CARDS (F10.4,I5)                                     TLUS  97
C     1-10 FRKINT(I)    MAX. FREQ. IN INT. RANGE I                      TLUS  98
C    11-15 KINT(I)      INT. CONTROL IN INT. RANGE I                    TLUS  99
C                                                                       TLUS 100
C   6. CONTROL CARD FOR OUTPUT (7I5)                                    TLUS 101
C     1- 5 KDISP         IF 1, SAVE INPUT DATA AND THE COMPUTED AMPLIFIC-TLUS 102
C                       ATION FUNCT. ON TAPE 1.                         TLUS 103
C     6-10 KSTRN        =0, NO STRAIN COMPUTATION                       TLUS 104
C                       =1, COMPUTE MAX. SHEAR STRAIN IN TIME DOMAIN TO TLUS 105
C                           ITERATE ON SOIL PROPERTIES                  TLUS 106
C                       =2, COMPUTE MAX. SHEAR STRAIN IN FREQ. DOMAIN TOTLUS 107
C                           ITERATE ON SOIL PROPERTIES                  TLUS 108
C    11-15 KPNCH        IF 1, PUNCH ELEMENT CARDS WITH NEW SOIL PROPERT.TLUS 109
C                       FOR THE FOLLOWING ITERATION.                    TLUS 110
C    16-20 NOUT         TOTAL NUMBER OF NODAL POINTS WHERE OUTPUT IS    TLUS 111
C                       REQUIRED                                        TLUS 112
C    21-25 ND           NUMBER OF DAMPING VALUES FOR RESPONSE SPECTRA   TLUS 113
C    26-30 NSKIP        EVERY NSKIP-TH POINT OF TIME HISTORY IS PLOTTED TLUS 114
C    31-35 NELS         NO. OF ELEMENTS AT WHICH STRESS TIME HISTORIES  TLUS 115
C                       ARE ASKED                                       TLUS 116
C                                                                       TLUS 117
C   7. CONTROL CARD FOR MASS MATRIX AND EFFECTIVE SHEAR STRAIN (2F10.4) TLUS 118
C     1-10 RATIA        RATIO OF CONSISTENT MASS MATRIX TO FORM MASS    TLUS 119
C                       THE MASS MATRIX USED IS (1.-RATIA) * LUMPED MASSTLUS 120
C                       MATRIX + RATIA * CONSISTENT MASS MATRIX + A     TLUS 121
C                       LUMPED MASS MATRIX FORMED FROM THE CONCENTRATED TLUS 122
C                       MASSES SPECIFIED ON THE NODAL POINT CARDS (SEE  TLUS 123
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C                       PT.15 BELOW).  TYPICAL VALUES ARE 0.5-0.75     TLUS 124
C     11-20 FCT         RATIO OF EFFECTIVE SHEAR STRAIN TO MAX. SHEAR  TLUS 125
C                       STRAIN. (TYPICAL VALUES ARE 0.6 TO 0.7)        TLUS 126
C                       USED FOR DETERMINING STRAIN COMPATIBLE SOIL    TLUS 127
C                       PROPERTIES.                                    TLUS 128
C                                                                      TLUS 129
C   8. CONTROL CARD FOR DAMPING CHARACTERISTICS (F10.4)                TLUS 130
C     1-10 SDAMP        IF UNIFORM DAMPING IS USED IN ALL ELEMENTS,    TLUS 131
C                       PUNCH THE UNIFORM DAMPING VALUE, OTHERWISE     TLUS 132
C                       LEAVE BLANK.  ( SIMULATION OF MODAL ANALYSIS ) TLUS 133
C                       DAMPING VALUE MUST BE PUNCHED ON ELEMENT CARDS TLUS 134
C                                                                      TLUS 135
C   9. CONTROL CARD FOR FREQUENCY OF ANALYSIS IN EACH ITERATION(8F10.4) TLUS 136
C     1-10 STEP(1)      HIGHEST FREQUENCY OF ANALYSIS DURING FIRST     TLUS 137
C                       ITERATION. -HZ                                 TLUS 138
C            *                                                         TLUS 139
C         STEP(NUMBER)=HIGHEST FREQUENCY OF ANALYSIS FOR THE LAST      TLUS 140
C                        ITERATION. - HZ(SHOULD BE EQUAL TO TOTFR)     TLUS 141
C                                                                      TLUS 142
C  10. CONTROL CARDS FOR RESPONSE SPECTRA.                             TLUS 143
C                       NOTE***SKIP THESE CARDS  IF ND=0               TLUS 144
C   10A. FREQUENCY CONTROL (2F10.4,I5)                                 TLUS 145
C                       IF THIS CARD IS BLANK THE STANDARD VALUES      TLUS 146
C                       FSTRT=0.4,FLAST=40.,NINT=40 ARE ASSUMED        TLUS 147
C                       THIS WILL LEAD TO A PLOT WHICH FILLS ONE PAGE. TLUS 148
C     1-10 FSTRT        FIRST FREQUENCY USED IN RESPONSE SPECTRUM      TLUS 149
C                       ANALYSIS. -HZ                                  TLUS 150
C     11-20 FLAST       LAST FREQUENCY USED IN RESPONSE SPECTRUM       TLUS 151
C                       ANALYSIS. -HZ                                  TLUS 152
C     21-25 NINT        TOTAL NUMBER OF FREQUENCY STEP FOR RESPONSE    TLUS 153
C                       SPECTRA.                                       TLUS 154
C   10B. DAMPINGS (8F10.4)                                             TLUS 155
C     1-10 DAMP(1)                                                     TLUS 156
C            *          DAMPING RATIOS FOR RESPONSE SPECTRA            TLUS 157
C          DAMP(ND)                                                    TLUS 158
C                                                                      TLUS 159
C  11. NODAL POINT OUTPUT CONTROL CARDS (4I5) - NOUT CARDS             TLUS 160
C                       NOTE***SKIP THESE CARDS  IF NOUT=0.            TLUS 161
C     1- 5 M            NODAL POINT NUMBER WHERE OUTPUTS ARE REQUIRED. TLUS 162
C                       M MUST BE LESS THAN NB1                        TLUS 163
C     6-10 KEYSPC(3M-2) OUTPUT CONTROL IN X DIRECTION                  TLUS 164
C    11-15 KEYSPC(3M-1) OUTPUT CONTROL IN Y DIRECTION                  TLUS 165
C    16-20 KEYSPC(3M)   OUTPUT CONTROL IN Z DIRECTION                  TLUS 166
C                                                                      TLUS 167
C                       CODES FOR KEYSPC - VALUES                      TLUS 168
C                           0--MAXIMUM ACCELERATION ONLY               TLUS 169
C                           1--PLOT ACC. TIME HISTORY                  TLUS 170
C                          10--PLOT ACC. AND VELOCITY RESPONSE SPECTRUM TLUS 171
C                         100--PUNCH ACC. TIME HISTORY                 TLUS 172
C                        1000--PLOT FOURIER AMP. OF ACCELERATION       TLUS 173
C                       10000--PLOT AMPLIFICATION FUNCT.               TLUS 174
C                                                                      TLUS 175
C                       SUM THESE VALUES FOR SEVERAL OPTIONS           TLUS 176
C                                                                      TLUS 177
C  12. OUTPUT CONTROL CARDS FOR STRESSES -NELS CARDS (2I5)             TLUS 178
C     1- 5 NSTR(N)      ELEMENT NUMBER AT WHICH STRESS TIME HISTORY IS TLUS 179
C                       ASKED                                          TLUS 180
C     6-10 KEYSTR(N)    OUTPUT CONTROL OF STRESS TIME HISTORY          TLUS 181
C                       CODES FOR KEYSTR                               TLUS 182
C                            1--PLOT TIME HISTORIES OF STRESSES        TLUS 183
C                           10--PRINT TIME HISTORIES OF STRESSES       TLUS 184
C                          100--PUNCH TIME HISTORIES OF STRESSES       TLUS 185
```

```
C                                                                        TLUS 186
C                       SUM THESE VALUES FOR COMBINED OPTIONS            TLUS 187
C                                                                        TLUS 188
C  13. ELEMENT CARDS (9I4,3I2,F4.3,3F10.4,F4.3)                          TLUS 189
C     1- 4 N            ELEMENT NUMBER                                   TLUS 190
C     5- 8 NP1(N)       SEQUENCE NO. OF NODAL POINT 1                    TLUS 191
C     9-12 NP2(N)       SEQUENCE NO. OF NODAL POINT 2                    TLUS 192
C    13-16 NP3(N)       SEQUENCE NO. OF NODAL POINT 3                    TLUS 193
C    17-20 NP4(N)       SEQUENCE NO. OF NODAL POINT 4                    TLUS 194
C    21-24 NP5(N)       SEQUENCE NO. OF NODAL POINT 5                    TLUS 195
C    25-28 NP6(N)       SEQUENCE NO. OF NODAL POINT 6                    TLUS 196
C    29-32 NP7(N)       SEQUENCE NO. OF NODAL POINT 7                    TLUS 197
C    33-36 NP8(N)       SEQUENCE NO. OF NODAL POINT 8                    TLUS 198
C    37-38 MTYPE(N)     MATERIAL TYPE NUMBER.  0 MEANS MATERIAL WITH     TLUS 199
C                       STRAIN-INDEPENDENT PROPERTIES.                   TLUS 200
C                       IF KMATYP=1, 1 MEANS CLAY AND 2 MEANS SAND.      TLUS 201
C    39-40 LX           GENERATION INCREMENT                             TLUS 202
C    41-42 IDEL(N)      IDENTIFICATION NO. OF THE ELEMENT                TLUS 203
C    43-46 PO(N)        POISSON S RATIO.  MUST BE LESS THAN .5           TLUS 204
C    47-56 DENS(N)      UNIT WEIGHT -PCF                                 TLUS 205
C    57-66 S3(N)        MAX. SHEAR MODULUS -KSF                          TLUS 206
C    67-76 G(N)         INITIAL ESTIMATE OF SHEAR MODULUS -KSF           TLUS 207
C    77-80 XL(N)        INITIAL ESTIMATE OF FRACTION OF CRITICAL DAMPINGTLUS 208
C                                                                        TLUS 209
C                       ELEMENT CARDS MUST BE IN NUMERICAL SEQUENCE. IF  TLUS 210
C                       CARDS ARE OMITTED THE ELEMENT DATA WILL BE       TLUS 211
C                       GENERATED WITH THE SAME MATERIAL PROPERTIES AND  TLUS 212
C                       WITH NODES INCREMENTED BY LX ON THE PREVIOUS     TLUS 213
C                       ELEMENT. LAST ELEMENT CARD MUST BE PROVIDED.     TLUS 214
C                       ELEMENTS WITH THE SAME ID NO. (DIFFERENT THAN 0)TLUS 215
C                       SHOULD HAVE THE SAME GEOMETRY. NORMALIZED STIF.  TLUS 216
C                       AND MASS MATRICES WILL THEN BE DUPLICATED.       TLUS 217
C                                                                        TLUS 218
C  14. MATERIAL CURVES -MATYP GROUPS OF THREE CARDS                      TLUS 219
C                       NOTE***SKIP IF MATYP=0 OR KMATYP=1               TLUS 220
C   14A. IDENTIFICATION (I5,12A6)                                        TLUS 221
C     1- 5 N            MATERIAL TYPE NUMBER                             TLUS 222
C     6-77 TTL          MATERIAL IDENTIFICATION                          TLUS 223
C   14B. SHEAR MODULUS REDUCTION FACTORS (11F5.3)                        TLUS 224
C     1- 5  REDUCTION FACTOR AT 10**(-4.0) PER CENT STRAIN               TLUS 225
C     6-10  REDUCTION FACTOR AT 10**(-3.5) PER CENT STRAIN               TLUS 226
C    11-15  REDUCTION FACTOR AT 10**(-3.0) PER CENT STRAIN               TLUS 227
C    16-20  REDUCTION FACTOR AT 10**(-2.5) PER CENT STRAIN               TLUS 228
C    21-25  REDUCTION FACTOR AT 10**(-2.0) PER CENT STRAIN               TLUS 229
C    26-30  REDUCTION FACTOR AT 10**(-1.5) PER CENT STRAIN               TLUS 230
C    31-35  REDUCTION FACTOR AT 10**(-1.0) PER CENT STRAIN               TLUS 231
C    36-40  REDUCTION FACTOR AT 10**(-0.5) PER CENT STRAIN               TLUS 232
C    41-45  REDUCTION FACTOR AT 10**(-0.0) PER CENT STRAIN               TLUS 233
C    46-50  REDUCTION FACTOR AT 10**( 0.5) PER CENT STRAIN               TLUS 234
C    51-55  REDUCTION FACTOR AT 10**( 1.0) PER CENT STRAIN               TLUS 235
C   14C. FRACTIONS OF CRITICAL DAMPINGS IN PER CENT (11F5.3)             TLUS 236
C     1- 5  DAMPING AT 10**(-4.0) PER CENT STRAIN                        TLUS 237
C     6-10  DAMPING AT 10**(-3.5) PER CENT STRAIN                        TLUS 238
C    11-15  DAMPING AT 10**(-3.0) PER CENT STRAIN                        TLUS 239
C    16-20  DAMPING AT 10**(-2.5) PER CENT STRAIN                        TLUS 240
C    21-25  DAMPING AT 10**(-2.0) PER CENT STRAIN                        TLUS 241
C    26-30  DAMPING AT 10**(-1.5) PER CENT STRAIN                        TLUS 242
C    31-35  DAMPING AT 10**(-1.0) PER CENT STRAIN                        TLUS 243
C    36-40  DAMPING AT 10**(-0.5) PER CENT STRAIN                        TLUS 244
C    41-45  DAMPING AT 10**(-0.0) PER CENT STRAIN                        TLUS 245
C    46-50  DAMPING AT 10**( 0.5) PER CENT STRAIN                        TLUS 246
C    51-55  DAMPING AT 10**( 1.0) PER CENT STRAIN                        TLUS 247
```

```
C                                                                       TLUS 248
C  15. NODAL POINT CARDS (I5,3F10.4,I5,F10.4,I5)                        TLUS 249
C       1- 5 M               NODAL POINT NUMBER                         TLUS 250
C       6-15 XORD(M)         X-COORDINATE  -FT                          TLUS 251
C      16-25 YORD(M)         Y-COORDINATE  -FT                          TLUS 252
C      26-35 ZORD(M)         Z-COORDINATE -FT                           TLUS 253
C      36-40 KEYBC(M)        KEY FOR DISPLACEMENT BOUNDARY CONDITIONS   TLUS 254
C                            RELATIVE TO MOVING RIGID BASE              TLUS 255
C                            0 - FREE POINT AND POINTS ON RIGID BOUNDARY TLUS 256
C                            1 - CANNOT MOVE IN X-DIRECTION             TLUS 257
C                            2 - CANNOT MOVE IN Y-DIRECTION             TLUS 258
C                            3 - CANNOT MOVE IN Z DIRECTION             TLUS 259
C                            4 - CANNOT MOVE IN X OR Y DIRECTION        TLUS 260
C                            5 - CANNOT MOVE IN Y OR Z DIRECTION        TLUS 261
C                            6 - CANNOT MOVE IN Z OR X DIRECTION        TLUS 262
C                            7 - FIXED                                  TLUS 263
C      41-50 SMAS(M)         WEIGHT OF MASS ACTING AT NODAL POINT M -KIPS TLUS 264
C      51-55 NG              GENERATOR INCREMENT                        TLUS 265
C                                                                       TLUS 266
C                            NODES NEED NOT BE IN ORDER. NODAL COORDINATES TLUS 267
C                            CAN  BE GENERATED ALONG A STRAIGHT LINE CONNECT-TLUS 268
C                            ING THE NODES  ON TWO SUCCESSIVE CARDS. NODE TLUS 269
C                            NUMBERS ARE COMPUTED AS M+NG,M+2NG ETC. USING TLUS 270
C                            M AND NG ON THE FIRST CARD. MASS IS INTERPOLATEDTLUS 271
C                            FROM THE TWO END VALUES AND THE BOUNDARY   TLUS 272
C                            CONDITIONS ARE SET EQUAL TO THOSE ON THE FIRST TLUS 273
C                            CARD IF INPUT POSITIVE OR SET TO ZERO OTHERWISE.TLUS 274
C                                                                       TLUS 275
C  16. EARTHQUAKE RECORD CARDS                                          TLUS 276
C   16A. EARTHQUAKE NAME CARD (12A6)                                    TLUS 277
C      1-72 EQN(12)          IDENTIFICATION OF EARTHQUAKE RECORD        TLUS 278
C   16B. EARTHQUAKE RECORD (8F9.6) - (N3+7)/8 CARDS                     TLUS 279
C            U2G(I)          INPUT ACCELETATIONS-G                      TLUS 280
C                            DIGITIZED AT THE SPECIFIED TIME INTERVAL DT.   TLUS 281
C-----------------------------------------------------------------------TLUS 282
C INPUT DATA FOR MODE2                                                  TLUS 283
C-----------------------------------------------------------------------TLUS 284
C   0. OPERATION MODE CARD (I5,I10)    SEE PT.0 ABOVE                   TLUS 285
C                                                                       TLUS 286
C   1. CONTROL DATA (10I5)                                              TLUS 287
C       1- 5 KDISP           SEE PT.6 ABOVE                             TLUS 288
C       6-10 KSTRN           SEE PT.6 ABOVE                             TLUS 289
C      11-15 KPNCH           SEE PT.6 ABOVE                             TLUS 290
C      16-20 NOUT            SEE PT.6 ABOVE                             TLUS 291
C      21-25 ND              SEE PT.6 ABOVE                             TLUS 292
C      26-30 NSKIP           SEE PT.6 ABOVE                             TLUS 293
C      31-35 NELS            SEE PT.6 ABOVE                             TLUS 294
C      36-40 NUMBER          SEE PT.2 ABOVE                             TLUS 295
C      41-45 KBLINE          SEE PT.3 ABOVE                             TLUS 296
C      46-50 NFORM           SEE PT.2 ABOVE                             TLUS 297
C                                                                       TLUS 298
C   2. FREQUENCY OF ANALYSIS CARD                                       TLUS 299
C    2A.  MASTER CONTROL (F10.4,I5)                                     TLUS 300
C       1-10 TOTFRN          NEW TOTFR,  SEE PT.5A ABOVE                TLUS 301
C      11-15 KINTSN          NEW KINTS,  SEE PT.5A ABOVE                TLUS 302
C                            IF BLANK, PREVIOUS INTERPOLATION RANGES WILL BE TLUS 303
C                            USED.  IN THIS CASE, SKIP 2B.              TLUS 304
C    2B.  (KINTS) CARDS (F10.4, I5)                                     TLUS 305
C       1-10 FRKINT(I)       SEE PT.5B ABOVE                            TLUS 306
C      11-15 KINT(I)         SEE PT.5B ABOVE                            TLUS 307
C                                                                       TLUS 308
C   3. CONTROL CARD FOR FREQUENCY OF ANALYSIS IN EACH ITERATION(8F10.4) TLUS 309
```

