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J. Ghaboussi, S. U. Dikmen

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A new method of analysis is described for evaluation of seismic response and liquefaction of horizontally layered ground subjected to three components of earthquake base acceleration. Heretofore, only one component--the horizontal one with highest peak acceleration--was chosen for analysis. However, it is generally agreed that the potential for liquefaction under the simultaneous action of both horizontal earthquake components is often higher than the liquefaction potential under the strongest horizontal component of earthquake base acceleration. Accordingly, saturated sand below the water table was modeled as a two-phase medium, with the porous granular solid and pore water as constituent materials. A new material model was introduced for the behavior of sand under cyclic bi-axial shear stresses. Results of analyses indicate the following: (1) the vertical component of base acceleration has minimal influence on the development and pattern of liquefaction, (2) interaction between the two horizontal components of shaking significantly influences the development and pattern of liquefaction, (3) increasing the amplitude of base acceleration in a one-directional analysis does not completely reproduce the major effects present in a two-dimensional analysis, and (4) interaction between the two horizontal components of shaking produces surface response spectra somewhat different from that of one-dimensional analysis.

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LASS-III, COMPUTER PROGRAM FOR
SEISMIC RESPONSE AND LIQUEFACTION
OF LAYERED GROUND UNDER MULTI-DIRECTIONAL SHAKING

By

Jamshid Ghaboussi
S. Umit Dikmen

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LASS-III, COMPUTER PROGRAM FOR SEISMIC RESPONSE AND LIQUEFACTION OF LAYERED GROUND UNDER MULTI-DIRECTIONAL SHAKING

INTRODUCTION

In analysis of seismic response and liquefaction of level ground, usually one horizontal component of earthquake acceleration history is considered (1, 6, 10, 11). The horizontal component with the higher peak acceleration is chosen for the purpose of analysis. At the present, to the authors' knowledge, no method of analysis is available for computation of seismic response and liquefaction of level ground subjected to simultaneous action of the three components of earthquake base acceleration time histories. However, it is generally recognized that the potential for liquefaction under the simultaneous action of both horizontal components of earthquake is often higher than the liquefaction potential under the stronger horizontal component of earthquake base acceleration. This effect has been demonstrated experimentally, (12, 13). The surface response in a horizontally layered ground is the result of vertical propagation of two shear waves and one compression wave. The coupling and the interaction between the two horizontal components of earthquake and the influence of the vertical component may significantly influence the character of the surface response.

A new method of analysis is presented here for computation of the response and the liquefaction potential of horizontally layered ground subjected to three components of earthquake base acceleration. This study and the proposed method of analysis are the extensions of the method of analysis presented recently in Ref. (6), which only considered the response to one horizontal component.

METHOD OF ANALYSIS

Most of the theoretical background for this study can be found elsewhere (2, 3, 5, 6). The basic approach is similar to that of Ref. (6) except that more than one direction of shaking is considered. Only the main features of the method of analyis will be described in this section and some more details of the formulation can be found in the above references.

The saturated sand below the water table is modeled as a coupled two phase medium; the two phases are the porous deformable granular solid and the pore water. These two phases are coupled through volumetric strains. D'Arcy flow law is assumed to govern the flow of pore water through the porous elastic solid, with the material constant for this process being the coefficient of permeability. A nonlinear material model to be described in the next section specifies the stress-strain relationship for the granular solid portion.

A vertical column of the horizontally layered ground is divided into a number of layer elements. At each nodal plane, separating two adjacent layer elements, there are four displacement degrees of freedom. Three components of displacement of granular solid and the vertical displacement of pore water. The stress state for the solid portion within each layer element consists of two horizontal shear stresses and effective pressure. An incremental relationship is established between the increments of these stresses and the increments of corresponding strains.

MATERIAL MODEL FOR CYCLIC BI-AXIAL SHEAR

In the horizontally layered ground the state of stress consists of two shear stresses τ_x and τ_y and the effective pressure σ'. The material model for these stress components is a specialized version of the general material model for the cyclic behavior of sand presented in Refs. (4, 8).

In this material model failure is assumed to correspond to very large plastic shear strains. Thus a failure surface exists, which acts as an asymptotic state for all the shear stress paths. Shear strength is assumed to be isotropic with respect to shear stresses, i.e. the shear strength is independent of the direction of the resultant shear stress. Moreover, the shear strength is assumed to vary linearly with the effective pressure. These considerations imply that the failure surface is a circular cone in the stress space, as shown in Fig. 1a and given in the following equation.

$$F(\boldsymbol{\sigma}) = \tau_x^2 + \tau_y^2 - (M\,\sigma')^2 = 0 \tag{1}$$

in which M is the failure parameter. The cross-section of the failure surface on a plane of σ' = constant is a circle with the radius $M\,\sigma'$, as shown in Fig. 1b. This circular shape is the direct consequence of the isotropy of the shear strength as described earlier.

The yield surface is also assumed to have a conical shape but the axis of the yield surface does not coincide with the σ' axis. Moreover, the axis of the yield surface and its radius change during the process of deformation and the yield surface undergoes a combination of isotropic and kinematic hardening. The cross-section of the yield surface on a plane of σ' = constant is an ellipse, as shown in Fig. 1b. The equation for the yield surface is of the following form.

$$f\ (\tau,\ \tau_c,\ b) = 0$$

in which τ_c is the stress vector to the center of the ellipse and b is the half minor axis of the ellipse as shown in Fig. 2. The quantities τ_c and b define the kinematic and the isotropic hardening, respectively. A stress vector τ' can be defined as the difference between the stress vectors τ and τ_c (Fig. 2).

$$\tau' = \begin{Bmatrix} \tau'_x \\ \tau'_y \end{Bmatrix} = \begin{Bmatrix} \tau_x - \tau_{cx} \\ \tau_y - \tau_{cy} \end{Bmatrix} \tag{3}$$

The equation for the elliptic yield surface is written in terms of stress vector τ'

$$f = \tau'^{\,T} A^T A\, \tau' - 1 = 0 \tag{4}$$

in which $A = \begin{bmatrix} \frac{1}{a}\cos\alpha & \frac{1}{a}\sin\alpha \\ -\frac{1}{b}\sin\alpha & \frac{1}{b}\cos\alpha \end{bmatrix}$

and α is the angle between the axes τ_x and τ_x', as shown in Fig. 2.

The plastic strain increments are related to the stress increments by using the associated flow rule, which specifies that the vector of the incremental plastic shear strains is normal to the yield surface.

$$d\gamma^p = \frac{1}{h}\,(n^T\,d\tau)\;n \tag{5}$$

in which n is the unit outward normal vector to the yield surface

$$n = \frac{1}{\left[(\partial f/\partial\tau_x)^2 + (\partial f/\partial\tau_y)^2\right]^{1/2}} \begin{Bmatrix} \partial f/\partial\tau_x \\ \partial f/\partial\tau_y \end{Bmatrix} \tag{6}$$

It can be seen from Eq 5 that the function h is the ratio of $d\tau$ projected along the normal to yield surface and $d\gamma^p$.

$$h = \frac{(n^T d\tau)}{|\,d\gamma^p|} \tag{7}$$

Therefore, it is appropriate that h be called the "plastic modulus".

The isotropic and the kinematic hardening of the material is given by the following two equations

$$db = g\;|d\gamma^p| \tag{8}$$

$$d\tau_c = c\;d\gamma^p \tag{9}$$

where g and c are the isotropic and the kinematic hardening functions, respectively. The second equation above indicates that the change of the center of the elliptic yield surface, $d\tau_c$, is along the normal of the yield surface, n.

The material behavior is defined through the three functions h, c and g, which are related through the consistancy condition, df = 0.

$$df = \frac{\partial f}{\partial \tau} \, d\tau + \frac{\partial f}{\partial \tau_c} \, d\tau_c + \left(\frac{\partial f}{\partial b} + \frac{\partial f}{\partial a} \frac{\partial a}{\partial b} \right) db = 0 \tag{10}$$

substituting the Eqs 9, 10 and 5 into Eq 10, the following relation between the three material functions can be obtained.

$$h - c - \frac{1}{\beta} g = 0 \tag{11}$$

in which $\beta = b \left[(\partial f/\partial \tau_x)^2 + (\partial f/\partial \tau_y)^2 \right]^{1/2}$

It is only necessary to specify two of the above three functions. The third function will be evaluated from Eq 11.

The plastic modulus is determined from the uni-directional stress-strain relation. Here, it is assumed that the uni-directional stress-strain relationship is given by a hyperbolic function, as shown in Fig 3.

$$\frac{\tau}{\sigma'} = \frac{M H_0 \gamma^p}{M + H_0 \gamma^p} \tag{12}$$

in which H_0 is the "initial plastic modulus". Such a hyperbolic function was proposed by Kondner and Zelask (9) and has been used earlier (4). The plastic modulus function, h, is the slope of the stress-strain equation.

$$h = H_o \sigma' \left(1 - \frac{1}{M}\frac{\tau}{\sigma'}\right)^2 \tag{13}$$

in which $\tau = \left[\tau_x^2 + \tau_y^2\right]^{1/2}$

It can be seen that the initial value of h (for $\tau = 0$) is $H_o\ \sigma'$ and when the failure is reached ($\tau = M\sigma'$) h becomes zero.

Of the remaining two functions, the kinematic hardening function c is specified and the isotropic hardening function g is determined from Eq 11. The equation for $d\tau_c$ can be written in following form by substituting Eq 5 into Eq 9.

$$d\tau_c = \frac{c}{h}\,(n^T d\tau)\ n \tag{14}$$

It can be seen from this equation that $\frac{c}{h}$ is the ratio the length of $d\tau_c$ and projection of $d\tau$ along normal to yield surface, $n^T d\tau$. It has been experimentally observed (8, 14) in uni-directional tests that when the yielding occurs in one direction, the yield stress in the opposite direction remains unaffected. To satisfy such a condition, as seen from Fig 4, requires the following relation.

$$\frac{c}{h} = \frac{\left|d\tau_c\right|}{(n^T d\tau)} = \frac{1}{2} \tag{15}$$

$$c = \frac{1}{2}\,h \tag{16}$$

The function g can now be determined from Eq 11.

$$g = \frac{1}{2} \beta h \qquad (17)$$

Both the hardening functions are related to the plastic modulus function which is the slope of the stress-strain curve. Here, a hyperbolic stress-strain relation has been used. However, this is not an essential part of the proposed model and other similar stress-strain relations can also be used.

The incremental shear stress-shear strain relations can be derived by using standard methods in plasticity (15). For the proposed model the incremental relations are as follows,

$$\begin{Bmatrix} d\tau_x \\ d\tau_y \end{Bmatrix} = \frac{G^2}{(n_x - n_y)\, G + h} \begin{bmatrix} n_y^2 + \frac{h}{G} & -n_x n_y \\ -n_x n_y & n_x^2 + \frac{h}{G} \end{bmatrix} \begin{Bmatrix} d\gamma_x \\ d\gamma_y \end{Bmatrix} \qquad (18)$$

$$\begin{Bmatrix} d\tau_{xc} \\ d\tau_{yc} \end{Bmatrix} = \frac{1}{2} \begin{bmatrix} n_x^2 & n_x n_y \\ n_x n_y & n_y^2 \end{bmatrix} \begin{Bmatrix} d\tau_x \\ d\tau_y \end{Bmatrix} \qquad (19)$$

in which n_x and n_y are the components of the unit outward normal to the yield surface. It is interesting to note that in uni-direction ($n_x = 1$, $n_y = 0$)

the incremental stress-strain relation is as follows

$$d\tau_x = \left[1 \,/\, (1/h + 1/G) \right] d\gamma_x \tag{20}$$

The quantity in the square brackets is an equivalent modulus composed of an elastic and a plastic modulus. The equivalent modulus is a decreasing function of the resultant shear stress, approaching zero at failure shear stress.

Effective Stress-- The method of determination of effective stresses is the same as in Ref (6). Undrained condition is assumed at each instant when the effective stresses are determined. However, the dissipation of pore pressures do occur from one time step to the next, when the coupled equations of motion are solved. The undrained effective stress path, similar to Ref (6), is assumed to be a quarter of an ellipse, as shown in Fig 5. The equation for the effective stress path is as follows.

$$f_e = \tau_x^2 + \tau_y^2 + \lambda^2 \left[\sigma'^2 - \left(\frac{2\lambda}{\lambda + M} \right) \sigma' \sigma'_0 + \left(\frac{\lambda - M}{\lambda + M} \right) \sigma_0'^2 \right] = 0$$

The two parameters σ'_0 and λ completely define the effective stress path. The effective isotropic pressure σ'_0 defines the position of the effective stress path. The material parameter λ is the ratio of vertical to horizontal axis of the elliptic stress path. It has been shown in Ref (6) that the parameter λ can be correlated to relative density. This correlation is shown in Fig 6 for a number of experiments reported in the literature. In general λ increases with relative density.

The effective stress path is followed only during the elasto-plastic shear stress increments when yielding takes place. When the stress increments are purely elastic and fall within the yield surface, it is assumed that no changes in the effective stresses occur other than those caused by the dissipation of pore pressures.

LIQUEFACTION CRITERION

As is commonly used, the word liquefaction refers to a state of zero or residual effective stress in a region within the sand mass. Obviously, in a liquefied region of sand the pore pressure is equal to or slightly less than the total mean stress. The liquefied soil has very little shear resistance and capable of undergoing flow and large deformations.

The criterion for the onset of liquefaction can therefore be stated as the effective stresses reaching a specified residual value (ususally a small percentage of the initial effective stress). Upon liquefaction the modulus of sand in the liquefied region must be reduced to a fraction of its original value.

Prior to liquefaction, as the pore pressures are increasing, the stress state (shear stress and effective stress) reaches a condition of "near failure"; a point very close to the failure line. Such a stress state in a monotonic drained test would be considered failure stress. However, under cyclic stresses complete failure has not occured but the strain amplitudes start increasing. Clearly at such a state of "near failure" the effective stresses have not vanished and the sand cannot be considered as liquefied but under additional cycles of stress, the sand is well on its way towards liquefaction. This state of "near failure" will be refered to as "initial liquefaction"

The response of sand to cyclic stresses after initial liquefaction is different than that of prior to initial liquefaction. This change of material behavior is evidenced by an increase in the strain amptidude and a change in the effective stress path in any typical constant stress amplitude test, (8). A post initial liquefaction model is required to represent the behavior after the occurance of initial liquefaction. However, the mechanism of the behavior of sand after initial liquefaction is not clearly understood at the present. Of necessity, the simple stress path model proposed in Ref. (6) has been used in this study. It must also be emphasized that the post initial liquefaction model is not considered a very important aspect of the method of analysis. Complete liquefaction usually follows the initial liquefaction. The few seconds difference between the occurance of initial liquefaction and the onset of the complete liquefaction is a minor detail. However, it is important to recognize the existance of the state of initial liquefaction as a critical intermediate point on the path to complete liquefaction.

INFLUENCE OF VERTICAL COMPONENT OF BASE ACCELERATION

To study the influence of the vertical component of base acceleration on the liquefaction potential, a 100 ft layer with the material properties shown in Fig. 7 was subjected to the vertical component and one horizontal (S00E) component of the El Centro earthquake record of 1940. The same system was also analyzed for one horizontal component of the earthquake. The pore pressure time histories for two points at the depths of 17.5 ft and 22.5 ft below the ground surface are given in Fig. 8. The horizontal component of the earthquake alone causes liquefaction extending to a depth of 25 ft. However, when the vertical components is included, the liquefied zone extends to only 20 ft. It can also be seen from Fig. 8 that at the depth of 17.5 ft below ground surface for the horizontal component alone the liquefaction occurs at about 5 seconds but for horizontal and vertical components the liquefaction occurs at about seven seconds. It appears that the inclusion of the vertical component slightly reduces both the zone and the time of liquefaction. The major effect of the vertical component of the base acrelration is to cause oscillations in the pore pressure. However, the effective stresses remain unaffected from the oscillations in the pore pressure.

In the analysis shown in Fig. 8 the depth of the water table was at 2 ft below the ground surface. The same analysis was repeated for water table at 5 ft below the ground surface. The pore pressure time histories for this case are shown in Fig. 9. In this analysis no liquefaction occurred. The same trend as in the previous analysis can also be observed in absence of liquefaction. It can be seen from Fig. 9 that at 10 seconds the pore pressures are slightly higher for the horizontal component alone than when the vertical component is included.

Overall, the analysis results presented in this section seem to indicate that the influence of the vertical component of the earthquake on the pore pressures is minor, aside from causing some oscillation in the pore pressures. The development of liquefaction and potential for liquefaction are not significantly affected by the vertical component of the base acceleration.

INTERACTION OF TWO HORIZONTAL COMPONENTS OF BASE ACCELERATION

In this section the result of some analyses of horizontally layered ground subjected to both components of horizontal acceleration will be presented. The material model described in the previous section was used in these analyses. The main purpose of the analyses presented in this section is to compare the response of the horizontally layered ground under the simultaneous action of the two horizontal components of base acceleration with the response of the same system when it is subjected only to one component of horizontal base acceleration.

The hypothetical soil profile analyzed is shown in Fig. 7. The water table is 5 ft below the ground surface. The material properties are shown in Fig. 7. This soil profile was analyzed with the following base accelerations:

(a) S00E component of El Centro earthquake record of 1940 with peak acceleration of 0.314 g,

(b) S90W component of the same earthquake with peak acceleration of 0.214 g,

(c) Both components (a) and (b) applied simultaneously in a two directional analysis.

Some selected results of these analyses are shown in Figs. 10 through 13. Stress-strain diagrams at two depths are shown in Figs. 10 and 11. The extent of interaction between two horizontal components of shaking evident by comparing the stress-strain diagrams for the one directional analysis of cases (a) and (b) with those of the two-directional analysis of case (c). The trace of the resultant shear stress for the two directional analysis of case (c) at several depths is given in Fig. 12. It is interesting to note that at greater depths a reasonably well defined main direction is present. However, near the ground surface no obvious main direction for the shear stress resultant exists and the shear stress components in two directions are of the same magnitude. This effect is the direct result of the interaction between two directions of shaking.

The pore pressure time histories for the three analyses are shown in Fig. 13. No liquefaction occurs in one-directional analyses but extensive liquefaction occurs in the two-directional analysis. The time history of liquefaction is shown in Fig. 14. Also shown in this Fig. 14 are the time histories of liquefaction for one directional analyses with SOOE component of El Centro earthquake record but with the acceleration amplitudes increased by factors of 1.2 and 1.3 to peak accelerations of 1.2 x 0.314 g = 0.377 g and 1.3 x 0.314 g = 0.408 g. It is sometimes argued that the main effects of two-directional shaking can be reproduced in a one-directional analysis if the base acceleration amplitudes are increased such that the peak base acceleration equals the value of the resultant of the peak accelerations from two directions. In this case for the El Centro earthquake the resultant peak acceleration is,

$$[(0.314\ g)^2 + (0.214\ g)^2]^{1/2} = 0.380\ g\ .$$

It can be seen from Fig. 14 that in the two-directional analysis the liquefaction occurs much earlier and is much more extensive than those of the one directional analyses with the increased peak base accelerations. This is an indication that some important features of the interaction between the two horizontal components of shaking, which increase the liquefaction potential, cannot be reproduced in a one directional analysis. It can easily be concluded from the results presented here, that in some cases the one-directional analysis, even with the increased base acceleration amplitudes as discussed earlier, may indicate no liquefaction, whereas a two-directional analysis of the same system may indicate occurrence of liquefaction.

Additional information on the differences between the one-directional and two-directional analyses is evident in Figure 15 which shows the distribution of the pore pressure with depth at 4.5 seconds, prior to occurance of liquefaction in two-directional analysis. It can be seen in Figure 15 that the pore pressure from water table to a depth of about 35 ft below ground surface is much higher in two-directional analysis than in one-directional analysis of S00E component. The reverse occurs from 35 to about 55 ft below the ground surface. Below 55 ft from the ground surface the pore pressures are almost the same for two-directional and one-directional analyses. When the amplitude of the base acceleration in one-directional S00E component is increased by a factor of 1.2, it can be seen from Figure 15 that the pore pressures increase almost uniformly over the whole soil profile but still the pore pressure distribution is different than that of two-directional analysis; the pore pressures are still smaller than the pore pressures in the two-directional analysis to a depth of about 30 ft below the ground surface. Since increasing the amplitude of the base acceleration does not bring the pore pressure distribution any closer to that of the two-directional analysis, it can be expected that the liquefaction patterns of one-directional analysis with increased base acceleration and the two-directional analysis will be quite different.

The extent of the response interaction between the two components of the horizontal shaking can be evaluated by studying the ground surface response spectra. The ground surface response spectra were computed for the cases (a) through (c) described earlier, but the peak base accelerations were reduced to prevent occurrence of liquefaction. The peak base accelerations used in these analyses were 0.150 g in S00E direction and 0.102 g in S90W direction. The ground surface response spectra computed from one-directional analyses along with those of the two-directional analysis are shown in Fig. 16. The two-directional analysis gives surface response spectra which are generally similar to those resulting from one-dimensional analysis. However, some significant differences do exist. The two-directional analysis yields higher peak spectral accelerations in both directions. Moreover, the position of the peak spectral acceleration in S00E direction has shifted to lower frequency in two-directional analysis. The spectral velocity in the high frequency region is lower in S00E direction and higher in S90W direction than those of the one-directional analysis. In summary, the interaction between the two components of shaking produces some changes in the surface response spectra, as compared to one-directional analyses, without drastically affecting their overall shape.

CONCLUDING REMARKS

A method of analysis was presented for evaluation of seismic response and liquefaction of horizontally layered ground subjected to multi-directional shaking. The saturated sand below the water table was modeled as a two-phase medium, with the porous granular solid and the pore water as the constituent materials. A new material model was introduced for the behavior of sand under cyclic bi-axial shear stresses. A new computer program LASS-III was developed and used in a few sample case studies. The results of the analyses presented in this paper indicate the following.

(a) The vertical component of base acceleration has a very minor influence on the development and the pattern of liquefaction.

(b) Interaction between the two horizontal components of shaking significantly influences the development and the pattern of liquefaction. The potential for liquefaction can increase significantly when both the horizontal components of base acceleration are considered simultaneously.

(c) Increasing the amplitude of the base acceleration in a one-directional analysis, such that the peak base acceleration equals the resultant of the peak base accelerations in two-directions, does not completely reproduce the major effects present in a two-directional analysis.

(d) Interaction between the two horizontal components of shaking produces surface response spectra which are somewhat different than those of one-directional analysis.

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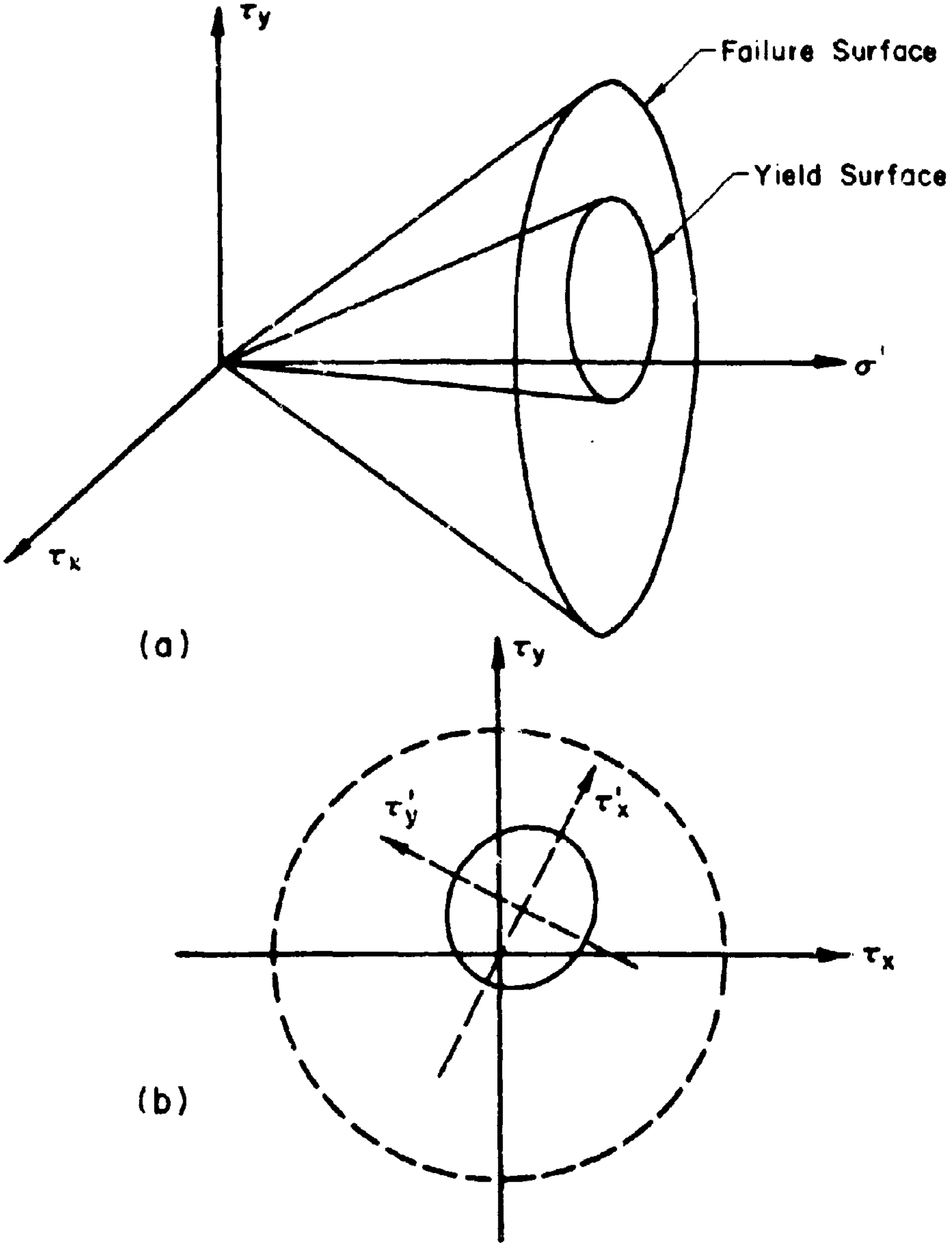


Figure 1 (a) Failure and yield surfaces, (b) Failure and yield surfaces in a plane of σ' = constant