```
C                        SEE PT.9 ABOVE                                   TLUS 310
C                                                                         TLUS 311
C    4. CONTROL CARD FOR RESPONSE SPECTRA (2F10.4,I5) AND (8F10.4)        TLUS 312
C                        SEE PT.10A AND 10B ABOVE                         TLUS 313
C                                                                         TLUS 314
C    5. OUTPUT CONTROL CARDS (4I5) - NOUT CARDS                           TLUS 315
C                        SEE PT.12 ABOVE                                  TLUS 316
C    6. OUTPUT FOR STRESSES (2I5) -NELS CARDS                             TLUS 317
C                        SEE PT.12 ABOVE                                  TLUS 318
C                                                                         TLUS 319
C-------------------------------------------------------------------------TLUS 320
C INPUT DATA FOR MODE3                                                    TLUS 321
C-------------------------------------------------------------------------TLUS 322
C    0. OPERATION MODE CARD (I5),  SEE PT.0 ABOVE                         TLUS 323
C                                                                         TLUS 324
C    1. CONTROL DATA (7I5)                                                TLUS 325
C       1- 5 KPNCH        SEE PT.6 ABOVE                                  TLUS 326
C       6-10 NOUT         SEE PT.6 ABOVE                                  TLUS 327
C      11-15 ND           SEE PT.6 ABOVE                                  TLUS 328
C      16-20 NSKIP        SEE PT.6 ABOVE                                  TLUS 329
C      21-25 NELS         SEE PT.6 ABOVE                                  TLUS 330
C      26-30 KBLINE       SEE PT.3 ABOVE                                  TLUS 331
C      31-35 KSTRN        SEE PT.6 ABOVE                                  TLUS 332
C                                                                         TLUS 333
C    2. CONTROL CARDS FOR RESPONSE SPECTRA (2F10.4,I5) AND (8F10.4)       TLUS 334
C                        SEE PT.10A AND 10B ABOVE                         TLUS 335
C                                                                         TLUS 336
C    3. OUTPUT CONTROL CARDS (4I5) - NOUT CARDS                           TLUS 337
C                        SEE PT.11 ABOVE                                  TLUS 338
C                                                                         TLUS 339
C    4. OUTPUT FOR STRESSES (2I5) -NELS CARDS                             TLUS 340
C                        SEE PT.12 ABOVE                                  TLUS 341
C                                                                         TLUS 342
C-------------------------------------------------------------------------TLUS 343
      COMMON XX(1)                                                        TLUS 344
C                                                                         TLUS 345
      CALL SECOND(TIM1)                                                   TLUS 346
      PRINT 6100,TIM1                                                     TLUS 347
1     CALL INPT (XX,TIM1)                                                 TLUS 348
      GO TO 1                                                             TLUS 349
 6100 FORMAT (10X,32HTIME REQUIRED FOR COMPILATION =  ,F10.3,6H   SEC   )TLUS 350
      END                                                                 TLUS 351
```

6. EXAMPLE PROBLEM

6.1 Problem Description

A fictitious earth dam founded in a V-shaped valley will be used as an example problem for TLUSH. The geometry of the dam along with the finite element model used in the analysis are shown in Figs. 5, 6 and 7. It can be seen that the dam is geometrically symmetrical with respect to the A-A and E-E planes. Since the analysis will be performed for earthquake motions in the x-direction the deformation pattern of the dam will be symmetrical with respect to the A-A plane and anti-symmetrical with respect to the E-E plane. Accordingly, only one quarter of the model needs to be considered in the analysis, and symmetry and anti-symmetry boundary conditions have to be provided on the A-A and E-E planes respectively.

The response of the dam will be evaluated for an earthquake motion digitized in 64 points at a time interval of 0.04 seconds. A quiet zone consisting of 64 zeroes will be added at the end of the record to give a total analysis duration of 5.12 seconds. The original motion has a peak acceleration of 0.05g but will be scaled to a peak value of 0.10g and will be baseline corrected. The highest frequency in the Fourier spectrum of this motion is 12.5 Hz. However, a cut-off frequency of 10 Hz will be used in the first two iterations and one of 12.0 Hz will be used in the third iteration.

The shells and core of the dam are assumed to be composed of sands and clays respectively. These materials are assumed to have strain compatible properties defined by the relationships built in the program,

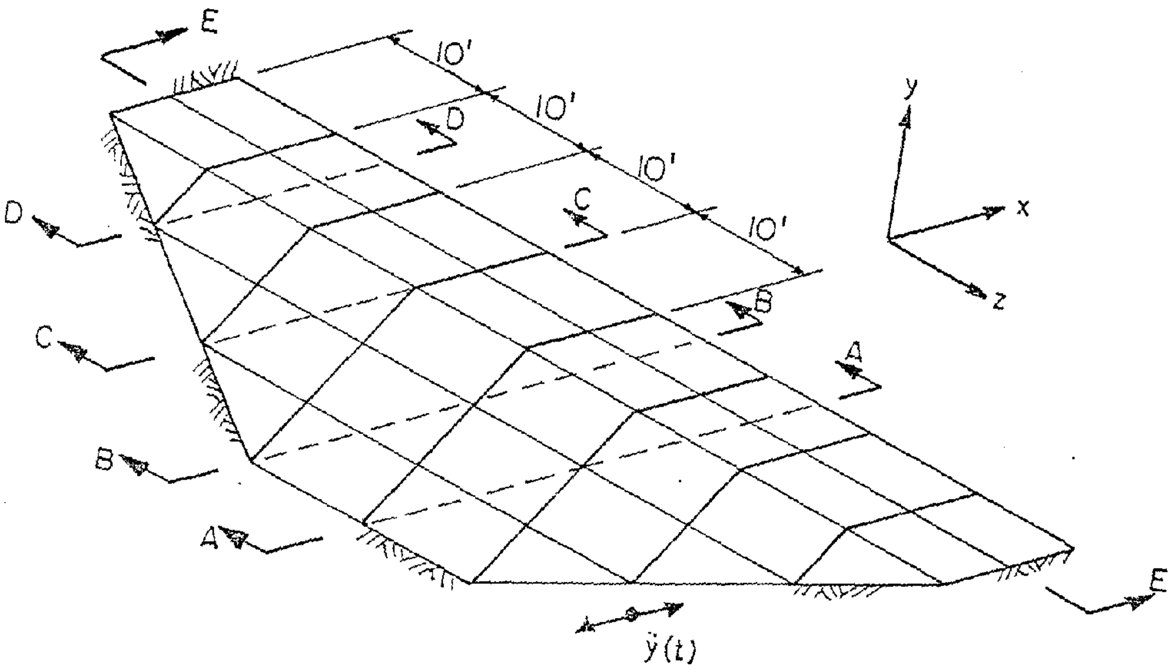
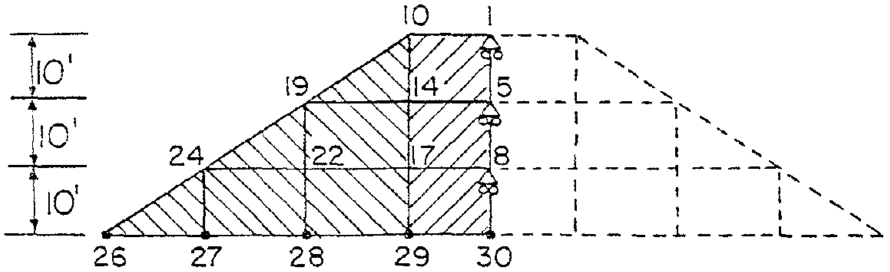
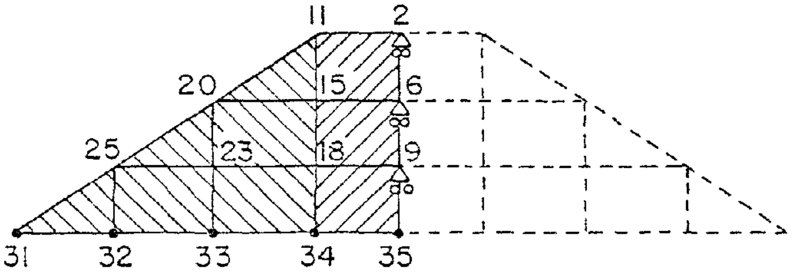


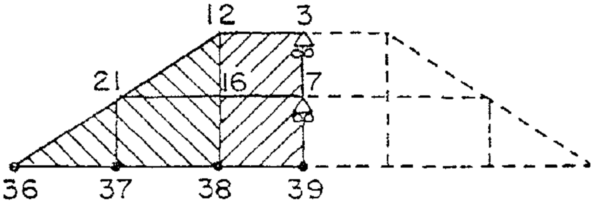
FIG. 5 FINITE ELEMENT MODEL FOR EXAMPLE PROBLEM



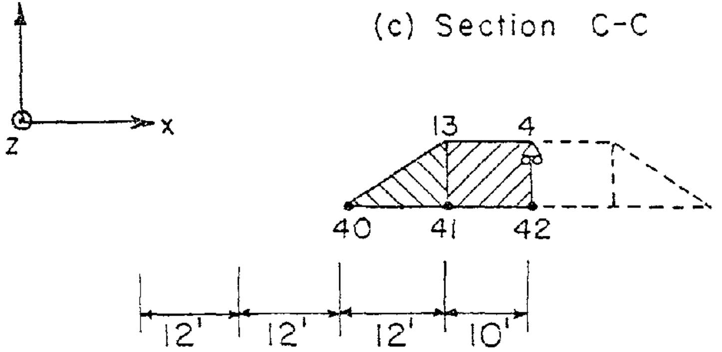
(a) Section A-A



(b) Section B-B



(c) Section C-C

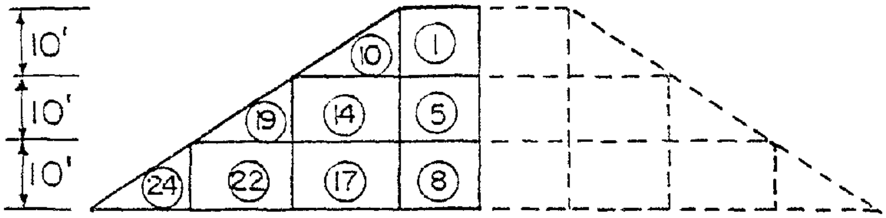


(d) Section D-D

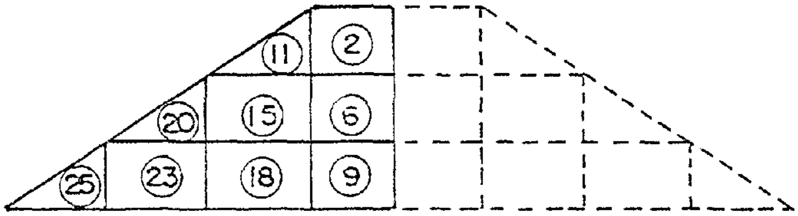
▧ Sand , G_{max} = 1500 ksf, γ = 120 pcf, ν = 0.35

▨ Clay , G_{max} = 1500 ksf, γ = 110 pcf, ν = 0.45

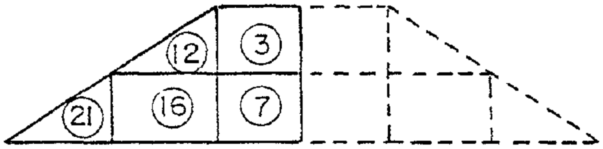
FIG. 6 NODAL POINT NUMBERING SYSTEM AND MATERIAL PROPERTIES



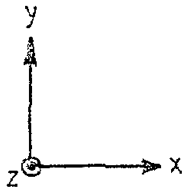
(a) Section A-A

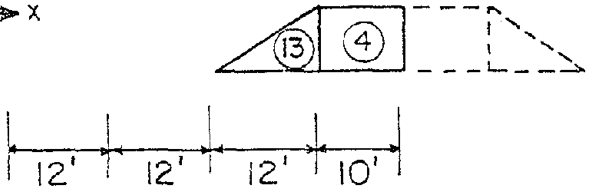


(b) Section B-B



(c) Section C-C





(d) Section D-D

FIG. 7 ELEMENT NUMBERING SYSTEM

and to have a shear modulus at low strains of 1500 ksf. Unit weights of 120 and 110 pcf have been assigned to the shell sands and the core clays respectively.

Although convergence of the strain-compatible soil properties might be achieved in two iterations, three iterations will be performed to illustrate operation of the program in MODE1 and MODE2. Two iterations will be performed using MODE1 and one iteration will be done in MODE2. The acceleration amplification functions, the Fourier spectra and the acceleration time histories for nodal points 1, 3 and 19 will be computed and plotted. The RMS procedure will be used for computing maximum shear strains in MODE1 and the time domain approach will be used in MODE2. Additionally MODE3 will be used to generate the Fourier spectrum and the response spectra for the acceleration time history at nodal point 1 and the stress time histories for element number 14.

6.2 Input Data Cards

Images of the data cards required for the example run are shown in the following pages. The data is shown exactly as it appears on the data cards and should be compared with the detailed description of the data format given in section 5.

INPUT DATA CARDS FOR MODEL

```
    1      15000
EXAMPLE PROBLEM FOR TLUSH
   25    44    26    18     2     2     1     0
  128    64 0.04      2.0                           1
1.0        0.0        0.0
10.0           4
3.0            5
6.0            3
8.0            5
10.0           8
    1     2     0     3     0     2     0
0.5        0.65

10.0       10.0
    110001     0     0
    310001     0     0
   1910001     0     0
   1  10  14   5   1  11  15   6   2 1 1 10.45 110.0     1500.0     900.0      0.05
   3  12  16   7   2  13  41  42   4 1   10.45 110.0     1500.0     900.0      0.05
   4  13  41  42   4  43  43  44  44 1   20.45 110.0     1500.0     900.0      0.05
   5  14  17   8   5  15  18   9   6 1   10.45 110.0     1500.0     900.0      0.05
   6  15  18   9   6  16  38  39   7 1   10.45 110.0     1500.0     900.0      0.05
   7  16  38  39   7  41  41  42  42 1   20.45 110.0     1500.0     900.0      0.05
   8  17  29  30   8  18  34  35   9 1   10.45 110.0     1500.0     900.0      0.05
   9  18  34  35   9  38  38  39  39 1   20.45 110.0     1500.0     900.0      0.05
  10  19  19  14  10  20  20  15  11 2 1 30.35 120.0     1500.0     900.0      0.05
  12  21  21  16  12  40  40  41  13 2   30.35 120.0     1500.0     900.0      0.05
  13  40  40  41  13  43  43  43  43 2   40.35 120.0     1500.0     900.0      0.05
  14  19  22  17  14  20  23  18  15 2   50.35 120.0     1500.0     900.0      0.05
  15  20  23  18  15  21  37  38  16 2   50.35 120.0     1500.0     900.0      0.05
  16  21  37  38  16  40  40  41  41 2   60.35 120.0     1500.0     900.0      0.05
  17  22  28  29  17  23  33  34  18 2   50.35 120.0     1500.0     900.0      0.05
  18  23  33  34  18  37  37  38  38 2   60.35 120.0     1500.0     900.0      0.05
  19  24  24  22  19  25  25  23  20 2   30.35 120.0     1500.0     900.0      0.05
  20  25  25  23  20  36  36  37  21 2   30.35 120.0     1500.0     900.0      0.05
  21  36  36  37  21  40  40  40  40 2   40.35 120.0     1500.0     900.0      0.05
  22  24  27  28  22  25  32  33  23 2   50.35 120.0     1500.0     900.0      0.05
  23  25  32  33  23  36  36  37  37 2   60.35 120.0     1500.0     900.0      0.05
  24  26  26  27  24  31  31  32  25 2   30.35 120.0     1500.0     900.0      0.05
  25  31  31  32  25  36  36  36  36 2   40.35 120.0     1500.0     900.0      0.05
     1 46.0      30.0       40.0            5
     2 46.0      30.0       30.0            2              1
     4 46.0      30.0       10.0            2
     5 46.0      20.0       40.0            5
     6 46.0      20.0       30.0            2
     7 46.0      20.0       20.0            2
     8 46.0      10.0       40.0            5
     9 46.0      10.0       30.0            2
    10 36.0      30.0       40.0           -3              1
    13 36.0      30.0       10.0
    14 36.0      20.0       40.0           -3              1
    16 36.0      20.0       20.0
    17 36.0      10.0       40.0            3
    18 36.0      10.0       30.0
    19 24.0      20.0       40.0           -3              1
    21 24.0      20.0       20.0
    22 24.0      10.0       40.0            3
    23 24.0      10.0       30.0
    24 12.0      10.0       40.0            3
    25 12.0      10.0       30.0
    26 00.0      00.0       40.0                           1
    29 36.0      00.0       40.0
    30 46.0      00.0       40.0
    31 00.0      00.0       30.0                           1
    34 36.0      00.0       30.0
    35 46.0      00.0       30.0
    36 12.0      10.0       20.0                           1
    38 36.0      10.0       20.0
    39 46.0      10.0       20.0
    40 24.0      20.0       10.0
    41 36.0      20.0       10.0
    42 46.0      20.0       10.0
    43 36.0      30.0       00.0
    44 46.0      30.0       00.0
    ** EXAMPLE  EARTHQUAKE **     0.04 SEC     64 POINTS
   .000204 -.000191  .000058  .001460  .004111  .004390  .009534 -.003481         1
   .013073  .009455  .000374  .018791 -.022305 -.018976 -.011557 -.048139         2
   .013707 -.029759  .011100 -.025240  .015560 -.013417  .023272 -.013397         3
   .050000  .000068  .012727  .006808  .010066  .010332  .006599 -.001122         4
   .008954 -.020449  .015687 -.005003 -.017561  .003863 -.010918 -.008641         5
  -.008450 -.010743  .001941 -.000952  .000568 -.001998  .010888  .008075         6
   .009841  .003844 -.005115  .001176 -.003725 -.008514  .001117 -.000450         7
   .000281 -.000221  .000197 -.000188  .000185 -.000188  .000193 -.000200         8
```

```
    2     15000                                         INPUT DATA CARDS FOR MODE2
    1    1    0    3    0    2    0    1    1    0
12.0          3
5.0           5
10.0          3
12.0          5
12.0
    111001    0    0
    311001    0    0
   1911001    0    0
```

```
    3     15000                                         INPUT DATA CARDS FOR MODE3
         1    1    2    1    1    2

0.05
    1 1010    0    0
   14    1
```

6.3 Computer Output

The printed output corresponding to the example problem is shown in the following pages, exactly as produced by a CDC 7600 computer, except for some blank space in between tables. It is once again noted that a complete record of the input data and solution remains stored on TAPE1. This additional output of the program is disposed onto a magnetic tape or disc.

```
**********
* MODEL  *
**********


*** BLANK COMMON REQUIREMENTS ***

            LENGTH OF BLANK COMMON =     15000

     BLANK COMMON REQUIRED FOR VEDDA =      1499

     BLANK COMMON FOR PERMANENT DATA =       940

    BLANK COMMON REQUIRED FOR STRAIN =      1757

              BLANK COMMON FOR BBBC =      6621

        MAX. WORDS REQUIRED FOR BBBC =        72

    BLANK COMMON REQUIRED FOR MOTION =       863

              BLANK COMMON FOR AAAC =      7068

        MAX. WORDS REQUIRED FOR AAAC =        12
```

```
EXAMPLE PROBLEM FOR TLUSH                                               RUN NUMBER =  1

*** INPUT DATA ***
          TOTAL NUMBER OF ELEMENTS =     25
       TOTAL NUMBER OF NODAL POINTS =     44
     1ST NODAL POINT OF RIGID BASE =     26
                DEGREES OF FREEDOM =     75
   NUMBER OF BOUNDARY CONDITIONS =     18
              NUMBER OF ITERATIONS =      2
          NUMBER OF MATERIAL TYPES =      2


*** INPUT MOTION ***
 TOTAL NO. OF POINTS USED IN FFT =   128
            LAST POINT TO BE READ =    64
              TIME STEP OF RECORD =    .040 SEC.
               DURATION OF RECORD =   2.560 SEC.
             QUIET ZONE OF RECORD =   2.560 SEC.
      TOTAL DURATION OF ANALYSIS =   5.120 SEC.
       EQ. MULTIPLICATION FACTOR =  2.0000
        MAX. ACCEL. AFTER SCALING =   .0585 (G)
          MOTION IN X-DIRECTION =  1.0000 TIMES INPUT MOTION
          MOTION IN Y-DIRECTION =  0.      TIMES INPUT MOTION
          MOTION IN Z-DIRECTION =  0.      TIMES INPUT MOTION

 BASE LINE CORRECTION WILL BE APPLIED


*** FREQUENCY CONTENT OF ANALYSIS ***
   HIGHEST FREQUENCY OF ANALYSIS =  10.000  HZ
     NO. OF INTERPOLATION RANGES =   4

     0.     --    3.000 HZ(KINT=  5)
     3.000 --    6.000 HZ(KINT=  3)
     6.000 --    8.000 HZ(KINT=  5)
     8.000 --   10.000 HZ(KINT=  3)
   FREQUENCY USED FOR ITERATION 1 =  10.000  HZ
   FREQUENCY USED FOR ITERATION 2 =  10.000  HZ


*** OUTPUT CONTROL ***
     SAVING AMP. FUNCTION ON TAPE =  YES
   COMPUTING NEW SOIL PROPERTIES =  YES
    PUNCHING NEW SOIL PROPERTIES =  NO
     STEPS TO FIND MAX. RESPONSE =   128
        SKIP POINTS FOR PLOTTING =     2
    FACTOR FOR EFF. SHEAR STRAIN =   .6500


*** MASS MATRIX ***
     FRACTION OF CONSISTENT MASS =   .5000
         FRACTION OF LUMPED MASS =   .5000


*** DAMPING CHARACTERISTICS ***
            UNIFORM DAMPING USED =  NO
```

```
*** OUTPUT REQUIREMENTS ***
              CODES FOR KEYSPC
              0--MAXIMUM ACCELERATION ONLY
              1--PLOT ACC. TIME HISTORY
             10--PLOT ACC. AND VELOCITY RESPONSE SPECTRUM
            100--PUNCH ACC. TIME HISTORY
           1000--PLOT FOURIER AMP. OF ACCELERATION
          10000--PLOT AMPLIFICATION FUNCTION


     VALUES OF KEYSPC

     N.P.NO.   X-OUTPUT   Y-OUTPUT   Z-OUTPUT
        1       10001         0          0
        3       10001         0          0
       19       10001         0          0
```

```
 *** SHEAR MODULUS AND DAMPING CURVES FOR MATERIALS WITH STRAIN-DEPENDENT PROPERTIES ***

   STANDARD BUILT IN CURVES ARE USED


   MAT. TYPE --        IDENTIFICATION

        1      SEED AND IDRISS (1970) -- CLAY
        2      SEED AND IDRISS (1970) -- SAND


       SHEAR MODULUS CURVES

                                                          SHEAR STRAIN IN PERCENT
MAT. -----------------------------------------------------------------------------------------------------------------
TYPE  10**(-4.0) 10**(-3.5) 10**(-3.0) 10**(-2.5) 10**(-2.0) 10**(-1.5) 10**(-1.0) 10**(-0.5) 10**( 0.0) 10**( 0.5) 10**( 1.0)
---------------------------------------------------------------------------------------------------------------------
  1     .10E+01    .91E+00    .76E+00    .57E+00    .40E+00    .25E+00    .15E+00    .76E-01    .37E-01    .13E-01    .40E-02
  2     .10E+01    .98E+00    .95E+00    .83E+00    .56E+00    .44E+00    .25E+00    .12E+00    .49E-01    .49E-01    .49E-01
---------------------------------------------------------------------------------------------------------------------


       DAMPING CURVES  (PERCENT)

                                                          SHEAR STRAIN IN PERCENT
MAT. -----------------------------------------------------------------------------------------------------------------
TYPE  10**(-4.0) 10**(-3.5) 10**(-3.0) 10**(-2.5) 10**(-2.0) 10**(-1.5) 10**(-1.0) 10**(-0.5) 10**( 0.0) 10**( 0.5) 10**( 1.0)
---------------------------------------------------------------------------------------------------------------------
  1     .25E+01    .25E+01    .25E+01    .35E+01    .48E+01    .65E+01    .93E+01    .14E+02    .20E+02    .26E+02    .29E+02
  2     .50E+00    .80E+00    .17E+01    .32E+01    .56E+01    .10E+02    .16E+02    .21E+02    .25E+02    .25E+02    .25E+02
---------------------------------------------------------------------------------------------------------------------
```

```
*** ELEMENT DATA ***

NO.   NP1   NP2   NP3   NP4   NP5   NP6   NP7   NP8  MTYPE   ID.EL     PO    UNIT WT.     G-MAX      G-USE    DMP-USE     VS-USE
                                                                              (PCF)       (KSF)      (KSF)  (FRACTION)    (FPS)

 1    10    14     5     1    11    15     6     2     1       1     .450    110.000  1500.000    900.000       .050    513.278
 2    11    15     6     2    12    16     7     3     1       1     .450    110.000  1500.000    900.000       .050    513.278
 3    12    16     7     3    13    41    42     4     1       1     .450    110.000  1500.000    900.000       .050    513.278
 4    13    41    42     4    43    43    44    44     1       2     .450    110.000  1500.000    900.000       .050    513.278
 5    14    17     8     5    15    18     9     6     1       1     .450    110.000  1500.000    900.000       .050    513.278
 6    15    18     9     6    16    38    39     7     1       1     .450    110.000  1500.000    900.000       .050    513.278
 7    16    38    39     7    41    41    42    42     1       2     .450    110.000  1500.000    900.000       .050    513.278
 8    17    29    30     8    18    34    35     9     1       1     .450    110.000  1500.000    900.000       .050    513.278
 9    18    34    35     9    38    38    39    39     1       2     .450    110.000  1500.000    900.000       .050    513.278
10    19    19    14    10    20    20    15    11     2       3     .350    120.000  1500.000    900.000       .050    491.426
11    20    20    15    11    21    21    16    12     2       3     .350    120.000  1500.000    900.000       .050    491.426
12    21    21    16    12    40    40    41    13     2       3     .350    120.000  1500.000    900.000       .050    491.426
13    40    40    41    13    43    43    43    43     2       4     .350    120.000  1500.000    900.000       .050    491.426
14    19    22    17    14    20    23    18    15     2       5     .350    120.000  1500.000    900.000       .050    491.426
15    20    23    18    15    21    37    38    16     2       5     .350    120.000  1500.000    900.000       .050    491.426
16    21    37    38    16    40    40    41    41     2       6     .350    120.000  1500.000    900.000       .050    491.426
17    22    28    29    17    23    33    34    18     2       5     .350    120.000  1500.000    900.000       .050    491.426
18    23    33    34    18    37    37    38    38     2       6     .350    120.000  1500.000    900.000       .050    491.426
19    24    24    22    19    25    25    23    20     2       3     .350    120.000  1500.000    900.000       .050    491.426
20    25    25    23    20    36    36    37    21     2       3     .350    120.000  1500.000    900.000       .050    491.426
21    36    36    37    21    40    40    40    40     2       4     .350    120.000  1500.000    900.000       .050    491.426
22    24    27    28    22    25    32    33    23     2       5     .350    120.000  1500.000    900.000       .050    491.426
23    25    32    33    23    36    36    37    37     2       6     .350    120.000  1500.000    900.000       .050    491.426
24    26    26    27    24    31    31    32    25     2       3     .350    120.000  1500.000    900.000       .050    491.426
25    31    31    32    25    36    36    36    36     2       4     .350    120.000  1500.000    900.000       .050    491.426


*** NODAL POINT DATA ***

                                                                         BOUNDARY  CONDITIONS
 N.P.      XORD(FT)      YORD(FT)      ZORD(FT)     MASS (KIPS)    X-DIRECTION   Y-DIRECTION   Z-DIRECTION

   1        46.000        30.000        40.000        -0.                          FIXED         FIXED
   2        46.000        30.000        30.000        -0.                          FIXED
   3        46.000        30.000        20.000         0.                          FIXED
   4        46.000        30.000        10.000        -0.                          FIXED
   5        46.000        20.000        40.000        -0.                          FIXED         FIXED
   6        46.000        20.000        30.000        -0.                          FIXED
   7        46.000        20.000        20.000        -0.                          FIXED
   8        46.000        10.000        40.000        -0.                          FIXED         FIXED
   9        46.000        10.000        30.000        -0.                          FIXED
  10        36.000        30.000        40.000        -0.                                        FIXED
  11        36.000        30.000        30.000         0.
  12        36.000        30.000        20.000         0.
  13        36.000        30.000        10.000        -0.
  14        36.000        20.000        40.000        -0.                                        FIXED
  15        36.000        20.000        30.000         0.
  16        36.000        20.000        20.000        -0.
  17        36.000        10.000        40.000        -0.                                        FIXED
  18        36.000        10.000        30.000        -0.
  19        24.000        20.000        40.000        -0.                                        FIXED
  20        24.000        20.000        30.000         0.
  21        24.000        20.000        20.000        -0.
  22        24.000        10.000        40.000        -0.                                        FIXED
  23        24.000        10.000        30.000        -0.
  24        12.000        10.000        40.000        -0.                                        FIXED
  25        12.000        10.000        30.000        -0.
  26         0.            0.           40.000        -0.            FIXED         FIXED         FIXED
  27        12.000         0.           40.000         0.            FIXED         FIXED         FIXED
  28        24.000         0.           40.000         0.            FIXED         FIXED         FIXED
  29        36.000         0.           40.000        -0.            FIXED         FIXED         FIXED
  30        46.000         0.           40.000        -0.            FIXED         FIXED         FIXED
  31         0.            0.           30.000        -0.            FIXED         FIXED         FIXED
  32        12.000         0.           30.000         0.            FIXED         FIXED         FIXED
  33        24.000         0.           30.000         0.            FIXED         FIXED         FIXED
  34        36.000         0.           30.000        -0.            FIXED         FIXED         FIXED
  35        46.000         0.           30.000        -0.            FIXED         FIXED         FIXED
  36        12.000        10.000        20.000        -0.            FIXED         FIXED         FIXED
  37        24.000        10.000        20.000         0.            FIXED         FIXED         FIXED
  38        36.000        10.000        20.000        -0.            FIXED         FIXED         FIXED
  39        46.000        10.000        20.000        -0.            FIXED         FIXED         FIXED
  40        24.000        20.000        10.000        -0.            FIXED         FIXED         FIXED
  41        36.000        20.000        10.000        -0.            FIXED         FIXED         FIXED
  42        46.000        20.000        10.000        -0.            FIXED         FIXED         FIXED
  43        36.000        30.000         0.           -0.            FIXED         FIXED         FIXED
  44        46.000        30.000         0.           -0.            FIXED         FIXED         FIXED
```

```
*** EARTHQUAKE RECORD ***


** EXAMPLE  EARTHQUAKE **     0.04 SEC     64 POINTS

  INPUT ACCEL. PRIOR TO SCALING


   MAX. ACC. =      .0500 (G)  AT TIME =      .9600 SEC.