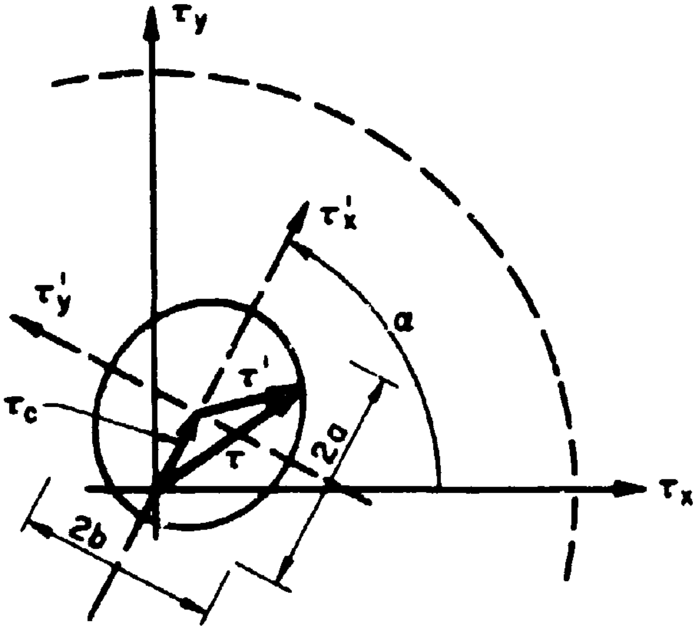


Figure 2 Elliptic yield surface in a plane of σ' = constant

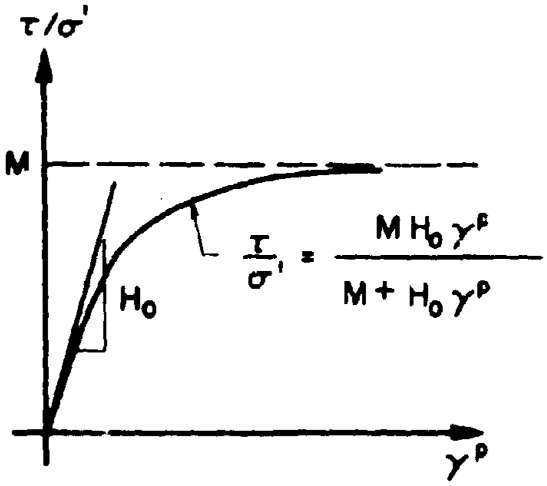


Figure 3 Generalized shear stress-strain curve

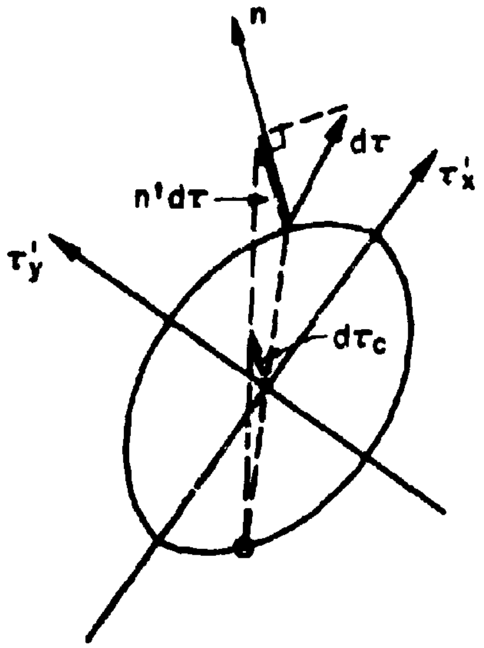


Figure 4 Determination of kinematic hardening

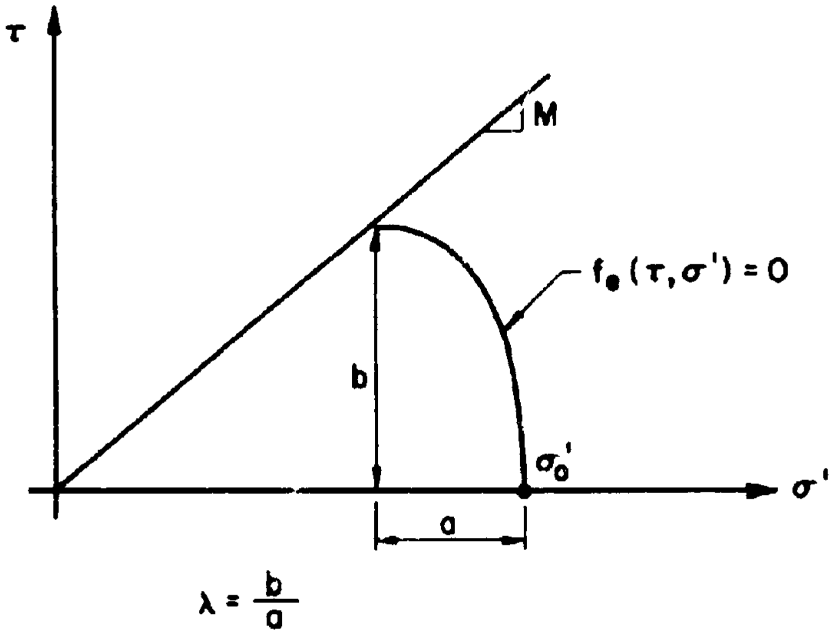


Figure 5 Effective stress path

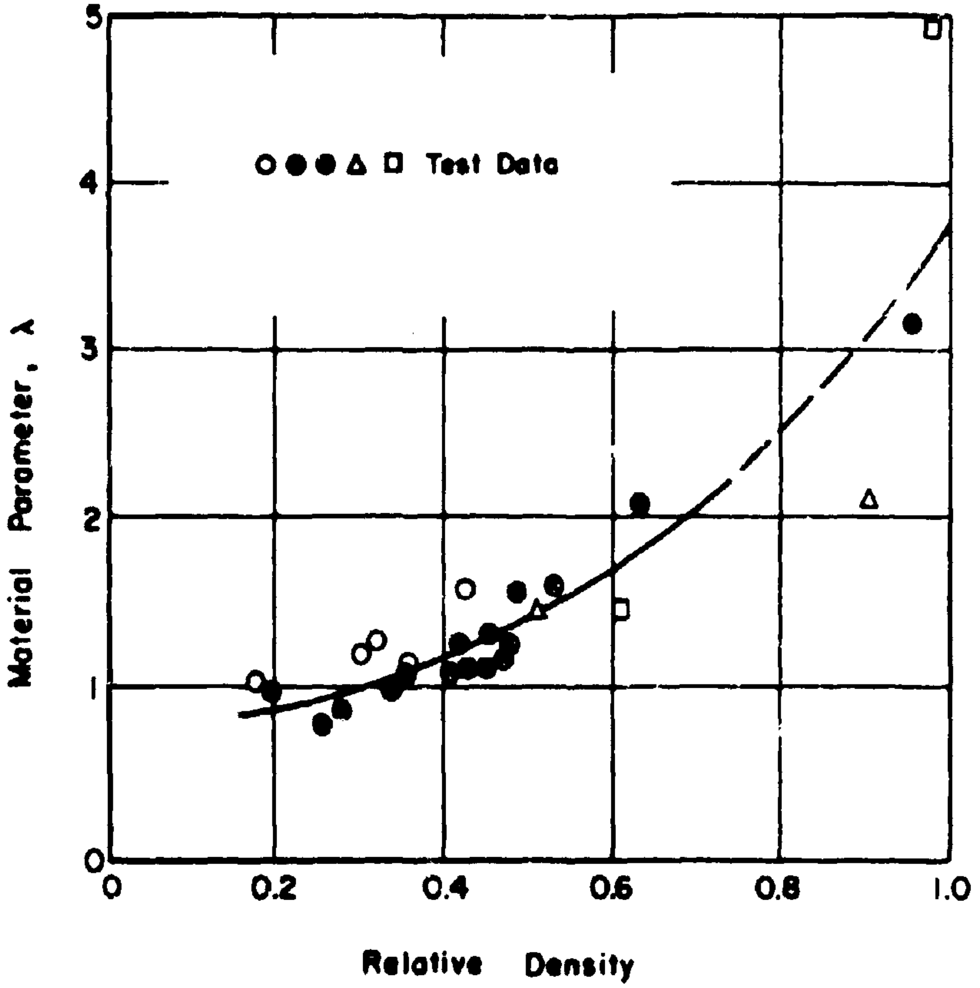


Figure 6 -Relationship Between Material Parameter λ and Relative Density, (Reference 6)

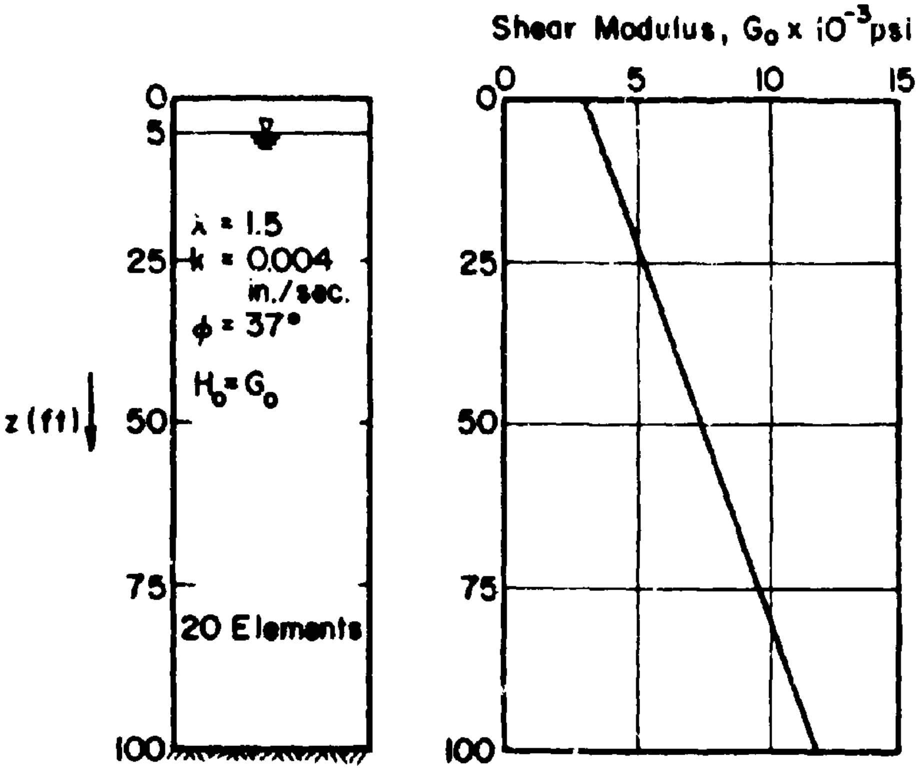


Figure 7 Soil profile used in the analyses

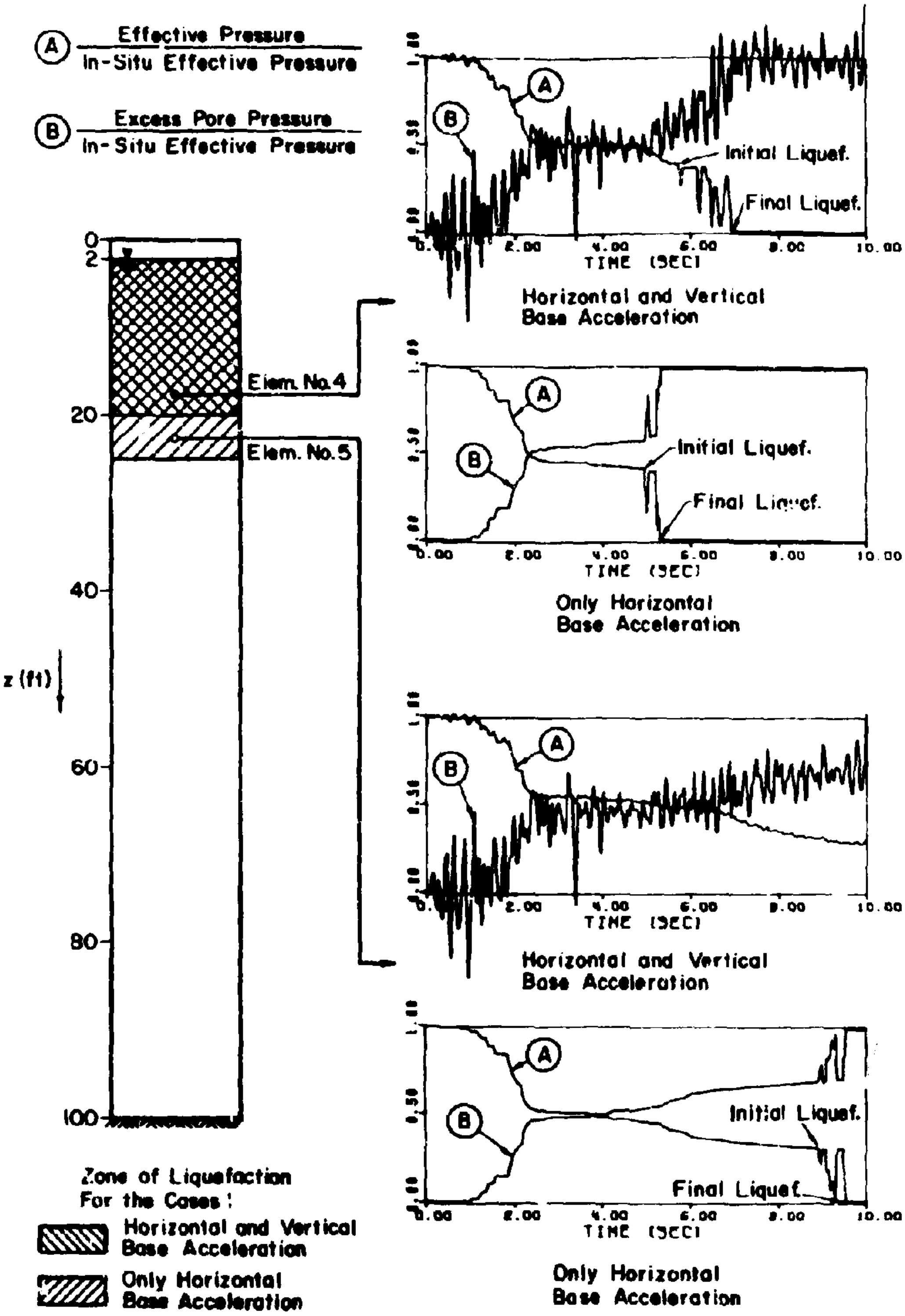


Figure 8 Influence of the vertical component of base acceleration on liquefaction

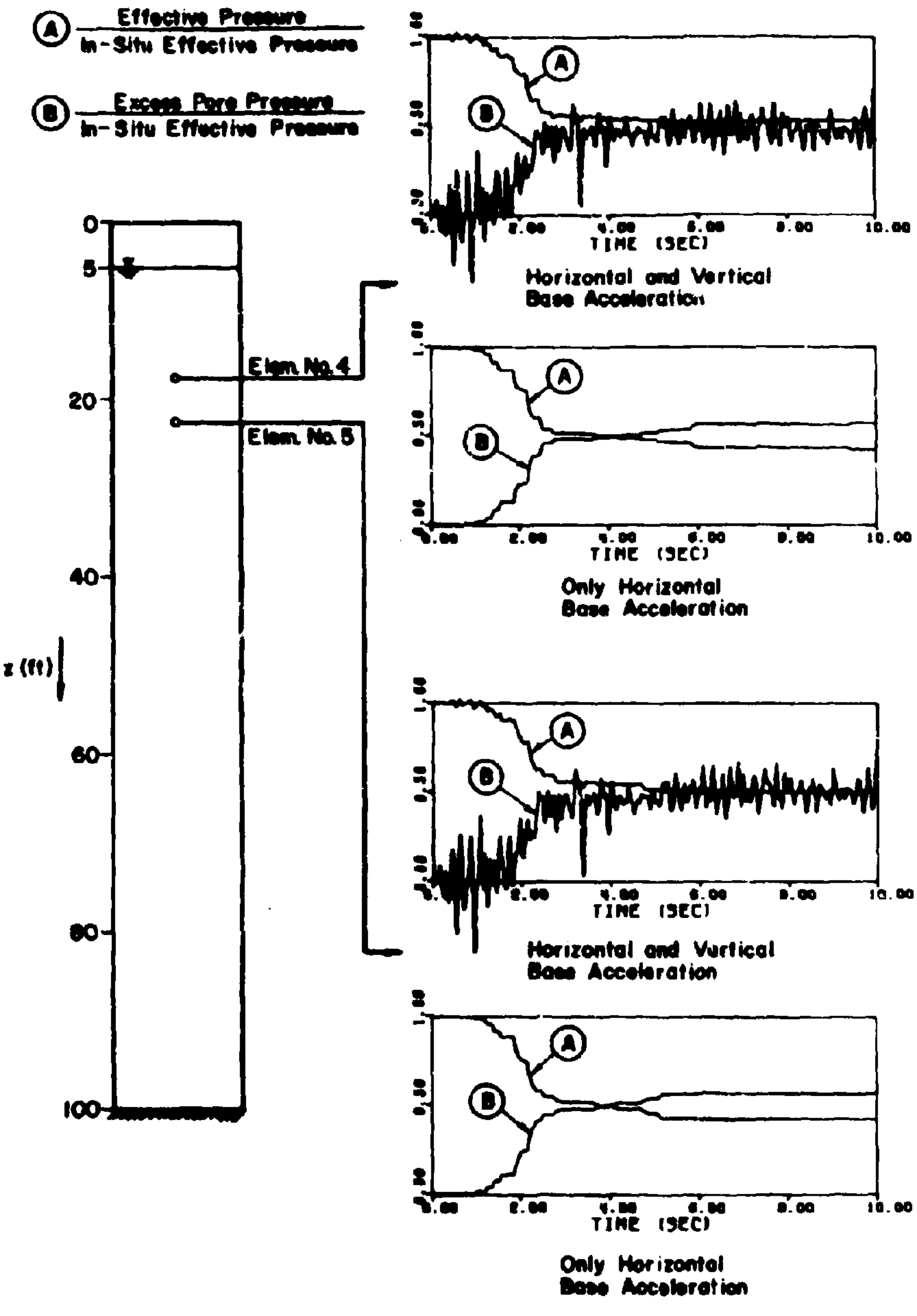


Figure 9 Influence of the vertical component of base motion on pore pressure increase

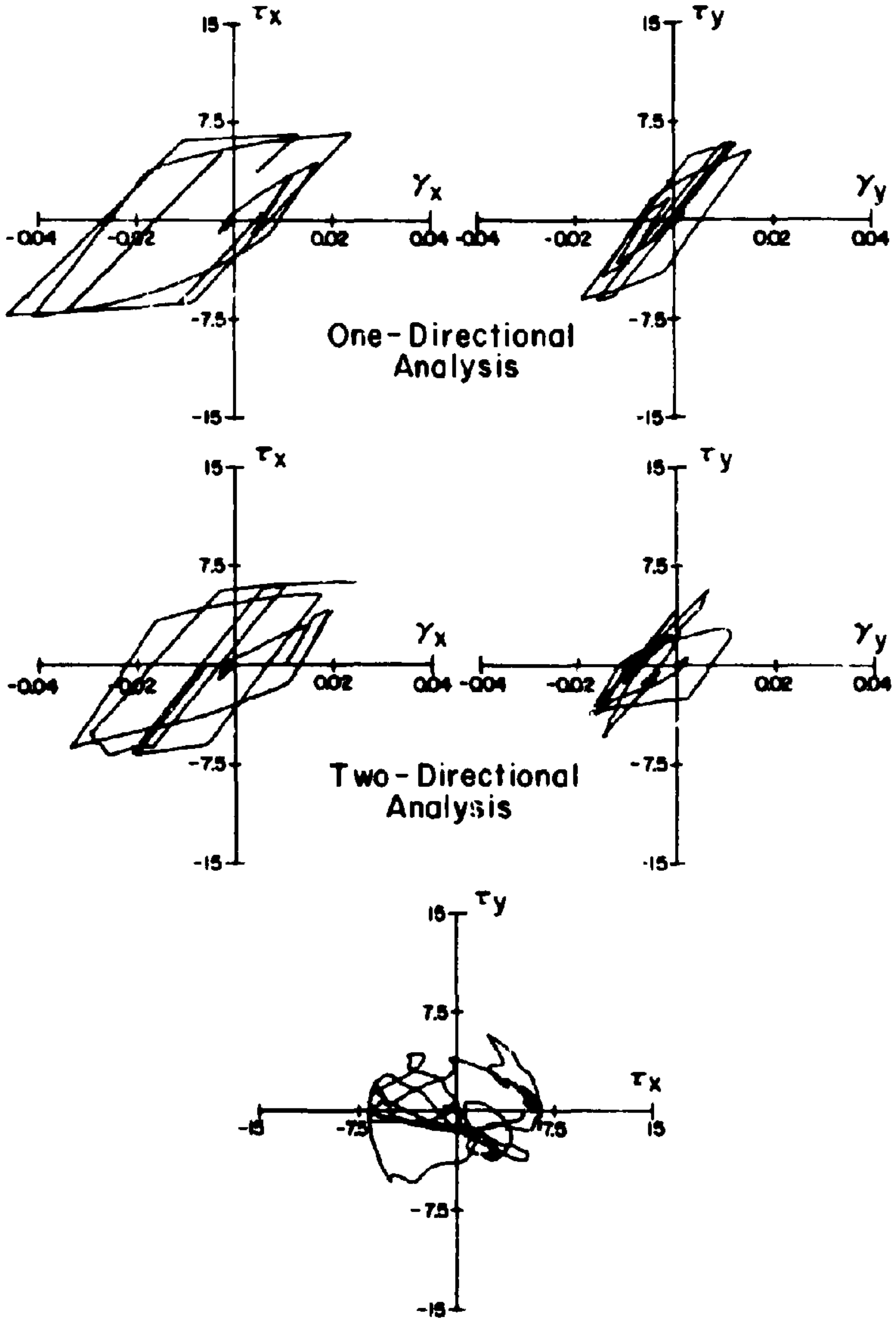


Figure 10 Comparison of stress-strain diagrams from one directional and two-directional analyses at a depth of 32.5 feet below ground surface.

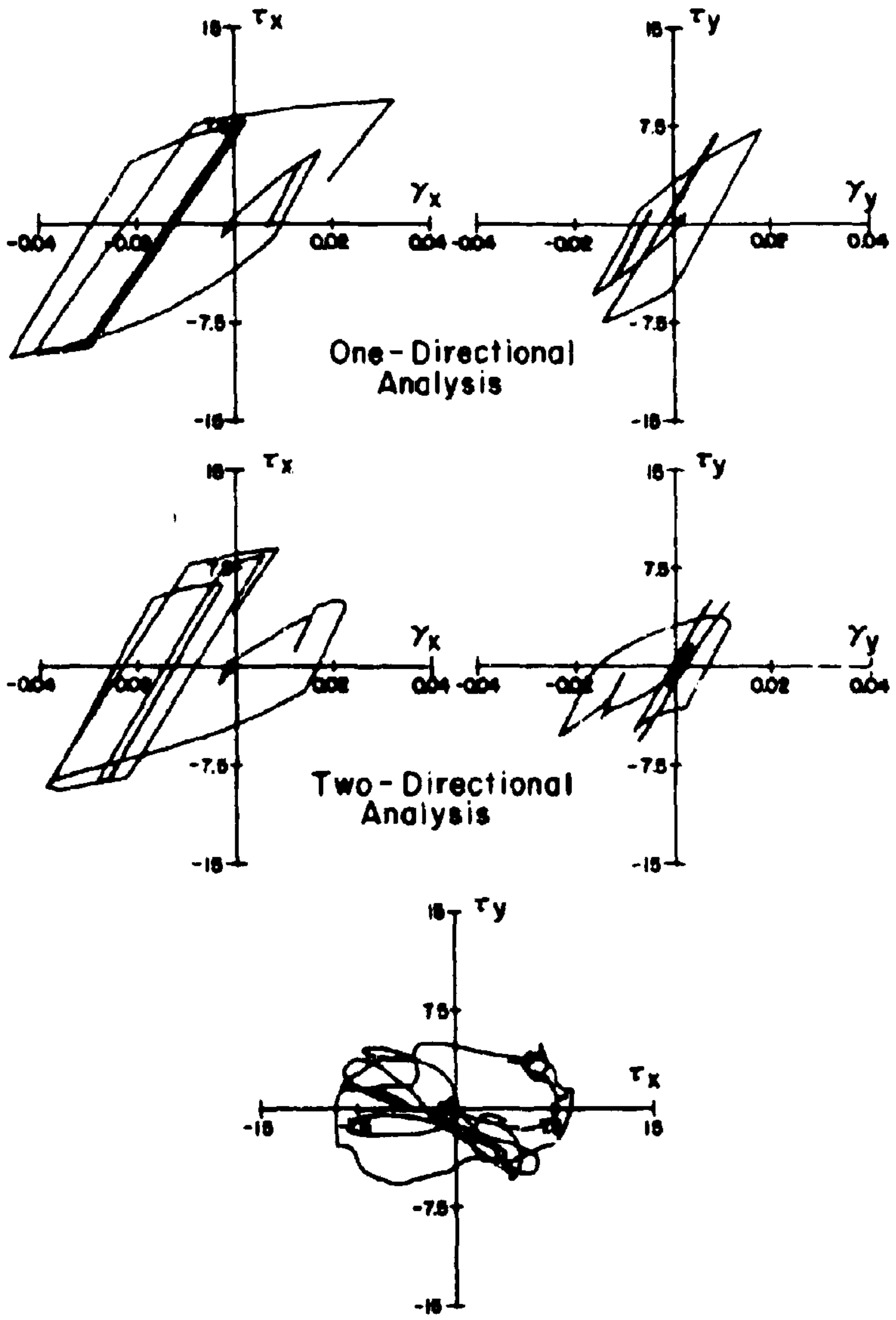


Figure 11 Comparison of stress-strain diagrams from one-directional and two-directional analyses at a depth of 47.5 feet below ground surface

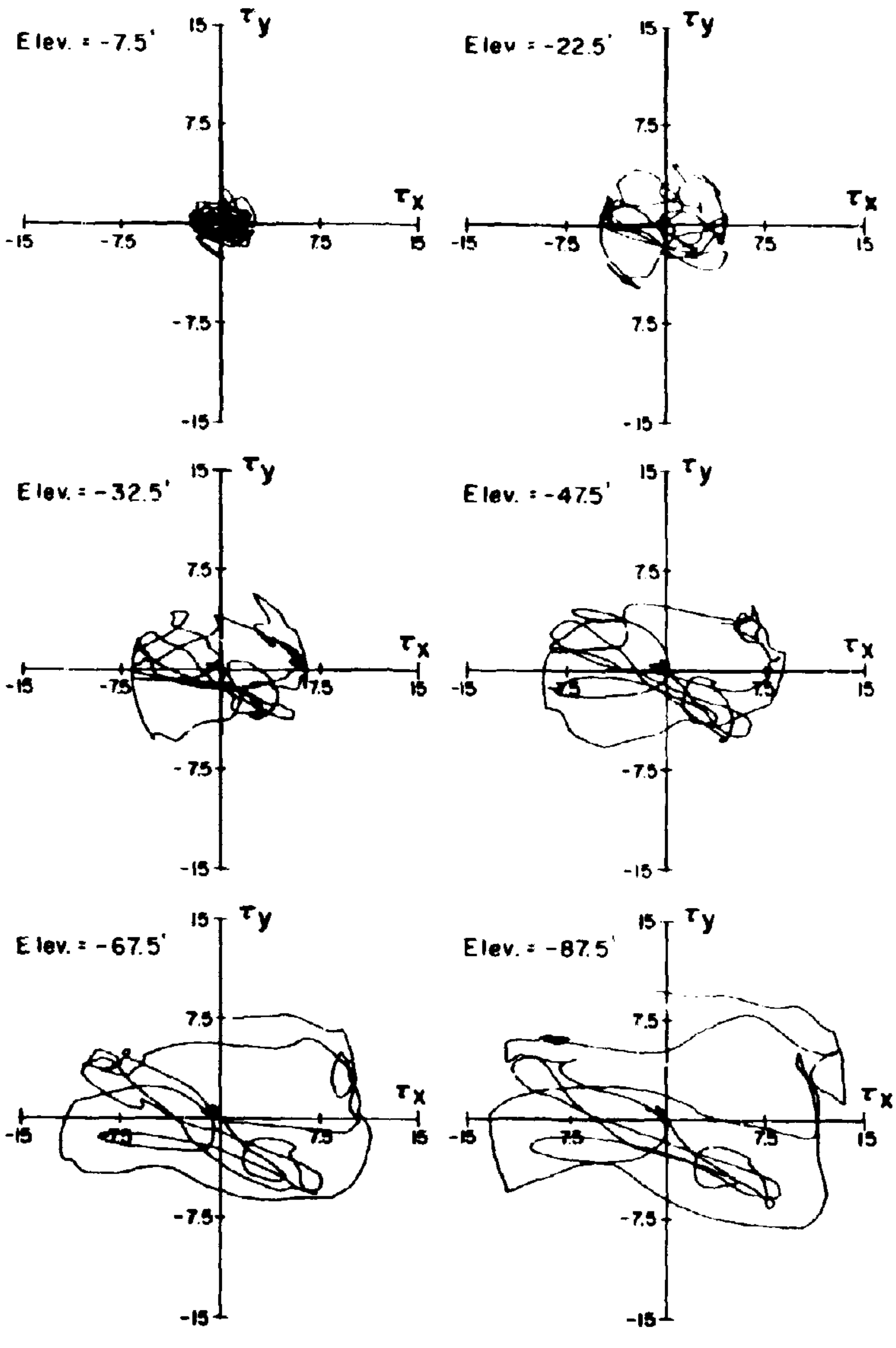


Figure 12 Traces of the shear stress resultant from two-directional analysis

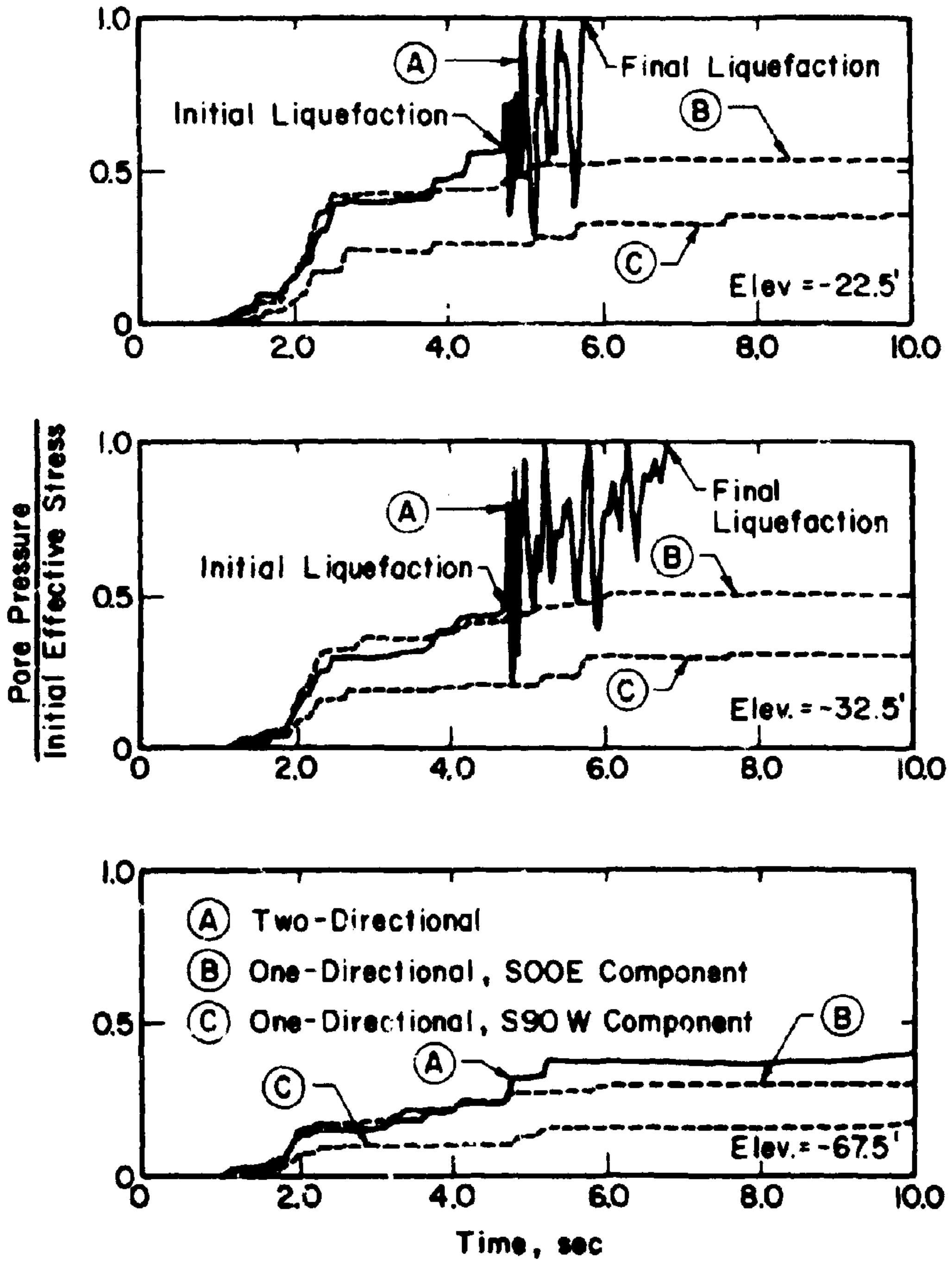
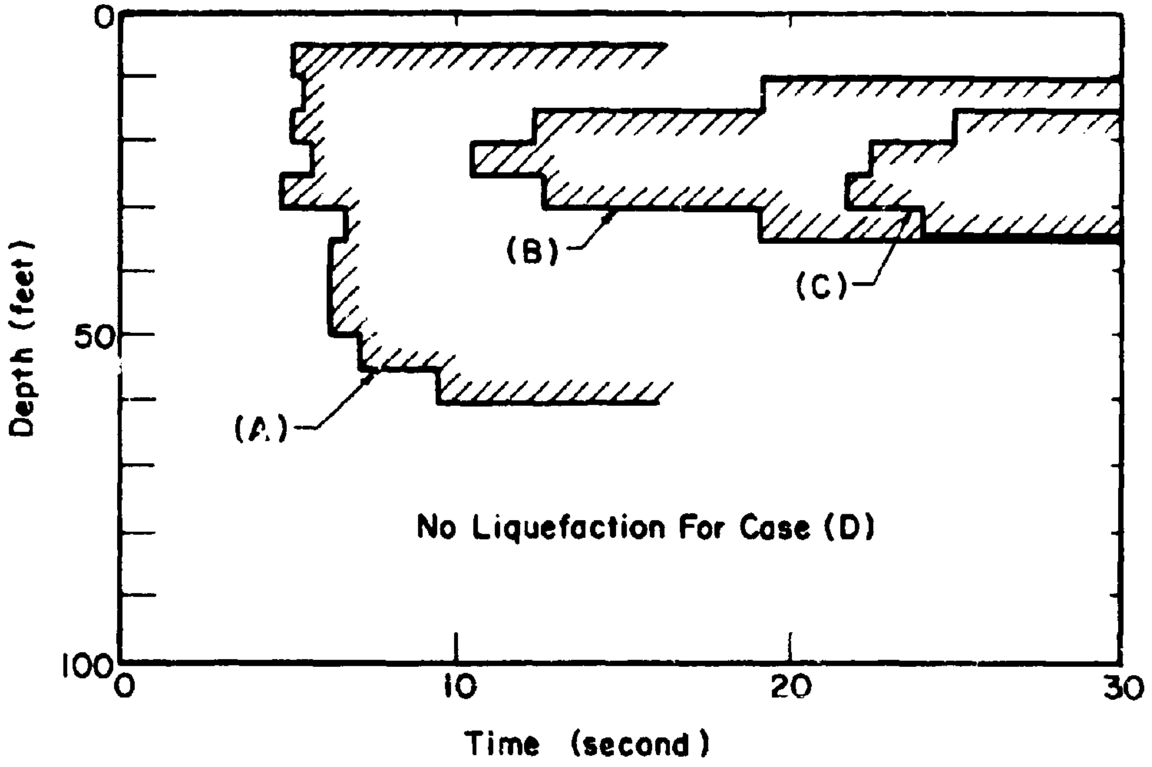