        .000204 -.000191  .000058  .001460  .004111  .004390  .009534 -.003481        1
        .013073  .009455  .000374  .018791 -.022305 -.018976 -.011557 -.048139        2
        .013707 -.029759  .011100 -.025240  .015560 -.013417  .023272 -.013397        3
        .050000  .000058  .012727  .006808  .010066  .010332  .006599 -.001122        4
        .008954 -.020449  .015687 -.005003 -.017561  .003863 -.010918 -.008641        5
       -.008450 -.010743  .001941 -.000952  .000968 -.001998  .010888  .008075        6
        .009841  .003844 -.005115  .001176 -.003725 -.006514  .001117 -.000450        7
        .000281 -.000221  .000197 -.000188  .000195 -.000188  .000193 -.000200        8
       0.       0.       0.       0.       0.       0.       0.       0.                9
       0.       0.       0.       0.       0.       0.       0.       0.               10
       0.       0.       0.       0.       0.       0.       0.       0.               11
       0.       0.       0.       0.       0.       0.       0.       0.               12
       0.       0.       0.       0.       0.       0.       0.       0.               13
       0.       0.       0.       0.       0.       0.       0.       0.               14
       0.       0.       0.       0.       0.       0.       0.       0.               15
       0.       0.       0.       0.       0.       0.       0.       0.               16


TIME REQUIRED FOR INPUT AND INITIALIZATION =      .103   SEC




 *** MATRICES AND LOAD VECTOR ARE FORMED IN THIS RUN ***

    ITERATION        1
  CORE SIZE AVAILABLE FOR EQUATION SOLUTION   =       14957
  TOTAL NUMBER OF EQUATIONS                   =          75
  MAXIMUM NUMBER OF TERMS IN A BLOCK          =        3701
  MAXIMUM NUMBER OF COLUMNS IN A BLOCK        =          75
  NUMBER OF BLOCKS                            =           1
  BANDWIDTH                                   =          45
  NUMBER OF TERMS IN STIFFNESS MATRIX         =        1701


     TIME REQUIRED FOR FORMATION OF STIFFNESS MATRIX  =        .303   SEC

      *** TIME FOR GAUSSIAN ELIMINATION ***

    FRQ NUMBER =      1  FRQ =      0.       HZ      CUMULATIVE   TIME   =       .0542  SEC.
    FRQ NUMBER =      2  FRQ =      .9766   HZ      CUMULATIVE   TIME   =       .1078  SEC.
    FRQ NUMBER =      3  FRQ =     1.9531   HZ      CUMULATIVE   TIME   =       .1615  SEC.
    FRQ NUMBER =      4  FRQ =     2.9297   HZ      CUMULATIVE   TIME   =       .2152  SEC.
    FRQ NUMBER =      5  FRQ =     3.5156   HZ      CUMULATIVE   TIME   =       .2689  SEC.
    FRQ NUMBER =      6  FRQ =     4.1016   HZ      CUMULATIVE   TIME   =       .3220  SEC.
    FRQ NUMBER =      7  FRQ =     4.6875   HZ      CUMULATIVE   TIME   =       .3757  SEC.
    FRQ NUMBER =      8  FRQ =     5.2734   HZ      CUMULATIVE   TIME   =       .4294  SEC.
    FRQ NUMBER =      9  FRQ =     5.8594   HZ      CUMULATIVE   TIME   =       .4831  SEC.
    FRQ NUMBER =     10  FRQ =     6.9359   HZ      CUMULATIVE   TIME   =       .5368  SEC.
    FRQ NUMBER =     11  FRQ =     7.8125   HZ      CUMULATIVE   TIME   =       .5904  SEC.
    FRQ NUMBER =     12  FRQ =     9.3750   HZ      CUMULATIVE   TIME   =       .6441  SEC.

    NO. OF FREQ. STEPS        49 (INCLUDING INTERPOLATED POINTS)
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  ELM      G-USED      G-NEW     DIF-G        DAMP-USED    DAMP-NEW   DIF-DAMP     VS-USED    VS-NEW    DIF-VS       MAX. S. STRAIN
           (KSF)       (KSF)    (PERCENT)    (FRACTION)   (FRACTION)  (PERCENT)    (FPS)      (FPS)    (PERCENT)      (PERCENT)

    1       900.        701.      28.3          .050         .042       18.0        513.       453.      13.3          .00960
    2       900.        740.      21.6          .050         .040       23.7        513.       456.      10.3          .00801
    3       900.        697.      29.1          .050         .043       17.4        513.       452.      13.6          .00980
    4       900.        796.      13.0          .050         .038       33.0        513.       483.       6.3          .00617
    5       900.        601.      49.8          .050         .047        5.3        513.       419.      22.4          .01533
    6       900.        585.      53.9          .050         .049        2.5        513.       414.      24.1          .01674
    7       900.        594.      51.5          .050         .048        4.2        513.       417.      23.1          .01590
    8       900.        623.      44.5          .050         .046        7.9        513.       427.      20.2          .01383
    9       900.        598.      50.6          .050         .048        4.8        513.       418.      22.7          .01558
   10       900.       1081.     -16.7          .050         .047        6.6        491.       539.      -8.7          .00994
   11       900.       1020.     -11.8          .050         .053       -5.0        491.       523.      -6.1          .01308
   12       900.       1025.     -12.2          .050         .052       -4.1        491.       524.      -6.3          .01278
   13       900.       1142.     -21.2          .050         .041       21.6        491.       554.     -11.2          .00753
   14       900.        998.      -9.8          .050         .055       -8.6        491.       517.      -5.0          .01446
   15       900.        972.      -7.4          .050         .058      -13.3        491.       511.      -3.8          .01608
   16       900.        993.      -9.4          .050         .055       -9.3        491.       516.      -4.8          .01475
   17       900.       1017.     -11.5          .050         .053       -5.4        491.       522.      -5.9          .01324
   18       900.        989.      -9.0          .050         .056      -10.0        491.       515.      -4.6          .01504
   19       900.        995.      -9.6          .050         .055       -9.0        491.       517.      -4.9          .01464
   20       900.        985.      -8.6          .050         .056      -10.6        491.       514.      -4.4          .01532
   21       900.        989.      -9.0          .050         .055      -10.0        491.       515.      -4.6          .01507
   22       900.       1058.     -14.9          .050         .049        2.0        491.       533.      -7.8          .01101
   23       900.       1031.     -12.7          .050         .052       -3.1        491.       526.      -6.5          .01247
   24       900.       1083.     -16.9          .050         .047        7.2        491.       539.      -8.9          .00982
   25       900.       1059.     -15.0          .050         .049        2.2        491.       533.      -7.8          .01095

*** MAX. SHEAR STRAIN COMPUTATION IN FREQ DOMAIN


TIME REQUIRED FOR COMPUTING STRESS AND STRAIN =      .956     SEC




ITERATION      2

TIME REQUIRED FOR FORMATION OF STIFFNESS MATRIX  =      .049   SEC

  *** TIME FOR GAUSSIAN ELIMINATION ***

   FRQ NUMBER =    1  FRQ =      0.       HZ     CUMULATIVE   TIME   =     .0460  SEC.
   FRQ NUMBER =    2  FRQ =      .9766    HZ     CUMULATIVE   TIME   =     .0931  SEC.
   FRQ NUMBER =    3  FRQ =     1.9531    HZ     CUMULATIVE   TIME   =     .1389  SEC.
   FRQ NUMBER =    4  FRQ =     2.9297    HZ     CUMULATIVE   TIME   =     .1963  SEC.
   FRQ NUMBER =    5  FRQ =     3.5156    HZ     CUMULATIVE   TIME   =     .2532  SEC.
   FRQ NUMBER =    6  FRQ =     4.1016    HZ     CUMULATIVE   TIME   =     .3092  SEC.
   FRQ NUMBER =    7  FRQ =     4.6875    HZ     CUMULATIVE   TIME   =     .3652  SEC.
   FRQ NUMBER =    8  FRQ =     5.2734    HZ     CUMULATIVE   TIME   =     .4211  SEC.
   FRQ NUMBER =    9  FRQ =     5.8594    HZ     CUMULATIVE   TIME   =     .4768  SEC.
   FRQ NUMBER =   10  FRQ =     6.8359    HZ     CUMULATIVE   TIME   =     .5327  SEC.
   FRQ NUMBER =   11  FRQ =     7.8125    HZ     CUMULATIVE   TIME   =     .5874  SEC.
   FRQ NUMBER =   12  FRQ =     9.3750    HZ     CUMULATIVE   TIME   =     .6413  SEC.

   NO. OF FREQ. STEPS        49 (INCLUDING INTERPOLATED POINTS)
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ELM    G-USED     G-NEW     DIF-G      DAMP-USED    DAMP-NEW    DIF-DAMP    VS-USED   VS-NEW    DIF-VS      MAX. S. STRAIN
       (KSF)      (KSF)    (PERCENT)   (FRACTION)  (FRACTION)  (PERCENT)   (FPS)     (FPS)    (PERCENT)     (PERCENT)

  1     701.       571.      4.5         .042        .044        -3.5       453.      443.        2.2          .01106
  2     740.       716.      3.3         .040        .042        -2.9       466.      458.        1.7          .00895
  3     697.       692.       .7         .043        .043         -.5       452.      450.         .3          .01001
  4     796.       800.      -.4         .038        .037          .5       483.      484.        -.2          .00607
  5     601.       577.      4.1         .047        .049        -3.9       419.      411.        2.0          .01745
  6     585.       570.      2.5         .049        .050        -2.4       414.      409.        1.3          .01812
  7     594.       584.      1.7         .048        .049        -1.7       417.      414.         .8          .01678
  8     623.       610.      2.1         .046        .047        -1.4       427.      423.        1.0          .01466
  9     598.       590.      1.3         .048        .048        -1.3       418.      416.         .6          .01624
 10    1081.      1125.     -3.9         .047        .043         9.8       539.      549.       -2.0          .00813
 11    1020.      1055.     -3.4         .053        .049         6.8       523.      532.       -1.7          .01115
 12    1025.      1050.     -2.4         .052        .050         4.7       524.      531.       -1.2          .01142
 13    1142.      1161.     -1.6         .041        .039         4.6       554.      558.        -.8          .00691
 14     998.      1021.     -2.3         .055        .053         4.1       517.      523.       -1.1          .01303
 15     972.       996.     -2.5         .058        .055         5.2       511.      517.       -1.2          .01457
 16     993.      1007.     -1.4         .055        .054         2.5       516.      520.        -.7          .01384
 17    1017.      1043.     -2.5         .053        .050         4.8       522.      529.       -1.2          .01179
 18     989.      1008.     -1.9         .056        .054         3.4       515.      520.       -1.0          .01378
 19     995.      1001.      -.6         .055        .054         1.1       517.      518.        -.3          .01422
 20     985.      1000.     -1.5         .056        .054         2.7       514.      518.        -.8          .01428
 21     989.      1002.     -1.4         .056        .054         2.4       515.      519.        -.7          .01416
 22    1058.      1096.     -3.5         .049        .045         7.9       533.      542.       -1.7          .00928
 23    1031.      1063.     -3.1         .052        .049         6.3       526.      534.       -1.5          .01077
 24    1083.      1122.     -3.5         .047        .043         8.6       539.      549.       -1.8          .00824
 25    1059.      1096.     -3.3         .049        .045         7.5       533.      542.       -1.7          .00929

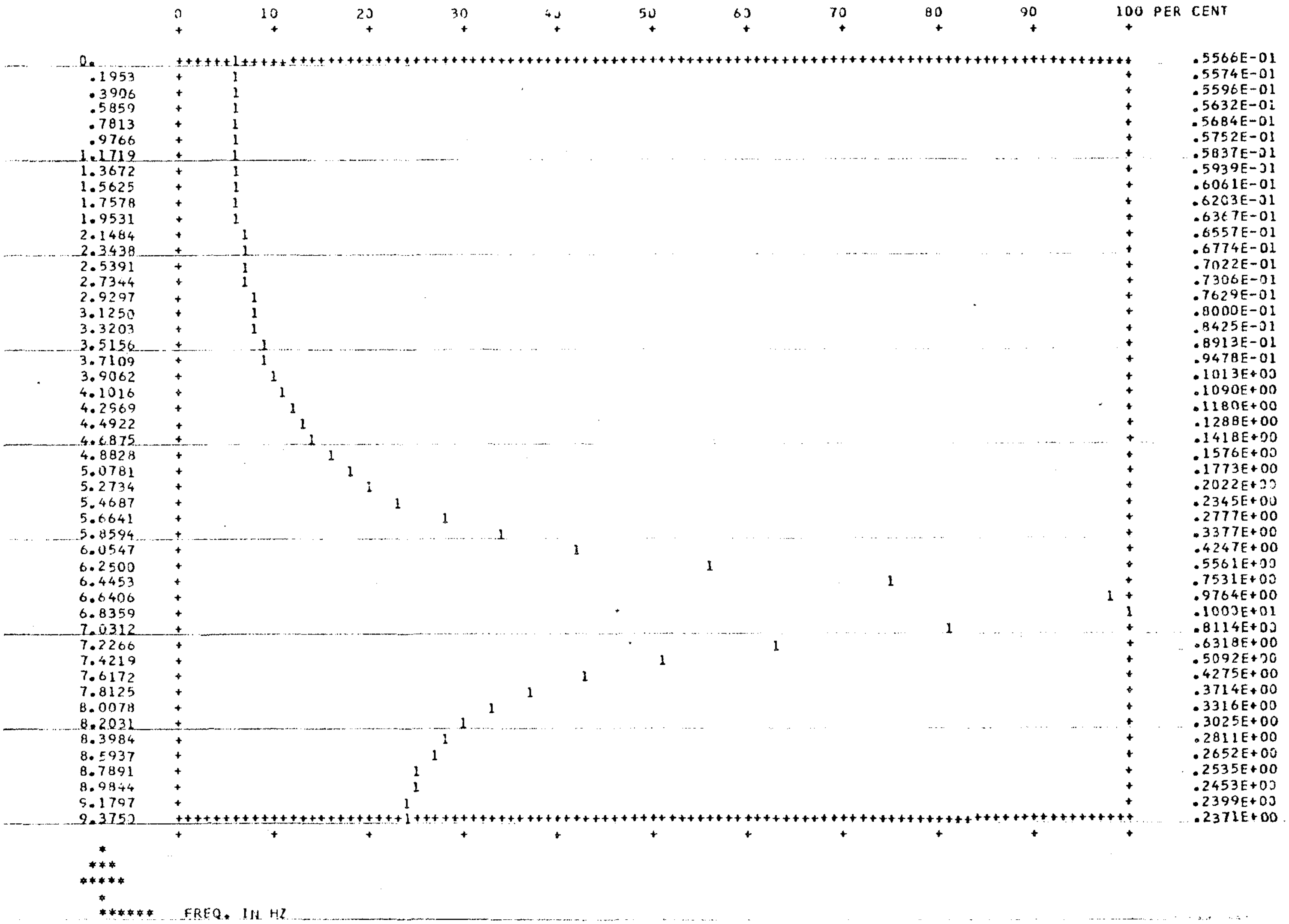
*** MAX. SHEAR STRAIN COMPUTATION IN FREQ DOMAIN

TIME REQUIRED FOR COMPUTING STRESS AND STRAIN =     .950     SEC

 *** TAPE 1 HAS BEEN COMPLETED ***
```

*** PLOT OF ACCELERATION AMPLIFICATION FUNCT.

X-ACC. AMPLIFICATION AT NODAL POINT 1, 100 PER CENT CORRESPONDS TO 17.9646



0.	.5566E-01
.1953	.5574E-01
.3906	.5596E-01
.5859	.5632E-01
.7813	.5684E-01
.9766	.5752E-01
1.1719	.5837E-01
1.3672	.5939E-01
1.5625	.6061E-01
1.7578	.6203E-01
1.9531	.6367E-01
2.1484	.6557E-01
2.3438	.6774E-01
2.5391	.7022E-01
2.7344	.7306E-01
2.9297	.7629E-01
3.1250	.8000E-01
3.3203	.8425E-01
3.5156	.8913E-01
3.7109	.9478E-01
3.9062	.1013E+00
4.1016	.1090E+00
4.2969	.1180E+00
4.4922	.1288E+00
4.6875	.1418E+00
4.8828	.1576E+00
5.0781	.1773E+00
5.2734	.2022E+00
5.4687	.2345E+00
5.6641	.2777E+00
5.8594	.3377E+00
6.0547	.4247E+00
6.2500	.5561E+00
6.4453	.7531E+00
6.6406	.9764E+00
6.8359	.1000E+01
7.0312	.8114E+00
7.2266	.6318E+00
7.4219	.5092E+00
7.6172	.4275E+00
7.8125	.3714E+00
8.0078	.3316E+00
8.2031	.3025E+00
8.3984	.2811E+00
8.5937	.2652E+00
8.7891	.2535E+00
8.9844	.2453E+00
9.1797	.2399E+00
9.3750	.2371E+00

```
*** PLOT OF ACCELERATION. (BASE ACC.+REL. ACC.)

X-COMP. OF ACCELERATION AT NODAL POINT      1,  100 PER CENT CORRESPONDS TO        .1875   G .

EVERY   2 TH POINTS ARE PLOTTED

              -100      -80       -60       -40       -20        0        20        40        60        80       100 PER CENT
                +         +         +         +         +         +         +         +         +         +         +

        0.      +++++++++++++++++++++++++++++++++++++++++++++1+++++++++++++++++++++++++++++++++++++++++++++++++++++++     -.1040E+00
     .0800      +                                          1      +                                                 +     -.1365E+00
     .1600      +                                                 +        1                                        +      .1784E+00
     .2400      +                                                 +             1                                   +      .2808E+00
     .3200      +                                  1              +                                                 +     -.2960E+00
     .4000      +                                                 +    1                                            +      .1016E+00
     .4800      +                                                 +             1                                   +      .2808E+00
     .5600      +                          1                      +                                                 +     -.4519E+00
     .6400      +                            1                    +                                                 +     -.4264E+00
     .7200      +                                                 +           1                                     +      .2413E+00
     .8000      +                                       1         +                                                 +     -.1936E+00
     .8800      +                                                 +              1                                  +      .3074E+00
     .9600      +                                           1     +                                                 +     -.1269E+00
    1.0400      +                                                 +           1                                     +      .2401E+00
    1.1200      +                                                 +               1                                 +      .3223E+00
    1.2000      +                                  1              +                                                 +     -.3013E+00
    1.2800      +                                                 +                       1                         +      .4740E+00
    1.3600      +          1                                      +                                                 +     -.7860E+00
    1.4400      +                                                 +                                      1          +      .7762E+00
    1.5200      +                           1                     +                                                 +     -.4460E+00
    1.6000      +                                   1             +                                                 +     -.2842E+00
    1.6800      +                                                 +       1                                         +      .1509E+00
    1.7600      +                                                 +    1                                            +      .1024E+00
    1.8400      +                                                 + 1                                               +      .3450E-01
    1.9200      +                                         1       +                                                 +     -.1563E+00
    2.0000      +                                                 +            1                                    +      .2590E+00
    2.0800      +                                               1 +                                                 +     -.4307E-01
    2.1600      +                                          1      +                                                 +     -.1363E+00
    2.2400      +                                                 1                                                 +     -.7465E-02
    2.3200      +                                                 +  1                                              +      .6812E-01
    2.4000      +                                                 +1                                                +      .1926E-01
    2.4800      +                                                 1                                                 +     -.6383E-02
    2.5600      +                                            1    +                                                 +     -.1057E+00
    2.6400      +                                                 +    1                                            +      .9371E-01
    2.7200      +                                                 1                                                 +      .6485E-02
    2.8000      +                                                 +1                                                +      .1169E-01
    2.8800      +                                            1    +                                                 +     -.9451E-01
    2.9600      +                                                 +  1                                              +      .5249E-01
    3.0400      +                                                 + 1                                               +      .4016E-01
    3.1200      +                                                 1                                                 +     -.5846E-02
    3.2000      +                                              1  +                                                 +     -.6776E-01
    3.2800      +                                                 +1                                                +      .1388E-01
    3.3600      +                                                 +  1                                              +      .6342E-01
    3.4400      +                                                1+                                                 +     -.1019E-01
    3.5200      +                                              1  +                                                 +     -.5774E-01
    3.6000      +                                                 1                                                 +     -.6186E-02
    3.6800      +                                                 +  1                                              +      .6954E-01
    3.7600      +                                                 1                                                 +      .5345E-03
    3.8400      +                                              1  +                                                 +     -.6058E-01
    3.9200      +                                                1+                                                 +     -.1682E-01
    4.0000      +                                                 +  1                                              +      .6881E-01
    4.0800      +                                                 +1                                                +      .1724E-01
    4.1600      +                                              1  +                                                 +     -.6685E-01
    4.2400      +                                                1+                                                 +     -.2831E-01
    4.3200      +                                                 +  1                                              +      .6935E-01
    4.4000      +                                                 + 1                                               +      .3570E-01
    4.4800      +                                             1   +                                                 +     -.7304E-01
    4.5600      +                                               1 +                                                 +     -.4599E-01
    4.6400      +                                                 +   1                                             +      .7429E-01
    4.7200      +                                                 +  1                                              +      .5873E-01
    4.8000      +                                             1   +                                                 +     -.8157E-01
    4.8800      +                                             1   +                                                 +     -.7507E-01
    4.9600      +                                                 +   1                                             +      .8734E-01
    5.0400      +++++++++++++++++++++++++++++++++++++++++++++++++++++++1+++++++++++++++++++++++++++++++++++++++++++++     .9814E-01
                +         +         +         +         +         +         +         +         +         +         +
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      ***
     *****
       *
       ******   TIME IN SECONDS
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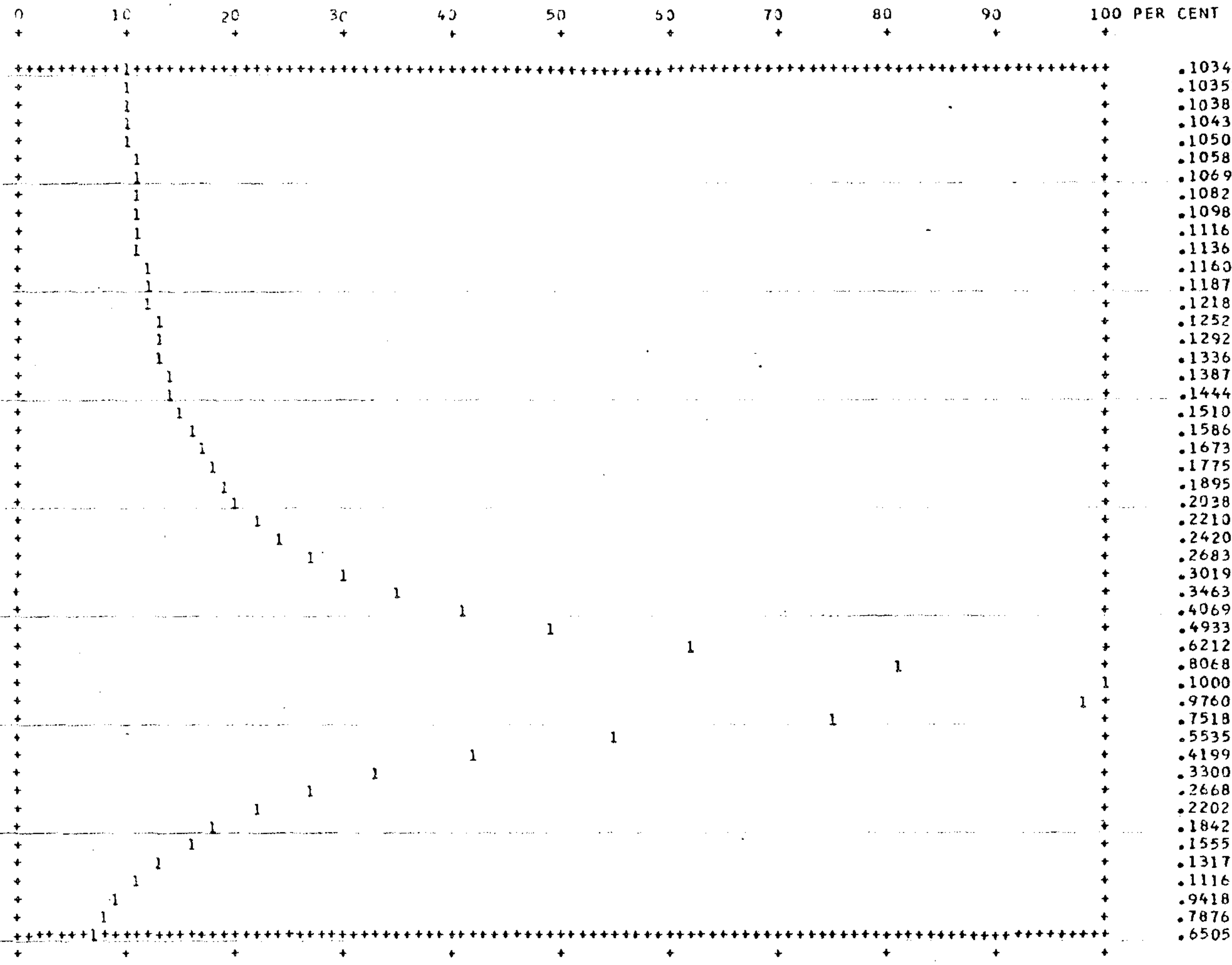
```
***  PLOT OF ACCELERATION AMPLIFICATION FUNCT.

X-ACC. AMPLIFICATION AT NODAL POINT          3,  100 PER CENT CORRESPONDS TO        9.6676
```



```
    0.       .1034E+00
    .1953    .1035E+00
    .3906    .1038E+00
    .5859    .1043E+00
    .7813    .1050E+00
    .9766    .1058E+00
   1.1719    .1069E+00
   1.3672    .1082E+00
   1.5625    .1098E+00
   1.7578    .1116E+00
   1.9531    .1136E+00
   2.1484    .1160E+00
   2.3438    .1187E+00
   2.5391    .1218E+00
   2.7344    .1252E+00
   2.9297    .1292E+00
   3.1250    .1336E+00
   3.3203    .1387E+00
   3.5156    .1444E+00
   3.7109    .1510E+00
   3.9062    .1586E+00
   4.1016    .1673E+00
   4.2969    .1775E+00
   4.4922    .1895E+00
   4.6875    .2038E+00
   4.8828    .2210E+00
   5.0781    .2420E+00
   5.2734    .2683E+00
   5.4687    .3019E+00
   5.6641    .3463E+00
   5.8594    .4069E+00
   6.0547    .4933E+00
   6.2500    .6212E+00
   6.4453    .8068E+00
   6.6406    .1000E+01
   6.8359    .9760E+00
   7.0312    .7518E+00
   7.2266    .5535E+00
   7.4219    .4199E+00
   7.6172    .3300E+00
   7.8125    .2668E+00
   8.0078    .2202E+00
   8.2031    .1842E+00
   8.3984    .1555E+00
   8.5937    .1317E+00
   8.7891    .1116E+00
   8.9844    .9418E-01
   9.1797    .7876E-01
   9.3750    .6505E-01

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   *****
     *
    ******   FREQ. IN HZ
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```
***  PLOT OF ACCELERATION. (BASE ACC.+REL. ACC.)

X-COMP. OF ACCELERATION AT NODAL POINT        3, 100 PER CENT CORRESPONDS TO          .1163   G

EVERY   2 TH POINTS ARE PLOTTED

           -100       -80       -60       -40       -20        0        20        40        60        80        100 PER CENT
             +         +         +         +         +         +         +         +         +         +         +

        0.   ++++++++++++++++++++++++++++++++++++++++++++++++++1++++++++++++++++++++++++++++++++++++++++++++++++++      .4084E-02
     .0800   +                                              1  +                                                 +     -.5702E-01
     .1600   +                                                 +  1                                              +      .5568E-01
     .2400   +                                                 +          1                                      +      .2274E+00
     .3200   +                                                1+                                                 +     -.2029E-01
     .4000   +                                                 +       1                                         +      .1681E+00
     .4800   +                                                1+                                                 +     -.2211E-01
     .5600   +                       1                         +                                                 +     -.5226E+00
     .6400   +                               1                 +                                                 +     -.3546E+00
     .7200   +                                                 +   1                                             +      .7002E-01
     .8000   +                                     1           +                                                 +     -.2434E+00
     .8800   +                                                 +             1                                   +      .2896E+00
     .9600   +                                                 +           1                                     +      .2457E+00
    1.0400   +                                                 +      1                                          +      .1368E+00
    1.1200   +                                                 +                1                                +      .3490E+00
    1.2000   +                                       1         +                                                 +     -.2065E+00
    1.2800   +                                                 +                     1                           +      .4477E+00
    1.3600   +                   1                             +                                                 +     -.6007E+00
    1.4400   +                                                 +                  1                              +      .3838E+00
    1.5200   +                                1                +                                                 +     -.3342E+00
    1.6000   +                                       1         +                                                 +     -.2023E+00
    1.6800   +                                                 +1                                                +      .2746E-01
    1.7600   +                                               1 +                                                 +     -.3284E-01
    1.8400   +                                                 +         1                                       +      .2009E+00
    1.9200   +                                                 +1                                                +      .2111E-01
    2.0000   +                                                 +   1                                             +      .8817E-01
    2.0800   +                                            1    +                                                 +     -.9908E-01
    2.1600   +                                               1 +                                                 +     -.4010E-01
    2.2400   +                                                 1                                                 +      .9248E-02
    2.3200   +                                                 1                                                 +      .9234E-02
    2.4000   +                                                1+                                                 +     -.1160E-01
    2.4800   +                                                 + 1                                               +      .3555E-01
    2.5600   +                                              1  +                                                 +     -.5907E-01
    2.6400   +                                                 + 1                                               +      .4638E-01
    2.7200   +                                                1+                                                 +     -.2929E-01
    2.8000   +                                                 + 1                                               +      .3883E-01
    2.8800   +                                               1 +                                                 +     -.4438E-01
    2.9600   +                                                 +1                                                +      .2095E-01
    3.0400   +                                                 1                                                 +     -.4056E-02
    3.1200   +                                                 +1                                                +      .1485E-01
    3.2000   +                                                1+                                                 +     -.1847E-01
    3.2800   +                                                 1                                                 +     -.4065E-02
    3.3600   +                                                 +1                                                +      .1314E-01
    3.4400   +                                                 1                                                 +      .3149E-02
    3.5200   +                                                 1                                                 +     -.7203E-02
    3.6000   +                                                1+                                                 +     -.1366E-01
    3.6800   +                                                 +1                                                +      .1556E-01
    3.7600   +                                                 1                                                 +      .4539E-02
    3.8400   +                                                 1                                                 +     -.6683E-02
    3.9200   +                                                1+                                                 +     -.1492E-01
    4.0000   +                                                 +1                                                +      .1152E-01
    4.0800   +                                                 +1                                                +      .1048E-01
    4.1600   +                                                 1                                                 +     -.8286E-02
    4.2400   +                                                1+                                                 +     -.1589E-01
    4.3200   +                                                 1                                                 +      .7319E-02
    4.4000   +                                                 +1                                                +      .1637E-01
    4.4800   +                                                 1                                                 +     -.7981E-02
    4.5600   +                                                1+                                                 +     -.1989E-01
    4.6400   +                                                 1                                                 +      .4081E-02
    4.7200   +                                                 +1                                                +      .2283E-01
    4.8000   +                                                 1                                                 +     -.5140E-02
    4.8800   +                                                1+                                                 +     -.2870E-01
    4.9600   +                                                 1                                                 +     -.2364E-03
    5.0400   ++++++++++++++++++++++++++++++++++++++++++++++++++++1++++++++++++++++++++++++++++++++++++++++++++++++      .3565E-01
             +         +         +         +         +         +         +         +         +         +         +
     *
    ***
   *****
     *
     ******   TIME IN SECONDS
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```
***  PLOT OF ACCELERATION AMPLIFICATION FUNCT.

X-ACC. AMPLIFICATION AT NODAL POINT        19,  100 PER CENT CORRESPONDS TO       12.5318

            0         10        20        30        40        50        60        70        80        90        100 PER CENT
            +         +         +         +         +         +         +         +         +         +         +

        0.  ++++++++1++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++      .7980E-01
     .1953  +       1                                                                                           +      .7988E-01
     .3906  +       1                                                                                           +      .8014E-01
     .5859  +       1                                                                                           +      .8057E-01
     .7812  +       1                                                                                           +      .8117E-01
     .9766  +       1                                                                                           +      .8196E-01
    1.1719  +       1                                                                                           +      .8295E-01
    1.3672  +       1                                                                                           +      .8413E-01
    1.5625  +        1                                                                                          +      .8554E-01
    1.7578  +        1                                                                                          +      .8717E-01
    1.9531  +        1                                                                                          +      .8907E-01
    2.1484  +        1                                                                                          +      .9124E-01
    2.3438  +        1                                                                                          +      .9372E-01
    2.5391  +         1                                                                                         +      .9654E-01
    2.7344  +         1                                                                                         +      .9975E-01
    2.9297  +         1                                                                                         +      .1034E+00
    3.1250  +          1                                                                                        +      .1075E+00
    3.3203  +          1                                                                                        +      .1123E+00
    3.5156  +           1                                                                                       +      .1177E+00
    3.7109  +           1                                                                                       +      .1239E+00
    3.9062  +            1                                                                                      +      .1311E+00
    4.1016  +             1                                                                                     +      .1394E+00
    4.2969  +              1                                                                                    +      .1492E+00
    4.4922  +               1                                                                                   +      .1607E+00
    4.6875  +                1                                                                                  +      .1746E+00
    4.8828  +                  1                                                                                +      .1913E+00
    5.0781  +                    1                                                                              +      .2119E+00
    5.2734  +                       1                                                                           +      .2379E+00
    5.4687  +                          1                                                                        +      .2713E+00
    5.6641  +                               1                                                                   +      .3157E+00
    5.8594  +                                     1                                                             +      .3768E+00
    6.0547  +                                             1                                                     +      .4646E+00
    6.2500  +                                                           1                                       +      .5958E+00
    6.4453  +                                                                              1                    +      .7894E+00
    6.6406  +                                                                                                   1      .1000E+01
    6.8359  +                                                                                                   1      .9996E+00
    7.0312  +                                                                              1                    +      .7905E+00
    7.2266  +                                                           1                                       +      .5991E+00
    7.4219  +                                              1                                                    +      .4693E+00
    7.6172  +                                     1                                                             +      .3823E+00
    7.8125  +                               1                                                                   +      .3217E+00
    8.0078  +                           1                                                                       +      .2777E+00
    8.2031  +                       1                                                                           +      .2445E+00
    8.3984  +                     1                                                                             +      .2188E+00
    8.5937  +                   1                                                                               +      .1984E+00
    8.7891  +                 1                                                                                 +      .1818E+00
    8.9844  +                1                                                                                  +      .1681E+00
    9.1797  +               1                                                                                   +      .1568E+00
    9.3750  +++++++++++++++1+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++      .1472E+00
            +         +         +         +         +         +         +         +         +         +         +
       *
      ***
     *****
       *
       ******   FREQ. IN HZ
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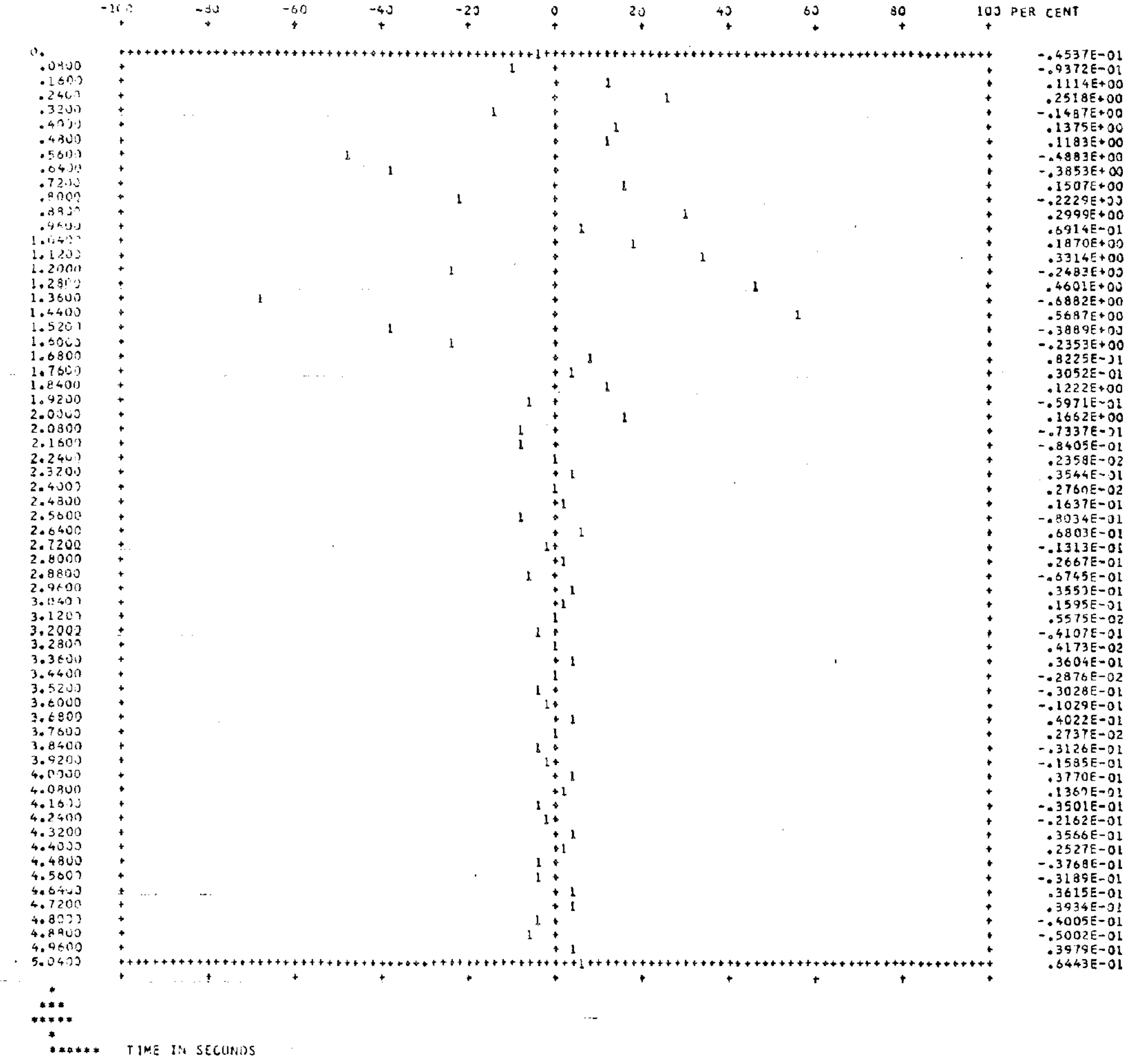
```
***  PLOT OF ACCELERATION. (BASE ACC.+REL. ACC.)

X-COMP. OF ACCELERATION AT NODAL POINT      19,  100 PER CENT CORRESPONDS TO         .1422   G

EVERY   2 TH POINTS ARE PLOTTED
```



```
  0.        -.4537E-01
   .0800    -.9372E-01
   .1600     .1114E+00
   .2400     .2518E+00
   .3200    -.1487E+00
   .4000     .1375E+00
   .4800     .1183E+00
   .5600    -.4883E+00
   .6400    -.3853E+00
   .7200     .1507E+00
   .8000    -.2229E+00
   .8800     .2999E+00
   .9600     .6914E-01
  1.0400     .1870E+00
  1.1200     .3314E+00
  1.2000    -.2483E+00
  1.2800     .4601E+00
  1.3600    -.6882E+00
  1.4400     .5687E+00
  1.5200    -.3889E+00
  1.6000    -.2353E+00
  1.6800     .8225E-01
  1.7600     .3052E-01
  1.8400     .1222E+00
  1.9200    -.5971E-01
  2.0000     .1662E+00
  2.0800    -.7337E-01
  2.1600    -.8405E-01
  2.2400     .2358E-02
  2.3200     .3544E-01
  2.4000     .2760E-02
  2.4800     .1637E-01
  2.5600    -.8034E-01
  2.6400     .6803E-01
  2.7200    -.1313E-01
  2.8000     .2667E-01
  2.8800    -.6745E-01
  2.9600     .3550E-01
  3.0400     .1595E-01
  3.1200     .5575E-02
  3.2000    -.4107E-01
  3.2800     .4173E-02
  3.3600     .3604E-01
  3.4400    -.2876E-02
  3.5200    -.3028E-01
  3.6000    -.1029E-01
  3.6800     .4022E-01
  3.7600     .2737E-02
  3.8400    -.3126E-01
  3.9200    -.1585E-01
  4.0000     .3770E-01
  4.0800     .1360E-01
  4.1600    -.3501E-01
  4.2400    -.2162E-01
  4.3200     .3566E-01
  4.4000     .2527E-01
  4.4800    -.3768E-01
  4.5600    -.3189E-01
  4.6400     .3615E-01
  4.7200     .3934E-01
  4.8000    -.4005E-01
  4.8800    -.5002E-01
  4.9600     .3979E-01
  5.0400     .6443E-01
```

```
    MAXIMUM ABSOLUTE ACCELERATIONS(G)

    ITERATION NO.  2         MAX. INPUT BASE ACC.  =   .0585 (G) IN X DIRECTION
                             MAX. INPUT BASE ACC.  =  0.     (G) IN Y DIRECTION
                             MAX. INPUT BASE ACC.  =  0.     (G) IN Z DIRECTION

         N.P.    XORD     YORD     ZORD      X-ACC     AT TIME      Y-ACC     AT TIME      Z-ACC     AT TIME

           1    46.00    30.00    40.00      .1875     1.0000      0.          .9600      0.          .9600
           3    46.00    30.00    20.00      .1163     1.0000      0.          .9600        .0492    1.0800
          19    24.00    20.00    40.00      .1422     1.0000        .0132    1.4400      0.          .9600

   TIME REQUIRED FOR COMPUTATION AND OUTPUT OF ACCELERATIONS AT      5   DEG. OF FOM. =     .161    SEC
```

```
**********0
* MODE2  *
**********


*** BLANK COMMON REQUIREMENTS ***

          LENGTH OF BLANK COMMON =      15000

  BLANK COMMON REQUIRED FOR VEDCA =      1481

 BLANK COMMON FOR PERMANENT DATA =       922

BLANK COMMON REQUIRED FOR STRAIN =      1740

           BLANK COMMON FOR BBBC =      6630

    MAX. WORDS REQUIRED FOR BBBC =        96

BLANK COMMON REQUIRED FOR MOTION =       904

           BLANK COMMON FOR AAAC =      7048

    MAX. WORDS REQUIRED FOR AAAC =        16


*** CONTENT OF TAPE 1 TRANSFERED TO TAPE 2 ***
```

```
EXAMPLE PROBLEM FOR TLUSH                                                   RUN NUMBER =  1

*** INPUT DATA ***
         TOTAL NUMBER OF ELEMENTS =    25
     TOTAL NUMBER OF NODAL POINTS =    44
   1ST NODAL POINT ON RIGID BASE =    26
               DEGREES OF FREEDOM =    75
   NUMBER OF BOUNDARY CONDITIONS =    18
             NUMBER OF ITERATIONS =     1
         NUMBER OF MATERIAL TYPES =     2


*** INPUT MOTION ***
 TOTAL NO. OF POINTS USED IN FFT =   128
              LAST POINT TO BE READ =    64
                TIME STEP OF RECORD =    .040 SEC.
                 DURATION OF RECORD =   2.560 SEC.
               QUIET ZONE OF RECORD =   2.560 SEC.
        TOTAL DURATION OF ANALYSIS =   5.120 SEC.
         EQ. MULTIPLICATION FACTOR =  2.0000
          MAX. ACCEL. AFTER SCALING =   .0728 (G)
              MOTION IN X-DIRECTION =  1.0000 TIMES INPUT MOTION
              MOTION IN Y-DIRECTION =  0.     TIMES INPUT MOTION
              MOTION IN Z-DIRECTION =  0.     TIMES INPUT MOTION

 BASE LINE CORRECTION WILL BE APPLIED


*** FREQUENCY CONTENT OF ANALYSIS ***
    HIGHEST FREQUENCY OF ANALYSIS =  12.000  HZ
      NO. OF INTERPOLATION RANGES =   3

     0.     --    5.000 HZ(KINT=  5)
     5.000 --  10.000 HZ(KINT=  3)
    10.000 --  12.000 HZ(KINT=  5)
   FREQUENCY USED FOR ITERATION 1 =  12.000  HZ


*** OUTPUT CONTROL ***
     SAVING AMP. FUNCTION ON TAPE =  YES
    COMPUTING NEW SOIL PROPERTIES =  YES
    PUNCHING NEW SOIL PROPERTIES =  NO
       STEPS TO FIND MAX. RESPONSE =   128
          SKIP POINTS FOR PLOTTING =     2
     FACTOR FOR EFF. SHEAR STRAIN =   .6500


*** MASS MATRIX ***
       FRACTION OF CONSISTENT MASS =   .5000
           FRACTION OF LUMPED MASS =   .5000


*** DAMPING CHARACTERISTICS ***
              UNIFORM DAMPING USED =  NO


*** OUTPUT REQUIREMENTS ***
                 CODES FOR KEYSPC
                0--MAXIMUM ACCELERATION ONLY
                1--PLOT ACC. TIME HISTORY
               10--PLOT ACC. AND VELOCITY RESPONSE SPECTRUM
              100--PUNCH ACC. TIME HISTORY
             1000--PLOT FOURIER AMP. OF ACCELERATION
            10000--PLOT AMPLIFICATION FUNCTION


      VALUES OF KEYSPC

      N.P.NO.   X-OUTPUT   Y-OUTPUT   Z-OUTPUT
         1       11001         0          0
         3       11001         0          0
        19       11001         0          0
```

```
*** SHEAR MODULUS AND DAMPING CURVES FOR MATERIALS WITH STRAIN-DEPENDENT PROPERTIES ***

STANDARD BUILT IN CURVES ARE USED

MAT. TYPE --       IDENTIFICATION

      1      SEED AND IDRISS (1970) -- CLAY
      2      SEED AND IDRISS (1970) -- SAND


  SHEAR MODULUS CURVES

                                                   SHEAR STRAIN IN PERCENT
MAT. ---------------------------------------------------------------------------------------------------------------------------
TYPE  10**(-4.0) 10**(-3.5) 10**(-3.0) 10**(-2.5) 10**(-2.0) 10**(-1.5) 10**(-1.0) 10**(-0.5) 10**( 0.0) 10**( 0.5) 10**( 1.0)
-------------------------------------------------------------------------------------------------------------------------------
  1     .10E+01    .91E+00    .76E+00    .57E+00    .40E+00    .26E+00    .15E+00    .76E-01    .37E-01    .13E-01    .40E-02
  2     .10E+01    .98E+00    .93E+00    .83E+00    .66E+00    .44E+00    .25E+00    .12E+00    .49E-01    .49E-01    .49E-01
-------------------------------------------------------------------------------------------------------------------------------


  DAMPING CURVES  (PERCENT)

                                                   SHEAR STRAIN IN PERCENT
MAT. ---------------------------------------------------------------------------------------------------------------------------
TYPE  10**(-4.0) 10**(-3.5) 10**(-3.0) 10**(-2.5) 10**(-2.0) 10**(-1.5) 10**(-1.0) 10**(-0.5) 10**( 0.0) 10**( 0.5) 10**( 1.0)
-------------------------------------------------------------------------------------------------------------------------------
  1     .25E+01    .25E+01    .25E+01    .35E+01    .48E+01    .65E+01    .93E+01    .14E+02    .20E+02    .26E+02    .29E+02
  2     .50E+00    .80E+00    .17E+01    .32E+01    .56E+01    .10E+02    .16E+02    .21E+02    .25E+02    .25E+02    .25E+02
-------------------------------------------------------------------------------------------------------------------------------


*** ELEMENT DATA ***

 NO.   NP1   NP2   NP3   NP4   NP5   NP6   NP7   NP8  MTYPE   ID.EL     PO    UNIT WT.    G-MAX      G-USE   DMP-USE     VS-USE
                                                                              (PCF)       (KSF)      (KSF) (FRACTION)    (FPS)