Figure 13 Comparison of the pore pressure time history from one-directional and two-directional analyses



		Peak Base Acceleration
(A)	Two - Directional	0.314g and 0.214g
(B)	One - Directional	0.408g
(C)		0.377g
(D)		0.314 g

Figure 14 Time histories of liquefaction in one- and two-directional analyses

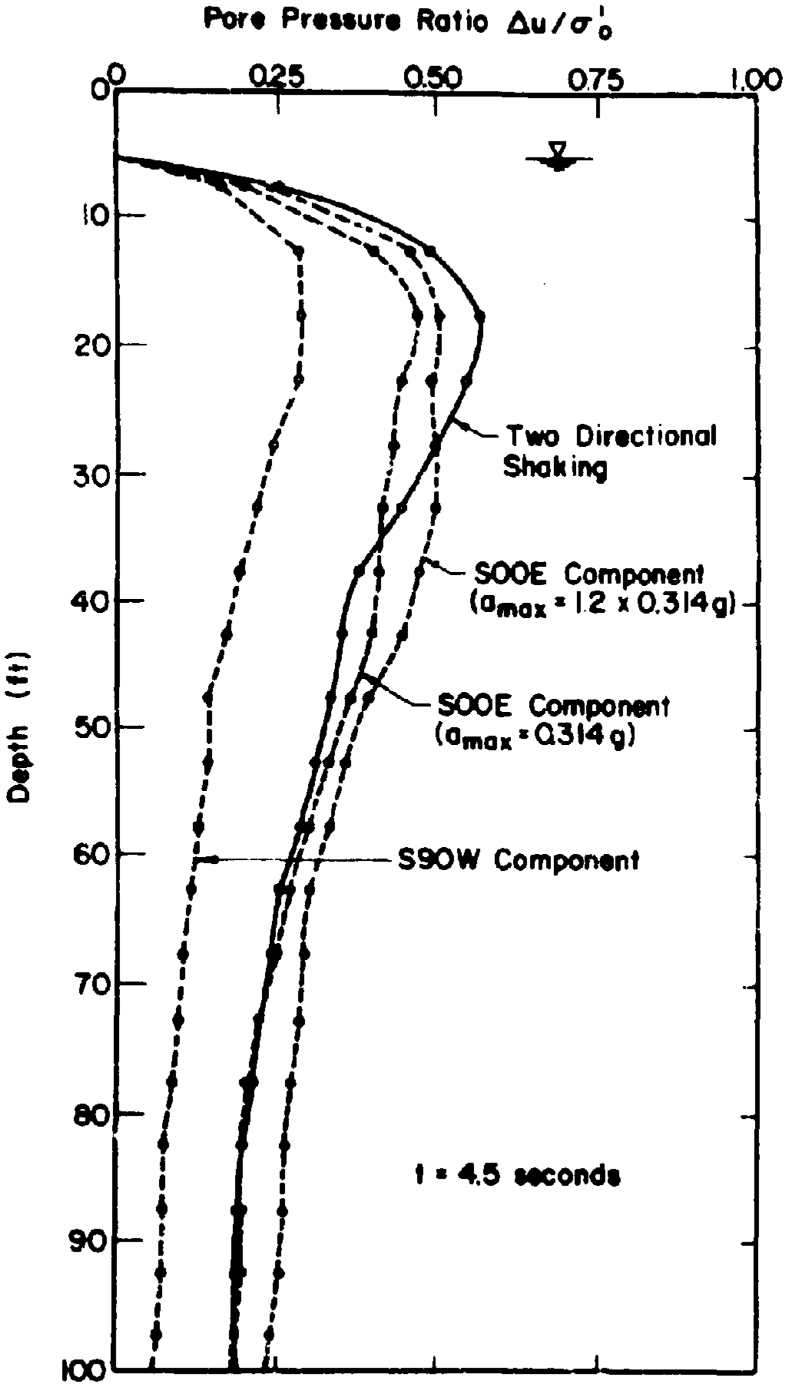


Figure 15 Pore pressures distribution with depth prior to liquefaction

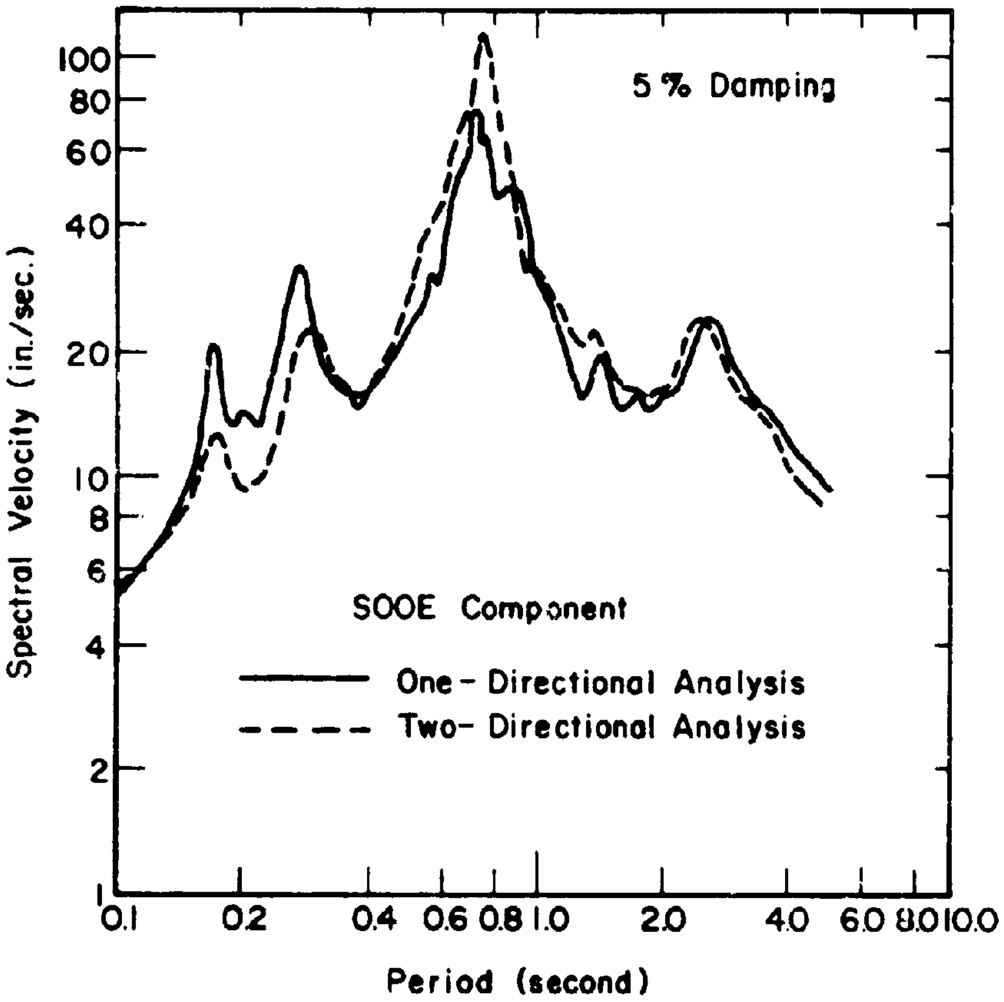


Figure 16 Comparison of the surface response spectra from one- and two-directional analyses

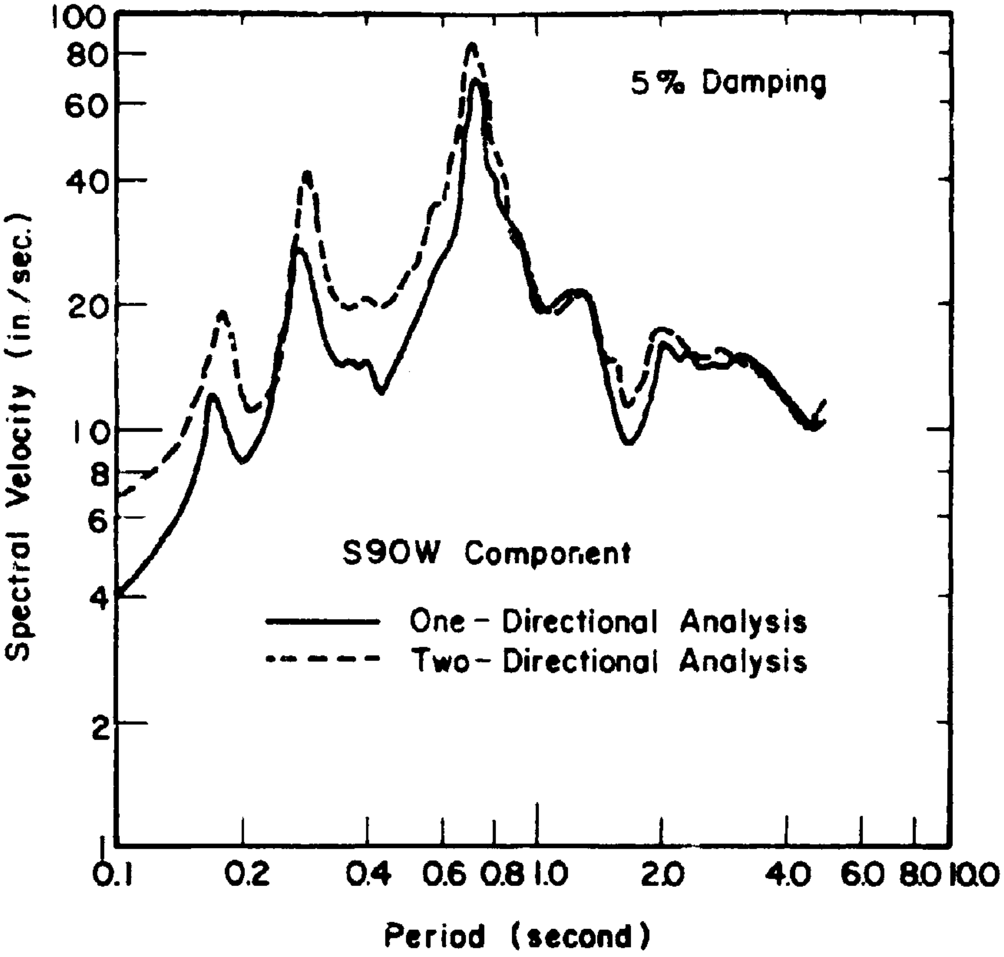


Figure 16 (continued)

APPENDIX A

A STUDY OF THE INFLUENCE OF SOME PARAMETERS ON LIQUEFACTION OF LEVEL GROUND

INTRODUCTION

The results of any method of analysis depend on the values of the input parameters. Such dependence may be linear or nonlinear. The degree of sensitivity of the results varies from parameter to parameter. Small changes in some parameters may cause large changes in the response of the system whereas changes in some other parameters have little influence on the response. On the other hand, there is always certain amount of uncertainty associated with the actual values of the input parameters. The knowledge of the manner in which the response of the system depends on the input parameters can be an important aid in interpreting the results of analysis. The purpose of this appendix is to present a study of the influence on the liquefaction potential of three important parameters; the depth of the water table, the pore pressure parameter λ and the coefficient of permeability. These three parameters are probably the most important factors in determining the potential for liquefaction in any site. The in-situ effective stress is significantly influenced by the water table. The pore pressure parameter, λ, is directly related to the relative density; the smaller value of λ implies looser sand. A correlation between the value of the parameter λ and the relative density is given in Ref. (6). The coefficient of permeability determines how rapidly the excess pore pressures can dissipate, thus influencing the potential for liquefaction.

CASES ANALYZED

A hypothetical reference site with the profile and the properties shown in Fig. A1 was chosen. The depth of the layer of sand is 100 ft and water table is 5 ft below the ground surface. Throughout this study the S00E component of the El Centro earthquake record of 1940 was used as the base acceleration. In each analysis only one of the parameters was changed while all the other properties were kept constant with the values shown in Fig. A1. All the cases analyzed are tabulated in Table A1. In cases A1 through A3 only the depth of the water table was varied. The variable in cases B1 through B7 was the pore pressure parameter λ. In cases C1 through C3 the value of the coefficient of permeability was varied.

Liquefaction characteristics of all the cases studied are summarized in Table A2. The data given in this table are: the time of occurrance and the depth of the first liquefaction and the final zone of liquefaction.

INFLUENCE OF THE DEPTH OF THE WATER TABLE

The overall effect of the variation of the depth of the water table is to vary the in-situ effective pressure. And generally the higher the in-situ effective pressure is, the less susceptible is the ground to liquefaction. This general pattern can be observed by comparing the results of the analyses of cases A1, A2 and A3, in which the depths of the water table are 2.5, 5.0 and 10.0 feet, respectively. The liquefaction time histories for these three cases are shown in Figure A2. Shown in Figure A3 are the variation with depth of the ratio of the excess pore water pressure and the in-situ effective pressure at t = 10 seconds.

No liquefaction has occurred in case A3 with the water table at 10 ft below the ground surface. Liquefaction does occur in both the cases A1 and A2. However, with water table at 2.5 ft below ground surface, the liquefaction occurs much earlier and is much more extensive than with the water table at 5.0 ft below the ground surface.

As indicated by the results of the analysis of cases A1 through A3, generally the lowering of the water table will reduce the potential for liquefaction. But this effect is more drastic when the water table is originally close to the ground surface.

INFLUENCE OF THE PORE PRESSURE PARAMETER, λ

In general, as the value of the pore pressure parameter λ decreases the potential for pore pressure build up increases and as mentioned earlier, this is due to the fact that the parameter λ is directly related to the relative density. The parameter λ was varied in cases B1 through B7 of Table A1.

Shown in Figure A4 are the liquefaction time histories for cases B1 through B4 with the values of the parameter λ at 1.0, 1.5, 2.0 and 2.5. The variation of the excess pore pressures with depth, at t = 10 seconds, are shown in Figure A5. It can be seen that the lower values of λ, corresponding to lower relative densities, cause generally higher excess pore pressures. For λ = 1.0, the first liquefaction occurs at 6.5 seconds and the final zone of liquefaction extends from 15 to 40 ft below the ground surface. The two analyses with λ = 1.5 and 2.0 yield very similar results; the first liquefactions occur within 1.5 seconds of each other, and much later than the case with λ = 1.0. No liquefaction occurs for the case with λ = 2.5.

The depth of the water table in cases B1 through B7 was at 5 ft below the ground surface. The first two of these cases with λ = 1.0 and 1.5 were repeated, with the water table lowered to 10 ft below the ground surface (cases B5 and B6 of Table A1). The liquefaction of time histories and the variation of the excess pore pressures with depth are shown in Figures A6 and A7. It can be seen that liquefaction only occurs for the case B5 with λ = 1.0 while the case with λ = 1.5 does not liquefy.

In all the analyses with the reference profile, λ was assumed to be constant with depth. To study the influence of the variation of λ with depth, in one analysis (case B7) λ was assumed to increase linearly from 1.0 at the ground surface to 3.0 at 100 ft. Such a variation of λ represents the increase of relative density with depth. The time history of liquefaction and the variation of the excess pore pressure with depth for this analysis are shown in Figures A8 and A9 and compared with the results the analysis in which λ is assumed to be constant and equal to 1.5 (Case B2). Note that in variable λ analysis, at 25 ft below the ground surface where the first liquefaction occurs λ is equal to 1.5. As is expected for variable λ case the pore pressures are higher near the ground surface than the pore pressures for the case of constant λ with depth. The reverse is true below the depth of 30 ft. Generally it can be stated the variation of λ with depth has increased the liquefaction potential, in spite of the fact that at the point where the first liquefaction has occurred in both cases B2 and B7 the value of λ is the same.

COEFFICIENT OF PERMEABILITY

The reference profile was analyzed with three coefficients of permeability; k = 0.04, 0.004 and 0.0004 inches per second (Cases C1 through C3). The time histories of liquefaction for these three cases are shown in Figure A10. Shown in Figures A11a to A11c are the variations of excess pore pressures with depth. The earliest liquefaction occurs for the smallest value of the coefficient of permeability. No liquefaction occurred for the highest coefficient permeability used, k = 0.04 inches per second. The main reason for this trend can be explained in terms of the potential for dissipation of the excess pore pressures. For higher coefficient of permeability as the pore pressures are generated they can dissipate into adjacent zone, therefore reducing the likelihood of liquefaction. Also, it can be seen from Figure A10 that for lower coefficient of permeability, although the likelihood of liquefaction is higher, the zone of liquefaction is less likely to spread much.

TABLE A1. Cases Analyzed

Case	Depth of Water Table (feet)	Parameter λ	Variation of λ with Depth	Coefficient of Permeability (in./sec)
A1	2.5	1.5	constant	0.004
A2	5.0	1.5	constant	0.004
A3	10.0	1.5	constant	0.004
B1	5.0	1.0	constant	0.004
B2 (same as A2)	5.0	1.5	constant	0.004
B3	5.0	2.0	constant	0.004
B4	5.0	2.5	constant	0.004
B5	10.0	1.0	constant	0.004
B6 (same as A3)	10.0	1.5	constant	0.004
B7	5.0	1.0 + 0.02 Z	linear	0.004
C1	5.0	1.5	constant	0.04
C2 (same as A2)	5.0	1.5	constant	0.004
C3	5.0	1.5	constant	0.0004

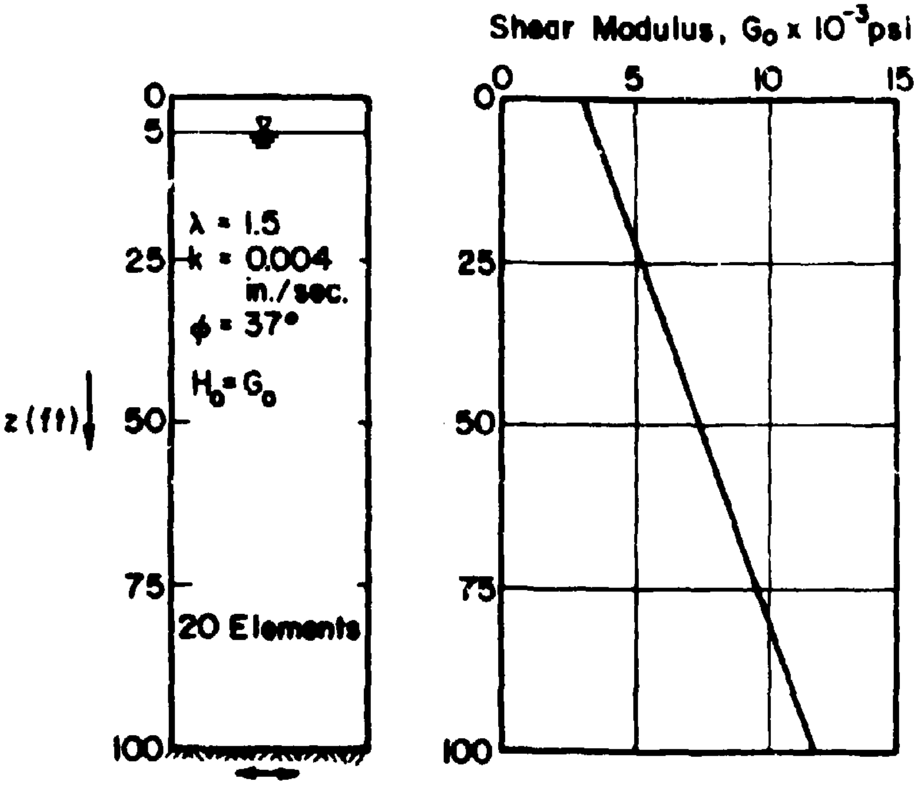
Table A2. Liquefaction Data for the Cases Studied

Case	Time of First Liquefaction (sec)*	Depth of First Liquefaction (ft)**	Depth of Final Liquefaction (ft)
A1	6.0	10	5 to 30
A2	24.0	20	15 to 30
A3	No Liquefaction		
B1	6.5	25	15 to 40
B2	24.0	20	15 to 30
B3	25.5	20	15 to 30
B4	No Liquefaction		
B5	13.5	25	20 to 35
B6	No Liquefaction		
B7	7.5	20	15 to 30
C1	No Liquefaction		
C2	24.0	20	15 to 30
C3	14.0	25	20 to 30

---

* Rounded off to the nearest 0.5 second.

** Depth to the top of the element which liquefied first (each element is 5 ft high).



Base Acceleration: SOOE Component of El Centro Earthquake Record of May 1940 (a_{max} = 0.314g)

Figure A1 Soil profile used in the analysis

A - 9

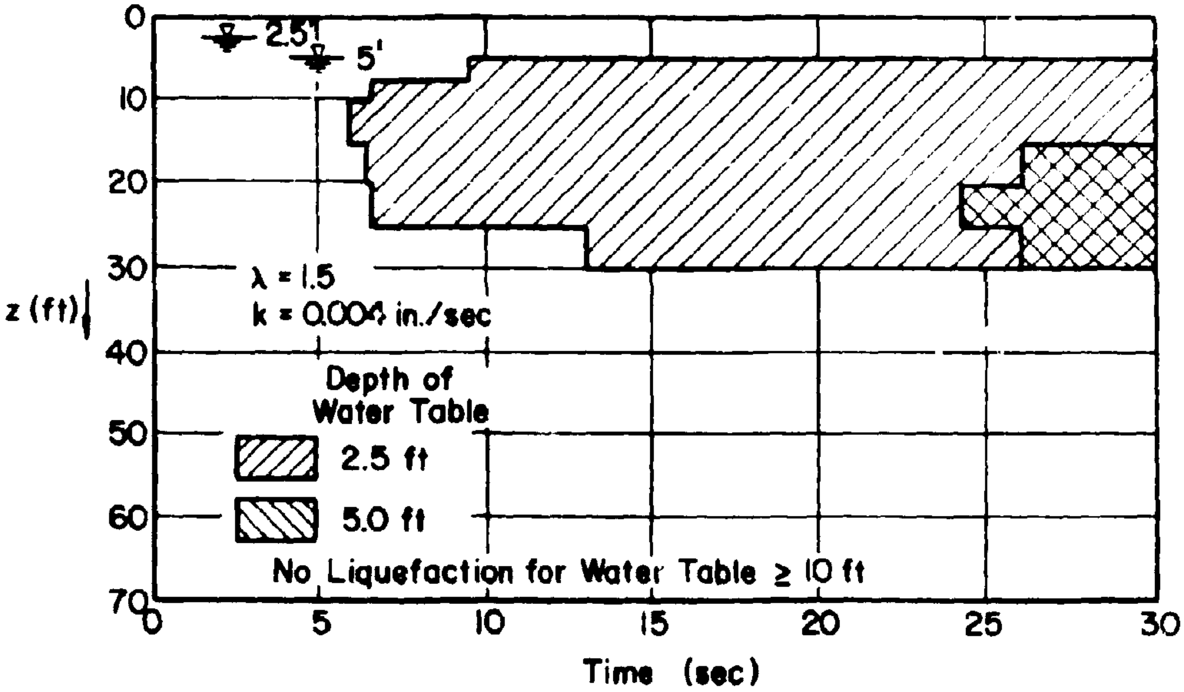


Figure A2 Time histories of liquefaction for water table depths of 2.5, 5.0 and 10.0 feet

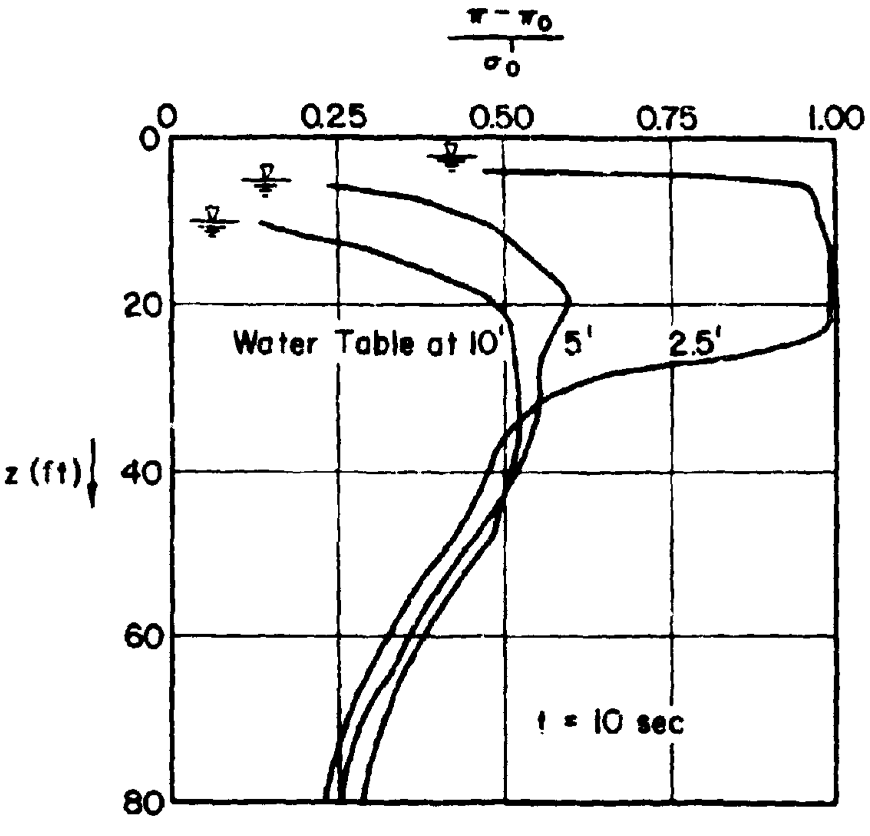


Figure A3 Variation with depth of the excess pore water pressure for water table depths of 2.5, 5.0 and 10.0 feet at t = 10 seconds

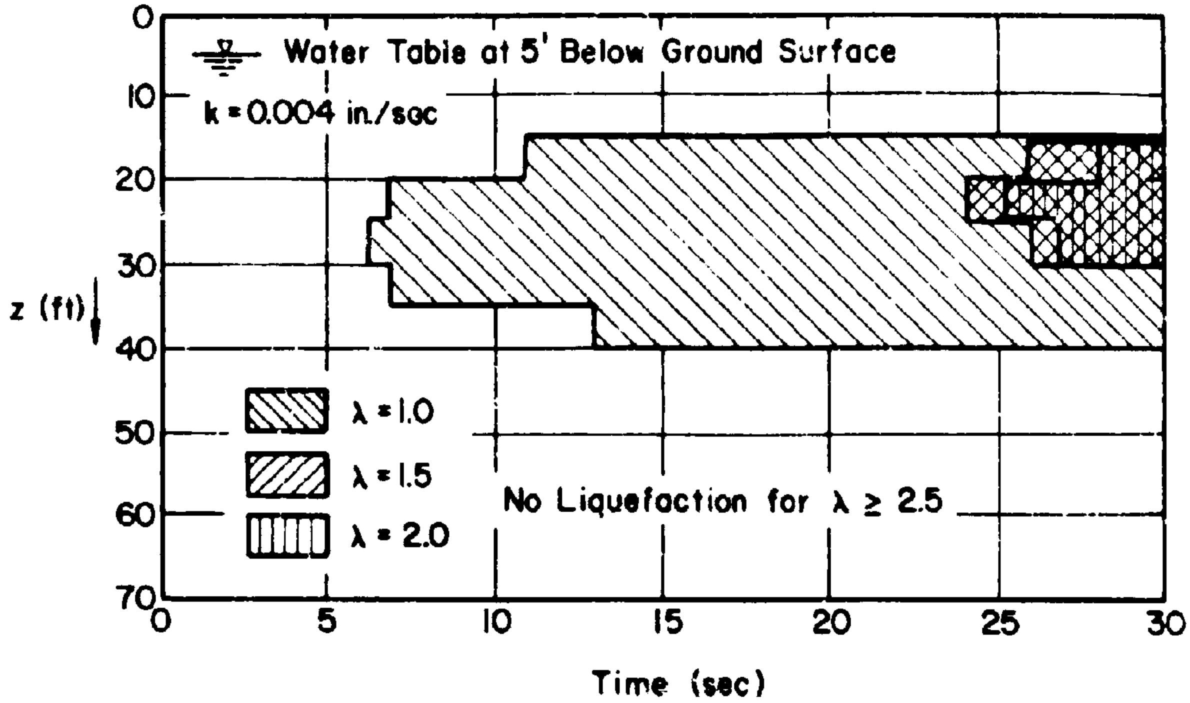


Figure A4 Time histories of liquefaction for parameter λ values of 1.0, 1.5, 2.0 and 2.5, and water table at 5 ft. below ground surface