   1    10    14     5     1    11    15     6     2     1       1    .450   110.000   1500.000    670.887      .044   443.156
   2    11    15     6     2    12    16     7     3     1       1    .450   110.000   1500.000    716.409      .042   457.944
   3    12    16     7     2    13    41    42     4     1       1    .450   110.000   1500.000    692.458      .043   450.224
   4    13    41    42     4    43    43    44    44     1       2    .450   110.000   1500.000    799.629      .037   483.872
   5    14    17     8     5    15    18     9     6     1       1    .450   110.000   1500.000    577.255      .049   411.063
   6    15    19     9     6    16    38    39     7     1       1    .450   110.000   1500.000    570.316      .050   408.591
   7    16    38    39     7    41    41    42    42     1       2    .450   110.000   1500.000    584.308      .049   413.573
   8    17    29    30     8    18    34    35     9     1       1    .450   110.000   1500.000    610.362      .047   422.693
   9    18    34    35     9    38    38    39    39     1       2    .450   110.000   1500.000    590.178      .048   415.646
  10    19    19    14    10    20    20    15    11     2       3    .350   120.000   1500.000   1125.169      .043   549.473
  11    20    20    15    11    21    21    16    12     2       3    .350   120.000   1500.000   1055.349      .049   532.164
  12    21    21    16    12    40    40    41    13     2       3    .350   120.000   1500.000   1050.056      .050   530.818
  13    40    40    41    13    43    43    43    43     2       4    .350   120.000   1500.000   1161.362      .039   558.240
  14    19    22    17    14    20    23    18    15     2       5    .350   120.000   1500.000   1020.782      .053   523.364
  15    20    23    18    15    21    37    38    16     2       5    .350   120.000   1500.000    996.117      .055   517.002
  16    21    37    38    16    40    40    41    41     2       6    .350   120.000   1500.000   1007.374      .054   519.915
  17    22    28    29    17    23    33    34    18     2       5    .350   120.000   1500.000   1043.016      .050   529.033
  18    23    33    34    18    37    37    38    38     2       6    .350   120.000   1500.000   1008.343      .054   520.165
  19    24    24    22    19    25    25    23    20     2       3    .350   120.000   1500.000   1001.486      .054   518.394
  20    25    25    23    20    36    36    37    21     2       3    .350   120.000   1500.000   1000.438      .054   518.123
  21    36    36    37    21    40    40    40    40     2       4    .350   120.000   1500.000   1002.356      .054   518.619
  22    24    27    28    22    25    32    33    23     2       5    .350   120.000   1500.000   1096.019      .045   542.308
  23    25    32    33    23    36    36    37    37     2       6    .350   120.000   1500.000   1062.967      .049   534.069
  24    26    26    27    24    31    31    32    25     2       3    .350   120.000   1500.000   1122.382      .043   548.792
  25    31    31    32    25    36    36    36    36     2       4    .350   120.000   1500.000   1095.696      .045   542.229
```

```
*** NODAL POINT DATA ***

                                                                                    BOUNDARY  CONDITIONS
 N.P.      XORD(FT)        YORD(FT)        ZORD(FT)        MASS (KIPS)      X-DIRECTION   Y-DIRECTION   Z-DIRECTION

  1          46.000          30.000          40.000          -0.                              FIXED         FIXED
  2          46.000          30.000          30.000          -0.                              FIXED
  3          46.000          30.000          20.000           0.                              FIXED
  4          46.000          30.000          10.000          -0.                              FIXED
  5          46.000          20.000          40.000          -0.                              FIXED         FIXED
  6          46.000          20.000          30.000          -0.                              FIXED
  7          46.000          20.000          20.000          -0.                              FIXED
  8          46.000          10.000          40.000          -0.                              FIXED         FIXED
  9          46.000          10.000          30.000          -0.                              FIXED
 10          36.000          30.000          40.000          -0.                                            FIXED
 11          36.000          30.000          30.000           0.
 12          36.000          30.000          20.000           0.
 13          36.000          30.000          10.000          -0.
 14          36.000          20.000          40.000          -0.                                            FIXED
 15          36.000          20.000          30.000           0.
 16          36.000          20.000          20.000          -0.
 17          36.000          10.000          40.000          -0.                                            FIXED
 18          36.000          10.000          30.000          -0.
 19          24.000          20.000          40.000          -0.                                            FIXED
 20          24.000          20.000          30.000           0.
 21          24.000          20.000          20.000          -0.
 22          24.000          10.000          40.000          -0.                                            FIXED
 23          24.000          10.000          30.000          -0.
 24          12.000          10.000          40.000          -0.                                            FIXED
 25          12.000          10.000          30.000          -0.
 26           0.              0.             40.000          -0.              FIXED         FIXED         FIXED
 27          12.000           0.             40.000           0.              FIXED         FIXED         FIXED
 28          24.000           0.             40.000           0.              FIXED         FIXED         FIXED
 29          36.000           0.             40.000          -0.              FIXED         FIXED         FIXED
 30          46.000           0.             40.000          -0.              FIXED         FIXED         FIXED
 31           0.              0.             30.000          -0.              FIXED         FIXED         FIXED
 32          12.000           0.             30.000           0.              FIXED         FIXED         FIXED
 33          24.000           0.             30.000           0.              FIXED         FIXED         FIXED
 34          36.000           0.             30.000          -0.              FIXED         FIXED         FIXED
 35          46.000           0.             30.000          -0.              FIXED         FIXED         FIXED
 36          12.000          10.000          20.000          -0.              FIXED         FIXED         FIXED
 37          24.000          10.000          20.000           0.              FIXED         FIXED         FIXED
 38          36.000          10.000          20.000          -0.              FIXED         FIXED         FIXED
 39          46.000          10.000          20.000          -0.              FIXED         FIXED         FIXED
 40          24.000          20.000          10.000          -0.              FIXED         FIXED         FIXED
 41          36.000          20.000          10.000          -0.              FIXED         FIXED         FIXED
 42          46.000          20.000          10.000          -0.              FIXED         FIXED         FIXED
 43          36.000          30.000           0.             -0.              FIXED         FIXED         FIXED
 44          46.000          30.000           0.             -0.              FIXED         FIXED         FIXED


*** EARTHQUAKE RECORD ***

** EXAMPLE  EARTHQUAKE **     0.04 SEC     64 POINTS

  INPUT ACCEL. PRIOR TO SCALING

  MAX. ACC. =     .0500 (G)  AT TIME =     .9600 SEC.

        .000204 -.000191  .000058  .001460  .004111  .004390  .009534 -.003481        1
        .013073  .009455  .000374  .018791 -.022305 -.018976 -.011557 -.048139        2
        .013707 -.029759  .011100 -.025240  .015560 -.013417  .023272 -.013397        3
        .050000  .000068  .012727  .006808  .010066  .010332  .006599 -.001122        4
        .008954 -.020449  .015687 -.005003 -.017561  .003863 -.010918 -.008041        5
       -.008450 -.010743  .001941 -.000952  .000968 -.001998  .010888  .008075        6
        .009841  .003844 -.005115  .001176 -.003725 -.006514  .001117 -.000450        7
        .000281 -.000221  .000197 -.000188  .000185 -.000188  .000193 -.000200        8
       0.       0.       0.       0.       0.       0.       0.       0.               9
       0.       0.       0.       0.       0.       0.       0.       0.              10
       0.       0.       0.       0.       0.       0.       0.       0.              11
       0.       0.       0.       0.       0.       0.       0.       0.              12
       0.       0.       0.       0.       0.       0.       0.       0.              13
       0.       0.       0.       0.       0.       0.       0.       0.              14
       0.       0.       0.       0.       0.       0.       0.       0.              15
       0.       0.       0.       0.       0.       0.       0.       0.              16


TIME REQUIRED FOR INPUT AND INITIALIZATION =      .136   SEC
```

```
*** MATRICES AND LOAD VECTOR ARE FORMED IN THIS RUN ***

   ITERATION      1
CORE SIZE AVAILABLE FOR EQUATION SOLUTION  =    14949
TOTAL NUMBER OF EQUATIONS                  =       75
MAXIMUM NUMBER OF TERMS IN A BLOCK         =     3699
MAXIMUM NUMBER OF COLUMNS IN A BLOCK       =       75
NUMBER OF BLOCKS                           =        1
BANDWIDTH                                  =       45
NUMBER OF TERMS IN STIFFNESS MATRIX        =     1701


   TIME REQUIRED FOR FORMATION OF STIFFNESS MATRIX  =      .302  SEC.

    *** TIME FOR GAUSSIAN ELIMINATION ***

    FRQ NUMBER =     1  FRQ =      0.      HZ     CUMULATIVE   TIME    =      .0547  SEC.
    FRQ NUMBER =     2  FRQ =       .9766  HZ     CUMULATIVE   TIME    =      .1084  SEC.
    FRQ NUMBER =     3  FRQ =     1.9531   HZ     CUMULATIVE   TIME    =      .1622  SEC.
    FRQ NUMBER =     4  FRQ =     2.9297   HZ     CUMULATIVE   TIME    =      .2160  SEC.
    FRQ NUMBER =     5  FRQ =     3.9063   HZ     CUMULATIVE   TIME    =      .2698  SEC.
    FRQ NUMBER =     6  FRQ =     4.8828   HZ     CUMULATIVE   TIME    =      .3236  SEC.
    FRQ NUMBER =     7  FRQ =     5.4688   HZ     CUMULATIVE   TIME    =      .3774  SEC.
    FRQ NUMBER =     8  FRQ =     6.0547   HZ     CUMULATIVE   TIME    =      .4311  SEC.
    FRQ NUMBER =     9  FRQ =     6.6406   HZ     CUMULATIVE   TIME    =      .4849  SEC.
    FRQ NUMBER =    10  FRQ =     7.2266   HZ     CUMULATIVE   TIME    =      .5387  SEC.
    FRQ NUMBER =    11  FRQ =     7.8125   HZ     CUMULATIVE   TIME    =      .5925  SEC.
    FRQ NUMBER =    12  FRQ =     8.3984   HZ     CUMULATIVE   TIME    =      .6462  SEC.
    FRQ NUMBER =    13  FRQ =     8.9844   HZ     CUMULATIVE   TIME    =      .6995  SEC.
    FRQ NUMBER =    14  FRQ =     9.5703   HZ     CUMULATIVE   TIME    =      .7533  SEC.
    FRQ NUMBER =    15  FRQ =    10.5469   HZ     CUMULATIVE   TIME    =      .8071  SEC.
    FRQ NUMBER =    16  FRQ =    11.5234   HZ     CUMULATIVE   TIME    =      .8609  SEC.

    NO. OF FREQ. STEPS  .    60 (INCLUDING INTERPOLATED POINTS)


  ELM     G-USED      G-NEW    DIF-G       DAMP-USED     DAMP-NEW   DIF-DAMP     VS-USED      VS-NEW     DIFF-VS
           (KSF)      (KSF)   (PERCENT)   (FRACTION)   (FRACTION)  (PERCENT)      (FPS)       (FPS)    (PERCENT)

   1       671.       635.     5.7          .044          .046       -4.0          443.        431.         2.8
   2       716.       718.     -.2          .042          .042         .2          458.        458.         -.1
   3       692.       677.     2.3          .043          .044       -1.8          450.        445.         1.1
   4       800.       775.     3.3          .037          .039       -3.3          484.        476.         1.6
   5       577.       574.      .5          .049          .050        -.5          411.        410.          .3
   6       570.       560.     1.9          .050          .051       -1.8          409.        405.         1.0
   7       584.       561.     4.1          .049          .051       -3.8          414.        405.         2.0
   8       610.       584.     4.6          .047          .049       -3.9          423.        413.         2.3
   9       590.       565.     4.4          .048          .050       -4.2          416.        407.         2.2
  10      1125.      1097.     2.6          .043          .045       -5.9          549.        542.         1.3
  11      1055.      1064.     -.9          .049          .048        1.8          532.        534.         -.4
  12      1050.      1031.     1.8          .050          .052       -3.4          531.        526.          .9
  13      1161.      1136.     2.2          .039          .042       -5.7          558.        552.         1.1
  14      1021.      1032.    -1.0          .053          .052        2.0          523.        526.         -.5
  15       996.       986.     1.0          .055          .056       -1.7          517.        514.          .5
  16      1007.       982.     2.6          .054          .056       -4.3          520.        513.         1.3
  17      1043.      1017.     2.5          .050          .053       -4.6          529.        522.         1.3
  18      1008.       983.     2.6          .054          .056       -4.4          520.        513.         1.3
  19      1001.      1007.     -.6          .054          .054        1.0          518.        520.         -.3
  20      1000.       994.      .7          .054          .055       -1.2          516.        516.          .3
  21      1002.       982.     2.1          .054          .056       -3.7          519.        513.         1.1
  22      1096.      1081.     1.4          .045          .047       -3.1          542.        539.          .7
  23      1063.      1045.     1.7          .049          .050       -3.4          534.        529.          .9
  24      1122.      1104.     1.6          .043          .045       -3.8          549.        544.          .8
  25      1096.      1078.     1.6          .045          .047       -3.5          542.        538.          .8
```

```
MAX. ELEMENT STRESSES IN PSF AND MAXIMUM SHEAR STRAIN IN PERCENT

   ELM.    SIG-X     SIG-Y     SIG-Z        TAU-XY        TAU-YZ        TAU-ZX      MAX.SHEAR STRN      AT TIME

     1      24.0      51.8      82.9          70.0           5.4          48.3          .01309          1.080
     2      15.5       6.3      10.8          53.9          20.3          38.2          .00889          1.000
     3     190.0     177.4     191.7          37.2           3.9          64.3          .01076          1.000
     4      27.7      34.6      37.8          43.5           5.1          34.4          .00683          1.160
     5      53.4      35.9      61.3          99.2           6.6          24.3          .01773          1.080
     6      17.4       6.6       6.4          84.9          15.3          67.5          .01924          1.000
     7      77.2      85.4     104.0          79.9          12.0          75.5          .01906          1.000
     8       8.1       9.5       7.5         101.3           2.8          14.8          .01684          1.000
     9      42.4      54.4      53.1          79.2           7.2          75.9          .01865          1.000
    10      96.9      34.5      31.5          57.0          17.0          61.7          .00926          1.080
    11      85.2      42.3      51.9          55.5          31.3          97.3          .01070          1.080
    12      72.4      36.1      89.5          67.9          24.1         109.8          .01242          1.000
    13      52.9      44.7     106.3          57.5          22.6          57.5          .00774          1.000
    14      78.2      31.6      11.3         115.6           8.7          41.2          .01241          1.000
    15      61.6      29.9      34.6         111.0          16.8         102.2          .01523          1.000
    16      62.9      53.1      87.7         112.9          17.7         105.3          .01548          1.000
    17      36.2      19.4      11.9         134.2           2.3          24.6          .01324          1.000
    18      21.8      19.9      23.7         108.9           5.9         111.1          .01546          1.000
    19     101.7      87.4      18.1         135.0          25.8          40.5          .01385          1.080
    20      84.4      70.3      73.3         114.8          51.3          90.0          .01473          1.000
    21     105.3     115.0     185.8         102.3          45.2         102.3          .01552          1.000
    22      83.0      78.2      41.5         106.9           7.5          20.7          .00994          1.000
    23      72.1      76.6      77.6          87.1          18.6          87.9          .01169          1.000
    24      39.6      80.2      32.9          97.5           9.3          10.1          .00894          1.000
    25      65.0      94.5      91.1          75.4          27.9          75.4          .01006          1.000

*** MAX. SHEAR STRAIN COMPUTATION IN TIME DOMAIN


TIME REQUIRED FOR COMPUTING STRESS AND STRAIN =    2.648    SEC


*** TAPE 1 HAS BEEN COMPLETED ***
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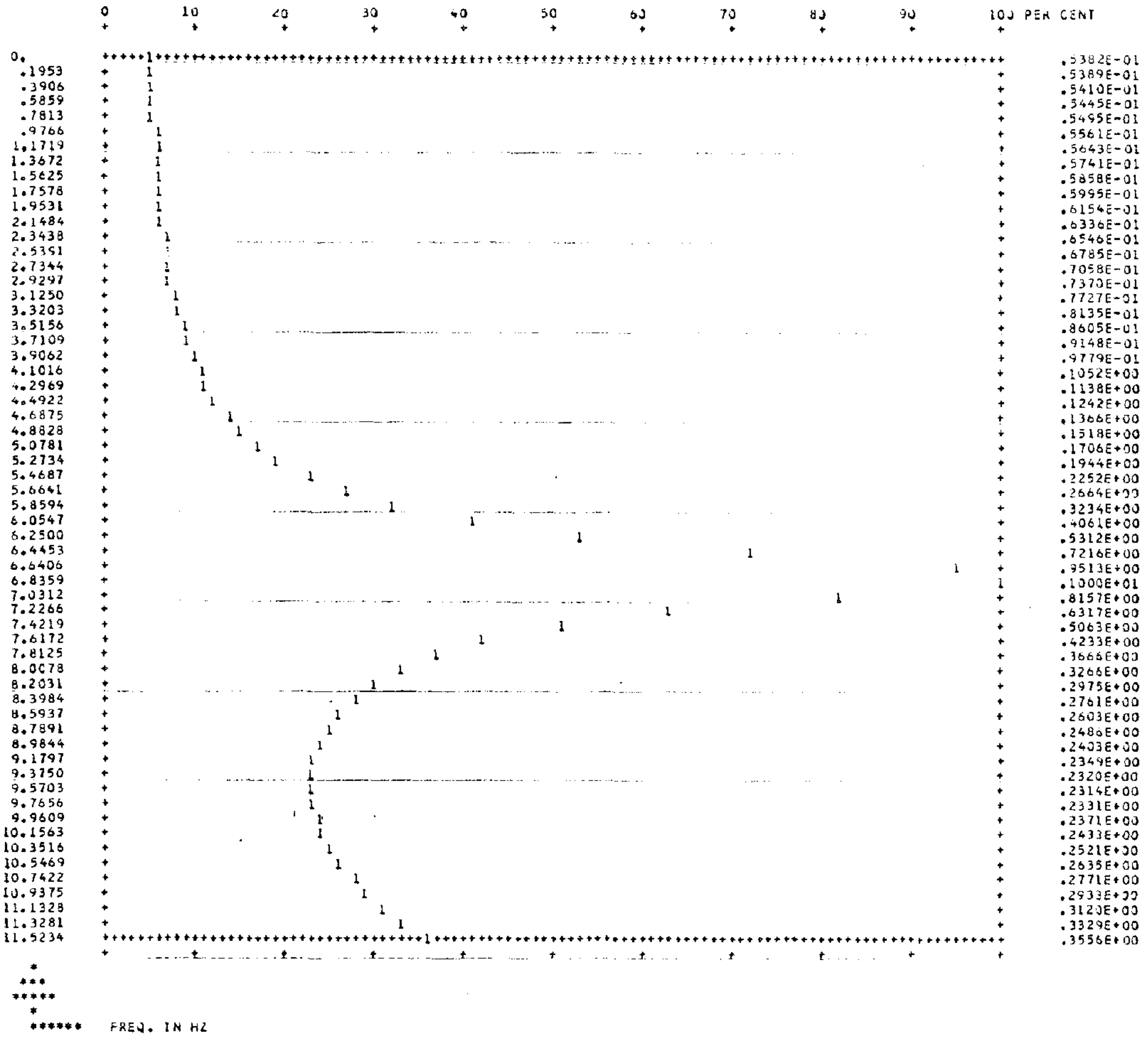
***  PLOT OF ACCELERATION AMPLIFICATION FUNCT.

X-ACC. AMPLIFICATION AT NODAL POINT          1,  100 PER CENT CORRESPONDS TO       18.5812
```



```
     0.              .5382E-01
      .1953          .5389E-01
      .3906          .5410E-01
      .5859          .5445E-01
      .7813          .5495E-01
      .9766          .5561E-01
     1.1719          .5643E-01
     1.3672          .5741E-01
     1.5625          .5858E-01
     1.7578          .5995E-01
     1.9531          .6154E-01
     2.1484          .6336E-01
     2.3438          .6546E-01
     2.5391          .6785E-01
     2.7344          .7058E-01
     2.9297          .7370E-01
     3.1250          .7727E-01
     3.3203          .8135E-01
     3.5156          .8605E-01
     3.7109          .9148E-01
     3.9062          .9779E-01
     4.1016          .1052E+00
     4.2969          .1138E+00
     4.4922          .1242E+00
     4.6875          .1366E+00
     4.8828          .1518E+00
     5.0781          .1706E+00
     5.2734          .1944E+00
     5.4687          .2252E+00
     5.6641          .2664E+00
     5.8594          .3234E+00
     6.0547          .4061E+00
     6.2500          .5312E+00
     6.4453          .7216E+00
     6.6406          .9513E+00
     6.8359          .1000E+01
     7.0312          .8157E+00
     7.2266          .6317E+00
     7.4219          .5063E+00
     7.6172          .4233E+00
     7.8125          .3666E+00
     8.0078          .3266E+00
     8.2031          .2975E+00
     8.3984          .2761E+00
     8.5937          .2603E+00
     8.7891          .2486E+00
     8.9844          .2403E+00
     9.1797          .2349E+00
     9.3750          .2320E+00
     9.5703          .2314E+00
     9.7656          .2331E+00
     9.9609          .2371E+00
    10.1563          .2433E+00
    10.3516          .2521E+00
    10.5469          .2635E+00
    10.7422          .2771E+00
    10.9375          .2933E+00
    11.1328          .3120E+00
    11.3281          .3329E+00
    11.5234          .3556E+00

      *
     ***
    *****
      *
      ******   FREQ. IN HZ
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***  PLOT OF FOURIER AMPLITUDE OF ACCELERATION

X-ACC. FOURIER SPECTRUM AT NODAL POINT        1,  100 PER CENT CORRESPONDS TO        .0303   G

              0         10        20        30        40        50        60        70        80        90        100 PER CENT
              +         +         +         +         +         +         +         +         +         +         +

        0.    1++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++     .1573E-15
     .1953    1                                                                                                   +     .3360E-02
     .3906    + 1                                                                                                 +     .2368E-01
     .5859    +      1                                                                                            +     .6886E-01
     .7813    +             1                                                                                     +     .1443E+00
     .9766    +                      1                                                                            +     .2343E+00
    1.1719    +                           1                                                                       +     .2841E+00
    1.3672    +                       1                                                                           +     .2416E+00
    1.5625    +           1                                                                                       +     .1240E+00
    1.7578    +         1                                                                                         +     .1014E+00
    1.9531    +              1                                                                                    +     .1523E+00
    2.1484    +          1                                                                                        +     .1115E+00
    2.3438    +1                                                                                                  +     .1260E-01
    2.5391    +      1                                                                                            +     .7073E-01
    2.7344    +       1                                                                                           +     .7950E-01
    2.9297    +   1                                                                                               +     .3761E-01
    3.1250    +       1                                                                                           +     .7543E-01
    3.3203    +          1                                                                                        +     .1095E+00
    3.5156    +        1                                                                                          +     .9126E-01
    3.7109    +         1                                                                                         +     .1006E+00
    3.9062    +               1                                                                                   +     .1557E+00
    4.1016    +               1                                                                                   +     .1593E+00
    4.2969    +         1                                                                                         +     .9924E-01
    4.4922    +  1                                                                                                +     .2995E-01
    4.6875    + 1                                                                                                 +     .2433E-01
    4.8828    +1                                                                                                  +     .9918E-02
    5.0781    +       1                                                                                           +     .8163E-01
    5.2734    +                 1                                                                                 +     .1773E+00
    5.4687    +                        1                                                                          +     .2522E+00
    5.6641    +                            1                                                                      +     .2922E+00
    5.8594    +                             1                                                                     +     .2952E+00
    6.0547    +                   1                                                                               +     .2015E+00
    6.2500    +        1                                                                                          +     .8960E-01
    6.4453    +                                               1                                                   +     .4841E+00
    6.6406    +                                                                                  1                +     .8327E+00
    6.8359    +                                                                                         1         +     .8972E+00
    7.0312    +                                                                                       1           +     .8825E+00
    7.2266    +                                                                                      1            +     .8686E+00
    7.4219    +                                                                          1                        +     .7501E+00
    7.6172    +                                                   1                                               +     .5239E+00
    7.8125    +                            1                                                                      +     .2915E+00
    8.0078    +             1                                                                                     +     .1362E+00
    8.2031    +      1                                                                                            +     .7464E-01
    8.3984    +                            1                                                                      +     .2917E+00
    8.5937    +                                       1                                                           +     .4039E+00
    8.7891    +                        1                                                                          +     .2542E+00
    8.9844    +           1                                                                                       +     .1220E+00
    9.1797    +                                                  1                                                +     .5128E+00
    9.3750    +                                                                        1                          +     .7324E+00
    9.5703    +                                                                              1                    +     .7903E+00
    9.7656    +                                                                            1                      +     .7700E+00
    9.9609    +                                                          1                                        +     .5932E+00
   10.1563    +                   1                                                                               +     .2039E+00
   10.3516    +                           1                                                                       +     .2827E+00
   10.5469    +                                                           1                                       +     .5954E+00
   10.7422    +                                                               1                                   +     .6385E+00
   10.9375    +                                                      1                                            +     .5488E+00
   11.1328    +                                                             1                                     +     .6167E+00
   11.3281    +                                                                               1                   +     .8031E+00
   11.5234    ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++1     .1000E+01
              +         +         +         +         +         +         +         +         +         +         +
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       ******   FREQ. IN HZ
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```
***  PLOT OF ACCELERATION. (BASE ACC.+REL. ACC.)

X-COMP. OF ACCELERATION AT NODAL POINT        1,  100 PER CENT CORRESPONDS TO          .2884   G

EVERY   2 TH POINTS ARE PLOTTED
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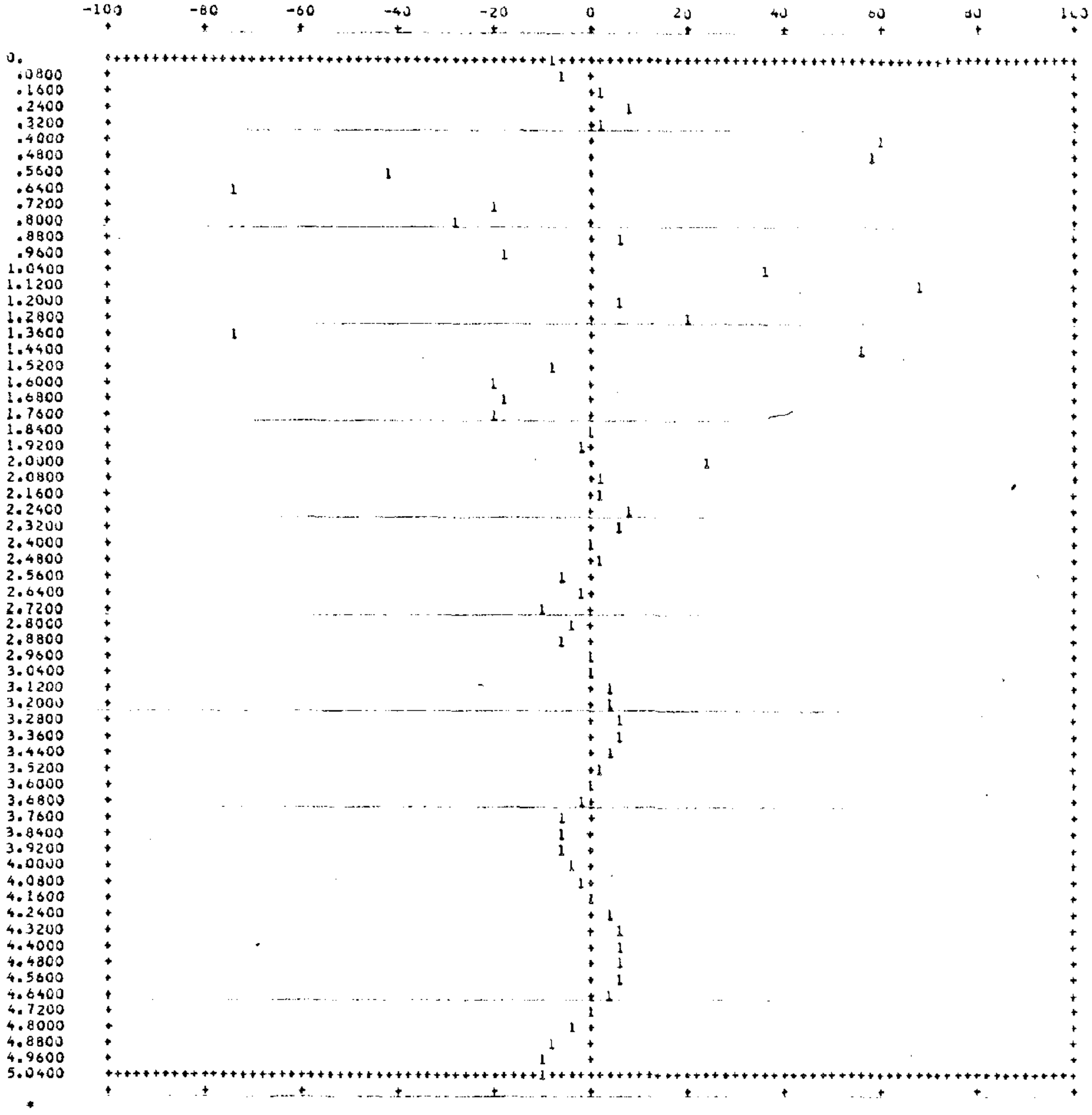

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    .2400     .7000E-01
    .3200     .1483E-01
    .4000     .6087E+00
    .4800     .5887E+00
    .5600    -.4205E+00
    .6400    -.7366E+00
    .7200    -.1954E+00
    .8000    -.2851E+00
    .8800     .5290E-01
    .9600    -.1761E+00
   1.0400     .3533E+00
   1.1200     .6789E+00
   1.2000     .6909E-01
   1.2800     .2056E+00
   1.3600    -.7499E+00
   1.4400     .5648E+00
   1.5200    -.3907E-01
   1.6000    -.2005E+00
   1.6800    -.1765E+00
   1.7600    -.2063E+00
   1.8400     .6798E-02
   1.9200    -.2838E-01
   2.0000     .2477E+00
   2.0800     .1561E-01
   2.1600     .2126E-01
   2.2400     .7647E-01
   2.3200     .6254E-01
   2.4000     .3806E-02
   2.4800     .2316E-01
   2.5600    -.6532E-01
   2.6400    -.1763E-01
   2.7200    -.9282E-01
   2.8000    -.3305E-01
   2.8800    -.6645E-01
   2.9600    -.7176E-02
   3.0400    -.6894E-02
   3.1200     .3484E-01
   3.2000     .4543E-01
   3.2800     .5708E-01
   3.3600     .5815E-01
   3.4400     .3977E-01
   3.5200     .2657E-01
   3.6000    -.7278E-02
   3.6800    -.2414E-01
   3.7600    -.5160E-01
   3.8400    -.5612E-01
   3.9200    -.6075E-01
   4.0000    -.4496E-01
   4.0800    -.2584E-01
   4.1600     .3070E-02
   4.2400     .3080E-01
   4.3200     .5434E-01
   4.4000     .6905E-01
   4.4800     .6942E-01
   4.5600     .5755E-01
   4.6400     .3091E-01
   4.7200    -.2415E-02
   4.8000    -.4028E-01
   4.8800    -.7228E-01
   4.9600    -.9411E-01
   5.0400    -.9810E-01
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*** PLOT OF ACCELERATION AMPLIFICATION FUNCT.

X-ACC. AMPLIFICATION AT NODAL POINT          3,  100 PER CENT CORRESPONDS TO        9.7253
             0        10        20        30        40        50        60        70        80        90        100 PER CENT
             +         +         +         +         +         +         +         +         +         +         +

        0.   ++++++++++1++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++     .1028E+00
     .1953   +         1                                                                                         +     .1029E+00
     .3906   +         1                                                                                         +     .1032E+00
     .5859   +         1                                                                                         +     .1037E+00
     .7813   +         1                                                                                         +     .1043E+00
     .9766   +          1                                                                                        +     .1052E+00
    1.1719   +          1                                                                                        +     .1063E+00
    1.3672   +          1                                                                                        +     .1076E+00
    1.5625   +          1                                                                                        +     .1091E+00
    1.7578   +          1                                                                                        +     .1109E+00
    1.9531   +          1                                                                                        +     .1129E+00
    2.1484   +           1                                                                                       +     .1153E+00
    2.3438   +           1                                                                                       +     .1179E+00
    2.5391   +           1                                                                                       +     .1209E+00
    2.7344   +           1                                                                                       +     .1244E+00
    2.9297   +            1                                                                                      +     .1283E+00
    3.1250   +            1                                                                                      +     .1327E+00
    3.3203   +             1                                                                                     +     .1377E+00
    3.5156   +             1                                                                                     +     .1433E+00
    3.7109   +              1                                                                                    +     .1498E+00
    3.9062   +               1                                                                                   +     .1573E+00
    4.1016   +                1                                                                                  +     .1659E+00
    4.2969   +                 1                                                                                 +     .1760E+00
    4.4922   +                  1                                                                                +     .1877E+00
    4.6875   +                   1                                                                               +     .2017E+00
    4.8828   +                     1                                                                             +     .2186E+00
    5.0781   +                       1                                                                           +     .2392E+00
    5.2734   +                         1                                                                         +     .2649E+00
    5.4687   +                             1                                                                     +     .2978E+00
    5.6641   +                                 1                                                                 +     .3411E+00
    5.8594   +                                       1                                                           +     .4001E+00
    6.0547   +                                               1                                                   +     .4841E+00
    6.2500   +                                                            1                                      +     .6087E+00
    6.4453   +                                                                              1                    +     .7927E+00
    6.6406   +                                                                                                   1     .9988E+00
    6.8359   +                                                                                                   1     .1000E+01
    7.0312   +                                                                            1                      +     .7740E+00
    7.2266   +                                                        1                                          +     .5663E+00
    7.4219   +                                          1                                                        +     .4268E+00
    7.6172   +                                1                                                                  +     .3338E+00
    7.8125   +                          1                                                                        +     .2687E+00
    8.0078   +                     1                                                                             +     .2209E+00
    8.2031   +                 1                                                                                 +     .1842E+00
    8.3984   +              1                                                                                    +     .1549E+00
    8.5937   +            1                                                                                      +     .1308E+00
    8.7891   +          1                                                                                        +     .1103E+00
    8.9844   +        1                                                                                          +     .9259E-01
    9.1797   +       1                                                                                           +     .7702E-01
    9.3750   +     1                                                                                             +     .6330E-01
    9.5703   +    1                                                                                              +     .5152E-01
    9.7656   +   1                                                                                               +     .4236E-01
    9.9609   +   1                                                                                               +     .3753E-01
   10.1563   +   1                                                                                               +     .3921E-01
   10.3516   +    1                                                                                              +     .4795E-01
   10.5469   +     1                                                                                             +     .6275E-01
   10.7422   +       1                                                                                           +     .8439E-01
   10.9375   +          1                                                                                        +     .1143E+00
   11.1328   +               1                                                                                   +     .1573E+00
   11.3281   +                     1                                                                             +     .2239E+00
   11.5234   ++++++++++++++++++++++++++++++++++1++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++     .3372E+00
             +         +         +         +         +         +         +         +         +         +         +
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      ******  FREQ. IN HZ
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```
***  PLOT OF FOURIER AMPLITUDE OF ACCELERATION

X-ACC. FOURIER SPECTRUM AT NODAL POINT       3,  100 PER CENT CORRESPONDS TO          .0151   G

              0         10        20        30        40        50        60        70        80        90        100 PER CENT
              +         +         +         +         +         +         +         +         +         +         +

        0.    1++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++     .3168E-15
     .1953    +1                                                                                                  +     .6766E-02
     .3906    +    1                                                                                              +     .4763E-01
     .5859    +             1                                                                                     +     .1382E+00
     .7813    +                            1                                                                      +     .2889E+00
     .9766    +                                              1                                                    +     .4673E+00
    1.1719    +                                                       1                                           +     .5642E+00
    1.3672    +                                               1                                                   +     .4773E+00
    1.5625    +                       1                                                                           +     .2434E+00
    1.7578    +                   1                                                                               +     .1977E+00
    1.9531    +                            1                                                                      +     .2946E+00
    2.1484    +                    1                                                                              +     .2139E+00
    2.3438    + 1                                                                                                 +     .2393E-01
    2.5391    +            1                                                                                      +     .1329E+00
    2.7344    +              1                                                                                    +     .1477E+00
    2.9297    +      1                                                                                            +     .6900E-01
    3.1250    +             1                                                                                     +     .1365E+00
    3.3203    +                   1                                                                               +     .1954E+00
    3.5156    +               1                                                                                   +     .1603E+00
    3.7109    +                1                                                                                  +     .1738E+00
    3.9062    +                         1                                                                         +     .2640E+00
    4.1016    +                         1                                                                         +     .2650E+00
    4.2969    +               1                                                                                   +     .1617E+00
    4.4922    +    1                                                                                              +     .4774E-01
    4.6875    +   1                                                                                               +     .3789E-01
    4.8828    + 1                                                                                                 +     .1506E-01
    5.0781    +           1                                                                                       +     .1207E+00
    5.2734    +                        1                                                                          +     .2549E+00
    5.4687    +                                  1                                                                +     .3517E+00
    5.6641    +                                      1                                                            +     .3944E+00
    5.8594    +                                     1                                                             +     .3850E+00
    6.0547    +                        1                                                                          +     .2532E+00
    6.2500    +          1                                                                                        +     .1083E+00
    6.4453    +                                                       1                                           +     .5608E+00
    6.6406    +                                                                                           1       +     .9218E+00
    6.8359    +                                                                                              1    +     .9460E+00
    7.0312    +                                                                                       1           +     .8829E+00
    7.2266    +                                                                                 1                 +     .8211E+00
    7.4219    +                                                                  1                                +     .6668E+00
    7.6172    +                                           1                                                       +     .4356E+00
    7.8125    +                      1                                                                            +     .2253E+00
    8.0078    +         1                                                                                         +     .9716E-01
    8.2031    +    1                                                                                              +     .4873E-01
    8.3984    +                1                                                                                  +     .1725E+00
    8.5937    +                    1                                                                              +     .2140E+00
    8.7891    +           1                                                                                       +     .1189E+00
    8.9844    +    1                                                                                              +     .4957E-01
    9.1797    +                 1                                                                                 +     .1773E+00
    9.3750    +                    1                                                                              +     .2107E+00
    9.5703    +                  1                                                                                +     .1855E+00
    9.7656    +              1                                                                                    +     .1475E+00
    9.9609    +         1                                                                                         +     .9903E-01
   10.1563    +  1                                                                                                +     .3464E-01
   10.3516    +     1                                                                                             +     .5670E-01
   10.5469    +              1                                                                                    +     .1495E+00
   10.7422    +                    1                                                                              +     .2150E+00
   10.9375    +                      1                                                                            +     .2256E+00
   11.1328    +                                1                                                                  +     .3279E+00
   11.3281    +                                                        1                                          +     .5696E+00
   11.5234    ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++1     .1000E+01
              +         +         +         +         +         +         +         +         +         +         +
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      ******   FREQ. IN HZ
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***  PLOT OF ACCELERATION, (BASE ACC.+REL. ACC.)

X-COMP. OF ACCELERATION AT NODAL POINT      3,  100 PER CENT CORRESPONDS TO        .1384   G

EVERY   2 TH POINTS ARE PLOTTED
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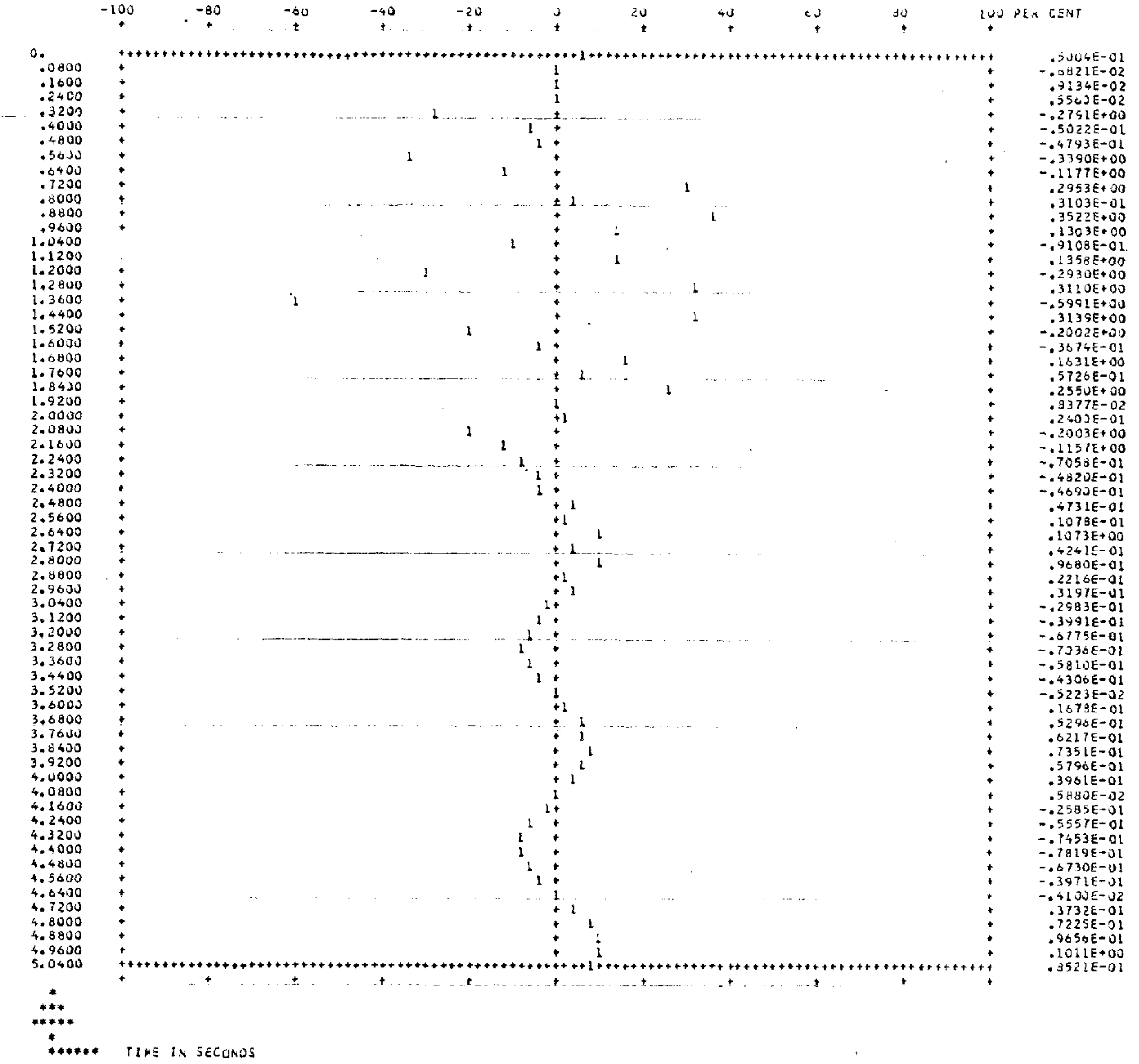

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  .5600    -.3390E+00
  .6400    -.1177E+00
  .7200     .2953E+00
  .8000     .3103E-01
  .8800     .3522E+00
  .9600     .1303E+00
 1.0400    -.9108E-01
 1.1200     .1358E+00
 1.2000    -.2930E+00
 1.2800     .3110E+00
 1.3600    -.5991E+00
 1.4400     .3139E+00
 1.5200    -.2002E+00
 1.6000    -.3674E-01
 1.6800     .1631E+00
 1.7600     .5726E-01
 1.8400     .2550E+00
 1.9200     .8377E-02
 2.0000     .2400E-01
 2.0800    -.2003E+00
 2.1600    -.1157E+00
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 2.3200    -.4820E-01
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 2.5600     .1078E-01
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 4.8000     .7225E-01
 4.8800     .9656E-01
 4.9600     .1011E+00
 5.0400     .8521E-01
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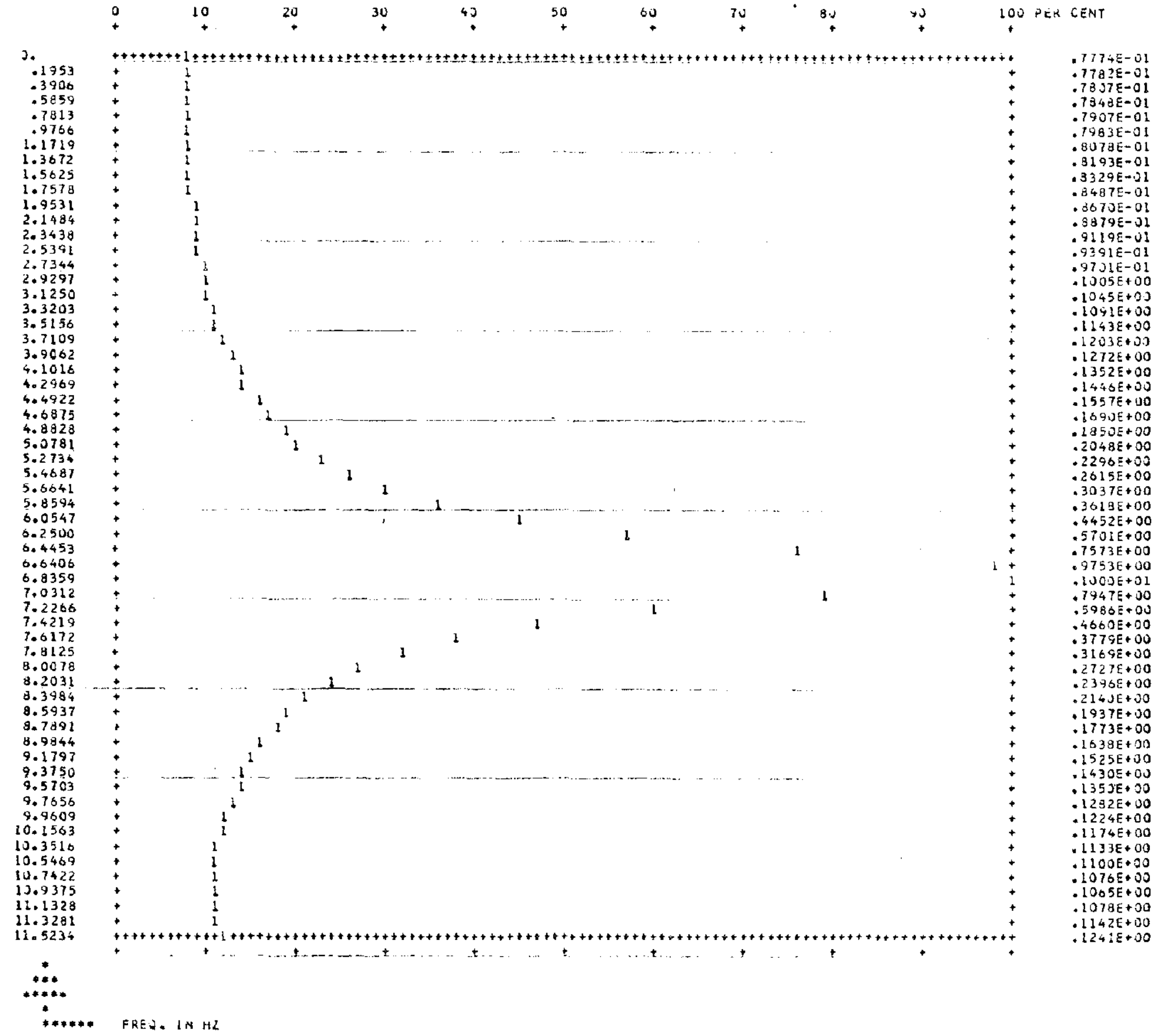
*** PLOT OF ACCELERATION AMPLIFICATION FUNCT.

X-ACC. AMPLIFICATION AT NODAL POINT 19, 100 PER CENT CORRESPONDS TO 12.8636



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*** PLOT OF FOURIER AMPLITUDE OF ACCELERATION

X-ACC. FOURIER SPECTRUM AT NODAL POINT      19,  100 PER CENT CORRESPONDS TO        .0188   G

               0         10        20        30        40        50        60        70        80        90        100 PER CENT
               +         +         +         +         +         +         +         +         +         +         +

          0.   1++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++      .2532E-15
       .1953   +1                                                                                                  +      .5408E-02
       .3906   +   1                                                                                               +      .3809E-01
       .5859   +          1                                                                                        +      .1106E+00
       .7813   +                      1                                                                            +      .2314E+00
       .9766   +                                    1                                                              +      .3749E+00
      1.1719   +                                            1                                                      +      .4534E+00
      1.3672   +                                     1                                                             +      .3843E+00
      1.5625   +                   1                                                                               +      .1964E+00
      1.7578   +               1                                                                                   +      .1600E+00
      1.9531   +                       1                                                                           +      .2391E+00
      2.1484   +                1                                                                                  +      .1742E+00
      2.3438   + 1                                                                                                 +      .1956E-01
      2.5391   +          1                                                                                        +      .1091E+00
      2.7344   +           1                                                                                       +      .1218E+00
      2.9297   +     1                                                                                             +      .5717E-01
      3.1250   +          1                                                                                        +      .1137E+00
      3.3203   +               1                                                                                   +      .1637E+00
      3.5156   +             1                                                                                     +      .1351E+00
      3.7109   +              1                                                                                    +      .1475E+00
      3.9062   +                      1                                                                            +      .2257E+00
      4.1016   +                      1                                                                            +      .2283E+00
      4.2969   +             1                                                                                     +      .1405E+00
      4.4922   +   1                                                                                               +      .4185E-01
      4.6875   +  1                                                                                                +      .3355E-01
      4.8828   +1                                                                                                  +      .1347E-01
      5.0781   +          1                                                                                        +      .1092E+00
      5.2734   +                      1                                                                            +      .2334E+00
      5.4687   +                                1                                                                  +      .3264E+00
      5.6641   +                                    1                                                              +      .3713E+00
      5.8594   +                                    1                                                              +      .3680E+00
      6.0547   +                        1                                                                          +      .2462E+00
      6.2500   +          1                                                                                        +      .1072E+00
      6.4453   +                                                        1                                          +      .5663E+00
      6.6406   +                                                                                              1    +      .9514E+00
      6.8359   +                                                                                                   1      .1000E+01
      7.0312   +                                                                                               1   +      .9582E+00
      7.2266   +                                                                                           1       +      .9175E+00
      7.4219   +                                                                            1                      +      .7695E+00
      7.6172   +                                                   1                                               +      .5212E+00
      7.8125   +                           1                                                                       +      .2808E+00
      8.0078   +            1                                                                                      +      .1268E+00
      8.2031   +      1                                                                                            +      .6701E-01
      8.3984   +                        1                                                                          +      .2520E+00
      8.5937   +                                 1                                                                 +      .3351E+00
      8.7891   +                   1                                                                               +      .2020E+00
      8.9844   +        1                                                                                          +      .9267E-01
      9.1797   +                                    1                                                              +      .3711E+00
      9.3750   +                                                 1                                                 +      .5033E+00
      9.5703   +                                                  1                                                +      .5138E+00
      9.7656   +                                              1                                                    +      .4718E+00
      9.9609   +                                 1                                                                 +      .3412E+00
     10.1563   +          1                                                                                        +      .1097E+00
     10.3516   +             1                                                                                     +      .1416E+00
     10.5469   +                           1                                                                       +      .2770E+00
     10.7422   +                           1                                                                       +      .2763E+00
     10.9375   +                     1                                                                             +      .2222E+00
     11.1328   +                       1                                                                           +      .2375E+00
     11.3281   +                              1                                                                    +      .3071E+00
     11.5234   +++++++++++++++++++++++++++++++++++++++1+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++      .3889E+00
               +         +         +         +         +         +         +         +         +         +         +
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        ******   FREQ. IN HZ
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***  PLOT OF ACCELERATION. (BASE ACC.+REL. ACC.)