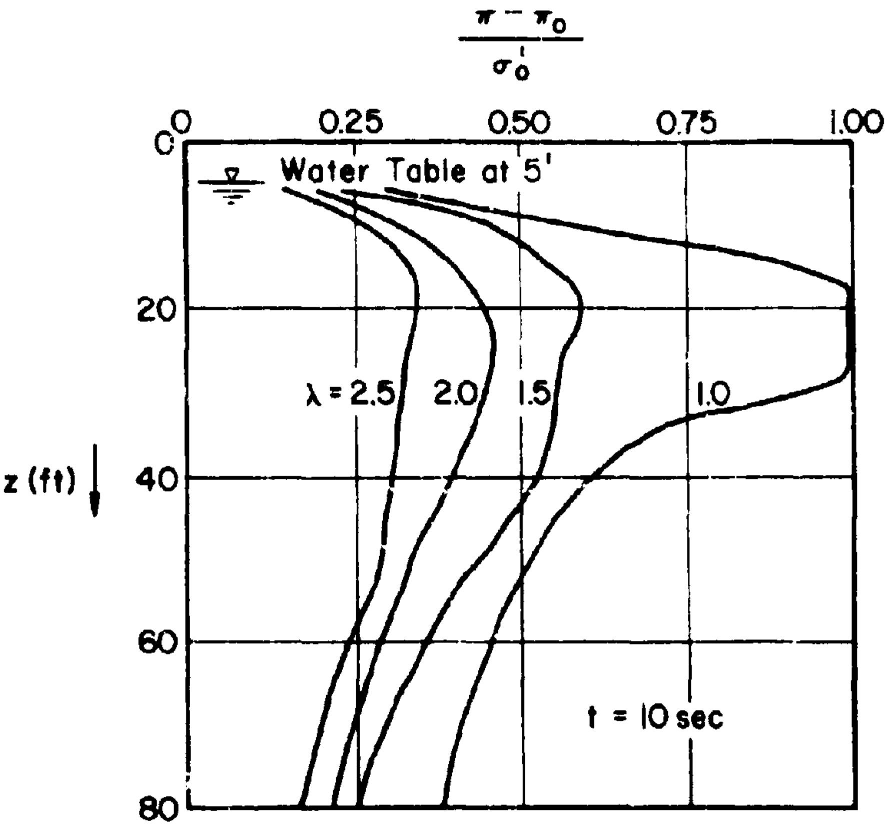


Figure A5 Variation with depth of the excess pore water pressure for values of parameter λ at 1.0, 1.5, 2.0 and 2.5, and water table at 5 ft below ground surface at t = 10 seconds

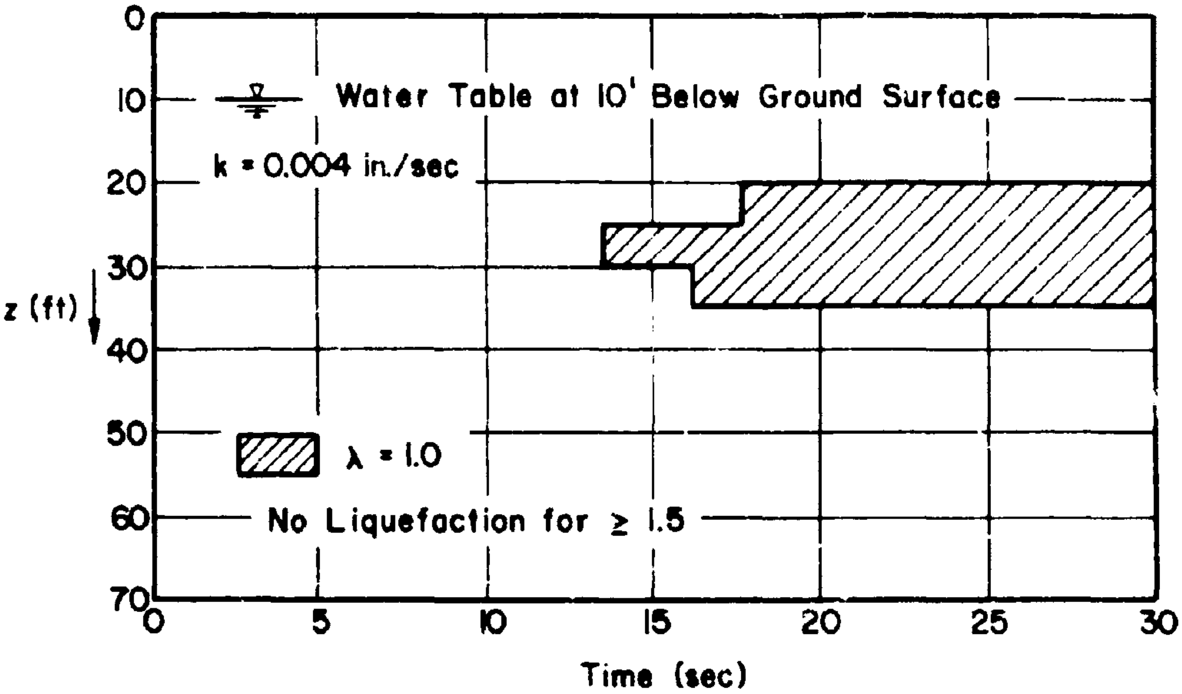


Figure A6 Time histories of liquefaction for parameter λ values of 1.0 and 1.5 and water table at 10 ft below ground surface

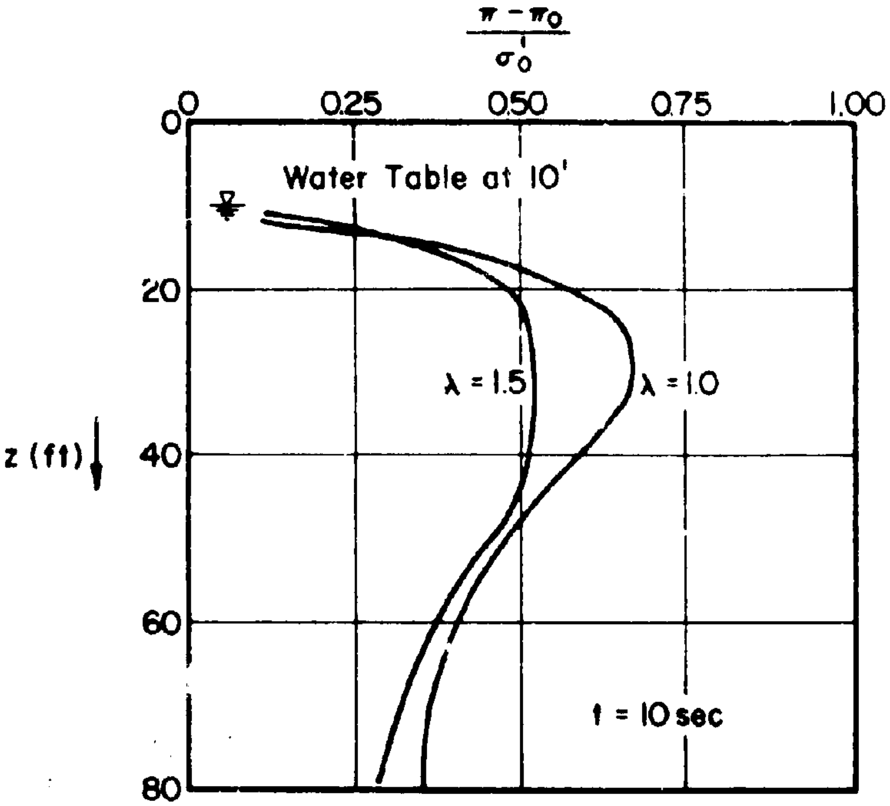


Figure A7 Variation with depth of the excess pore water pressure for parameter λ values of 1.0 and 1.5 and water table at 10 ft below ground surface at t = 10 seconds

A 15

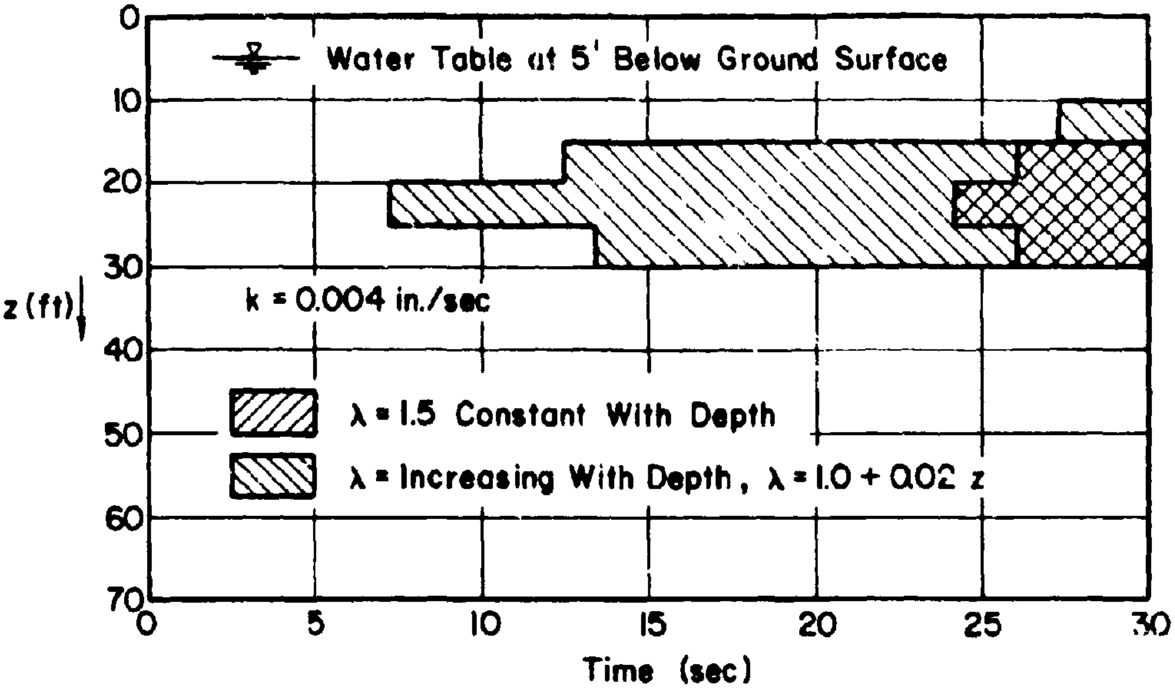


Figure A8 Time histories of liquefaction for cases of constant and increasing λ parameter with depth

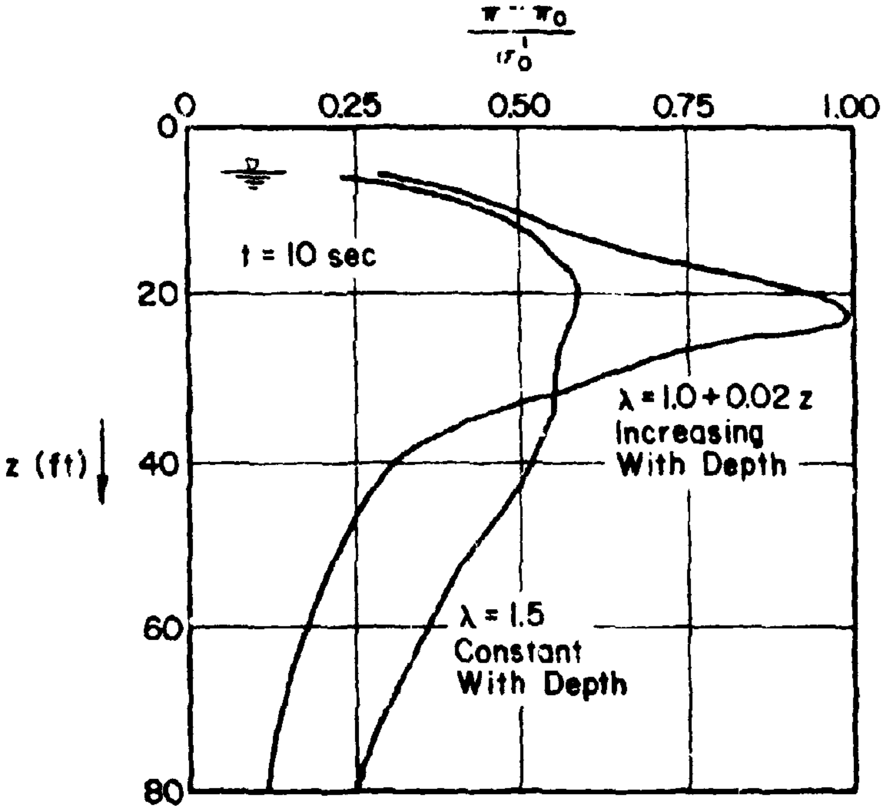


Figure A9 Variation with depth of the excess pore water pressure for cases of constant and increasing λ parameter with depth

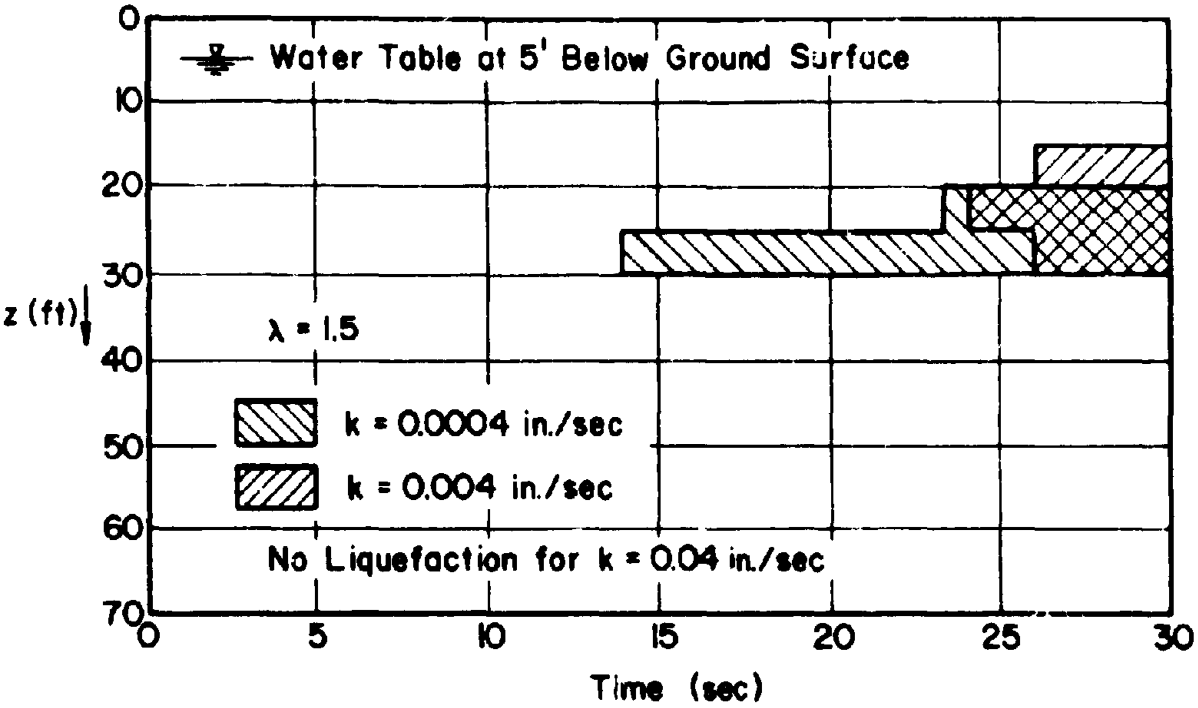


Figure A10 Time histories of liquefaction for coefficients of permeability 0.04, 0.40, 0.004 and 0.0004 in/sec

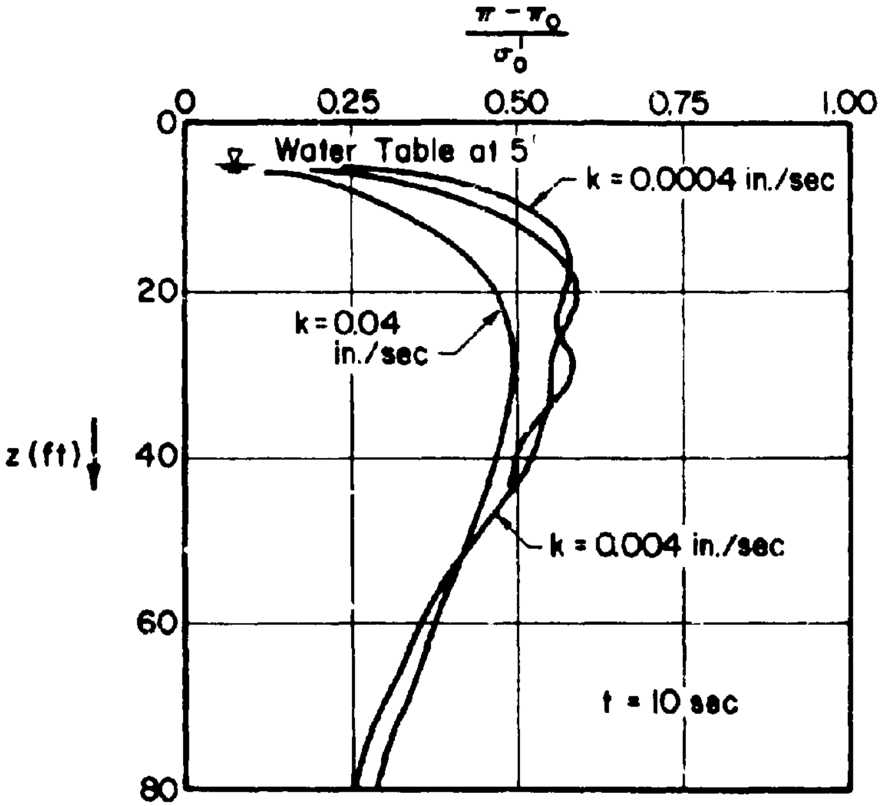


Figure A11 Variation with depth of the excess pore water pressure for coefficients of permeability 0.04, and 0.004 and 0.0004 in/sec. at (a) t = 10 seconds, (b) t = 12.5 seconds, (c) t = 15 seconds

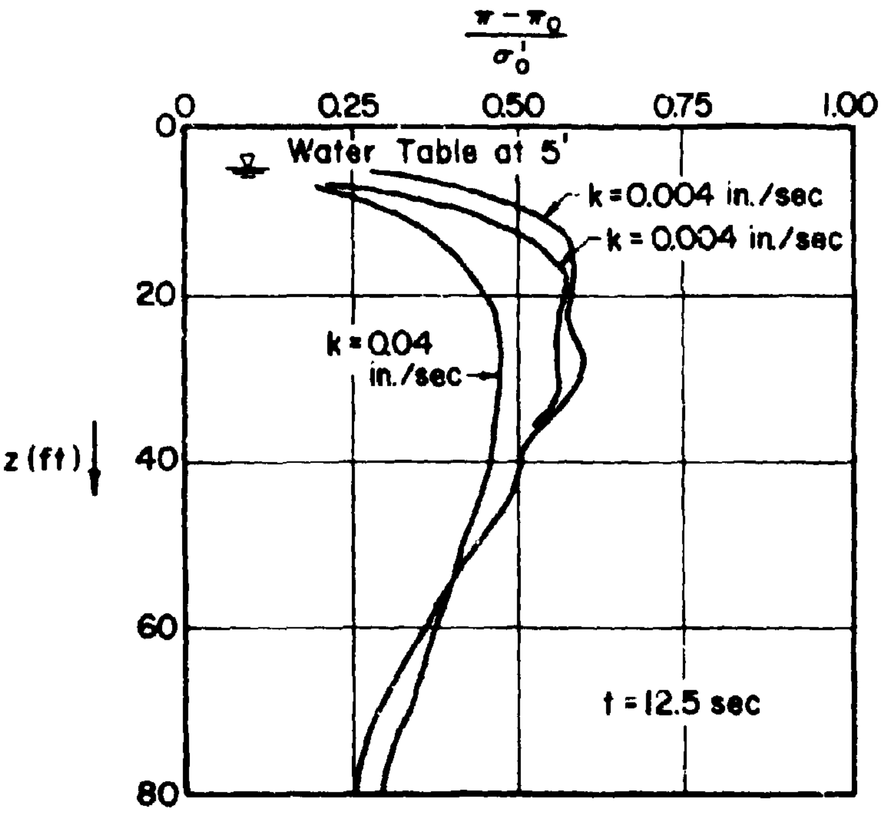


Figure A11 (continued)

A-20

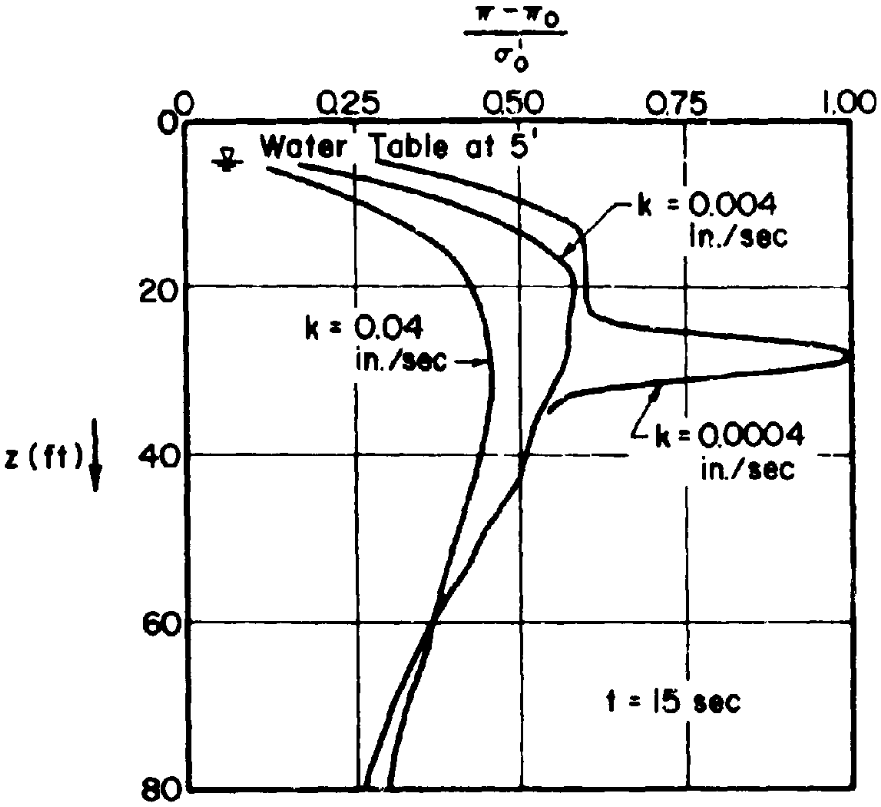


Figure A11 (continued)

APPENDIX B

INPUT DATA FOR COMPUTER PROGRAM LASS-III

The computer program LASS-III is for Liquefaction Analysis of Saturated Soil Deposits. This version is capable of dynamic analysis of horizontally layered saturated cohesionless soil deposits under multi-directional base motion.

I. CONTROL CARDS

Card 1 (18A4)

Columns	1-72	Problem title (To be printed in output)

Card 2 (6I5, F10.0)

Columns	1-5	Number of layers
	6-10	Number of different material properties
	11-15	Maximum number of subincrements per plastic step (Default value is 10).
	16-20	A non-zero value indicates a request for a transmitting boundary at the base (see Card 13)
	21-25	A non-zero value indicates a request for the usage of mass and stiffness proportional damping (see Card 14)
	26-30	Number of dynamic time steps
	31-40	Dynamic time step (Δt)

Card 3 (3I5)

Columns 1-5	Existence of first horizontal component of base motion (0 = No, 1 = Yes)
6-10	Existence of second horizontal component of base motion (0 = No, 1 = Yes)
11-15	Existence of the vertical component of base motion (0 = No, 1 = Yes)

Card 4 (4I5)

Columns 1-5	Interval of steps for printing of response (displacements, velocities, accelerations, strains and stresses).
6-10	Interval of steps for saving of response at selected points to be specified later for the purpose of plotting.
11-15	Step number for starting printing of response at intervals indicated in columns 1-5 of this card.
16-20	Interval of steps for updating of stiffness matrix.

Card 5 (3I5, 6F10.0)

Columns 1-5	Number of nodes for which the time histories of acceleration, velocity and displacement are to be plotted.
6-10	Number of elements for which the time histories of shear stress and shear strain, and the shear stress vs. the shear strain are to be plotted.

Columns 11-15	Number of elements at which the time histories of pore water pressure are to be plotted.
16-25	Height of the plotter paper in inches, (Default value is 10).
26-35	Height of the stress and strain time history diagram in inches, (Default value is 2).
36-45	Length of the time axis in inches, (Default value is 10).
46-55	Size (height = length) of the stress vs strain diagrams in inches, (Default value is 8).
56-65	Height of the pore pressure history diagrams in inches, (Default value is 4).
66-75	Maximum time value to be plotted in seconds, (Default value is 10).

Card 6 (4I5)

Columns 1-5	A non-zero value indicates a request for the computation of response spectras (Acceleration, velocity and displacement).
6-10	A non-zero value indicates a request for the plot of response spectras.
11-15	Number of damping values to be used in the computation of response spectra, (Default value is 3). Maximum value that can be specified is 10.

Columns 16-20	Number of nodes for which the response spectras to be computed. Maximum value that can be specified is 10.

Card Group 7 (8F10.0)

This card is required if a non-zero value is specified in columns 11-15 of Card 6. In the above format give the damping values as percent of critical damping. If a zero is specified in columns 11-15 of Card 6, program computes spectras for .02, .05, .1 damping.

Card 8 (10I5)

This card is required if the computation of response spectra is requested. In the above format give the node numbers.

Card 9 (2I5)

Columns 1-5	A non-zero value indicates a request for the post-earthquake analysis.
6-10	If a non-zero value is specified in the column 1-5 of this card, give the number of different time steps which will be used in post-earthquake analysis. Maximum value that can be specified is 10.

Card Group 10 (F10.0, 2I5)

One card must be provided for each time step indicated in columns 6-10 of card 9.

Columns	1-10	Time step.
	11-15	Number of times that this time step is to be repeated.
	16-20	Print interval of the time step.

Card 11 (2F10.0)

Columns	1-10	Depth of water table.
	11-20	Gravity, g, (Default value is 386.2 in/sec^2).

II. SOIL DEPOSIT DATA

Card Group 12 (F10.0, 2I5)

One card required for each layer of soil.

Columns	1-10	Depth of the base of the layer.
	11-15	Number of elements the layer is to be subdivided.
	16-20	Material number of layer. This number is to identify the type of material properties in the sequence given in the next card group to be assigned to this layer.

This data is provided for the layers in the sequence of increasing depth starting at the layer at the ground surface.

Card 13 (210.0)

Transmitting boundary coefficients at the base can be defined as follows, in horizontal directions

$$c_2 = \rho V_s$$

in vertical direction,

$$c_1 = \rho V_p$$

where c_1 and c_2 are dashpot constants, ρ is the mass density of the base, V_s and V_p are shear wave and compression wave velocities at the base respectively.

The following card must be provided if a non-zero value was specified in columns 16-20 of card 2.

Columns	1-10	c_2, dashpot constant in horizontal direction
	11-20	c_1, dashpot constant in vertical direction

Card 14 (2F10.0)

Mass and stiffness proportional damping is defined as follows,

$$c = \alpha' M + \beta' K_0$$

The following card must be provided if a non-zero value was specified in columns 21-25 of card 2.

Columns	1-10	α', factor for mass proportional damping
	11-20	β', factor for stiffness proportional damping

Card Group 15 (8F10.0)

The following cards must be provided for each material type as indicated in columns 6-10 of Card 2.

Card 15.1

Columns	1-10	Constrained modulus for effective stresses.
	11-20	Shear modulus at the top of the layer.
	21-30	Change in shear modulus per unit of depth.

Columns 31-40	Plastic modulus at the top of the layer.
41-50	Change in plastic modulus per unit of depth.
51-60	Bulk modulus of fluid.
61-70	Permeability.
71-80	Mass density of solid.

Card 15.2

Columns 1-10	Mass density of fluid.
11-20	S_{max}.
21-30	$1/\lambda$
31-40	Tolerance for subincrementing at each plastic step (Default value is .001).
41-50	α
51-60	Constant for the direction of stress vector in p'-q stress plane for post-initial liquefaction calculation.
61-70	Effective stress at final liquefaction.
71-80	Void ratio.

III. PLOT DATA

Card Group 16 (16I5)

This card group is required if a non-zero value is specified in columns 1-5 of Card 5. In the above format give the node numbers of the nodes where the motion plots are required.

Card Group 17 (16I5)

This card group is required if a non-zero value is specified in columns 6-10 of Card 5. In the above format give the element numbers of the elements for which the time histories of shear stresses and shear strains, and the stress-strain diagrams are to be plotted.

Card Group 18 (16I5)

This card group is required if a non-zero value is specified in columns 11-14 of Card 5. In the above format give the element numbers of the elements for which the time histories of pore water pressures are to be plotted.

IV. EARTHQUAKE DATA

Card 19 (12A6)

Columns	1-72	Earthquake identification title (to be printed in output).

Card 20 (2F10.0, 3I5)

Columns	1-10	Time scale factor. Earthquake time points are multiplied by this time scale factor. (If zero or blank, a value of one is used). This is not required if a non-zero value is specified in columns 26-30 of this card.

Columns 11-20	Amplitude scale factor. Earthquake amplitudes are multiplied by this scale factor (If zero or blank, a value of one is used).
21-25	Number of time points to define the time history of base acceleration.
26-30	Base acceleration data type: zero or blank when the base acceleration data are given at irregular time intervals; any non-zero value when the base acceleration is given at equal intervals with the same time step as specified in columns 31-40 of Card 2.
31-35	A non-zero value will suppress the output of the base acceleration time history.

If the value in columns 26-30 of Card 20 is zero provide Card group 21, otherwise provide Card group 22.

Card Group 21 (8F10.0)

In the above format for each base acceleration time point give sequentially the values of time and corresponding base acceleration. The program interpolates to determine the value of base acceleration at intervals of time step Δt.

Card Group 22 (8F9.0)

In the above format for each base acceleration time point give sequentially the values of base acceleration at intervals of time step Δt.