X-COMP. OF ACCELERATION AT NODAL POINT      19,  100 PER CENT CORRESPONDS TO        .1553   G

EVERY    2 TH POINTS ARE PLOTTED
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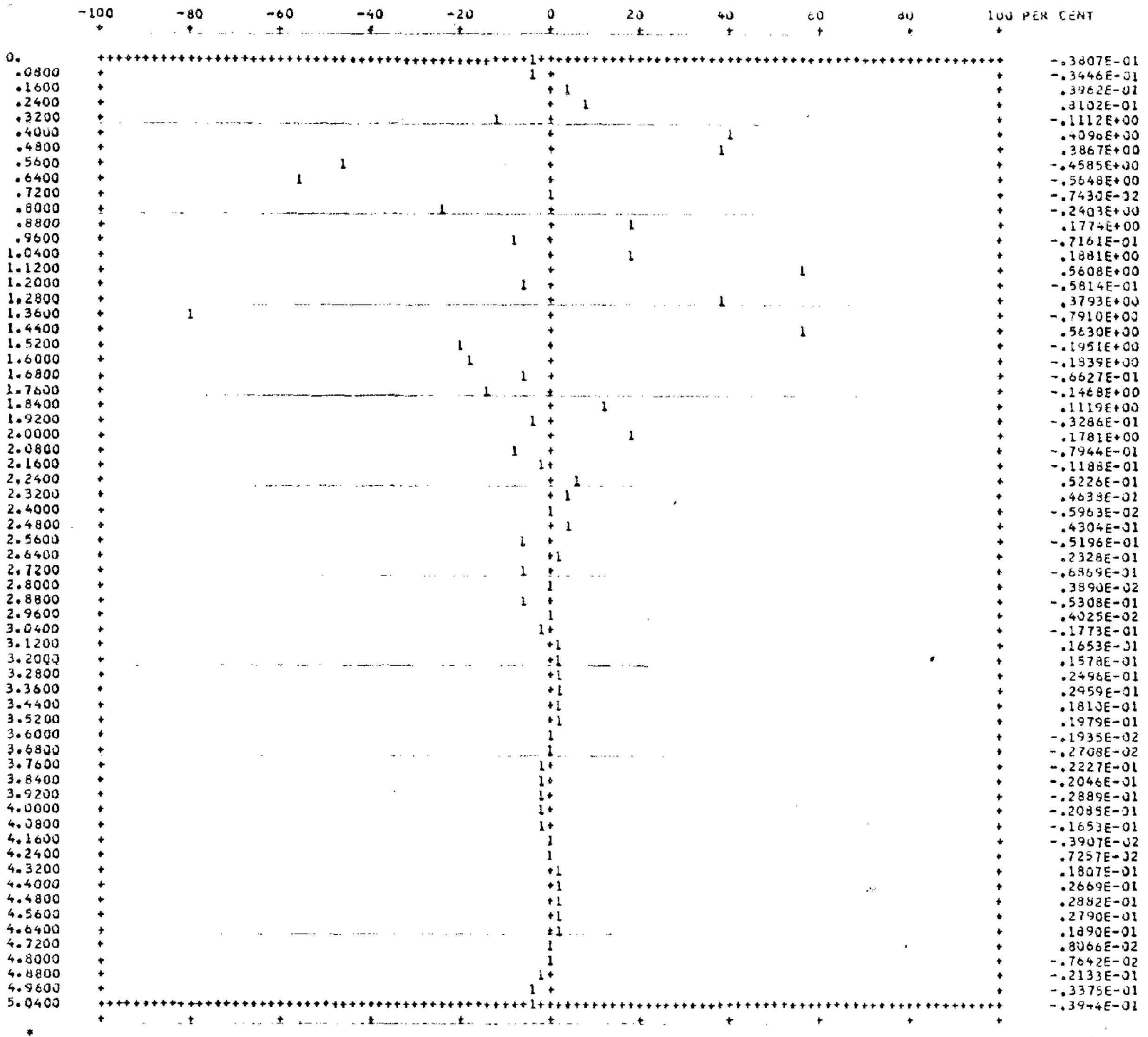

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   .2400    .3102E-01
   .3200   -.1112E+00
   .4000    .4096E+00
   .4800    .3867E+00
   .5600   -.4585E+00
   .6400   -.5648E+00
   .7200   -.7430E-02
   .8000   -.2403E+00
   .8800    .1774E+00
   .9600   -.7161E-01
  1.0400    .1881E+00
  1.1200    .5608E+00
  1.2000   -.5814E-01
  1.2800    .3793E+00
  1.3600   -.7910E+00
  1.4400    .5630E+00
  1.5200   -.1951E+00
  1.6000   -.1939E+00
  1.6800   -.6627E-01
  1.7600   -.1468E+00
  1.8400    .1119E+00
  1.9200   -.3286E-01
  2.0000    .1781E+00
  2.0800   -.7944E-01
  2.1600   -.1188E-01
  2.2400    .5226E-01
  2.3200    .4639E-01
  2.4000   -.5963E-02
  2.4800    .4304E-01
  2.5600   -.5196E-01
  2.6400    .2328E-01
  2.7200   -.6969E-01
  2.8000    .3890E-02
  2.8800   -.5308E-01
  2.9600    .4025E-02
  3.0400   -.1773E-01
  3.1200    .1653E-01
  3.2000    .1578E-01
  3.2800    .2496E-01
  3.3600    .2959E-01
  3.4400    .1810E-01
  3.5200    .1979E-01
  3.6000   -.1935E-02
  3.6800   -.2708E-02
  3.7600   -.2227E-01
  3.8400   -.2046E-01
  3.9200   -.2889E-01
  4.0000   -.2085E-01
  4.0800   -.1653E-01
  4.1600   -.3907E-02
  4.2400    .7257E-02
  4.3200    .1807E-01
  4.4000    .2669E-01
  4.4800    .2882E-01
  4.5600    .2790E-01
  4.6400    .1890E-01
  4.7200    .8066E-02
  4.8000   -.7642E-02
  4.8800   -.2133E-01
  4.9600   -.3375E-01
  5.0400   -.3944E-01
```

```
     *
    ***
   *****
     *
     ******   TIME IN SECONDS
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```
MAXIMUM ABSOLUTE ACCELERATIONS(G)

IITERATION NO. 1          MAX. INPUT BASE ACC. =   .0728 (G) IN X DIRECTION
                          MAX. INPUT BASE ACC. =  0.     (G) IN Y DIRECTION
                          MAX. INPUT BASE ACC. =  0.     (G) IN Z DIRECTION

     N.P.    XORD      YORD      ZORD        X-ACC     AT TIME        Y-ACC     AT TIME        Z-ACC     AT TIME

      1     46.00     30.00     40.00        .2884     1.0800       0.           .9600       0.           .9600
      3     46.00     30.00     20.00        .1384     1.0000       0.           .9600        .1113      1.0800
     19     24.00     20.00     40.00        .1553     1.0000        .0374      1.0800       0.           .9600

 TIME REQUIRED FOR COMPUTATION AND OUTPUT OF ACCELERATIONS AT       5    DEG. OF FDM. =      .234    SEC
```

```
***********
* MODE3   *
***********

*** BLANK COMMON REQUIREMENTS ***

           LENGTH OF BLANK COMMON =      15000
  BLANK COMMON REQUIRED FOR VEDDA =       1497
  BLANK COMMON FOR PERMANENT DATA =        938
 BLANK COMMON REQUIRED FOR STRAIN =       1767
            BLANK COMMON FOR BBBC =       6616
     MAX. WORDS REQUIRED FOR BBBC =         96
 BLANK COMMON REQUIRED FOR MOTION =       1168
            BLANK COMMON FOR AAAC =       6916
     MAX. WORDS REQUIRED FOR AAAC =         16
```

```
EXAMPLE PROBLEM FOR TLUSH                                                   RUN NUMBER =  1

*** INPUT DATA ***
         TOTAL NUMBER OF ELEMENTS =     25
    TOTAL NUMBER CF NODAL PCINTS =     44
   1ST NODAL POINT ON RIGID BASE =     26
              DEGREES CF FREEDCM =     75
  NUMBER OF BOUNDARY CONDITIONS =     18
           NUMBER OF ITERATIONS =      1
        NUMBER OF MATERIAL TYPES =      2


*** INPUT MCTION ***
 TOTAL NO. OF POINTS USED IN FFT =    128
           LAST POINT TO BE READ =     64
             TIME STEP CF RECORD =    .040 SEC.
              DURATION OF RECORD =   2.560 SEC.
            QUIET ZONE OF RECORD =   2.560 SEC.
      TOTAL DURATICN OF ANALYSIS =   5.120 SEC.
       EQ. MULTIPLICATION FACTOR =  2.0000
       MAX. ACCEL. AFTER SCALING =   .0728 (G)
         MOTION IN X-DIRECTION =  1.0000 TIMES INPUT MOTION
         MOTION IN Y-DIRECTION =  0.      TIMES INPUT MOTION
         MOTION IN Z-DIRECTION =  0.      TIMES INPUT MOTION

 BASE LINE CORRECTION WILL BE APPLIED


*** FREQUENCY CONTENT CF ANALYSIS ***
   HIGHEST FREQUENCY OF ANALYSIS =  12.000  HZ
     NC. CF INTERPOLATICN RANGES =    3

     0.     --    5.000 HZ(KINT=  5)
     5.000 --   10.000 HZ(KINT=  3)
    10.000 --   12.000 HZ(KINT=  5)
   FREQ. USED IN
              THE LAST ITERATION = 12.000  HZ


*** OUTPUT C3NTROL ***
    SAVING AMP. FUNCTION ON TAPE =  NO
   COMPUTING NEW SOIL PRCPERTIES =  YES
    PUNCHING NEW SOIL PROPERTIES =  NO
     STEPS TO FIND MAX. RESPONSE =    128
         SKIP POINTS FOR PLCTTING =      2
    FACTOR F3R EFF. SHEAR STRAIN =   .6500


*** MASS MATRIX ***
   FRACTION CF CCNSISTENT MASS =   .5000
       FRACTION OF LUMPED MASS =   .5000
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*** RESPONSE SPECTRUM ***
      NUMBER OF DAMPING VALUES =      1
    FRACTION OF CRITICAL DAMPING =   .0500
     FIRST FREQUENCY OF SPECTRUM =   .4000 HZ
      LAST FREQUENCY OF SPECTRUM = 40.0000 HZ
        NO. OF FREQUENCY STEPS =    41


*** DAMPING CHARACTERISTICS ***
            UNIFORM DAMPING USED =  NO


*** OUTPUT REQUIREMENTS ***
              CODES FOR KEYSPC
              0--MAXIMUM ACCELERATION ONLY
              1--PLOT ACC. TIME HISTORY
             10--PLOT ACC. AND VELOCITY RESPONSE SPECTRUM
            100--PUNCH ACC. TIME HISTORY
           1000--PLOT FOURIER AMP. OF ACCELERATION
          10000--PLOT AMPLIFICATION FUNCTION


      VALUES OF KEYSPC


      N.P.NO.   X-OUTPUT   Y-OUTPUT   Z-OUTPUT
        1         1010         0          0


              CODES FOR KEYSTR
              1--PLOT  TIME HISTORIES OF STRESSES
             10--PRINT TIME HISTORIES OF STRESSES
            100--PUNCH TIME HISTORIES OF STRESSES



      VALUES OF KEYSTR

      EL.NO.     KEYSTR

        14         1



 *** SHEAR MODULUS AND DAMPING CURVES FOR MATERIALS WITH STRAIN-DEPENDENT PROPERTIES ***

 STANDARD BUILT IN CURVES ARE USED


 MAT. TYPE --       IDENTIFICATION

      1     SEED AND IDRISS (1970) -- CLAY
      2     SEED AND IDRISS (1970) -- SAND


    SHEAR MODULUS CURVES

                                                  SHEAR STRAIN IN PERCENT
MAT. ----------------------------------------------------------------------------------------------------------------------
TYPE  10**(-4.0) 10**(-3.5) 10**(-3.0) 10**(-2.5) 10**(-2.0) 10**(-1.5) 10**(-1.0) 10**(-0.5) 10**( 0.0) 10**( 0.5) 10**( 1.0)
---------------------------------------------------------------------------------------------------------------------------
 1     .10E+01    .91E+00    .76E+00    .57E+00    .40E+00    .26E+00    .15E+00    .76E-01    .37E-01    .13E-01    .40E-02
 2     .10E+01    .98E+00    .93E+00    .83E+00    .66E+00    .44E+00    .25E+00    .12E+00    .49E-01    .49E-01    .49E-01
---------------------------------------------------------------------------------------------------------------------------


    DAMPING CURVES  (PERCENT)

                                                  SHEAR STRAIN IN PERCENT
MAT. ----------------------------------------------------------------------------------------------------------------------
TYPE  10**(-4.0) 10**(-3.5) 10**(-3.0) 10**(-2.5) 10**(-2.0) 10**(-1.5) 10**(-1.0) 10**(-0.5) 10**( 0.0) 10**( 0.5) 10**( 1.0)
---------------------------------------------------------------------------------------------------------------------------
 1     .25E+01    .25E+01    .25E+01    .35E+01    .48E+01    .65E+01    .93E+01    .14E+02    .20E+02    .26E+02    .29E+02
 2     .50E+00    .80E+00    .17E+01    .32E+01    .56E+01    .10E+02    .16E+02    .21E+02    .25E+02    .25E+02    .25E+02
---------------------------------------------------------------------------------------------------------------------------
```

```
*** ELEMENT DATA ***

NO.   NP1   NP2   NP3   NP4   NP5   NP6   NP7   NP8  MTYPE  ID.EL    PO    UNIT WT.     G-MAX      G-USE   DMP-USE     VS-USE
                                                                          (PCF)        (KSF)      (KSF)  (FRACTION)   (FPS)

  1    10    14     5     1    11    15     6     2    1      1    .450    110.000   1500.000    670.887      .044    443.156
  2    11    15     6     2    12    16     7     3    1      1    .450    110.000   1500.000    716.409      .042    457.944
  3    12    16     7     2    13    41    42     4    1      1    .450    110.000   1500.000    692.458      .043    450.224
  4    13    41    42     4    43    43    44    44    1      2    .450    110.000   1500.000    799.829      .037    483.872
  5    14    17     8     5    15    18     9     6    1      1    .450    110.000   1500.000    577.235      .049    411.063
  6    15    18     9     6    16    38    39     7    1      1    .450    110.000   1500.000    570.316      .050    408.591
  7    16    38    39     7    41    41    42    42    1      2    .450    110.000   1500.000    584.308      .049    413.573
  8    17    29    30     8    18    34    35     9    1      1    .450    110.000   1500.000    610.362      .047    422.693
  9    18    34    35     9    38    38    39    39    1      2    .450    110.000   1500.000    590.178      .048    415.646
 10    19    19    14    10    20    20    15    11    2      3    .350    120.000   1500.000   1125.169      .043    549.473
 11    20    20    15    11    21    21    16    12    2      3    .350    120.000   1500.000   1055.399      .049    532.164
 12    21    21    16    12    40    40    41    13    2      3    .350    120.000   1500.000   1050.066      .050    530.818
 13    40    40    41    13    43    43    43    43    2      4    .350    120.000   1500.000   1161.362      .039    558.240
 14    19    22    17    14    20    23    18    15    2      5    .350    120.000   1500.000   1020.782      .053    523.364
 15    20    23    18    15    21    37    38    15    2      5    .350    120.000   1500.000    996.117      .055    517.002
 16    21    37    38    16    40    40    41    41    2      6    .350    120.000   1500.000   1307.374      .054    519.915
 17    22    28    29    17    23    33    34    18    2      5    .350    120.000   1500.000   1043.016      .050    529.033
 18    23    33    34    18    37    37    38    38    2      6    .350    120.000   1500.000   1008.343      .054    520.165
 19    24    24    22    19    25    25    23    20    2      3    .350    120.000   1500.000   1001.486      .054    518.394
 20    25    25    23    20    36    36    37    21    2      3    .350    120.000   1500.000   1000.438      .054    518.123
 21    36    36    37    21    40    40    40    40    2      4    .350    120.000   1500.000   1002.356      .054    518.619
 22    24    27    28    22    25    32    33    23    2      5    .350    120.000   1500.000   1096.019      .045    542.308
 23    25    32    33    23    36    36    37    37    2      6    .350    120.000   1500.000   1062.967      .049    534.069
 24    26    26    27    24    31    31    32    25    2      3    .350    120.000   1500.000   1122.382      .043    548.792
 25    31    31    32    25    36    36    36    36    2      4    .350    120.000   1500.000   1095.696      .045    542.229


*** NODAL POINT DATA ***

                                                                           BOUNDARY   CONDITIONS
 N.P.      XORD(FT)       YORD(FT)       ZORD(FT)       MASS (KIPS)     X-DIRECTION   Y-DIRECTION   Z-DIRECTION

   1        46.000         30.000         40.000          -0.                           FIXED         FIXED
   2        46.000         30.000         30.000          -0.                           FIXED
   3        46.000         30.000         20.000           0.                           FIXED
   4        46.000         30.000         10.000          -0.                           FIXED
   5        46.000         20.000         40.000          -0.                           FIXED         FIXED
   6        46.000         20.000         30.000          -0.                           FIXED
   7        46.000         20.000         20.000          -0.                           FIXED
   8        46.000         10.000         40.000          -0.                           FIXED         FIXED
   9        46.000         10.000         30.000          -0.                           FIXED
  10        36.000         30.000         40.000          -0.                                         FIXED
  11        36.000         30.000         30.000           0.
  12        36.000         30.000         20.000           0.
  13        36.000         30.000         10.000          -0.
  14        36.000         20.000         40.000          -0.                                         FIXED
  15        36.000         20.000         30.000           0.
  16        36.000         20.000         20.000          -0.
  17        36.000         10.000         40.000          -0.                                         FIXED
  18        36.000         10.000         30.000          -0.
  19        24.000         20.000         40.000          -0.                                         FIXED
  20        24.000         20.000         30.000           0.
  21        24.000         20.000         20.000          -0.
  22        24.000         10.000         40.000          -0.                                         FIXED
  23        24.000         10.000         30.000          -0.
  24        12.000         10.000         40.000          -0.                                         FIXED
  25        12.000         10.000         30.000          -0.
  26         0.             0.            40.000          -0.              FIXED         FIXED         FIXED
  27        12.000          0.            40.000           0.              FIXED         FIXED         FIXED
  28        24.000          0.            40.000           0.              FIXED         FIXED         FIXED
  29        36.000          0.            40.000          -0.              FIXED         FIXED         FIXED
  30        46.000          0.            40.000          -0.              FIXED         FIXED         FIXED
  31         0.             0.            30.000          -0.              FIXED         FIXED         FIXED
  32        12.000          0.            30.000           0.              FIXED         FIXED         FIXED
  33        24.000          0.            30.000           0.              FIXED         FIXED         FIXED
  34        36.000          0.            30.000          -0.              FIXED         FIXED         FIXED
  35        46.000          0.            30.000          -0.              FIXED         FIXED         FIXED
  36        12.000         10.000         20.000          -0.              FIXED         FIXED         FIXED
  37        24.000         10.000         20.000           0.              FIXED         FIXED         FIXED
  38        36.000         10.000         20.000          -0.              FIXED         FIXED         FIXED
  39        46.000         10.000         20.000          -0.              FIXED         FIXED         FIXED
  40        24.000         20.000         10.000          -0.              FIXED         FIXED         FIXED
  41        36.000         20.000         10.000          -0.              FIXED         FIXED         FIXED
  42        46.000         20.000         10.000          -0.              FIXED         FIXED         FIXED
  43        36.000         30.000          0.             -0.              FIXED         FIXED         FIXED
  44        46.000         30.000          0.             -0.              FIXED         FIXED         FIXED
```

```
*** EARTHQUAKE RECORD ***


** EXAMPLE  EARTHQUAKE **    0.04 SEC    64 POINTS

  INPUT ACCEL. PRIOR TO SCALING

   MAX. ACC. =      .0500 (G)  AT TIME =     .9600 SEC.

        .000204 -.000191  .000058  .001460  .004111  .004390  .039534 -.003481        1
        .013073  .009455  .000374  .018791 -.022305 -.018976 -.011557 -.048139        2
        .013707 -.029759  .011100 -.025240  .015560 -.013417  .023272 -.013397        3
        .050000  .000068  .012727  .006808  .010056  .010332  .006599 -.001122        4
        .008954 -.020449  .015687 -.005003 -.017561  .003863 -.010918 -.008641        5
       -.008450 -.013743  .001941 -.000952  .000968 -.001998  .010888  .008075        6
        .009841  .003844 -.005115  .001176 -.003725 -.006514  .001117 -.000450        7
        .000281 -.000221  .000197 -.000188  .000185 -.000188  .000193 -.000200        8
       0.       0.       0.       0.       0.       0.       0.       0.                9
       0.       0.       0.       0.       0.       0.       0.       0.               10
       0.       0.       0.       0.       0.       0.       0.       0.               11
       0.       0.       0.       0.       0.       0.       0.       0.               12
       0.       0.       0.       0.       0.       0.       0.       0.               13
       0.       0.       0.       0.       0.       0.       0.       0.               14
       0.       0.       0.       0.       0.       0.       0.       0.               15
       0.       0.       0.       0.       0.       0.       0.       0.               16


TIME REQUIRED FOR INPUT AND INITIALIZATION =      .088    SEC



ELM     G-USED      G-NEW     DIF-G       DAMP-USED     DAMP-NEW   DIF-DAMP    VS-USED   VS-NEW    DIF-VS      MAX. S. STRAIN
        (KSF)      (KSF)    (PERCENT)    (FRACTION)   (FRACTION)  (PERCENT)   (FPS)     (FPS)    (PERCENT)       (PERCENT)

 1       671.       611.      9.8          .044          .047       -6.4        443.      423.       4.8            .01461
 2       716.       682.      5.0          .042          .043       -4.0        458.      447.       2.5            .01049
 3       692.       677.      2.3          .043          .044       -1.8        450.      445.       1.1            .01075
 4       800.       763.      4.8          .037          .039       -4.7        484.      473.       2.4            .00721
 5       577.       546.      5.7          .049          .052       -5.0        411.      400.       2.8            .02070
 6       570.       555.      2.7          .050          .051       -2.5        409.      403.       1.4            .01972
 7       584.       573.      1.9          .049          .050       -1.9        414.      410.       1.0            .01784
 8       610.       598.      2.1          .047          .048       -1.5        423.      418.       1.0            .01557
 9       590.       580.      1.7          .048          .049       -1.7        416.      412.        .8            .01715
10      1125.      1075.      4.6          .043          .047       -9.9        549.      537.       2.3            .01019
11      1055.      1030.      2.5          .049          .052       -4.7        532.      525.       1.2            .01251
12      1050.      1039.      1.1          .050          .051       -2.0        531.      528.        .5            .01200
13      1161.      1129.      2.9          .039          .042       -7.2        558.      550.       1.4            .00800
14      1021.       998.      2.3          .053          .055       -3.9        523.      518.       1.1            .01443
15       996.       985.      1.1          .055          .056       -1.8        517.      514.        .5            .01529
16      1007.       996.      1.1          .054          .055       -2.0        520.      517.        .6            .01458
17      1043.      1035.       .8          .050          .051       -1.5        529.      527.        .4            .01224
18      1008.       999.       .9          .054          .055       -1.5        520.      518.        .4            .01435
19      1001.       969.      3.4          .054          .058       -6.5        518.      513.       1.7            .01627
20      1000.       986.      1.5          .054          .056       -2.5        518.      514.        .8            .01528
21      1002.       989.      1.3          .054          .055       -2.2        519.      515.        .7            .01501
22      1096.      1089.       .6          .045          .046       -1.4        542.      541.        .3            .00957
23      1063.      1056.       .7          .049          .049       -1.4        534.      532.        .3            .01113
24      1122.      1116.       .6          .043          .044       -1.5        549.      547.        .3            .00849
25      1096.      1089.       .6          .045          .046       -1.4        542.      541.        .3            .00958

*** MAX. SHEAR STRAIN COMPUTATION IN FREQ DOMAIN


TIME REQUIRED FOR COMPUTING STRESS AND STRAIN =     .452     SEC
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***  PLOT OF FOURIER AMPLITUDE OF ACCELERATION

X-ACC. FOURIER SPECTRUM AT NODAL POINT        1,  100 PER CENT CORRESPONDS TO          .0303   G

            0         10        20        30        40        50        60        70        80        90        100 PER CENT
            +         +         +         +         +         +         +         +         +         +         +

        0.  1++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++    .1573E-15
     .1953  1                                                                                                   +    .3360E-02
     .3906  + 1                                                                                                 +    .2368E-01
     .5859  +      1                                                                                            +    .6886E-01
     .7813  +             1                                                                                     +    .1443E+00
     .9766  +                      1                                                                            +    .2343E+00
    1.1719  +                           1                                                                       +    .2841E+00
    1.3672  +                       1                                                                           +    .2416E+00
    1.5625  +           1                                                                                       +    .1240E+00
    1.7578  +         1                                                                                         +    .1014E+00
    1.9531  +              1                                                                                    +    .1523E+00
    2.1484  +          1                                                                                        +    .1115E+00
    2.3438  +1                                                                                                  +    .1260E-01
    2.5391  +      1                                                                                            +    .7073E-01
    2.7344  +       1                                                                                           +    .7950E-01
    2.9297  +   1                                                                                               +    .3761E-01
    3.1250  +       1                                                                                           +    .7543E-01
    3.3203  +          1                                                                                        +    .1095E+00
    3.5156  +        1                                                                                          +    .9126E-01
    3.7109  +         1                                                                                         +    .1006E+00
    3.9062  +               1                                                                                   +    .1557E+00
    4.1016  +               1                                                                                   +    .1593E+00
    4.2969  +         1                                                                                         +    .9924E-01
    4.4922  +  1                                                                                                +    .2995E-01
    4.6875  + 1                                                                                                 +    .2433E-01
    4.8828  +1                                                                                                  +    .9918E-02
    5.0781  +       1                                                                                           +    .8163E-01
    5.2734  +                 1                                                                                 +    .1773E+00
    5.4687  +                        1                                                                          +    .2522E+00
    5.6641  +                            1                                                                      +    .2922E+00
    5.8594  +                             1                                                                     +    .2952E+00
    6.0547  +                   1                                                                               +    .2015E+00
    6.2500  +        1                                                                                          +    .8960E-01
    6.4453  +                                               1                                                   +    .4841E+00
    6.6406  +                                                                                  1                +    .8327E+00
    6.8359  +                                                                                         1         +    .8972E+00
    7.0312  +                                                                                       1           +    .8825E+00
    7.2266  +                                                                                      1            +    .8686E+00
    7.4219  +                                                                          1                        +    .7501E+00
    7.6172  +                                                   1                                               +    .5239E+00
    7.8125  +                            1                                                                      +    .2915E+00
    8.0078  +             1                                                                                     +    .1362E+00
    8.2031  +      1                                                                                            +    .7464E-01
    8.3984  +                            1                                                                      +    .2917E+00
    8.5937  +                                       1                                                           +    .4039E+00
    8.7891  +                        1                                                                          +    .2542E+00
    8.9844  +           1                                                                                       +    .1220E+00
    9.1797  +                                                  1                                                +    .5128E+00
    9.3750  +                                                                        1                          +    .7324E+00
    9.5703  +                                                                              1                    +    .7903E+00
    9.7656  +                                                                            1                      +    .7700E+00
    9.9609  +                                                          1                                        +    .5932E+00
   10.1563  +                   1                                                                               +    .2039E+00
   10.3516  +                           1                                                                       +    .2827E+00
   10.5469  +                                                           1                                       +    .5954E+00
   10.7422  +                                                               1                                   +    .6385E+00
   10.9375  +                                                      1                                            +    .5488E+00
   11.1328  +                                                             1                                     +    .6167E+00
   11.3281  +                                                                               1                   +    .8031E+00
   11.5234  ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++1    .1000E+01
            +         +         +         +         +         +         +         +         +         +         +
      *
     ***
    *****
      *
     ******    FREQ. IN HZ
```

```
EXAMPLE PROBLEM FOR TLUSH
X-COMPONENT OF MOTION AT NODAL POINT        1
MAXIMUM ACCELERATION =  .2884
TIME INTERVAL =   .0400 SEC.

DAMPING RATIO = .05

    TIMES AT WHICH MAX. SPECTRAL VALUES OCCUR
         TD = TIME FOR MAX. RELATIVE DISP.
         TV = TIME FOR MAX. RELATIVE VEL.
         TA = TIME FOR MAX. ABSOLUTE ACC.

    PER = 2.5000     TIMES FOR MAXIMA --   TD =   .9600   TV =   .7600   TA =   .9600
    PER = 2.2281     TIMES FOR MAXIMA --   TD =   .9600   TV =  1.2800   TA =   .9600
    PER = 1.9858     TIMES FOR MAXIMA --   TD =   .9600   TV =  1.2800   TA =   .9600
    PER = 1.7699     TIMES FOR MAXIMA --   TD =   .9500   TV =  1.2800   TA =   .9600
    PER = 1.5774     TIMES FOR MAXIMA --   TD =  1.5600   TV =  1.1600   TA =  1.4400
    PER = 1.4059     TIMES FOR MAXIMA --   TD =  1.4400   TV =  1.1600   TA =  1.4400
    PER = 1.2530     TIMES FOR MAXIMA --   TD =  1.4400   TV =  1.6400   TA =  1.4400
    PER = 1.1167     TIMES FOR MAXIMA --   TD =  1.8400   TV =  1.6400   TA =  1.8400
    PER =  .9953     TIMES FOR MAXIMA --   TD =  1.8000   TV =  1.4800   TA =  1.7600
    PER =  .8870     TIMES FOR MAXIMA --   TD =  1.6800   TV =  1.8800   TA =  1.6800
    PER =  .7906     TIMES FOR MAXIMA --   TD =  2.0000   TV =  1.0000   TA =  1.1600
    PER =  .7046     TIMES FOR MAXIMA --   TD =  1.1200   TV =  1.0000   TA =  1.1200
    PER =  .6280     TIMES FOR MAXIMA --   TD =  1.0400   TV =  1.2400   TA =  1.0400
    PER =  .5597     TIMES FOR MAXIMA --   TD =  1.0400   TV =  1.0800   TA =  1.0000
    PER =  .4988     TIMES FOR MAXIMA --   TD =   .6400   TV =  1.0800   TA =   .6400
    PER =  .4446     TIMES FOR MAXIMA --   TD =   .6400   TV =   .7200   TA =   .6400
    PER =  .3962     TIMES FOR MAXIMA --   TD =   .6400   TV =   .7200   TA =   .6400
    PER =  .3531     TIMES FOR MAXIMA --   TD =   .6400   TV =  1.0000   TA =   .6400
    PER =  .3147     TIMES FOR MAXIMA --   TD =  1.0400   TV =  1.0000   TA =  1.0400
    PER =  .2805     TIMES FOR MAXIMA --   TD =  1.0400   TV =  1.0800   TA =  1.0000
    PER =  .2500     TIMES FOR MAXIMA --   TD =  1.2000   TV =  1.1500   TA =  1.2000
    PER =  .2228     TIMES FOR MAXIMA --   TD =   .5600   TV =  1.2400   TA =   .5600
    PER =  .1986     TIMES FOR MAXIMA --   TD =  1.2000   TV =  1.2400   TA =  1.2000
    PER =  .1770     TIMES FOR MAXIMA --   TD =  1.2400   TV =  1.2800   TA =  1.2400
    PER =  .1577     TIMES FOR MAXIMA --   TD =  1.3200   TV =  1.2800   TA =  1.2400
    PER =  .1406     TIMES FOR MAXIMA --   TD =  1.5600   TV =  1.6000   TA =  1.5600
    PER =  .1253     TIMES FOR MAXIMA --   TD =  1.1200   TV =  1.1600   TA =  1.1200
    PER =  .1117     TIMES FOR MAXIMA --   TD =  1.1200   TV =   .5600   TA =  1.1200
    PER =  .0995     TIMES FOR MAXIMA --   TD =   .6800   TV =   .6000   TA =   .7200
    PER =  .0887     TIMES FOR MAXIMA --   TD =  1.2800   TV =  1.0800   TA =  1.2800
    PER =  .0791     TIMES FOR MAXIMA --   TD =  1.0400   TV =   .4800   TA =  1.0400
    PER =  .0705     TIMES FOR MAXIMA --   TD =  1.2000   TV =   .6400   TA =   .7600
    PER =  .0628     TIMES FOR MAXIMA --   TD =   .6400   TV =  1.0800   TA =   .6400
    PER =  .0560     TIMES FOR MAXIMA --   TD =  1.0800   TV =  1.5200   TA =  1.0800
    PER =  .0499     TIMES FOR MAXIMA --   TD =  1.0400   TV =  1.0400   TA =  1.0400
    PER =  .0445     TIMES FOR MAXIMA --   TD =  1.0400   TV =  1.0400   TA =  1.0400
    PER =  .0396     TIMES FOR MAXIMA --   TD =  1.0400   TV =  1.0400   TA =  1.0400
    PER =  .0353     TIMES FOR MAXIMA --   TD =  1.0400   TV =  1.0400   TA =  1.0400
    PER =  .0315     TIMES FOR MAXIMA --   TD =  1.0400   TV =  1.0400   TA =  1.0400
    PER =  .0281     TIMES FOR MAXIMA --   TD =  1.0400   TV =  1.0800   TA =  1.0400
    PER =  .0250     TIMES FOR MAXIMA --   TD =  1.0400   TV =  1.0800   TA =  1.0400
```

```
SPECTRAL VALUES
DAMPING RATIO = .050

   NO.    PERIOD      REL. DISP.      REL. VEL.    PSU.REL.VEL.      ABS. ACC.  PSU.ABS.ACC.    FREQ.
           (SEC)        (FT)          (FT/SEC)     (FT/SEC)          (G/S)        (G/S)         (HZ)

     1    2.5000        .04483         .23270         .11266         .00926        .00879       .4000
     2    2.2281        .04719         .24548         .13307         .01210        .01165       .4488
     3    1.9858        .04937         .27277         .15621         .01570        .01535       .5036
     4    1.7699        .05104         .30166         .18118         .02012        .01998       .5650
     5    1.5774        .05447         .33476         .21697         .02764        .02684       .6340
     6    1.4059        .06244         .37859         .27905         .04020        .03873       .7113
     7    1.2530        .06689         .42458         .33541         .05225        .05223       .7981
     8    1.1167        .07125         .48912         .40090         .07106        .07005       .8955
     9     .9953        .07244         .48134         .45733         .08952        .08966      1.0048
    10     .8870        .06931         .54892         .49093         .10817        .10800      1.1274
    11     .7906        .05588         .50806         .44410         .10997        .10961      1.2649
    12     .7046        .04445         .43642         .39640         .11010        .10978      1.4193
    13     .6280        .04121         .38724         .41233         .12881        .12812      1.5924
    14     .5597        .03068         .30630         .34439         .11723        .12007      1.7867
    15     .4988        .02106         .30086         .26527         .10688        .10377      2.0047
    16     .4446        .01791         .19697         .25311         .11212        .11110      2.2494
    17     .3962        .01436         .19366         .22774         .11107        .11216      2.5238
    18     .3531        .01105         .22465         .19662         .10549        .10865      2.8318
    19     .3147        .01248         .24778         .24911         .15118        .15444      3.1773
    20     .2805        .00998         .30136         .22353         .15463        .15549      3.5650
    21     .2500        .00908         .24915         .22816         .17642        .17809      4.0000
    22     .2228        .00652         .20412         .18372         .15554        .16089      4.4881
    23     .1986        .00666         .24195         .21072         .19281        .20706      5.0357
    24     .1770        .00905         .36878         .32120         .37902        .35412      5.6502
    25     .1577        .01350         .56752         .53783         .64011        .65531      6.3396
    26     .1406        .01444         .64357         .64552         .91197        .89596      7.1131
    27     .1253        .00888         .38144         .44512         .70423        .69320      7.9810
    28     .1117        .00749         .31623         .42151         .73998        .73654      8.9549
    29     .0995        .00578         .35238         .36498         .72526        .71556     10.0475
    30     .0887        .00386         .29290         .27341         .59121        .60146     11.2735
    31     .0791        .00132         .23861         .10478         .25257        .25862     12.6491
    32     .0705        .00171         .17589         .15278         .43702        .42309     14.1925
    33     .0628        .00141         .09919         .14153         .45446        .43978     15.9243
    34     .0560        .00104         .05693         .11656         .41955        .40639     17.8673
    35     .0499        .00074         .01727         .09336         .37196        .36520     20.0475
    36     .0445        .00052         .00552         .07314         .32346        .32103     22.4937
    37     .0396        .00036         .00299         .05777         .28597        .28450     25.2383
    38     .0353        .00026         .00450         .04554         .25415        .25166     28.3178
    39     .0315        .00020         .01177         .04030         .25715        .24985     31.7731
    40     .0281        .00019         .01705         .04190         .29727        .29147     35.6500
    41     .0250        .00014         .01301         .03564         .28350        .27820     40.0000
```

```
RESPONSE SPECTRUM ANALYSIS FOR EXAMPLE PROBLEM FOR TLUSH
 X-COMPONENT OF MOTION AT NODAL POINT          1
 ABSOLUTE SPECTRAL ACCELERATIONS (G)

 CURVE 1 IS FOR .050 DAMPING  AMAX=  .912  AT FRQ= 7.113
                                                                                   100 PER CENT CORRESPONDS TO  2.0000

             0        10        20        30        40        50        60        70        80        90        100 PER CENT
             +         +         +         +         +         +         +         +         +         +         +

    .4000    1++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
    .4488    +1                                                                                                  +
    .5036    +1                                                                                                  +
    .5650    +1                                                                                                  +
    .6340    +1                                                                                                  +
    .7113    + 1                                                                                                 +
    .7981    +  1                                                                                                +
    .8955    +   1                                                                                               +
   1.0048    +   1                                                                                               +
   1.1274    +    1                                                                                              +
   1.2649    +    1                                                                                              +
   1.4193    +     1                                                                                             +
   1.5924    +     1                                                                                             +
   1.7867    +     1                                                                                             +
   2.0047    +    1                                                                                              +
   2.2494    +     1                                                                                             +
   2.5238    +     1                                                                                             +
   2.8318    +    1                                                                                              +
   3.1773    +       1                                                                                           +
   3.5650    +       1                                                                                           +
   4.0000    +        1                                                                                          +
   4.4881    +       1                                                                                           +
   5.0357    +         1                                                                                         +
   5.6502    +                  1                                                                                +
   6.3396    +                               1                                                                   +
   7.1131    +                                             1                                                     +
   7.9810    +                                  1                                                                +
   8.9549    +                                    1                                                              +
  10.0475    +                                   1                                                               +
  11.2735    +                             1                                                                     +
  12.6491    +            1                                                                                      +
  14.1925    +                     1                                                                             +
  15.9243    +                      1                                                                            +
  17.8673    +                    1                                                                              +
  20.0475    +                  1                                                                                +
  22.4937    +               1                                                                                   +
  25.2383    +             1                                                                                     +
  28.3178    +            1                                                                                      +
  31.7731    +            1                                                                                      +
  35.6500    +              1                                                                                    +
  40.0000    ++++++++++++++1++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
             +         +         +         +         +         +         +         +         +         +         +
     *
    ***
   *****
     *
     ******   CYCLES PER SEC.
```

```
RESPONSE SPECTRUM ANALYSIS FOR EXAMPLE PROBLEM FOR TLUSH
  X-COMPONENT OF MOTION AT NODAL POINT          1
 RELATIVE SPECTRAL VELOCITY (FT/SEC)

 CURVE 1 IS FOR .050 DAMPING  AMAX=  .644  AT FRQ= 7.113
                                                                                   100 PER CENT CORRESPONDS TO    2.0000

             0         10        20        30        40        50        60        70        80        90        100 PER CENT
             +         +         +         +         +         +         +         +         +         +         +

     .4000   ++++++++++++1++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
     .4488   +           1                                                                                       +
     .5036   +             1                                                                                     +
     .5650   +              1                                                                                    +
     .6340   +                1                                                                                  +
     .7113   +                  1                                                                                +
     .7981   +                    1                                                                              +
     .8955   +                       1                                                                           +
    1.0048   +                       1                                                                           +
    1.1274   +                          1                                                                        +
    1.2649   +                        1                                                                          +
    1.4193   +                     1                                                                             +
    1.5924   +                  1                                                                                +
    1.7867   +              1                                                                                    +
    2.0047   +              1                                                                                    +
    2.2494   +         1                                                                                         +
    2.5238   +         1                                                                                         +
    2.8318   +          1                                                                                        +
    3.1773   +           1                                                                                       +
    3.5650   +              1                                                                                    +
    4.0000   +           1                                                                                       +
    4.4881   +         1                                                                                         +
    5.0357   +           1                                                                                       +
    5.6502   +                 1                                                                                 +
    6.3396   +                           1                                                                       +
    7.1131   +                               1                                                                   +
    7.9810   +                  1                                                                                +
    8.9549   +               1                                                                                   +
   10.0475   +                 1                                                                                 +
   11.2735   +              1                                                                                    +
   12.6491   +           1                                                                                       +
   14.1925   +        1                                                                                          +
   15.9243   +    1                                                                                              +
   17.8673   +  1                                                                                                +
   20.0475   +1                                                                                                  +
   22.4937   1                                                                                                   +
   25.2383   1                                                                                                   +
   28.3178   1                                                                                                   +
   31.7731   +1                                                                                                  +
   35.6500   +1                                                                                                  +
   40.0000   +1+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
             +         +         +         +         +         +         +         +         +         +         +
      *
     ***
    *****
      *
      ******   CYCLES PER SEC.


       MAXIMUM ABSOLUTE ACCELERATIONS(G)

     ITERATION NO.  1           MAX. INPUT BASE ACC.  =     .0728 (G) IN X DIRECTION
                                MAX. INPUT BASE ACC.  =    0.      (G) IN Y DIRECTION
                                MAX. INPUT BASE ACC.  =    0.      (G) IN Z DIRECTION

           N.P.    XORD     YORD     ZORD        X-ACC     AT TIME       Y-ACC     AT TIME       Z-ACC     AT TIME

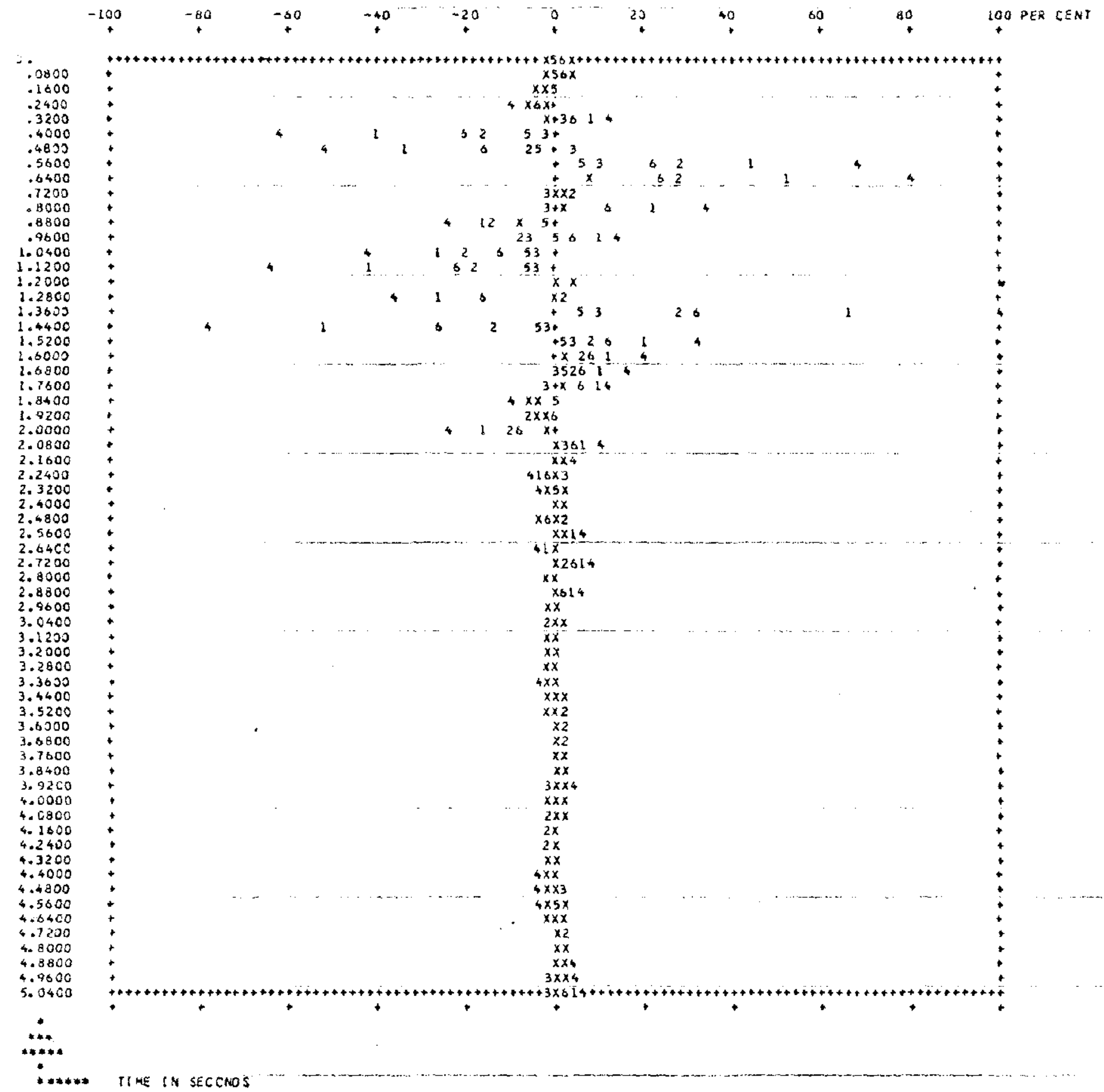
             1    46.00    30.00    40.00        .2884     1.0800       0.          .9600      0.           .9600


   TIME REQUIRED FOR COMPUTATION AND OUTPUT OF ACCELERATIONS AT      1   DEG. OF FDM. =     .134    SEC
```

```
*** PLOT OF STRESS TIME HISTORY AT ELEMENT NO.   14 ***

  EVERY  2 TH PCINTS ARE PLOTTED
CURVE NO. 1 CORRESPCNDS TO SIG-X
   ''     2      ''        SIG-Y
   ''     3      ''        SIG-Z
   ''     4      ''        SIG-XY
   ''     5      ''        SIG-YZ
   ''     6      ''        SIG-ZX

                                                  100 PER CENT CORRESPCNDS TO  95.3839
```



```
TIME FOR OUTPUT OF STRESS HISTORIES =    .045    SEC
```

7. ACKNOWLEDGEMENTS

The computer program TLUSH is one of the results of a research program conducted at the Geotechnical Engineering division of the University of California, Berkeley by a group of faculty and graduate students for many years. The list of those who have contributed in some way to the development of the program is too long to mention herein. Special thanks are due to Freddie Tajirian for providing most of the interpolation routines and to J. C. Chen for helping in the initial stages of development. The financial support of the National Science Foundation through Grant No. PFR-7918267 and of the Department of Water Resources is greatly appreciated.

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