APPENDIX C

LISTING OF COMPUTER
PROGRAM LASS-III

```
      PROGRAM LASSIII(INPUT,OUTPUT,TAPE1,TAPE5=INPUT,TAPE6=OUTPUT)
C
C
C     PROGRAM FOR SEISMIC ANALYSIS OF HORIZONTALLY LAYERED
C     SATURATED SOILS WITH EVALUATION OF LIQUEFACTION POTENTIAL
C
C     DEVELOPED BY  JAMSHID GHABOUSSI AND UMIT DIKMEN
C                   CIVIL ENGINEERING DEPARTMENT
C                   UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN
C                   JANUARY 1979
C
C
      COMMON A (40000)
      COMMON/CONTL/HED(18),NCYCL,DT,NDI,NLOP,NPRNT,NSAVE,
     *  LUN,NC,NUPDAT,NSTPRT
      COMMON/WLVL/ WTABLE,GRAV
      COMMON/PLTING/ NPLOTH,NPLTSS,NSETS,HPAP,HPLOT,BPLOT,DPLOT,EPLOT,
     *  TEND,NPLPNT
      COMMON/SPEC/DV(10),NODE(10),NNODE,IRS,IRSP
      COMMON/POSEQ/NTREP(10),TS(10),TLIMIT,NTS,NPEQPR(10)
      COMMON/BASDAM/IBDMP,C1,C2
      COMMON/DIRECT/NX,NY,NZ
      COMMON/DAMP/IVDMP,ALFA,BETA
C
      WRITE(6,2014)
      WRITE(6,2015)
      MTOT=40000
      LUN=1
      IPLOT=0
      READ (5,1000) HED
      READ (5,1001)NLAYER,NMAT,NXINC,IBDMP,IVDMP,NCYCL,DT
      IF(NXINC.LE.0) NXINC=10
      WRITE (6,2000) HED,NLAYER,NMAT,NXINC,NCYCL,DT
      READ(5,1003) NX,NY,NZ
      IF(NX.EQ.0.AND.NY.NE.0) NY=0
      IF(NX.EQ.0) NX=1
      WRITE(6,2013) NX,NY,NZ
      READ (5,1003) NPRNT,NSAVE,NSTPRT,NUPDAT
      WRITE (6,2001) NPRNT,NSAVE,NSTPRT,NUPDAT
      READ(5,1004) NPLOTH,NPLTSS,NSETS,HPAP,HPLOT,BPLOT,DPLOT,EPLOT,TEND
      NPLTOT=NPLOTH+NPLTSS+NSETS
      IF(NPLTOT.LE.0) GO TO 200
      IPLOT=1
      IF(HPAP.LT.1..OR.HPLOT.LT.1..OR.BPLOT.LT.1..OR.DPLOT.LT.1..OR.TEND
     *  .LT.1..OR.EPLOT.LT.1.) WRITE(6,2004)
      IF(HPAP.LT.1.) HPAP=10.
      IF(HPLOT.LT.1.) HPLOT=2.
      IF(BPLOT.LT.1.) BPLOT=10.
      IF(DPLOT.LT.1.) DPLOT=8.
      IF(EPLOT.LT.1.) EPLOT=4.
      IF(TEND.LT.1.) TEND=10.
      WRITE(6,2003) NPLOTH,NPLTSS,NSETS,HPAP,HPLOT,BPLOT,DPLOT,EPLOT,
     *  TEND
  200 READ(5,1005) IRS,IRSP,NDV,NNODE
      NHD=1
      IF(NY.NE.0) NHD=2
      IF(IRSP.NE.0)IPLOT=1
      IF(IRS.EQ.0) GO TO 215
      WRITE(6,2005)
      IF(NDV.LE.0) GO TO 230
```

```
      READ(5,1006) (DV(L),L=1,NDV)
      GO TO 240
  230 NDV=3
      WRITE(6,2006)
      DV(1)=0.02
      DV(2)=0.05
      DV(3)=0.1
  240 WRITE(6,2007) (DV(L),L=1,NDV)
      READ(5,1007) (NODE(L),L=1,NNODE)
      WRITE(6,2008) (NODE(L),L=1,NNODE)
  215 READ(5,1007) IPOSEQ,NTS
      IF(IPOSEQ.EQ.0) GO TO 210
      WRITE(6,2009)
      READ(5,1008) (TS(I),NTREP(I),NPEQPR(I),I=1,NTS)
      WRITE(6,2010) (TS(I),NTREP(I),NPEQPR(I),I=1,NTS)
  210 CONTINUE
      NDI=NX+NY+NZ
      NC=NDI+1
      IF(NZ.EQ.0) NC=NC+1
      NDOF=4
      READ (5,1002) WTABLE,GRAV
      IF (GRAV.LE.0.0) GRAV=386.2
      WRITE (6,2002) WTABLE,GRAV
      N1=1
      N2=N1+NLAYER
      N3=N2+NLAYER
      N4=N3+NLAYER
      N5=N4+35*NMAT
      IF(NDI.EQ.0) NDI=1
      N6=N5+NDI*NCYCL
      KK1=N6
      KK2=KK1+NPLOTH
      KK3=KK2+NPLTSS
      KK4=KK3+NSETS
      K1=KK4
      CALL REED (A(N1),A(N2),A(N3),A(N4),A(N5),A(KK1),A(KK2),A(KK3),
     *  NLAYER,NMAT,NUMNP,A(K1),NCYCL,NDI)
      K2=K1+NUMNP
      K3=K2+NUMNP
      K4=K3+NUMNP
      CALL MESH (A(N1),A(N2),A(N3),A(K1),A(K2),A(K3),WTABLE,
     *  NLAYER)
      NEQ=NC*NUMNP+NC
      IF(IBDMP.EQ.0) NEQ=NEQ-NC
      MBAND=2*NC
      K5=K4+NEQ*MBAND
      K6=K5+NEQ*MBAND
      K7=K6+NEQ
      K8=K7+NEQ
      K9=K8+NEQ
      K10=K9+NEQ
      K11=K10+NEQ
      K12=K11+NEQ
      K13=K12+NEQ
      K14=K13+NDOF*NUMNP
      K15=K14+NDOF*NUMNP
      KK15=K15+NEQ
      KK16=KK15+2*NUMNP
      KK17=KK16+15*NUMNP
      KK18=KK17+NEQ*6
      KK19=KK18+NUMNP*(4*(NHD+1))
```

```
      K16=KK19+NNODE*NCYCL*NHD
      NCCY=NCYCL
      NTLL=0
      NPLPNT=TEND/DT
      IF(NPLTOT.LE.0) GO TO 130
      RTSAVE=(NPLPNT-1.0)/NSAVE+1.0
      NTSAVE=RTSAVE
      IF(NTSAVE.GT.RTSAVE) NTSAVE=NTSAVE-1
      KN1=K16
      KN2=KN1+NTSAVE+2
      K16=KN2+NTSAVE+2
      NBLK=NTSAVE
      NPTOT=3*NPLOTH+2*NPLTSS+NSETS+3
      IF(NY.NE.0) NPTOT=NPTOT+3*NPLOTH+2*NPLTSS
      IF(NZ.NE.0) NPTOT=NPTOT+3*NPLOTH
      IF (NPTOT.LE.0) GO TO 100
      NLEFT=NTOT-K16-1
      NEED=NPTOT*NTSAVE
      IF (NEED.LE.NLEFT) GO TO 100
      NUM=(NEED-1)/NLEFT+1
      NBLK=NLEFT/NPTOT
      REWIND LUN
  100 CONTINUE
      NTLL=NPTOT*NBLK
  130 CONTINUE
      K17=K16+NTLL
      IF(IRS.NE.0) GO TO 135
      K21=K17
      GO TO 137
  135 CONTINUE
      K18=K17+NDV*89*NHD
      K19=K18+NDV*89*NHD
      K20=K19+NDV*89*NHD
      K21=K20+89
  137 IF(IPOSEQ.NE.0) GO TO 138
      K30=K21
      GO TO 139
  138 CONTINUE
      K22=K21+NUMNP*2
      K23=K22+NUMNP*2
      K24=K23+NUMNP*2
      K25=K24+NUMNP*2
      K26=K25+NUMNP
      K27=K26+NUMNP
      K28=K27+NUMNP
      K29=K28+NUMNP
      K30=K29+NUMNP
  139 CONTINUE
      K31=K30+2*NEQ
      K32=K31+NEQ
      WRITE(6,2012) NTOT,K32
      IF(K32.LT.NTOT) GO TO 140
      WRITE(6,2011)
      STOP
  140 CONTINUE
      NTLL=K32-K4+1
      CALL SZERO (A(K4),NTLL)
      IF(IPLOT.GT.0) CALL PLOTS(0,0,10)
      CALL MASSMT (A(K10),A(K1),A(K2),A(K3),A(N4),NUMNP,NC)
      CALL SELFLD (A(K1),A(K2),A(K3),A(N4),A(K13),A(K15),NUMNP,NC)
      CALL SOLVE (A(K1),A(K2),A(K3),A(N4),A(N5),A(K4),A(K5),A(K6),A(K7),
```

```
     *  A(K8),A(K9),A(K10),A(K11),A(K12),A(K13),A(K14),A(K15),A(KK1),
     *  A(KK2),A(KK3),A(K16),A(KK15),A(KK19),A(K30),A(K31),A(KK17),
     *  A(KK18),A(KK16),NBLK,NPTOT,NUMNP,NMAT,NEQ,NBAND,NCCY,
     *  MXINC)
      CALL OUTP (A(KK1),A(KK2),A(KK3),A(KM1),A(KM2),A(K16),A(KK15),
     *  NUMNP,LUN,NBLK,NPTOT,NTSAVE,NDI)
  150 CONTINUE
      IF(NNODE.LE.0) GO TO 160
      CALL RESPEC(A(KK19),NCYCL,A(K17),A(K18),A(K19),A(K20),NDV,DT,NHD)
  160 IF(IPOSEQ.EQ.0) GO TO 170
      IF(IPOSEQ.GE.1) CALL SOLPEQ (A(N4),A(K1),A(K2),A(K3),A(K13),
     *  A(K21),A(K22),A(K23),A(K24),A(K25),A(K26),A(K27),A(K28),A(K29),
     *  NUMNP)
  170 CONTINUE
      IF(IPLOT.GT.0) CALL PLOT(0,0,999)
      STOP
 1000 FORMAT(18A4)
 1001 FORMAT (6I5,F10.0)
 1002 FORMAT (8F10.0)
 1003 FORMAT (16I5)
 1004 FORMAT(3I5,6F10.0)
 1005 FORMAT(4I5)
 1006 FORMAT(8F10.0)
 1007 FORMAT(16I5)
 1008 FORMAT(F10.0,2I5)
 2000 FORMAT (////18A4////
     * 35H NUMBER OF LAYERS .............    = ,I5//
     * 35H NUMBER OF MATERIALS ..........    = ,I5//
     * 35H MAX. NO. OF SUBINC. PER               /
     * 35H PLASTIC STEP .................    = ,I5//
     * 35H NUMBER OF CYCLES .............    = ,I5//
     * 35H TIME STEP (DT) ...............    = ,E10.4 )
 2001 FORMAT (// 35H PRINT INTERVAL  .............    = ,I5//
     * 35H INTERVAL FOR SAVING RESPONSE      = ,I5//
     * 35H STEP FOR STARTING PRINT ....      = ,I5//
     * 35H STIFFNESS UPDATE CYCLE .....      = ,I5//)
 2002 FORMAT (//
     * 35H DEPTH OF WATER TABLE ........     = ,F10.3//
     * 35H GRAVITY  .....................    = ,F10.3//)
 2003 FORMAT (//25H ..... PLOT DATA .....        //
     * 55H NUMBER OF MOTION PLOTS  ........................   =  ,I5,/
     * 55H NUMBER OF STRESS, STRAIN, TIME PLOTS  ...........  =  ,I5,/
     * 55H NUMBER OF PORE PRESSURE VS. TIME PLOTS ..........  =  ,I5,/
     * 55H HEIGHT OF THE PLOT PAPER (INCHES)  ..............  =  ,F5.1,/
     * 55H HEIGHT OF THE STRESS AND STRAIN HISTORY PLOTS (IN) =  ,F5.1,/
     * 55H LENGTH OF THE TIME AXIS (INCHES)  ...............  =  ,F5.1,/
     * 55H SIZE OF THE STRESS VS. STRAIN PLOTS (INCHES)  ...  =  ,F5.1,/
     * 55H HEIGHT OF THE PORE PRESSURE HISTORY PLOTS (IN) ..  =  ,F5.1,/
     * 55H MAX. TIME VALUE TO BE PLOTTED (SECONDS)  ........  =  ,F5.1,
     *  //)
 2004 FORMAT(//,50H DEFAULT VALUE(S) ASSUMED FOR PLOT PARAMETER(S)      )
 2005 FORMAT(30H  ....RESPONSE SPECTRA DATA...   /)
 2006 FORMAT(54H DEFAULT VALUES WILL BE ASSUMED FOR DAMPING VALUES      )
 2007 FORMAT(16H DAMPING VALUES=   ,10F10.5)
 2008 FORMAT(45H RESPONSE SPECTRA WILL CALCULATED FOR NODES   ,10I5//)
 2009 FORMAT(//40H ...DATA FOR POST EARTHQUAKE ANALYSIS...     //
     *  11H TIME STEPS ,3X,10H NO. REP. ,3X,11H PRINT INT.      )
 2010 FORMAT(F10.5,9X,I5,9X,I5)
 2011 FORMAT(45H PROBLEM DEFINED IS TOO LARGE TO BE COMPUTED  )
 2012 FORMAT(//22H STORAGE INFORMATION     //
     *  23H CORE SPACE AVAILABLE=   ,I6,
```

```
    *  23H CORE SPACE REQUESTED=     ,I6)
2013 FORMAT(35H ACCELARATION IN X-DIRECTION=      ,I5/
    *       35H                 Y-DIRECTION=      ,I5/
    *       35H                 Z-DIRECTION=      ,I5/
    *       35H ( YES=1, NO=0 )                       )
2014 FORMAT(1H1/
    */35X,58H**********************************************************
    */35X,58H*                                                        *
    */35X,58H*  LL      AAAAA   SSSSSS   SSSSSS    IIIII IIIII IIIII  *
    */35X,58H*  LL     AA   AA SS       SS           I     I     I    *
    */35X,58H*  LL     AA   AA SSSSSS   SSSSSS       I     I     I    *
    */35X,58H*  LL     AAAAAAA  SSSSSS   SSSSSS ===  I     I     I    *
    */35X,58H*  LL     AA   AA      SS       SS      I     I     I    *
    */35X,58H*  LLLLLL AA   AA SSSSSS   SSSSSS     IIIII IIIII IIIII  *
    */35X,58H*                                                        *
    */35X,58H*   PROGRAM FOR SEISMIC RESPONSE AND LIQUEFACTION OF     *
    */35X,58H*    LAYERED GROUND UNDER MULTI-DIRECTIONAL SHAKING      *
    */35X,58H*                                                        *
    *  )
2015 FORMAT(
    * 35X,58H*                     DEVELOPED BY                       *
    */35X,58H*                                                        *
    */35X,58H*         JAMSHID GHABOUSSI  AND UMIT DIKMEN             *
    */35X,58H*     UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN         *
    */35X,58H*                     JANUARY 1979                       *
    */35X,58H*                                                        *
    */35X,58H**********************************************************
    *  )
     END
```

```
      SUBROUTINE BEED (DEPTH,NEL,MATYP,EMATL,BACC,JPLTM,JPLTSS,
     *  JSETS,NLAYER,NMAT,NUMNP,ACC,NCYCL,NDI)
C
      DIMENSION DEPTH(NLAYER),NEL(NLAYER),MATYP(NLAYER),EMATL(35,NMAT),
     *  BACC(NCYCL,NDI),ACC(2,1),TITLE(18),JPLTM(1),JPLTSS(1),JSETS(1)
C
      COMMON/CONTL/ HED(18),DUMM,DT
      COMMON/PLTING/ NPLOTM,NPLTSS,NSETS,NMAP,NPLOT,BPLOT,DPLOT,EPLOT,
     *  TEND,NPLPNT
      COMMON/WLVL/ WTABLE,GRAV
      COMMON/BASDAM/IBDMP,C1,C2
      COMMON/DAMP/IVDMP,ALFA,BETA
      COMMON/DIRECT/NX,NY,NZ
C
      READ (5,1000) (DEPTH(I),NEL(I),MATYP(I),I=1,NLAYER)
      WRITE (6,2000)
      WRITE (6,2001)  (I,DEPTH(I),NEL(I),MATYP(I),I=1,NLAYER)
      IF(IBDMP.EQ.0) GO TO 80
      READ(5,1006) C2,C1
      WRITE(6,2019) C2,C1
   80 CONTINUE
      IF(IVDMP.EQ.0) GO TO 90
      READ(5,1006) ALFA,BETA
      WRITE(6,2020) ALFA,BETA
   90 CONTINUE
      WRITE (6,2002)
      DO 100 L=1,NMAT
      READ (5,1001) (EMATL(I,L),I=1,5),(EMATL(I,L),I=12,22)
  100 CONTINUE
      DO 103 L=1,NMAT
      IF(EMATL(18,L).LE.0) EMATL(18,L)=0.001
  103 CONTINUE
      WRITE(6,2016)
      DO 101 L=1,NMAT
      WRITE(6,2003) L,(EMATL(I,L),I=1,5),(EMATL(I,L),I=12,14)
  101 CONTINUE
      WRITE(6,2017)
      DO 102 L=1,NMAT
      WRITE(6,2003) L,(EMATL(I,L),I=15,22)
  102 CONTINUE
      NUMNP=0
      DO 110 I=1,NLAYER
  110 NUMNP=NUMNP+NEL(I)
      IF (NPLOTM.LE.0) GO TO 130
      READ  (5,1005) (JPLTM(I),I=1,NPLOTM)
      WRITE (6,2008)
      WRITE (6,2013) (JPLTM(I),I=1,NPLOTM)
  130 IF (NPLTSS.LE.0) GO TO 140
      READ  (5,1005) (JPLTSS(I),I=1,NPLTSS)
      WRITE (6,2010)
      WRITE (6,2013) (JPLTSS(I),I=1,NPLTSS)
  140 IF (NSETS.LE.0) GO TO 150
      READ  (5,1005) (JSETS(I),I=1,NSETS)
      WRITE (6,2011)
      WRITE (6,2013) (JSETS(I),I=1,NSETS)
  150 CONTINUE
C
C     READ AND INTERPOLATE BASE ACCEL.
C
      DO 400 LL=1,NDI
```

```
      READ (5,1002) TITLE,TSCAL,ASCAL,NPOINT,NTYPE,IPRNT
      WRITE (6,2004) TITLE,TSCAL,ASCAL
      IF (NTYPE.NE.0) GO TO 162
      WRITE(6,2014)
      READ (5,1003) (ACC(1,I),ACC(2,I),I=1,NPOINT)
      IF(IPRNT.NE.0) GO TO 155
      WRITE (6,2005) (ACC(1,I),ACC(2,I),I=1,NPOINT)
      GO TO 156
  155 CONTINUE
      WRITE(6,2021)
  156 CONTINUE
      IF (TSCAL.LE.0.0) GO TO 170
      DO 160 I=1,NPOINT
  160 ACC(1,I)=ACC(1,I)*TSCAL
      GO TO 170
  162 READ (5,1004) (ACC(2,I),I=1,NPOINT)
      IF(IPRNT.NE.0) GO TO 163
      WRITE(6,2015)
      WRITE (6,2005) (ACC(2,I),I=1,NPOINT)
      GO TO 164
  163 CONTINUE
      WRITE(6,2021)
  164 CONTINUE
  170 CONTINUE
      DO 180 I=1,NPOINT
  180 ACC(2,I)=ACC(2,I)*ASCAL
      IF (NTYPE.NE.0) GO TO 300
      GA1=0
      I=1
      T=DT
      K=0
  200 IF(ACC(1,I).GE.T) GO TO 250
  220 I=I+1
      IF (I.LE.NPOINT) GO TO 200
      WRITE (6,2007)
      STOP
  250 SLOPE=(ACC(2,I)-ACC(2,I-1))/(ACC(1,I)-ACC(1,I-1))
  280 K=K+1
      IF (K.GT.NCYCL) GO TO 400
      BACC(K,LL)=ACC(2,I-1)+SLOPE*(T-ACC(1,I-1))
      T=T+DT
      IF (ACC(1,I).GE.T) GO TO 280
      GO TO 220
  300 GRAVTY=GRAV
      DO 320 I=1,NCYCL
  320 BACC(I,LL)=ACC(2,I)*GRAVTY
  400 CONTINUE
      RETURN
 1000 FORMAT (F10.0,2I5)
 1001 FORMAT (8F10.0)
 1002 FORMAT (18A4/2F10.0,3I5)
 1003 FORMAT (8F10.0)
 1004 FORMAT (8F9.0)
 1005 FORMAT (16I5)
 1006 FORMAT(2F10.0)
 2000 FORMAT (1H1/45H ----------- PROPERTIES OF LAYERS -----------  ,//
     *  5X,5HLAYER,15X,5HDEPTH,11X,9HNUMBER OF,12X,8HMATERIAL /4X,
     *  6HNUMBER,32X,8HELEMENTS,14X6HNUMBER//)
 2001 FORMAT (I10,F20.3,2I20)
 2002 FORMAT (1H1/45H ----------- MATERIAL PROPERTIES ------------  ,// )
 2003 FORMAT(I5,8E15.6)
```

```
2004 FORMAT (1H1//18A4//
    * 29H TIME SCALE -------------    =,F10.4 //
    * 29H AMPLITUDE SCALE ---------   =,F10.4 //)
2005 FORMAT (8E15.6)
2007 FORMAT (///////
    * 60H ------   INPUT BASE ACCEL. IS LESS THAN REQUESTED RESPONSE //
    * 21H EXECUTION TERMINATED /)
2008 FORMAT (/30H MOTION PLOT REQUEST FOR NODES  /)
2010 FORMAT (/40H STRESS-STRAIN PLOT REQUEST FOR ELEMENTS /)
2011 FORMAT(/,39H PORE PRESSURE PLOTS FOR ELEMENTS :      )
2013 FORMAT (10I5)
2014 FORMAT(4(11X,4HTIME,10X,5HACCEL)//)
2015 FORMAT(15H ACCELERATION :,//)
2016 FORMAT(10H MAT. NO.   ,
    *  11H CONS. MOD.   1X,
    *  11H SHEAR MOD.   ,2X,
    *  15H SH. MOD. CHGE.     ,
    *  18H IN. PL. SH. MOD.    ,2X,
    *  15H PL. MOD. CHGE.     ,2X,
    *  15H BULK MOD.(FL.)    ,
    *  13H PERMEABILITY   ,2X,
    *  17H MASS DEN.(TOTAL)    /        )
2017 FORMAT(//10H MAT. NO.              ,
    *  15H MASS DEN.(FL.)     ,2X,
    *  8H S(MAX)           ,3X,
    *  10H 1./LAMBDA    ,4X,
    *  8H    TLRNC,6X,
    *  6H ALPHA  ,9X,
    *  6H THETA  ,9X,
    *  16H RES. EFF. STRS.      ,
    *  10H VOID RAT.        /)
2019 FORMAT(53H ---------- TRANSMITTING BOUNDARY COEFF. ----------  ,/
    *  25H HORIZONTAL DIRECTION =      ,E13.4,/
    *  25H VERTICAL DIRECTION   =      ,E13.4)
2020 FORMAT(//
    *  53H ---------- PROPORTIONAL DAMPING COEFF. ----------     ,//
    *  20H MASS DEPENDENT   =  ,F10.4,/
    *  20H STIFF. DEPENDENT =  ,F10.4,/)
2021 FORMAT(65H OUTPUT OF BASE MOTION INPUT IS SUPPRESSED DUE TO USER R
    *EQUEST         )
     END
```

```
      SUBROUTINE MESH (DEPTH,NEL,MATYP,XLENT,MATNUM,INTBL,WTABLE,
     *  NLAYER)
C
      DIMENSION DEPTH(1),NEL(1),MATYP(1),XLENT(1),MATNUM(1),INTBL(1)
C
      ZCOORD=0.0
      NUM=0
      DO 200 I=1,NLAYER
      NTL=NEL(I)
      IF (I.EQ.1) XL=DEPTH(I)/NTL
      IF (I.GT.1) XL=(DEPTH(I)-DEPTH(I-1))/NTL
      DO 150 J=1,NTL
      NUM=NUM+1
      ZCOORD=ZCOORD+XL
      XLENT(NUM)=XL
      MATNUM(NUM)=MATYP(I)
      IF (ZCOORD.LE.WTABLE) INTBL(NUM)=0
      IF (ZCOORD.GT.WTABLE) INTBL(NUM)=1
  150 CONTINUE
  200 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE SELFLD (XLENT,MATNUM,IWTBL,EMATL,STRS,SLVCT,NUMNP,NC)
C
C     SUBROUTINE TO COMPUTE INSITU FORCE VECTOR
C
      DIMENSION XLENT(1),MATNUM(1),IWTBL(1),EMATL(35,1),STRS(4,1),
     *  SLVCT(1)
C
      COMMON/WLVL/WTABLE,GRAV
      COMMON/BASDAM/IBDMP,C1,C2
C
      DEPT=0.
      SYN=-1.0
      DO 500 LL=1,NUMNP
      ZLENT=XLENT(LL)
      NUM=MATNUM(LL)
      IW=IWTBL(LL)
      GMA=GRAV*EMATL(14,NUM)
      GMAW=GRAV*EMATL(15,NUM)
      DEPT=DEPT+0.5*ZLENT
      STRS2=0.5*SYN*GMA*ZLENT
      IF(IW.EQ.0) GO TO 100
      STRS(4,LL)=(DEPT-WTABLE)*GMAW*SYN
      STRS2=STRS2+0.5*GMAW*ZLENT
  100 CONTINUE
      LT=LL*NC-1
      LB=LT+NC
      SLVCT(LT)=SLVCT(LT)+STRS2
      IF(IBDMP.EQ.0.AND.LL.GE.NUMNP) GO TO 150
      SLVCT(LB)=SLVCT(LB)+STRS2
  150 CONTINUE
      DEPT=DEPT+0.5*ZLENT
  500 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE MASSMT (EM,XLENT,MATNUM,IWTBL,EMATL,NUMNP,NC)
C
C     SUBROUTINE TO FORM MASS MATRIX
C
      DIMENSION EM(1),XLENT(1),MATNUM(1),IWTBL(1),EMATL(35,1)
C
      COMMON/BASDAM/IBDMP,C1,C2
C
      NCC=NC-1
      K=0
      L=NC
      DO 300 LL=1,NUMNP
      NUM=MATNUM(LL)
      RHO=EMATL(14,NUM)
      RHOW=EMATL(15,NUM)
      ZLENT=XLENT(LL)
      EMAS=0.5*RHO*ZLENT
      DO 100 I=1,NCC
      EM(K+I)=EMAS+EM(K+I)
       IF(IBDMP.EQ.0.AND.LL.GE.NUMNP) GO TO 100
      EM(L+I)=EMAS
  100 CONTINUE
      IF (IWTBL(LL).EQ.0) GO TO 200
      EMAS=0.5*RHOW*ZLENT
      EM(K+NC)=EMAS+EM(K+NC)
      IF(IBDMP.EQ.0.AND.LL.GE.NUMNP) GO TO 200
      EM(L+NC)=EMAS
  200 CONTINUE
      K=L
      L=L+NC
  300 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE GSTIF (A,C,NC,NEQ,LFLAG)
C
C     SUBROUTINE TO FORM STIFFNESS MATRIX
C
      DIMENSION A(1),C(4,4)
C
      DO 400 N=1,NC
      L=N
      DO 100 K=N,NC
      A(L)=A(L)+C(N,K)
  100 L=L+NEQ
      IF (LFLAG.EQ.0) GO TO 400
      DO 200 K=1,NC
      A(L)=-C(N,K)
  200 L=L+NEQ
      L=NC+N
      DO 300 K=N,NC
      A(L)=C(N,K)
  300 L=L+NEQ
  400 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE SOLVE (XLENT,MATNUM,INTBL,EMATL,BACC,ST,DD,DI,VE,AC,
     *  DU,EM,ELD,NBW,STRS,STRN,SLVCT,JPLTH,JPLTSS,JSETS,
     *  PL,TLIQ,AHIST,MDD,BVC,RMAX,EXTSS,ENVAR,NBLK,NPTOT,NUMNP,NMAT,
     *  NEQ,MBAND,NCCY,NXINC)
C
      COMMON/CONTL/MED(18),NCYCL,DT,NDI,NDOF,NPRNT,NSAVE,
     *  LUN,NC,NUPDAT,NSTPNT
      COMMON/PLTING/ NPLOTH,NPLTSS,NSETS,HPAP,HPLOT,BPLOT,DPLOT.EPLOT,
     *  TEND,NPLPNT
      COMMON/SPEC/DV(10),NODE(10),NNODE,IRS,IRSP
      COMMON/BASDAM/IBDMP,C1,C2
      COMMON/DAMP/IVDMP,ALFA,BETA
      COMMON/DIRECT/NX,NY,NZ
C
      DIMENSION KLENT(1),MATNUM(1),INTBL(1),EMATL(35,1),BACC(NCCY,1),
     *  ST(NEQ,1),DD(NEQ,1),DI(1),VE(1),AC(1),DU(1),EM(1),ELD(1),NBW(1),
     *  STRN(4,1),STRS(4,1),DEPSL(4),SK(4,4),SLVCT(1),
     *  JPLTH(1),JPLTSS(1),JSETS(1),PL(NBLK,1),TLIQ(NUMNP,1),
     *  AHIST(NCCY,1),MDD(1),BVC(1),ENVAR(15,1),IX(4),
     *  RMAX(NEQ,3,1),EXTSS(NUMNP,4,1)
C
C
C     INTEGRATION CONSTANT
C
      TETA=2.0
      TAU=TETA*DT
      A0=6.0/(TAU*TAU)
      A1=6.0/TAU
      A2=2.0
      A3=A0/TETA
      A4=-6.0/(TETA*TAU)
      A5=1.0-3.0/TETA
      A6=DT/2.0
      A7=DT*DT/6.0
      B0=3.0/TAU
      B1=2.0
      B2=TAU/2.0
C
      IF(NY.EQ.0) GO TO 10
      IX(1)=3
      IX(2)=1
      IX(3)=2
      IX(4)=4
      GO TO 15
   10 CONTINUE
      IX(1)=2
      IX(2)=1
      IX(3)=0
      IX(4)=3
   15 CONTINUE
      TIME=0.0
C
C
      NQB=NEQ*MBAND
      KPRNT=0
      KSAVE=0
      KUPDAT=0
      NCYST=NCYCL+1
      XINCRT=0.0
      NFIRST=0
```

```
      IF(IVDMP.NE.0) GO TO 16
      ALFA=0.0
      BETA=0.0
   16 CONTINUE
      CALL SZERO (SK(1,1),16)
      AST=0.0
      NM=0
      DO 30 I=1,NUMNP
      J=I*NC-1
      AST=AST+SLVCT(J)
      SLVCT(J+1)=SLVCT(J+1)+STRS(4,I)
      SLVCT(J)=SLVCT(J)+SLVCT(J+1)
      IF (I.NE.NUMNP) SLVCT(J+NC+1)=-STRS(4,I)
      STRS(1,I)=AST
   30 CONTINUE
      DO 40 I=1,NUMNP
      IF (MATNUM(I).EQ.NM) GO TO 20
      NM=MATNUM(I)
      DPT=0.0
      GZRO=EMATL(2,NM)
      DG=EMATL(3,NM)
      HO=EMATL(4,NM)
      DH=EMATL(5,NM)
   20 CONTINUE
      DPT=DPT+0.5*XLENT(I)
      G=GZRO+DG*DPT
      EMVAR(1,I)=-G/STRS(1,I)
      H=HO+DH*DPT
      EMVAR(15,I)=-H/STRS(1,I)
      DPT=DPT+0.5*XLENT(I)
   40 CONTINUE
      G=GZRO+DG*DPT
      IF(IBDMP.NE.0) SLVCT(NEQ-1)=0.0
      DO 45 I=1,NUMNP
      TLIQ(I,1)=-1.0
   45 TLIQ(I,2)=-1.0
C
C     MAIN DYNAMIC SOLUTION LOOP
C
      DO 46 I=1,NDOF
   46 DEPSL(I)=0.0
      DO 800 NCNT=1,NCYST
      LFLAG=1
      KUPDAT=KUPDAT+1
      IF (NCNT.EQ.1) KUPDAT=NUPDAT
      IF(KUPDAT.EQ.NUPDAT) CALL SZERO (ST(1,1),NQB)
      NUMYLD=0
C
C     ELEMENT LOOP
C
      DO 200 LL=1,NUMNP
      ZLENT=XLENT(LL)
      IL2=LL*NC
      IL1=IL2-NC
      IF(IBDMP.EQ.0.AND.LL.GE.NUMNP) LFLAG=0
      IF(LFLAG.EQ.0) GO TO 50
C
C     STRAINS
C
      DO 47 I=1,4
      J=IX(I)
```

```
      IF(J.EQ.0) GO TO 47
      DEPSL(I)=(DU(IL1+J)-DU(IL2+J))/ZLENT
   47 CONTINUE
      GO TO 60
   50 CONTINUE
      DO 55 I=1,4
      J=IX(I)
      IF(J.EQ.0) GO TO 55
      DEPSL(I)=DU(IL1+J)/ZLENT
   55 CONTINUE
   60 CONTINUE
      NM=MATNUM(LL)
      BLK=EMATL(1,NM)
      IN=INTBL(LL)
      DELP=0
      IF(IN.EQ.1) DELP=-DEPSL(1)*BLK
      IF(TLIQ(LL,1).GT.0.0) DELP=0
      DO 100 I=1,4
  100 STRN(I,LL)=STRN(I,LL)+DEPSL(I)
C
C     STRESS AND MATERIAL PROPERTIES
C
      CALL MATPAC (STRN(1,LL),STRS(1,LL),DEPSL,SK,EMATL(1,NM),
     *  EMATL(16,NM),EMVAR(1,LL),TLIQ,TIME,DELP,LL,NC,NFIRST,IN,NUMNP,
     *  MXINC)
      IF (NCNT.LE.1) GO TO 110
      IF (IN.EQ.0) GO TO 110
      BULKF=EMATL(12,NM)
      STRS(4,LL)=STRS(4,LL)+BULKF*(DEPSL(4)+DEPSL(1))
  110 CONTINUE
C
C     INTERNAL RESISTING FORCE VECTOR
C
      DO 115 I=1,4
      J=IX(I)
      IF(J.EQ.0) GO TO 115
      ELD(IL1+J)=ELD(IL1+J)-STRS(I,LL)
      IF(LFLAG.EQ.0) GO TO 115
      ELD(IL2+J)=ELD(IL2+J)+STRS(I,LL)
  115 CONTINUE
      J=IX(1)
      ELD(IL1+J)=ELD(IL1+J)-STRS(4,LL)
      IF(LFLAG.EQ.0) GO TO 120
      ELD(IL2+J)=ELD(IL2+J)+STRS(4,LL)
  120 CONTINUE
C
C     SYSTEM STIFFNESS MATRIX
C
      IF(NCNT.EQ.1) GO TO 145
      IF(KUPDAT.NE.NUPDAT) GO TO 180
  145 CONTINUE
      DO 150 I=1,4
      DO 150 J=1,4
  150 SK(I,J)=SK(I,J)/ZLENT
      NPOS=NC*(LL-1)+1
      CALL GSTIF (ST(NPOS,1),SK,NC,NEQ,LFLAG)
      IF (IN.EQ.0) ST(NPOS+NC-1,1)=1.0
C
C     DISSIPATION RESISTANCE MATRIX
C
      PERM=EMATL(13,NM)
```

```
      FAC=ZLENT/(6.0*PERM)
      NPOS=NPOS+NC-1
      IF(NCNT.NE.1) GO TO 180
      IF (IN.EQ.0) GO TO 180
      I=NPOS
      DD(I,1)=DD(I,1)+2.0*FAC
      IF(LFLAG.EQ.0) GO TO 160
      DD(I,NC+1)=DD(I,NC+1)+FAC
      DD(I+NC,1)=DD(I+NC,1)+2.0*FAC
  160 CONTINUE
      IF(IVDMP.EQ.0) GO TO 180
C
C     MASS AND STIFFNESS PROPORTIONAL
C               DAMPING
C
      I=I-NC
      JJJ=2
      DO 172 J=2,NC
      JI=1
      DO 171 JJ=JJJ,NC
      DD(I+J,JI)=DD(I+J,JI)+BETA*SK(J,JJ)
      JI=JI+1
  171 CONTINUE
      JJJ=JJJ+1
  172 CONTINUE
      DD(I+NC,1)=DD(I+NC,1)+ALFA*EM(I+NC)
      IF(LFLAG.EQ.0) GO TO 180
      I=I+NC
      JJJ=2
      DO 174 J=2,NC
      JI=1
      DO 173 JJ=JJJ,NC
      DD(I+J,JI)=DD(I+J,JI)+BETA*SK(J,JJ)
      JI=JI+1
  173 CONTINUE
      JJJ=JJJ+1
  174 CONTINUE
      I=I-NC
      JI=NC+1
      DO 177 J=2,NC
      DO 176 JJ=2,NC
      DD(I+J,JI)=DD(I+J,JI)-BETA*SK(J,JJ)
      JI=JI+1
  176 CONTINUE
      JI=JI-NC
  177 CONTINUE
      I=I+2*NC
      DD(I,1)=DD(I,1)+ALFA*EM(I)
  180 CONTINUE
  200 CONTINUE
C
C     ABSORBING BOUNDARY
C
      IF(NCNT.NE.1) GO TO 208
       IF(IBDMP.EQ.0) GO TO 240
      DD(NEQ,1)=0.0
      DO 207 I=2,MBAND
      J=I-1
  207 DD(NEQ-J,I)=0.0
  240 CONTINUE
      CALL PROFIL(DD,NDD,NEQ,MBAND)
```

```
  208 CONTINUE
      DO 209 I=1,NEQ
      DO 209 J=1,MBAND
  209 ST(I,J)=ST(I,J)+BO*DD(I,J)
      IF(IBDMP.EQ.0) GO TO 206
      ELD(NEQ-1)=0.0
      ST(NEQ-1,1)=ST(NEQ-1,1)+BO*C1
      ST(NEQ-2,1)=ST(NEQ-2,1)+BO*C2
      IF(NY.EQ.0) GO TO 215
      ST(NEQ-3,1)=ST(NEQ-3,1)+BO*C2
  215 CONTINUE
      ST(NEQ)=1.0
      DO 204 I=2,MBAND
      J=I-1
  204 ST(NEQ-J,I)=0.0
  206 CONTINUE
C
C     SAVE DATA FOR PLOTING
C
      IF(NPTOT.LE.0) GO TO 201
      IF(TIME.GE.TEND) GO TO 201
      IF (NCNT.LE.1) GO TO 201
      IF (NFIRST.EQ.0) GO TO 201
      KSAVE=KSAVE+1
      IF (KSAVE.LT.NSAVE) GO TO 201
      CALL SAVE (JPLTN,JPLTSS,JSETS,PL,AC,VE,DI,STRN,STRS,
     *  NUMNP,NBLK,TIME,NPTOT,LUN,BACELX,BACELY,BACELZ,NDI,NC)
      KSAVE=0
  201 CONTINUE
C
C     PRINT STRESSES
C
      IF (KPRNT.NE.0) GO TO 205
      IF(NFIRST.NE.0) GO TO 202
      WRITE (6,2004)
      WRITE (6,2005) (I,STRS(1,I),STRS(4,I),I=1,NUMNP)
      IF(NPTOT.LE.0) GO TO 190
      DO 203 I=1,NUMNP
      PL(I,NPTOT-1)=STRS(4,I)
  203 PL(I,NPTOT)=STRS(1,I)
  190 CONTINUE
      GO TO 205
  202 CONTINUE
      IF (NCNT.LT.NSTPRT) GO TO 205
      IF(NY.NE.0) GO TO 211
      WRITE (6,2006) TIME
      WRITE (6,2007) (I,STRN(1,I),STRN(2,I),STRN(4,I),STRS(1,I),STRS(2,
     *I),STRS(4,I),I=1,NUMNP)
      GO TO 205
  211 WRITE(6,2009) TIME
      WRITE(6,2010) (I,(STRN(J,I),J=1,4),(STRS(J,I),J=1,4),I=1,NUMNP)
  205 CONTINUE
C
C     COMPUTE MAXIMUM STRESSES AND STRAINS
C
      K=1
      DO 216 I=2,4
      IF(NY.EQ.0.AND.I.EQ.3) GO TO 214
      DO 213 J=1,NUMNP
      IF(ABS(STRS(I,J)).LT.ABS(EXTSS(J,1,I-K))) GO TO 210
      EXTSS(J,1,I-K)=STRS(I,J)
```

```
      EXTSS(J,2,I-K)=TIME
  210 CONTINUE
      IF(I.EQ.4) GO TO 217
      IF(ABS(STRN(I,J)).LT.ABS(EXTSS(J,3,I-K))) GO TO 212
      EXTSS(J,3,I-K)=STRN(I,J)
      EXTSS(J,4,I-K)=TIME
      GO TO 212
  217 EXTSS(J,3,I-K)=STRS(1,J)
  212 CONTINUE
  213 CONTINUE
  214 CONTINUE
      IF(NY.EQ.0.AND.I.EQ.2) K=2
  216 CONTINUE
      NFIRST=NFIRST+1
      NDL=0
      IF (NCNT.EQ.NCYST) GO TO 800
C
C     K+A0*M
C
C
      IF(KUPDAT.NE.NUPDAT) GO TO 230
      DO 220 I=1,NEQ
  220 ST(I,1)=ST(I,1)+A0*EM(I)
  230 CONTINUE
C
C     EQUIVALENT LOAD VECTOR
C
      DO 250 I=1,NEQ
      AA=A1*VE(I)+A2*AC(I)
  250 ELD(I)=ELD(I)+EM(I)*AA+SLVCT(I)
      DO 280 I=1,NEQ
  280 BVC(I)=B1*VE(I)+B2*AC(I)
      CALL MLTPLY(DD,ELD,BVC,MDD,NEQ)
      IF(IBDMP.EQ.0) GO TO 290
      IF(NY.EQ.0) GO TO 285
      AA=B1*VE(NEQ-3)+B2*AC(NEQ-3)
      ELD(NEQ-3)=ELD(NEQ-3)+AA*C2
  285 CONTINUE
      AA=B1*VE(NEQ-2)+B2*AC(NEQ-2)
      ELD(NEQ-2)=ELD(NEQ-2)+AA*C2
      AA=B1*VE(NEQ-1)+B2*AC(NEQ-1)
      ELD(NEQ-1)=ELD(NEQ-1)+AA*C1
      ELD(NEQ)=0.0
  290 CONTINUE
      L=0
      IF(NX.EQ.0) GO TO 292
      L=L+1
      BACELX=BACC(NCNT,L)
  292 IF(NY.EQ.0) GO TO 294
      L=L+1
      BACELY=BACC(NCNT,L)
  294 IF(NZ.EQ.0) GO TO 296
      L=L+1
      BACELZ=BACC(NCNT,L)
  296 CONTINUE
      NND=0
      DO 330 I=1,NEQ,NC
      NND=NND+1
      IF(NND.LE.NDL) GO TO 330
      L=I-1
      IF(NX.EQ.0) GO TO 300
```

```
      L=L+1
      ELD(L)=ELD(L)-EM(L)*BACELY
  300 IF(NY.EQ.0) GO TO 320
      L=L+1
      ELD(L)=ELD(L)-EM(L)*BACELY
  320 IF(NZ.EQ.0) GO TO 330
      L=L+1
      ELD(L)=ELD(L)-EM(L)*BACELZ
  330 CONTINUE
C
C     SOLVE
C
      IF (NCNT.EQ.1) GO TO 351
      IF (KUPDAT.NE.NUPDAT) GO TO 352
  351 CALL TRIA (ST,NBW,NEQ,NBAND)
  352 CONTINUE
      CALL BACKS (ST,ELD,NBW,NEQ,NBAND)
C
C     DISPL.,VELOCITY,ACCEL.
C
      DO 400 I=1,NEQ
      ACCEL=A3*ELD(I)+A4*VE(I)+A5*AC(I)
      VELOC=VE(I)+A6*(AC(I)+ACCEL)
      DISPL=DI(I)+DT*VE(I)+A7*(2.*AC(I)+ACCEL)
      AC(I)=ACCEL
      VE(I)=VELOC
      DU(I)=DISPL-DI(I)
      DI(I)=DISPL
      ELD(I)=0.0
  400 CONTINUE
C
C     SAVE DATA FOR RESPONSE SPECTRA CALC.
C
      IF(NNODE.LE.0) GO TO 409
      DO 408 I=1,NNODE
      J=(NODE(I)-1)*NC+1
      AHIST(NCNT,I)=AC(J)+BACELX
      IF(NY.NE.0) AHIST(NCNT,I+NNODE)=AC(J+1)+BACELY
  408 CONTINUE
  409 CONTINUE
      TIME=TIME+DT
C
C     COMPUTE MAXIMUM RESPONSE
C
      J=0
      INDEX=3
      IF(NY.NE.0) INDEX=4
      DO 407 I=1,NEQ,INDEX
      II=I+INDEX-1
      M=0
      DO 404 K=I,II
      J=K
      M=M+1
      IF(ABS(DI(K)).LT.ABS(RMAX(J,1,1))) GO TO 401
      RMAX(J,1,1)=DI(K)
      RMAX(J,1,2)=TIME
  401 CONTINUE
      IF(ABS(VE(K)).LT.ABS(RMAX(J,2,1))) GO TO 402
      RMAX(J,2,1)=VE(K)
      RMAX(J,2,2)=TIME
  402 CONTINUE
```

```
      ACM=AC(K)
      IF(M.EQ.1) ACM=ACM+BACELX
      IF(M.EQ.2.AND.INDEX.EQ.4) ACM=ACM+BACELY
      IF(M.EQ.3.AND.INDEX.EQ.4) ACM=ACM+BACELZ
      IF(M.EQ.2.AND.INDEX.EQ.3) ACM=ACM+BACELZ
      IF(ABS(ACM).LT.ABS(RMAX(J,3,1))) GO TO 403
      RMAX(J,3,1)=ACM
      RMAX(J,3,2)=TIME
  403 CONTINUE
  404 CONTINUE
  407 CONTINUE
C
C     PRINT RESPONSE
C
      KPRNT=KPRNT+1
      IF (KPRNT.LT.NPRNT) GO TO 420
      KPRNT=0
      IF (NCNT.LT.NSTPRT) GO TO 420
      IF(NY.EQ.0) GO TO 405
      WRITE(6,2002) TIME
      GO TO 406
  405 WRITE (6,2000) TIME
  406 CONTINUE
      J=0
      INDEX=3
      IF(NY.NE.0) INDEX=4
      DO 410 I=1,NEQ,INDEX
      J=J+1
      II=I+INDEX-1
      IF(NY.NE.0) GO TO 411
      WRITE (6,2001) J,(DI(K),K=I,II),(VE(K),K=I,II),(AC(K),K=I,II)
      GO TO 410
  411 WRITE(6,2008) J,(DI(K),K=I,II),(VE(K),K=I,II),(AC(K),K=I,II)
  410 CONTINUE
  420 CONTINUE
      IF (KUPDAT.EQ.NUPDAT) KUPDAT=0
  800 CONTINUE
C
C     PRINT MAXIMUM RESPONSE
C               AND
C     EXTREME STRESSES AND STRAINS
C
      INDEX=3
      IF(NY.NE.0) INDEX=4
      WRITE(6,2011)
      DO 960 I=1,INDEX
      J=0
      IF(INDEX.EQ.4) GO TO 925
      GO TO (920,921,922),I
  920 WRITE(6,2013)
      GO TO 940
  921 WRITE(6,2015)
      GO TO 940
  922 WRITE(6,2016)
      GO TO 940
  925 GO TO (930,931,932,933),I
  930 WRITE(6,2013)
      GO TO 940
  931 WRITE(6,2014)
      GO TO 940
  932 WRITE(6,2015)
```

```
      GO TO 940
  933 WRITE(6,2016)
  940 CONTINUE
      WRITE(6,2017)
      DO 950 K=I,NEQ,INDEX
      J=J+1
      II=K
      WRITE(6,2018) J,RMAX(II,1,1),RMAX(II,1,2),RMAX(II,2,1),
     *  RMAX(II,2,2),RMAX(II,3,1),RMAX(II,3,2)
  950 CONTINUE
  960 CONTINUE
      WRITE(6,2019)
      WRITE(6,2013)
      WRITE(6,2020)
      WRITE(6,2021)  (I,(EXTSS(I,J,1),J=1,4),I=1,NUMNP)
      K=2
      IF(NY.EQ.0) GO TO 970
      K=3
      WRITE(6,2014)
      WRITE(6,2020)
      WRITE(6,2021)  (I,(EXTSS(I,J,2),J=1,4),I=1,NUMNP)
  970 WRITE(6,2022)
      WRITE(6,2023)
      WRITE(6,2024)  (I,(EXTSS(I,J,K),J=1,3),I=1,NUMNP)
      RETURN
 2000 FORMAT (1H1/ 40H  ---------- RESPONSE AT TIME -----   =  ,F10.5//
     * 2X,1HN,5X,2HDX,11X,2HDZ,11X,2HDW,11X,2HVX,11X,2HVZ,11X,2HVW,11X,
     * 2HAX,11X,2HAZ,11X,2HAW  / )
 2001 FORMAT (I3,9E13.4)
 2002 FORMAT (1H1/ 40H  ---------- RESPONSE AT TIME -----   =   ,F10.5//
     *  2X,1HN,8X,2HDX,8X,2HDY,8X,2HDZ,8X,2HDW,8X,2HVX,8X,2HVY,8X,2HVZ,
     *  8X,2HVW,8X,2HAX,8X,2HAY,8X,2HAZ,8X,2HAW   / )
 2004 FORMAT (//40H  ----- INSITU STRESS CONDITION -----    /
     *  3X,7HELEMENT,5X,9HEFFECTIVE,6X,4HPORE/3X,6HNUMBER,6X,8HPRESSURE,
     *  7X,8HPRESSURE//)
 2005 FORMAT (5X,I5,5X,2E15.4)
 2006 FORMAT (//45H  ----- STRAINS AND STRESSES AT TIME ----- = ,F10.5//
     *  3X,7HELEMENT,10X,6HVOLUME,9X,5HSHEAR,10X,9HFLUID VOL,6X,
     *  9HEFFECTIVE,6X,5HSHEAR,10X,4HPORE/3X,6HNUMBER,11X,6HSTRAIN,9X,
     *  6HSTRAIN,9X,6HCHANGE,9X,8HPRESSURE,7X,6HSTRESS,9X,8HPRESSURE//)
 2007 FORMAT (5X,I5,5X,6E15.4)
 2008 FORMAT (1X,I3,3(1PE12.2,3(1PE10.2)))
 2009 FORMAT (//44H  ----- STRAINS AND STRESSES AT TIME ----- =,F10.5//
     *  1X,7HELEMENT,3X,6HVOLUME,8X,5HSHEAR,8X,5HSHEAR,10X,9HFLUID VOL,
     *  6X,9HEFFECTIVE,6X,5HSHEAR,10X,5HSHEAR,8X,4HPORE/1X,6HNUMBER,
     *  4X,6HSTRAIN,8X,7HSTRN. X,6X,7HSTRN. Y,8X,6HCHANGE,9X,8HPRESSURE,
     *  7X,6HSTRESS,7X,6HSTRESS,7X,8HPRESSURE//)
 2010 FORMAT(I3,5X,8E13.4)
 2011 FORMAT(1H1///40H ------- MAXIMUM RESPONSE --------        /)
 2013 FORMAT(//25H ------ X-DIRECTION ----      ,/)
 2014 FORMAT(//25H ------ Y-DIRECTION ----      ,/)
 2015 FORMAT(//25H ------ Z-DIRECTION ----      ,/)
 2016 FORMAT(//25H ------ WATER       ----      ,/)
 2017 FORMAT(3X,2H N,2X,11H MAX. DISP.,4X,5H TIME,4X,10H MAX. VEL.,4X,
     *  5H TIME,3X,10H MAX. ACC.,3X,5H TIME/)
 2018 FORMAT(I5,3(E13.4,F10.5))
 2019 FORMAT(1H1///50H -------- EXTREME STRESSES AND STRAINS --------
     *      /)
 2020 FORMAT(//3X,2H N,2X,12H SHEAR STRS.    ,5X,5H TIME,5X,
     *  12H SHEAR STRN.    ,5X,5H TIME/)
 2021 FORMAT(I5,E13.4,F10.5,E13.4,F10.5)
```

```
2022 FORMAT(//50H ------- EFFECTIVE STRS. AND PORE PRESS. -------      )
2023 FORMAT(3X,2H N,2X,12H PORE PRES.    ,3X,5H TIME,4X,12H EFF. STRS.
    *   /)
2024 FORMAT(I5,E13.4,F10.5,E13.4)
     END
```

```
      SUBROUTINE MATPAC (STRN,STRS,DEPSL,SK,EMATLA,EMATLB,EMVAR,
     *  TLIQ,TIME,DELP,LL,NC,NFIRST,IW,NUMNP,NYINC)
C
      DIMENSION STRN(4),STRS(4),SK(4,4),EMATLA(1),EMATLB(1),
     *  TLIQ(NUMNP,1),EMVAR(15),DEPSL(4),EM(2,2),
     *  CEP(2,2),AV(2)
C
C
C     MAIN MATERIAL PROPERTY SUBROUTINE
C
      FY=0.
      ELAMDA=1.0/EMATLB(2)
      EM=EMATLB(1)
      BLK=EMATLA(1)
      BLKP=EMATLA(12)
      FAIL=EMATLB(4)*EM
      PE=-STRS(1)
      IF(TLIQ(LL,1).GT.0.0) PE=EMVAR(10)
      GG=EMVAR(1)*PE
      TLRNC=EMATLB(3)*PE
      HO=EMVAR(15)
      CEP(1,1)=GG
      CEP(2,2)=GG
      CEP(1,2)=0.0
      CEP(2,1)=0.0
      DGAMAX=DEPSL(2)
      DGAMAY=DEPSL(3)
      TAUX=STRS(2)
      TAUY=STRS(3)
      YIELD=EMVAR(2)
      TAUCX=EMVAR(3)
      TAUCY=EMVAR(4)
      TAUAX=EMVAR(5)
      TAUAY=EMVAR(6)
      PEO=EMVAR(9)
      BBAA=EMVAR(13)
      B2=EMVAR(14)
      IF(NFIRST.EQ.0) GO TO 790
      IF(TLIQ(LL,1).GT.0.0) GO TO 50
      PP=(PE+DELP)/PE
      TAUCX=TAUCX*PP
      TAUCY=TAUCY*PP
      TAUAX=TAUAX*PP
      TAUAY=TAUAY*PP
      TAUX=TAUX*PP
      TAUY=TAUY*PP
      PE=PE+DELP
      TAUP=SQRT(TAUAX*TAUAX+TAUAY*TAUAY)/PE
      CALL FINDPO (PE,TAUP,ELAMDA,EM,PEO)
   50 CONTINUE
      DTEX=GG*DGAMAX
      DTEY=GG*DGAMAY
      IF(IW.NE.0) GO TO 60
      TAUX=TAUX+DTEX
      TAUY=TAUY+DTEY
      GO TO 600
   60 CONTINUE
      IF(NFIRST.GT.1) GO TO 90
      RE=DTEX*DTEX+DTEY*DTEY
      RE=SQRT(RE)
```

```
      IF(RE.GT.0.1) GO TO 90
      TAUAX=0.10001
      TAUAY=0.0
      TAUCX=0.00001
      TAUCY=0.0
      TAUX=DTEX
      TAUY=DTEY
      YIELD=-1.0
      TAUP=SQRT(TAUAX*TAUAX+TAUAY*TAUAY)
      CALL FINDPO(PE,TAUP,ELAMDA,EM,PEO)
      CALL FINDBA (TAUAX,TAUAY,TAUCX,TAUCY,PE,BBAA,B2)
      GO TO 600
   90 CONTINUE
      CALL FINDBA (TAUAX,TAUAY,TAUCX,TAUCY,PE,BBAA,B2)
      DTE=SQRT(DTEX*DTEX+DTEY*DTEY)
      IF(YIELD.LE.0.0) GO TO 200
C
C     PREVIOUS STEP PLASTIC
C
      CALL CALFA (TAUCX,TAUCY,ALFA)
      INDEX=1
      CALL TRNFRM(TAUAX,TAUAY,TAUCX,TAUCY,TTAX,TTAY,ALFA,INDEX)
      VNX=BBAA*TTAX
      VNY=TTAY
      INDEX=2
      CALL TRNFRM (VNNX,VNNY,0.0,0.0,VNX,VNY,ALFA,INDEX)
      AA=VNNX*DTEX+VNNY*DTEY
      IF(AA.LT.0.0) GO TO 100
      GO TO 500
  100 CONTINUE
      CALL FINDB (TAUAX,TAUAY,TX,TY,TAUCX,TAUCY,DTEX,DTEY,DTE,PE,YIELD,
     *  BBAA)
      IF(YIELD.LT.0.) GO TO 300
      PLPART=(DTEX-TX+TAUX)/DTEX
      DGAMAX=PLPART*DGAMAX
      DGAMAY=PLPART*DGAMAY
      TAUAX=TX
      TAUAY=TY
      GO TO 400
C
C     PREVIOUS STEP ELASTIC
C
  200 CONTINUE
      TX=TAUX+DTEX
      TY=TAUY+DTEY
      CALL CKYLD (TX,TY,TAUCX,TAUCY,PE,FY,BBAA,B2)
      IF(FY.LT.0.0) GO TO 300
      CALL FINDD (TAUX,TAUY,TX,TY,TAUAX,TAUAY,TAUCX,TAUCY,PE,BBAA,B2)
      TAUX=TAUAX
      TAUY=TAUAY
      PLPART=(TX-TAUAX)/DTEX
      DGAMAX=PLPART*DGAMAX
      DGAMAY=PLPART*DGAMAY
      GO TO 400
C
C     ELASTIC STEP
C
  300 CONTINUE
      TAUX=TX
      TAUY=TY
      YIELD=-1.0
```

```
      GO TO 600
C
C     FROM ELASTIC TO PLASTIC
C
  400 CONTINUE
      IF(TLIQ(LL,1).GT.0.0) GO TO 500
      TAUP=SQRT(TAUAX*TAUAX+TAUAY*TAUAY)/PE
      CALL FINDPO (PE,TAUP,ELAMDA,EM,PEO)
C
C     PLASTIC STEP
C
  500 CONTINUE
      TAUP=SQRT(TAUAX*TAUAX+TAUAY*TAUAY)/PE
      HH=1.0-TAUP/EM
      HH=HO*PE*HH*HH
      CALL AVECT (AV,TAUAX,TAUAY,TAUCX,TAUCY,B2,BBAA)
      EN(1,1)=AV(2)*AV(2)
      EN(2,1)=-AV(1)*AV(2)
      EN(1,2)=EN(2,1)
      EN(2,2)=AV(1)*AV(1)
      ENC=AV(1)-AV(2)
      ENC=ENC*ENC*GG+HH
      ENC=GG*GG/ENC
      DTAUX=ENC*((EN(1,1)+HH/GG)*DGAMAX+EN(1,2)*DGAMAY)
      DTAUY=ENC*(EN(2,1)*DGAMAX+(EN(2,2)+HH/GG)*DGAMAY)
      DTAU=SQRT(DTAUX*DTAUX+DTAUY*DTAUY)
      IF(DTAU.LE.TLRNC) GO TO 520
      NSINC=DTAU/TLRNC+1
      IF(NSINC.GT.MXINC) NSINC=MXINC
      DDGAMX=DGAMAX/NSINC
      DDGAMY=DGAMAY/NSINC
      DO 510 N=1,NSINC
      DTAUX=ENC*((EN(1,1)+HH/GG)*DDGAMX+EN(1,2)*DDGAMY)
      DTAUY=ENC*(EN(2,1)*DDGAMX+(EN(2,2)+HH/GG)*DDGAMY)
      DTAUCX=0.5*(EN(2,2)*DTAUX-EN(1,2)*DTAUY)
      DTAUCY=0.5*(-EN(2,1)*DTAUX+EN(1,1)*DTAUY)
      TAUAX=TAUAX+DTAUX
      TAUAY=TAUAY+DTAUY
      TAUCX=TAUCX+DTAUCX
      TAUCY=TAUCY+DTAUCY
      CALL FINDBA(TAUAX,TAUAY,TAUCX,TAUCY,PE,BBAA,B2)
      CALL AVECT(AV,TAUAX,TAUAY,TAUCX,TAUCY,B2,BBAA)
      TAUP=SQRT(TAUAX*TAUAX+TAUAY*TAUAY)/PE
      HH=1.0-TAUP/EM
      HH=HO*PE*HH*HH
      EN(1,1)=AV(2)*AV(2)
      EN(2,1)=-AV(1)*AV(2)
      EN(1,2)=EN(2,1)
      EN(2,2)=AV(1)*AV(1)
      ENC=AV(1)-AV(2)
      ENC=ENC*ENC*GG+HH
      ENC=GG*GG/ENC
  510 CONTINUE
      GO TO 530
  520 TAUAX=TAUAX+DTAUX
      TAUAY=TAUAY+DTAUY
      TAUCX=TAUCX+0.5*(EN(2,2)*DTAUX-EN(1,2)*DTAUY)
      TAUCY=TAUCY+0.5*(-EN(2,1)*DTAUX+EN(1,1)*DTAUY)
  530 CONTINUE
      TAUX=TAUAX
      TAUY=TAUAY
```

```
      TAUP=SQRT(TAUX*TAUX+TAUY*TAUY)/PE
      CEP(1,1)=ENC*(EN(1,1)+HH/GG)
      CEP(2,1)=ENC*EN(2,1)
      CEP(1,2)=CEP(2,1)
      CEP(2,2)=ENC*(EN(2,2)+HH/GG)
      IF(IW.EQ.0) GO TO 600
      IF(TLIQ(LL,1).GT.0.0) GO TO 561
      IF(TAUP.GE.FAIL) TAUP=FAIL
      ETA=EN/ELAMDA
      ELLA=TAUP/ELAMDA
      ELLA=ELLA*ELLA
      AA=1.0+ELLA
      BB=ETA*ETA
      BB=BB*AA-ELLA
      BB=SQRT(BB)
      BB=1.0+BB
      AA=1.0/AA
      PP=PE0*AA*BB/(1.0+ETA)
      PP=PP/PE
      IF(PP.GT.1.0) PP=1.0
      TAUAX=TAUAX*PP
      TAUAY=TAUAY*PP
      TAUCX=TAUCX*PP
      TAUCY=TAUCY*PP
      TAUX=TAUX*PP
      TAUY=TAUY*PP
      PE=PP*PE
  561 CONTINUE
      CALL FINDBA (TAUAX,TAUAY,TAUCX,TAUCY,PE,BPAA,B2)
      YIELD=1.0
  600 CONTINUE
      IF(TLIQ(LL,1).GT.0.0) GO TO 705
      TAUP=SQRT(TAUAX*TAUAX+TAUAY*TAUAY)/PE
      IF(TAUP.LT.FAIL) GO TO 790
C
C     POST-INITIAL LIQUEFACTION
C
      TLIQ(LL,1)=TIME
      ENVAR(10)=PE
      PEVAR=ENVAR(10)
      ENVAR(11)=FAIL*PE
      ENVAR(12)=FAIL*PE
  705 CONTINUE
      TAU=TAUX
      IF(TLIQ(LL,2).LE.0.0) GO TO 710
      PENEW=-STRS(1)
      GO TO 760
  710 FK=EMATLB(5)
      QT=ENVAR(11)
      QR=ENVAR(12)
      IF(QR.LT.0.0) GO TO 720
      IF(TAU.GT.QR) GO TO 730
      PR=FK*QT*QT/(FAIL*QR)
      PENEW=TAU/FAIL+PR*(1.0-TAU/QR)
      AB=TAU/PENEW
      IF(ABS(AB).LE.FAIL) GO TO 740
      BETA=QT/QR
      BETA=FAIL/(1.0-FK*BETA*BETA)
      QF=FAIL*BETA*PR/(BETA+FAIL)
      PENEW=ABS(TAU)/FAIL
      QT=-QF
```

```
      QR=TAU
      GO TO 740
  720 IF(TAU.LT.QR) GO TO 730
      PR=-EK*QT*QT/(FAIL*QR)
      PENEW=-TAU/FAIL+PR*(1.0-TAU/QR)
      AB=TAU/PENEW
      IF(ABS(AB).LE.FAIL) GO TO 740
      BETA=QT/QR
      BETA=FAIL/(1.0-EK*BETA*BETA)
      QP=FAIL*BETA*PR/(BETA+FAIL)
      PENEW=ABS(TAU/FAIL)
      QT=QP
      QR=TAU
      GO TO 740
  730 CONTINUE
      PENEW=ABS(TAU/FAIL)
      QR=TAU
  740 CONTINUE
      CL=EMATLB(6)
      IF(PENEW.GT.CL) GO TO 750
      IF((QT/FAIL).GT.CL) GO TO 750
      IF(TLIQ(LL,2).GT.0.0) GO TO 750
      TLIQ(LL,2)=TIME
      PENEW=CL
  750 CONTINUE
      EMVAR(11)=QT
      EMVAR(12)=QR
  760 CONTINUE
      STRS(1)=-PENEW
      GO TO 800
  790 CONTINUE
      STRS(1)=-PE
  800 CONTINUE
      EMVAR(2)=YIELD
      EMVAR(3)=TAUCX
      EMVAR(4)=TAUCY
      EMVAR(5)=TAUAX
      EMVAR(6)=TAUAY
      EMVAR(9)=PEO
      EMVAR(13)=BBAA
      EMVAR(14)=B2
      STRS(2)=TAUX
      STRS(3)=TAUY
      IF(IW.EQ.0) BLKF=0.0
      IF(NC.EQ.3) GO TO 850
      SK(1,1)=CEP(1,1)
      SK(2,2)=CEP(2,2)
      SK(3,3)=BLK+BLKF
      SK(1,2)=CEP(1,2)
      SK(1,3)=0.0
      SK(2,1)=CEP(2,1)
      SK(2,3)=0.0
      SK(3,1)=0.0
      SK(3,2)=0.0
      SK(1,4)=0.0
      SK(2,4)=0.0
      SK(4,2)=0.0
      SK(3,4)=BLKF
      SK(4,3)=BLKF
      SK(4,4)=BLKF
      GO TO 900
```

```
850 CONTINUE
    SK(1,1)=CFP(1,1)
    SK(2,2)=BLK+BLKP
    SK(3,3)=BLKP
    SK(1,2)=0.0
    SK(1,3)=0.0
    SK(2,1)=0.0
    SK(3,1)=0.0
    SK(3,2)=BLKP
    SK(2,3)=BLKP
900 CONTINUE
    RETURN
    END
```

```
      SUBROUTINE AVECT (AV,TAUAX,TAUAY,TAUCX,TAUCY,B2,BBAA)
C
      DIMENSION AV(2),AM(2,2)
C
      CALL CALFA (TAUCX,TAUCY,ALFA)
      CC=COS(ALFA)
      SS=SIN(ALFA)
      A2=B2/BBAA
      AM(1,1)=CC*CC/A2+SS*SS/B2
      AM(2,1)=CC*SS/A2-CC*SS/B2
      AM(1,2)=AM(2,1)
      AM(2,2)=SS*SS/A2+CC*CC/B2
      TAX=TAUAX-TAUCX
      TAY=TAUAY-TAUCY
      AV(1)=(AM(1,1)*TAX+AM(2,1)*TAY)*2.0
      AV(2)=(AM(1,2)*TAX+AM(2,2)*TAY)*2.0
      AA=AV(1)*AV(1)+AV(2)*AV(2)
      AA=SQRT(AA)
      AV(1)=AV(1)/AA
      AV(2)=AV(2)/AA
C
      RETURN
      END
```

```
      SUBROUTINE CKYLD (TX,TY,TCX,TCY,PE,FY,BBAA,BB)
C
      CALL CALFA (TCX,TCY,ALFA)
      INDEX=1
      CALL TRNFRM (TX,TY,TCX,TCY,TTX,TTY,ALFA,INDEX)
      AA=BBAA
      FY=AA*TTX*TTX+TTY*TTY-BB
      RETURN
      END
```

```
      SUBROUTINE FINDBA (TAUAX,TAUAY,TAUCX,TAUCY,PE,BBAA,B2)
C
      CALL CALFA (TAUCX,TAUCY,BETA)
      INDEX=1
      CALL TRNFRM (TAUAX,TAUAY,TAUCX,TAUCY,TAX,TAY,BETA,INDEX)
      TGAMA=(TAUCX*TAUCX+TAUCY*TAUCY)
      TGAMA=SQRT(TGAMA)/PE
      AB=TGAMA*(TAY*TAY+PE*PE)
      CX=TAX*TAX+TAY*TAY-2.0*PE*TAX*TGAMA+PE*PE
      TALFA=SQRT(CX*CX+4.0*TGAMA*PE*PE*AB)-CX
      TALFA=TALFA/(2.0*AB)
      BBAA=1.0/(1.0+TALFA*TGAMA)
      B2=BBAA*TAX*TAX+TAY*TAY
      RETURN
      END
```

```
      SUBROUTINE FINDB (TAX,TAY,TBX,TBY,TCX,TCY,DTX,DTY,DTE,PE,YIELD,
     *  BBAA)
C
      CALL CALFA (TCX,TCY,ALFA)
      INDEX=1
      CALL TRNFRM (TAX,TAY,TCX,TCY,TTAX,TTAY,ALFA,INDEX)
      CALL TRNFRM (DTX,DTY,0.0,0.0,DDTX,DDTY,ALFA,INDEX)
      CALL CALFA (DDTX,DDTY,BETA)
      CC=COS(BETA)
      SS=SIN(BETA)
      AA=BBAA
      DDTE=AA*TTAX*CC+TTAY*SS
      DDTE=-(2.0*DDTE)/(AA*CC*CC+SS*SS)
      IF(ABS(DDTE).LE.DTE) GO TO 100
      DDTE=DTE
      YIELD=-1.0
  100 CONTINUE
      TTBX=TTAX+DDTE*CC
      TTBY=TTAY+DDTE*SS
      INDEX=2
      CALL TRNFRM (TBX,TBY,TCX,TCY,TTBX,TTBY,ALFA,INDEX)
      RETURN
      END
```

```
      SUBROUTINE FINDD (TIX,TIY,TEX,TEY,TAX,TAY,TCX,TCY,PE,BBAA,BB)
C
      CALL CALFA (TCX,TCY,ALFA)
      INDEX=1
      CALL TRNFRM (TIX,TIY,TCX,TCY,TTIX,TTIY,ALFA,INDEX)
      CALL TRNFRM (TEX,TEY,TCX,TCY,TTEX,TTEY,ALFA,INDEX)
      CALL TRNFRM (TAX,TAY,TCX,TCY,TTAX,TTAY,ALFA,INDEX)
      D=TTEX-TTIX
      D=D*D
      AA=BBAA
      A=AA+(TTEY-TTIY)**2.0/D
      B=(TTEX*TTIY-TTIX*TTEY)*(TTEY-TTIY)/D
      C=(TTEX*TTIY-TTIX*TTEY)**2.0/D-BB
      CC=SQRT(B*B-A*C)
      TTAX=(-B+CC)/A
      S=(TTAX-TTIX)/(TTEX-TTIX)
      IF(S.GT.0.0) GO TO 100
      TTAX=-(B+CC)/A
      S=(TTAX-TTIX)/(TTEX-TTIX)
  100 CONTINUE
      TTAY=S*(TTEY-TTIY)+TTIY
      INDEX=2
      CALL TRNFRM (TAX,TAY,TCX,TCY,TTAX,TTAY,ALFA,INDEX)
      RETURN
      END
```

```
      SUBROUTINE PINDPO (PE,TAUP,ELAMDA,EM,PEO)
C
      ETA=EM/ELAMDA
      EX=TAUP/ELAMDA
      EX=EX*EX
      EY=ETA*ETA*(1.0+EX)-EX
      EY=1.0-SQRT(EX)
      PEO=PE*EY/(1.0-ETA)
      RETURN
      END
```

```
      SUBROUTINE TRNFRM (AX,AY,CX,CY,AAX,AAY,ALFA,N)
C
      CC=COS(ALFA)
      SS=SIN(ALFA)
      GO TO (100,200),N
  100 CONTINUE
      AAX=(AX-CX)*CC+(AY-CY)*SS
      AAY=-(AX-CX)*SS+(AY-CY)*CC
      GO TO 300
  200 CONTINUE
      AX=AAX*CC-AAY*SS+CX
      AY=AAX*SS+AAY*CC+CY
  300 RETURN
      END
```

```
      SUBROUTINE CALFA (X,Y,ALFA)
C
      PI=2.0*ACOS(0.0)
      TOL=1.0E-20
      IF(ABS(X).GT.TOL) GO TO 100
      ALFA=PI/2.0
      IF(Y.LT.0.0) ALFA=ALFA+PI
      GO TO 400
  100 IF(ABS(Y).GT.TOL) GO TO 200
      ALFA=0.0
      IF(X.LT.0.0) ALFA=PI
      GO TO 400
  200 ALFA=ATAN(Y/X)
      XY=X*Y
      IF(XY.LT.0.0) GO TO 300
      IF(X.GT.0.0) GO TO 400
      ALFA=ALFA+PI
      GO TO 400
  300 ALFA=ALFA+PI
      IF(X.GT.0.0) ALFA=ALFA+PI
  400 RETURN
      END
```

```
      SUBROUTINE OUTP (JPLTH,JPLTSS,JSETS,X,Y,PL,TLIQ,NUMNP,LUN,
     *  NBLK,NPTOT,NCYCL,NDI)
C
      DIMENSION JPLTH(1),JPLTSS(1),JSETS(1),X(1),Y(1),PL(NBLK,NPTOT),
     *  TLIQ(NUMNP,1)
C
      COMMON/PLTING/ NPLOTH,NPLTSS,NSETS,NPAP,NPLOT,BPLOT,DPLOT,EPLOT,
     *  TEND,NPLPNT
C
      WRITE (6,2002)
      DO 100 I=1,NUMNP
      TT=TLIQ(I,1)
      IF(TT.GT.0.0) GO TO 40
      WRITE(6,2003)  I
      GO TO 100
   40 TTT=TLIQ(I,2)
      IF(TTT.GT.0.0) GO TO 50
      WRITE(6,2018) I,TT
      GO TO 100
   50 CONTINUE
      WRITE(6,2004) I,TT,TTT
  100 CONTINUE
      NT=NBLK
      N=1
      NN=NPLOTH+NPLTSS+NSETS
      IF(NN.LE.0) GO TO 600
      IF (NPLOTH.EQ.0) GO TO 200
      DO 150 I=1,NPLOTH
      DO 140 K=1,NDI
      N=N+1
      IF(K.EQ.2) GO TO 141
      WRITE(6,2005) JPLTH(I)
      GO TO 142
  141 WRITE(6,2015) JPLTH(I)
  142 WRITE (6,2001) (PL(J,N),J=1,NT)
  140 CONTINUE
      DO 147 K=1,NDI
      N=N+1
      IF(K.EQ.2) GO TO 143
      WRITE (6,2006) JPLTH(I)
      GO TO 144
  143 WRITE(6,2016) JPLTH(I)
  144 WRITE (6,2001) (PL(J,N),J=1,NT)
  147 CONTINUE
      DO 148 K=1,NDI
      N=N+1
      IF(K.EQ.2) GO TO 145
      WRITE (6,2007) JPLTH(I)
      GO TO 146
  145 WRITE(6,2017) JPLTH(I)
  146 WRITE (6,2001) (PL(J,N),J=1,NT)
  148 CONTINUE
  150 CONTINUE
  200 CONTINUE
      IF (NPLTSS.EQ.0) GO TO 400
      DO 350 I=1,NPLTSS
      N=N+1
      WRITE (6,2010) JPLTSS(I)
      WRITE (6,2001) (PL(J,N),J=1,NT)
      N=N+1
```

```
      WRITE (6,2009) JPLTSS(I)
      WRITE (6,2001) (PL(J,N),J=1,NT)
  350 CONTINUE
  400 CONTINUE
      IF (NSETS.EQ.0) GO TO 500
      DO 450 I=1,NSETS
      N=N+1
      WRITE (6,2012) JSETS(I)
      WRITE (6,2001) (PL(J,N),J=1,NT)
  450 CONTINUE
  500 CONTINUE
      CALL PLTLAS(PL,JPLTM,JPLTSS,JSETS,X,Y,NBLK,NCYCL,LUN,NDI)
  600 RETURN
 2001 FORMAT (10E12.4)
 2002 FORMAT (//30H ELEMENT LIQUEFACTION DATA      //10H   EL. NO. /)
 2003 FORMAT (3X,I5,5X,20H NO LIQUEFACTION      )
 2004 FORMAT(3X,I5,5X,26H INITIAL LIQUEF. AT TIME =    ,F10.4,18H LIQUEF.
     * AT TIME =   ,F10.4)
 2005 FORMAT (// 45H ----- ACCELERATION TIME HISTORY FOR NODE NO ,I4,
     * 12H X-DIRECTION  /)
 2006 FORMAT (// 45H --------- VELOCITY TIME HISTORY FOR NODE NO ,I4,
     * 12H X-DIRECTION  /)
 2007 FORMAT (// 45H ----- DISPLACEMENT TIME HISTORY FOR NODE NO ,I4,
     * 12H X-DIRECTION  /)
 2009 FORMAT (// 45H ----- SHEAR STRAIN TIME HISTORY FOR ELEM NO ,I4 /)
 2010 FORMAT (// 45H ----- SHEAR STRESS TIME HISTORY FOR ELEM NO ,I4 /)
 2012 FORMAT (// 45H ----- PORE PRESSURE TIME HISTORY FOR ELEM NO,I4 /)
 2015 FORMAT (// 45H ----- ACCELERATION TIME HISTORY FOR NODE NO ,I4,
     * 12H Y-DIRECTION  /)
 2016 FORMAT (// 45H --------- VELOCITY TIME HISTORY FOR NODE NO ,I4,
     * 12H Y-DIRECTION  /)
 2017 FORMAT (// 45H ----- DISPLACEMENT TIME HISTORY FOR NODE NO ,I4,
     * 12H Y-DIRECTION  /)
 2018 FORMAT(3X,I5,5X,26H INITIAL LIQUEF. AT TIME =    ,F10.4,
     *  18H NO FINAL LIQUEF.      )
      END
```

```
      SUBROUTINE SAVE (JPLTH,JPLTSS,JSETS,PL,AC,VE,DI,STRN,
     * STRS,NUMNP,NBLK,TIME,NPTOT,LUN,BACELX,BACELY,BACELZ,NDI,NC)
C
      DIMENSION JPLTH(1),JPLTSS(1),JSETS(1),PL(NBLK,
     * NPTOT),AC(1),VE(1),DI(1),STRN(4,1),STRS(4,1)
C
      COMMON/PLTING/ NPLOTH,NPLTSS,NSETS,HPAP,HPLOT,BPLOT,DPLOT,TEND
     *   ,NPLPNT
      COMMON/DIRECT/NX,NY,NZ
C
      DATA IR/0/
C
      IF (IR.LE.NBLK) GO TO 600
      IR=0
      WRITE (LUN) PL
      N=NPTOT*NBLK
      CALL SZERO (PL,N)
  600 CONTINUE
      IC=1
      IR=IR+1
      PL(IR,IC)=TIME
      IF (NPLOTH.LE.0) GO TO 120
      DO 100 N=1,NPLOTH
      JL=JPLTH(N)
      JL=(JL-1)*NC+1
      IC=IC+1
      PL(IR,IC)=AC(JL)+BACELX
      IC=IC+1
      PL(IR,IC)=VE(JL)
      IC=IC+1
      PL(IR,IC)=DI(JL)
      I=1
      IF(NY.EQ.0) GO TO 50
      IC=IC+1
      PL(IR,IC)=AC(JL+I)+BACELY
      IC=IC+1
      PL(IR,IC)=VE(JL+I)
      IC=IC+1
      PL(IR,IC)=DI(JL+I)
      I=I+1
   50 CONTINUE
      IF(NZ.EQ.0) GO TO 100
      IC=IC+1
      PL(IR,IC)=AC(JL+I)+BACELZ
      IC=IC+1
      PL(IR,IC)=VE(JL+I)
      IC=IC+1
      PL(IR,IC)=DI(JL+I)
  100 CONTINUE
  120 CONTINUE
      IF (NPLTSS.LE.0) GO TO 320
      DO 300 N=1,NPLTSS
      JL=JPLTSS(N)
      IC=IC+1
      PL(IR,IC)=STRS(2,JL)
      IC=IC+1
      PL(IR,IC)=STRN(2,JL)
      IF(NY.EQ.0) GO TO 300
      IC=IC+1
      PL(IR,IC)=STRS(3,JL)
```

```
      IC=IC+1
      PL(IR,IC)=STRN(3,JL)
  300 CONTINUE
  320 CONTINUE
      IF (NSETS.LE.0) GO TO 420
      DO 400 N=1,NSETS
      JL=JSETS(N)
      PIO=PL(JL,NPTOT-1)
      SIG=PL(JL,NPTOT)
      IC=IC+1
      PL(IR,IC)=(STRS(4,JL)-PIO)/SIG
  400 CONTINUE
  420 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE PLTLAS(PL,JPLTM,JPLTSS,JSETS,X,Y,NBLK,NCYCL,LUN,NDI)
C
      COMMON/PLTING/ NPLOTM,NPLTSS,NSETS,HPAP,HPLOT,BPLOT,DPLOT,EPLOT,
     *  TEND,NPLPNT
      COMMON/DIRECT/ NX,NY,NZ
C
      DIMENSION PL(NBLK,1),JPLTM(1),JPLTSS(1),JSETS(1)
      DIMENSION X(1),Y(1),DMAX(3),SCA(6,2)
C
C     SCALE DETERMINATION FOR THE MOTION DIAGRAMS
C
      CALL LOADXY(X,Y,1,0,PL,NBLK,NCYCL,LUN)
      DO 100 I=1,NCYCL
      IF(X(I).GT.TEND) GO TO 24
      N=I
  100 CONTINUE
      GO TO 25
   24 NCYCL=N
   25 CONTINUE
      SCC=TEND/BPLOT
      ILN=0
      IF(NPLOTM.NE.0) GO TO 23
      CALL PLOT(0.0,HPAP,-3)
      GO TO 200
   23 CONTINUE
      DO 1 I=1,3
    1 DMAX(I)=-9999.
      N=1
      DO 2 I=1,NPLOTM
      DO 2 J=1,3
      N=N+1
      CALL LOADXY(X,Y,N,0,PL,NBLK,NCYCL,LUN)
      XMAX=-9999.
      XMIN=+9999.
      DO 3 K=1,NCYCL
      IF(X(K).GT.XMAX) XMAX=X(K)
    3 IF(X(K).LT.XMIN) XMIN=X(K)
      DX=XMAX
      IF(ABS(XMIN).GT.DX) DX=ABS(XMIN)
      IF(DX.LE.DMAX(J)) GO TO 2
      DMAX(J)=DX
    2 CONTINUE
      DO 4 I=1,3
    4 CALL SCAL(DMAX(I),HPLOT,SCA(I,1),SCA(I,2))
C
C     PLOTTING OF THE MOTION DIAGRAMS
C
      HGAP=(HPAP-HPLOT*3)/4.
      CALL PLOT(0.0,HPAP,-3)
      HTIT=HGAP/3.
      N=1
C
      DO 5 I=1,NPLOTM
      DO 50 III=1,NDI
      CALL PLOT(1.0,0.0,-3)
      YY=-(2./3.)*HGAP
      CALL SYMBOL(0.0,YY,HTIT,8HNODE N. ,0.0,8)
      CALL NUMBER(0.0,0.0,-HTIT,FLOAT(JPLTM(I)) ,0.0,-1)
      IF(III.EQ.2) GO TO 110
      CALL SYMBOL(0.0,0.0,-HTIT,7H X-DIR. ,0.0,7)
```

```
      GO TO 120
  110 CALL SYMBOL(0.0,0.0,-HTIT,7H Y-DIR. ,0.0,7)
  120 CONTINUE
      ILN=ILN+1
C
      DO 10 J=1,3
      YY=-(HGAP+HPLOT)
      CALL PLOT(0.0,YY,-3)
      N=N+1
      CALL LOADXY(X,Y,1,N,PL,NBLK,NCYCL,LUN)
      X(NCYCL+1)=0.0
      X(NCYCL+2)=SCC
      Y(NCYCL+1)=SCA(J,1)
      Y(NCYCL+2)=SCA(J,2)
      CALL AXIS(0.0,0.0,10HTIME (SEC),-10,BPLOT,0.0,0.0,SCC)
      GO TO (6,7,8),J
    6 CALL AXIS(0.0,0.0,4HACC.,4,HPLOT,90.,SCA(J,1),SCA(J,2))
      GO TO 9
    7 CALL AXIS(0.0,0.0,4HVEL.,4,HPLOT,90.,SCA(J,1),SCA(J,2))
      GO TO 9
    8 CALL AXIS(0.0,0.0,6HDISPL.,6,HPLOT,90.,SCA(J,1),SCA(J,2))
    9 CALL PLOT(0.0,HPLOT,3)
      CALL PLOT(BPLOT,HPLOT,2)
      CALL PLOT(BPLOT,0.0,2)
      YY=HPLOT/2.
      CALL PLOT(BPLOT,YY,3)
      CALL PLOT(0.0,YY,2)
   10 CALL LINE(X,Y,NCYCL,1,0,0)
C
      YY=HPAP-HGAP
      CALL PLOT(BPLOT,YY,-3)
   50 CONTINUE
C
C     PLOTTING MOTION INTERACTION DIAGRAMS
C
      IF(NY.EQ.0) GO TO 60
      PMOVE=(HPAP-DPLOT)/2.0+DPLOT
      DO 55 III=1,3
      CALL PLOT(2.0,-PMOVE,-3)
      N1=N+III-3
      N2=N+III-6
      CALL LOADXY(X,Y,N2,N1,PL,NBLK,NCYCL,LUN)
      X(NCYCL+1)=SCA(III,1)
      SCA(III,2)=(SCA(III,2)/DPLOT)*HPLOT
      X(NCYCL+2)=SCA(III,2)
      Y(NCYCL+1)=SCA(III,1)
      Y(NCYCL+2)=SCA(III,2)
      GO TO (51,52,53),III
   51 CALL AXIS(0.0,0.0,10H ACC. (X)  ,10,DPLOT,0.0,SCA(III,1),
     *  SCA(III,2))
      CALL AXIS(0.0,0.0,10H ACC. (Y)  ,-10,DPLOT,90.0,SCA(III,1),
     *  SCA(III,2))
      GO TO 54
   52 CALL AXIS(0.0,0.0,10H VEL. (X)  ,10,DPLOT,0.0,SCA(III,1),
     *  SCA(III,2))
      CALL AXIS(0.0,0.0,10H VEL. (Y)  ,-10,DPLOT,90.0,SCA(III,1),
     *  SCA(III,2))
      GO TO 54
   53 CALL AXIS(0.0,0.0,10H DISP. (X) ,10,DPLOT,0.0,SCA(III,1),
     *  SCA(III,2))
      CALL AXIS(0.0,0.0,10H DISP. (X) ,-10,DPLOT,90.0,SCA(III,1),
```

```
     *  SCA(III,2))
   54 CONTINUE
      CALL PLOT(0.0,DPLOT,3)
      CALL PLOT(DPLOT,DPLOT,2)
      CALL PLOT(DPLOT,0.0,2)
      YY=DPLOT/2.0
      CALL PLOT(DPLOT,YY,3)
      CALL PLOT(0.0,YY,2)
      CALL PLOT(YY,DPLOT,3)
      CALL PLOT(YY,0.0,2)
      CALL LINE(X,Y,NCYCL,1,0,0)
      CALL PLOT(DPLOT,PMOVE,-3)
   55 CONTINUE
   60 CONTINUE
      WRITE(6,2000) JPLTH(I)
    5 CONTINUE
  200 CONTINUE
C
C     SCALE DETERMINATION FOR THE STRESS AND STRAIN DIAGRAMS
C
      IF(NPLTSS.EQ.0) GO TO 400
      NP=NPLTSS
      IF(NY.GT.0) NP=NP*2
      N=1+NPLOTH*NDI*3
   13 DMAX(1)=-9999.
      DMAX(2)=-9999.
      DO 12 I=1,NP
      N=N+2
      CALL LOADXY(X,Y,N-1,N,PL,NBLK,NCYCL,LUN)
      XMAX=-9999.
      XMIN=9999.
      YMAX=-9999.
      YMIN=9999.
      DO 11 J=1,NCYCL
      IF(X(J).GT.XMAX) XMAX=X(J)
      IF(Y(J).GT.YMAX) YMAX=Y(J)
      IF(X(J).LT.XMIN) XMIN=X(J)
   11 IF(Y(J).LT.YMIN) YMIN=Y(J)
      DX=XMAX
      IF(ABS(XMIN).GT.DX) DX=ABS(XMIN)
      IF(DX.GT.DMAX(1)) DMAX(1)=DX
      DX=YMAX
      IF(ABS(YMIN).GT.DX) DX=ABS(YMIN)
      IF(DX.GT.DMAX(2)) DMAX(2)=DX
   12 CONTINUE
C
      CALL SCAL(DMAX(1),HPLOT,SCA(6,1),SCA(6,2))
      CALL SCAL(DMAX(2),HPLOT,SCA(5,1),SCA(5,2))
      CALL SCAL(DMAX(1),DPLOT,SCA(4,1),SCA(4,2))
      CALL SCAL(DMAX(2),DPLOT,SCA(3,1),SCA(3,2))
C
  400 CONTINUE
C
C     PLOTTING OF THE STRESS AND STRAIN DIAGRAMS
C
      MAXS=0
      MAXP=0
      IF(NPLTSS.EQ.0) GO TO 500
      DO 16 I=1,NPLTSS
   16 IF(JPLTSS(I).GT.MAXP) MAXP=JPLTSS(I)
  500 IF(NSETS.EQ.0) GO TO 600
```

```
      DO 17 I=1,NSETS
   17 IF(JSETS(I).GT.MAXS) MAXS=JSETS(I)
  600 IF(MAXS.EQ.0.AND.MAXP.EQ.0) GO TO 102
      I=0
C
   18 I=I+1
      IF(I.GT.MAXS.AND.I.GT.MAXP) GO TO 102
      KP=0
      JS=0
      IF(NSETS.EQ.0) GO TO 800
      DO 19 J=1,NSETS
      IF(JSETS(J).NE.I) GO TO 19
      JS=JSETS(J)
      GO TO 800
   19 CONTINUE
  800 IF(NPLTSS.EQ.0) GO TO 900
      DO 20 K=1,NPLTSS
      IF(JPLTSS(K).NE.I) GO TO 20
      KP=JPLTSS(K)
      GO TO 900
   20 CONTINUE
  900 IF(KP.EQ.0.AND.JS.EQ.0) GO TO 18
C
      ILN=ILN+1
      IF(KP.EQ.0) GO TO 101
      CALL PLOT(1.0,0.0,-3)
      HGAP=(HPAP-HPLOT*2.)/3.
      HTIT=HGAP/3.
      YY=-2.*HTIT
      CALL SYMBOL(0.0,YY,HTIT,9HELEM. N.   ,0.0,9)
      DX=FLOAT(KP)
      CALL NUMBER(0.0,0.0,-HTIT,DX,0.0,-1)
C
      M=NPLOTM*NDI*3+K*2
      NJT=1
      IF(NY.NE.0) M=M+(K-1)*2
      IF(NY.NE.0) NJT=NJT+1
      DO 30 NLJ=1,NJT
      M=M+(NLJ-1)*2
      N=M
      DO 21 L=1,2
      CALL PLOT(1.0,0.0,-3)
      HGAP=(HPAP-HPLOT*2.)/3.
      YY=-(HGAP+HPLOT)
      CALL PLOT(0.0,YY,-3)
      N=N+L-1
      CALL LOADXY(X,Y,1,N,PL,NBLK,NCYCL,LOW)
      Y(NCYCL+1)=SCA(6-L+1,1)
      Y(NCYCL+2)=SCA(6-L+1,2)
      X(NCYCL+1)=0.0
      X(NCYCL+2)=SCC
      CALL AXIS(0.0,0.0,10HTIME (SEC),-10,BPLOT,0.0,0.0,SCC)
      IF(L.EQ.1) CALL AXIS(0.0,0.0,10HSH. STRESS,10,HPLOT,90.,SCA(6,1),
     *  SCA(6,2))
      IF(L.EQ.2) CALL AXIS(0.0,0.0,10HSH. STRAIN,10,HPLOT,90.,SCA(5,1),
     *  SCA(5,2))
      CALL PLOT(0.0,HPLOT,3)
      CALL PLOT(BPLOT,HPLOT,2)
      CALL PLOT(BPLOT,0.0,2)
      YY=HPLOT/2.
      CALL PLOT(BPLOT,YY,3)
```

```
      CALL PLOT(0.0,YY,2)
   21 CALL LINE(X,Y,NCYCL,1,0,0)
C
      YY=HGAP
      HGAP=(HPAP-DPLOT)/2.
      YY=HGAP-YY
      CALL PLOT(BPLOT+1,YY,-3)
      N=M
      CALL LOADXY(X,Y,N+1,N,PL,NBLK,NCYCL,LUN)
      X(NCYCL+1)=SCA(3,1)
      X(NCYCL+2)=SCA(3,2)
      Y(NCYCL+1)=SCA(4,1)
      Y(NCYCL+2)=SCA(4,2)
      CALL AXIS(0.0,0.0,10HSH. STRAIN ,-10,DPLOT,0.,SCA(3,1),SCA(3,2))
      CALL AXIS(0.0,0.0,10HSH. STRESS,10,DPLOT,90.,SCA(4,1),SCA(4,2))
      CALL PLOT(0.0,DPLOT,3)
      CALL PLOT(DPLOT,DPLOT,2)
      CALL PLOT(DPLOT,0.0,2)
      YY=DPLOT/2.
      CALL PLOT(DPLOT,YY,3)
      CALL PLOT(0.0,YY,2)
      CALL PLOT(YY,DPLOT,3)
      CALL PLOT(YY,0.0,2)
      CALL LINE(X,Y,NCYCL,1,0,0)
      YY=HPAP-HGAP
      CALL PLOT(DPLOT,YY,-3)
   30 CONTINUE
      IF(NY.EQ.0)GO TO 150
      CALL PLOT(1.0,-YY,-3)
      N=N-2
      CALL LOADXY (X,Y,N,N+2,PL,NBLK,NCYCL,LUN)
      X(NCYCL+1)=SCA(4,1)
      X(NCYCL+2)=SCA(4,2)
      Y(NCYCL+1)=SCA(4,1)
      Y(NCYCL+2)=SCA(4,2)
      CALL AXIS (0.0,0.0,11HSH. STRS. X,-11,DPLOT,0.,SCA(4,1),SCA(4,2))
      CALL AXIS (0.0,0.0,11HSH. STRS. Y,11,DPLOT,90.,SCA(4,1),SCA(4,2))
      CALL PLOT (0.0,DPLOT,3)
      CALL PLOT (DPLOT,DPLOT,2)
      CALL PLOT (DPLOT,0.0,2)
      YY=DPLOT/2.
      CALL PLOT (DPLOT,YY,3)
      CALL PLOT (0.0,YY,2)
      CALL PLOT (YY,DPLOT,3)
      CALL PLOT (YY,0.0,2)
      CALL LINE (X,Y,NCYCL,1,0,0)
      YY=HPAP-HGAP
      CALL PLOT (DPLOT,YY,-3)
  150 CONTINUE
      IF(JS.EQ.0) WRITE(6,3000) KP
  101 IF(JS.EQ.0) GO TO 18
      CALL PLOT(1.0,0.0,-3)
      HGAP=(HPAP-EPLOT)/2.
      IF(KP.NE.0) GO TO 300
      HTIT=HGAP/3.
      YY=-2.*HTIT
      CALL SYMBOL(0.0,YY,HTIT,9HELEM. N.   ,0.0,9)
      DX=FLOAT(JS)
      CALL NUMBER(0.0,0.0,-HTIT,DX,0.0,-1)
  300 YY=-(HGAP+EPLOT)
      CALL PLOT(0.0,YY,-3)
```

```
      DX=1./EPLOT
      CALL AXIS(0.0,0.0,10HTIME (SEC),-10,BPLOT,0.0,0.0,SCC)
      CALL AXIS(0.0,0.0,12H PORE PRESS.  ,12,EPLOT,90.,0.0,DX)
      CALL PLOT(0.0,EPLOT,3)
      CALL PLOT(BPLOT,EPLOT,2)
      CALL PLOT(BPLOT,0.0,2)
      N=NPLOTM*NDI*3+NPLTSS*2+J*2
      IF(NY.GT.0) N=N+NPLTSS*2
      CALL LOADXY(X,Y,1,N,PL,NBLK,NCYCL,LUN)
      Y(NCYCL+1)=0.0
      Y(NCYCL+2)=DX
      X(NCYCL+1)=0.0
      X(NCYCL+2)=SCC
      CALL LINE(X,Y,NCYCL,1,0,0)
      YY=HPAP-HGAP
      CALL PLOT(BPLOT,YY,-3)
      WRITE(6,3000) JS
      GO TO 18
C
  102 WRITE(6,1000) ILN
      YY=-HPAP+0.2
      CALL PLOT(0.0,YY,-3)
      RETURN
C
 1000 FORMAT(//,I5,25H SETS OF PLOTS COMPLETED      )
 2000 FORMAT(/,20H PLOTS FOR NODE NO.      ,I4,10H COMPLETED
 3000 FORMAT(/,20H PLOTS FOR ELEM NO.     ,I4,10H COMPLETED
      END
```

```
      SUBROUTINE LOADXY(X,Y,IX,IY,PL,NBLK,NCYCL,LUN)
C
      DIMENSION X(1),Y(1),PL(NBLK,1)
C
      NB=NCYCL/NBLK
      IF(NB.LT.1) NB=1
      IF(NCYCL.LE.NBLK) GO TO 4
      REWIND LUN
    4 N=-NBLK
      DO 1 I=1,NB
      N=N+NBLK
      IF(NCYCL.GT.NBLK) READ(LUN) PL
      IF(IX.EQ.0) GO TO 3
      DO 2 J=1,NBLK
    2 X(J+N)=PL(J,IX)
    3 IF(IY.EQ.0) GO TO 1
      DO 6 J=1,NBLK
    6 Y(J+N)=PL(J,IY)
    1 CONTINUE
      IF(NCYCL.LE.NBLK) RETURN
      READ(LUN) PL
      N=NB*NBLK
      NB=NCYCL-N
      N=N+1
      IF(IX.EQ.0) GO TO 8
      DO  7 J=1,NB
    7 X(N+J)=PL(J,IX)
    8 IF(IY.EQ.0) RETURN
      DO 9 J=1,NB
    9 Y(N+J)=PL(J,IY)
      RETURN
      END
```

```
      SUBROUTINE RESPEC (ACC,NP,R1,R2,R3,R4,NDV,DT,NHD)
C
      DIMENSION R1(89,NDV),R2(89,NDV),R3(89,NDV),R4(1),ACC(1),
     *   DW(10),NM(10),SDISP(10),SVP(10),SACC(10),SI(10),SAMAX(10)
C
      COMMON/SPEC/DV(10),NODE(10),NNODE,IRS,IRSP
      COMMON/WLVL/ WTABLE,GRAV
C
      DATA DW(1)/.01/,DW(2)/.02/,DW(3)/.04/,DW(4)/.05/,DW(5)/.1/,
     *   DW(6)/.2/,DW(7)/.4/,DW(8)/.5/,DW(9)/1.0/,DW(10)/2.0/
      DATA NM(1)/11/,NM(2)/10/,NM(3)/5/,NM(4)/8/,NM(5)/10/,
     *   NM(6)/10/,NM(7)/5/,NM(8)/8/,NM(9)/10/,NM(10)/10/
C
C     THIS SUBROUTINE COMPUTES RESPONSE SPECTRA BY
C     SIMPSON'S RULE FOR PERIODS .1 TO 40.0 SECONDS
C
C
C
C     SORT THE GIVEN DAMPING VALUES IN INCREASING ORDER
C
      IF(NDV.EQ.1) GO TO 101
      INDV=NDV-1
      DO 100 IK=1,INDV
      IP=IK+1
      DO 100 IJ=IP,NDV
      IF(DV(IK).LE.DV(IJ)) GO TO 100
      TDV=DV(IK)
      DV(IK)=DV(IJ)
      DV(IJ)=TDV
  100 CONTINUE
  101 CONTINUE
C
C     COMPUTE SPECTRAL VALUES
C
      DO 160 K=1,NNODE
      NNOD=NODE(K)
      WRITE(6,2002) NODE(K)
      WRITE(6,2000)
      KK=(K-1)*NP+1
      DO 159 NN=1,NHD
      PERIO=0.09
      IND=0
      IF(NN.EQ.1) WRITE(6,2006)
      IF(NN.EQ.2) WRITE(6,2007)
      IF(NN.EQ.2) KK=KK+NNODE*NP
      KL=KK+NP-1
      KP=KK+1
      DO 150 L=1,10
      M=NM(L)
      DO 150 LOOP=1,M
      IND=IND+1
      PERIO=PERIO+DW(L)
      W=6.2831853/PERIO
      DO 140 J=1,NDV
      SVP(J)=0.0
      TIME=0.0
      EXPP=EXP(DV(J)*W*DT)
      AMULT=1.0/(EXPP*EXPP)
      BMULT=4.0/EXPP
      W=SQRT(1-DV(J)*DV(J))*W
```

```
      WT=TIME*W
      SINWT=SIN(WT)
      COSWT=COS(WT)
      ACCL=ACC(KK)
      A11=COSWT*ACCL
      B11=SINWT*ACCL
      AA=0.0
      BB=0.0
      DDT=DT/3.0
      SVPP=0.0
      DO 130 N=KF,KL,2
      A21=AA+A11
      A31=AMULT*A21
      B21=BB+B11
      B31=AMULT*B21
      SV=(AA*SINWT-BB*COSWT)*DDT
      SVV=ABS(SV)
      IF(SVV.GT.SVPP) SVPP=SVV
      TIME=TIME+DT
      WT=W*TIME
      ACCL=ACC(N)
      A12=COS(WT)*ACCL
      A32=A12*BMULT
      B12=SIN(WT)*ACCL
      B32=B12*BMULT
      TIME=TIME+DT
      WT=W*TIME
      SINWT=SIN(WT)
      COSWT=COS(WT)
      ACCL=ACC(N+1)
      A11=COSWT*ACCL
      B11=SINWT*ACCL
      AA=A31+A32+A11
      BB=B31+B32+B11
  130 CONTINUE
      SVP(J)=SVPP
      SACC(J)=SVP(J)*W/GRAV
      SDISP(J)=SVP(J)/W
      R1(IND,J)=SDISP(J)
      R2(IND,J)=SVP(J)
      R3(IND,J)=SACC(J)
      R4(IND)=PERIO
  140 CONTINUE
      WRITE(6,2001) PERIO,(DV(J),SDISP(J),SVP(J),SACC(J),J=1,NDV)
  150 CONTINUE
C
C     COMPUTE SPECTRUM INTENSITIES
C
      DO 155 J=1,NDV
      SI(J)=0.0
      DO 155 INT=1,46
      IN=INT
      SI(J)=(R2(IN,J)+R2(IN+1,J))/2*(R4(IN+1)-R4(IN))+SI(J)
  155 CONTINUE
C
C
C     FIND MAXIMUMS OF SPECTRAL VALUES
C
      DO 156 N=1,NDV
      SAMAX(N)=0.0
      DO 156 M=1,IND
```

```
  156 IF(R3(M,N).GT.SAMAX(N)) SAMAX(N)=R3(M,N)
      WRITE(6,2005) (DV(J),SAMAX(J),J=1,NDV)
      WRITE(6,2003) (DV(J),SI(J),J=1,NDV)
      IF(IRSP.LE.0) GO TO 159
C
C     PLOT RESPONSE SPECTRA IF REQUESTED
C
      CALL PLORES(NNOD,IND,R1,R2,R3,R4,NDV)
  159 CONTINUE
  160 CONTINUE
      RETURN
 2000 FORMAT(27X,11H DAMP. RAT.,7X,11H SPEC. DIS.,9X,11H SPEC. VEL.,10X,
     *  20H SPEC. ACC.(/GRAV.)      )
 2001 FORMAT(8H PERIOD=,F8.5/(27X,F10.5,3X,3(E15.6,5X)))
 2002 FORMAT(37X,31H ***RESPONSE SPECTRA OF NODE N.,I5,4H ***//)
 2003 FORMAT(//,35H  * RESPONSE SPECTRUM INTENSITIES * ,/6X,11H DAMP. RA
     *T.,5X,11H SPEC. INT./(4X,F10.5,3X,E15.6))
 2005 FORMAT(/11H DAMP. RAT.,5X,25H MAX. SPEC. ACCELARATION /(3X,F10.5,
     *  8X,E15.6))
 2006 FORMAT(10X,15H X-DIRECTION       //)
 2007 FORMAT(10X,15H Y-DIRECTION       //)
      END
```

```
      SUBROUTINE PLORES(NNOD,IND,R1,R2,R3,R4,NDV)
C
      DIMENSION  R1(89,1),R2(89,1),R3(89,1),R4(1)
C
      CALL SYMBOL(1.0,8.3,0.5,16HRESPONSE SPECTRA  ,0.0,16)
      CALL SYMBOL(1.0,7.3,0.5,7HNODE N.,0.0,7)
      CALL NUMBER(4.5,7.3,0.5,FLOAT(NNOD),0.0,-1)
      R1MAX=0.0
      R2MAX=0.0
      R3MAX=0.0
      DO 100 K=1,IND
      IF(R1(K,1).GT.R1MAX) R1MAX=R1(K,1)
      IF(R2(K,1).GT.R2MAX) R2MAX=R2(K,1)
      IF(R3(K,1).GT.R3MAX) R3MAX=R3(K,1)
  100 CONTINUE
      IS1=R1MAX*1.05
      IS2=R2MAX*1.05
      IS3=R3MAX*1.40
      YINC1=IS1/4.0
      YINC2=IS2/4.0
      YINC3=IS3/4.0
      DO 350 J=1,NDV
      R1(IND+1,J)=0.0
      R1(IND+2,J)=YINC1
      R2(IND+1,J)=0.0
      R2(IND+2,J)=YINC2
      R3(IND+1,J)=0.0
      R3(IND+2,J)=YINC3
  350 CONTINUE
      R4(IND+1)=0.0
      R4(IND+2)=1.
      DO 400 LOOP=1,3
      CALL PLOT(1.0,2.3,-3)
      CALL AXIS(0.0,0.0,12HPERIOD (SEC) ,-12,5.0,0.0,0.0,1.0)
      IF(LOOP.EQ.1) CALL AXIS(0.0,0.0,11HSPEC. DISP.,11,4.0,90.,0.0,
     *  YINC1)
      IF(LOOP.EQ.2) CALL AXIS(0.0,0.0,11HSPEC. VEL. ,11,4.0,90.,0.0,
     *  YINC2)
      IF(LOOP.EQ.3) CALL AXIS(0.0,0.0,11HSPEC. ACC. ,11,4.0,90.,0.0,
     *  YINC3)
      CALL PLOT(0.0,4.0,3)
      CALL PLOT(5.0,4.0,2)
      CALL PLOT(5.0,0.0,2)
      DO 375 J=1,NDV
      IF(LOOP.EQ.1) CALL LINE(R4,R1(1,J),55,1,0,0)
      IF(LOOP.EQ.2) CALL LINE(R4,R2(1,J),55,1,0,0)
      IF(LOOP.EQ.3) CALL LINE(R4,R3(1,J),55,1,0,0)
  375 CONTINUE
      CALL PLOT(5.0,-2.3,-3)
  400 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE MATAB (AM,BM,NDRY,NSEL,EMATL,XLENT,MATNUM,INTBL,NUM)
C
      DIMENSION AM(NUM,1),BM(NUM,1),EMATL(35,1),XLENT(1),MATNUM(1),
     * INTBL(1)
      NSEL=0
      DO 100 I=1,NUM
      IF(INTBL(I).LE.0) GO TO 100
      NSEL=NSEL+1
      MM=MATNUM(I)
      AM(NSEL,1)=EMATL( 1,MM)/XLENT(I)
      BM(NSEL,1)=XLENT(I)/EMATL(13,MM)/3.
  100 CONTINUE
      N=NSEL-1
      DO 200 K=1,N
      AM(K,1)=AM(K,1)+AM(K+1,1)
      AM(K,2)=-AM(K+1,1)
      BM(K,1)=BM(K,1)+BM(K+1,1)
      BM(K,2)=BM(K+1,1)/2.
  200 CONTINUE
      AM(NSEL,2)=0.0
      BM(NSEL,2)=0.0
      NDRY=NUM-NSEL
      RETURN
      END
```

```
      SUBROUTINE SOLPEQ (EMATL,XLENT,MATNUM,INTBL,STRS,A,B,C,D,E,PPO,
     *  PI,MB,PPE,NUM)
C
      COMMON/WLVL/ WTABLE,GRAV
      COMMON/EOSEQ/NTREP(10),DT(10),TLIMIT,NTS,NPEQPR(10)
C
      DIMENSION EMATL(35,1)    ,MATNUM(1),INTBL(1),XLENT(1),A(NUM,1),
     *  B(NUM,1),C(NUM,1),D(NUM,1),E(1),PPO(1),PI(1),MB(1)
     *  ,PPE(1),STRS(4,1)
C
      WRITE(6,2000)
      DO 850 I=1,NUM
      PPE(I)=-STRS(4,I)
  850 CONTINUE
      TLIMIT=0.0
      DO 800 I=1,NTS
      M=NTREP(I)
      DO 800 J=1,M
      TLIMIT=TLIMIT+DT(I)
  800 CONTINUE
      GMAW=EMATL(15,1)*GRAV
      TIME=0.0
      WTCH=0.0
      SETTL=0.0
      KONTR=0
      KOUNT=0
      DO 500 J=1,2
      DO 500 I=1,NUM
      A(I,J)=0.0
      B(I,J)=0.0
  500 CONTINUE
      DO 550 I=1,NUM
      C(I,1)=1.0
      C(I,2)=0.0
      D(I,1)=1.0
      D(I,2)=0.0
      E(I)=0.0
  550 CONTINUE
      CALL MATAB (A,B,NDRY,NSEL,EMATL,XLENT,MATNUM,INTBL,NUM)
      MDRY=NDRY
C
C     CALCULATE HYDROSTATIC WATER PRESSURES
C
      DEPT=0.0
      DO 100 I=1,NUM
      PPO(I)=0.0
      MI=MATNUM(I)
      DEPT=DEPT+0.5*XLENT(I)
      IF(INTBL(I).EQ.0) GO TO 95
       PPO(I)=(DEPT-WTABLE)*EMATL(15,MI)  *GRAV
   95 DEPT=DEPT+0.5*XLENT(I)
  100 CONTINUE
C
C     CALCULATE EXCESS PORE PRESSURE AFTER EQ
C
      DO 90 I=1,NSEL
      PI(I)=PPE(NDRY+I)-PPO(NDRY+I)
   90 CONTINUE
      WRITE(6,2010)
      IF(NDRY.EQ.0) GO TO 120
```

```
      DO 110 I=1,NDRY
      WRITE(6,2011) I,PPO(I),PPE(I)
  110 CONTINUE
  120 I1=NDRY+1
      DO 130 I=I1,NUM
      WRITE(6,2012) I,PPO(I),PPE(I),PI(I-NDRY)
  130 CONTINUE
C
C     CALCULATE EXCESS PORE PRESSURE DISSIPATION
C
      WRITE(6,2008) TLIMIT
      DO 400 I=1,NTS
      M=NTREP(I)
      DO 400 J=1,M
      NSEL=NUM-NDRY
      DO 200 K=1,2
      DO 200 L=1,NSEL
      C(L,K)=A(L,K)/2.+B(L,K)/DT(I)
      D(L,K)=B(L,K)/DT(I)-A(L,K)/2.0
  200 CONTINUE
      NSE=NSEL-1
      E(1)=D(1,1)*PI(1)+D(1,2)*PI(2)
      DO 210 K=2,NSE
      E(K)=D(K,1)*PI(K)+D(K,2)*PI(K+1)+D(K-1,2)*PI(K-1)
  210 CONTINUE
      E(NSEL)=D(NSEL,1)*PI(NSEL)+D(NSEL-1,2)*PI(NSEL-1)
      CALL TRIA(C,MB,NUM,2)
      CALL BACKS(C,E,MB,NUM,2)
      TIME=TIME+DT(I)
C
C     CALCULATE SETTLEMENT
C
      DO 230 K=1,NSEL
      M1=MATNUM(NDRY+K)
      SETTL=SETTL+XLENT(NDRY+K)/EMATL(1,M1)*(PI(K)-E(K))
  230 CONTINUE
C
C     CALCULATE WATER TABLE RISE
C
      M1=MATNUM(NDRY+1)
      DWTCH=DT(I)*EMATL(13,M1)*E(1)/XLENT(NDRY+1)/EMATL(22,M1)
      WTCH=WTCH+DWTCH
      WTABLE=WTABLE-DWTCH
      DO 220 K=1,NSEL
      PI(K)=E(K)
  220 CONTINUE
      KOUNT=KOUNT+1
      IF(KOUNT.LT.NPEQPR(I)) GO TO 261
      KOUNT=0
      WRITE(6,2001) TIME,SETTL,WTABLE
      WRITE(6,2002)
      IF(NDRY.EQ.0) GO TO 257
      Z=0.0
      DO 250 K=1,NDRY
  250 WRITE(6,2003) K,Z
  257 IF(NDRY.EQ.MDRY) GO TO 256
      DO 255 K=NDRY,MDRY
      IND=K+1
      WRITE(6,2003) IND,E(IND-NDRY)
  255 CONTINUE
  256 K1=NDRY+1
```

```
      TDSPR=0.0
      TXLENT=0.0
      DO 260 K=K1,NUM
      DSPR=1.0-E(K-NDRY)/(PPE(K)-PPO(K))
      TDSPR=XLENT(K)*DSPR+TDSPR
      TXLENT=TXLENT+XLENT(K)
      WRITE(6,2004) K, E(K-NDRY),DSPR
  260 CONTINUE
      ODSPR=TDSPR/TXLENT
      WRITE(6,2009) ODSPR
  261 CONTINUE
      IF(NDRY.EQ.0) GO TO 400
      IF(KONTR.NE.1) GO TO 900
      IF(WTCH.LT.XDUM) GO TO 950
      WTCH=WTCH-XDUM
      XLENT(NDRY)=XDUM
      KONTR=0
      CALL MATAB(A,B,NDRY,NSEL,EMATL,XLENT,MATNUM,IWTBL,NUM)
      GO TO 950
  900 WTCR=WTCH/XLENT(NDRY)
      IF(WTCR.LT.0.5) GO TO 950
      XDUM=XLENT(NDRY)
      XLENT(NDRY)=WTCH
      IWTBL(NDRY)=1
      CALL MATAB(A,B,NDRY,NSEL,EMATL,XLENT,MATNUM,IWTBL,NUM)
      KONTR=1
      NSE=NSEL-1
      DO 295 K=1,NSE
      PI(K+1)=E(K)
  295 CONTINUE
      PI(1)=WTCH*GMAW/2.
      GO TO 400
  950 IF(NDRY.EQ.0) GO TO 951
      M0=MATNUM(NDRY)
  951 M1=MATNUM(NDRY+1)
      M2=MATNUM(NDRY+2)
      AEMAT=(EMATL(1,M0)*WTCH+EMATL(1,M1)*XLENT(NDRY+1))/(WTCH+
     *XLENT(NDRY+1))
      A(1,1)=EMATL(1,M2)/XLENT(NDRY+2)+AEMAT/(WTCH+XLENT(NDRY+1))
      B(1,1)=B(1,1)+DWTCH/EMATL(13,M0)/3.
  400 CONTINUE
      RETURN
 2000 FORMAT(1H1,37X,35H *** POST-EARTHQUAKE ANALYSIS ***   //)
 2001 FORMAT(// 15H -----TIME---=  ,F10.5/
     * 12H SETTLEMENT=  ,F10.5/
     * 20H WATER TABLE DEPTH=  ,F10.5//)
 2002 FORMAT(3X,12H NODE N.      ,5X11H EXCESS PP. ,5X,14H DISSIP. RAT. )
 2003 FORMAT(5X,I5,5X,E15.6,5X,10H UNDEFINED )
 2004 FORMAT(5X,I5,5X,E15.6,5X,F10.5)
 2008 FORMAT(5X,37H TOTAL TIME FOR DISSIPATION ANALYSIS=  ,F10.5)
 2009 FORMAT(3X,28H OVERALL DISSIPATION RATIO=     ,F10.5)
 2010 FORMAT(30X,15H PORE PRESSURES    /
     *  8H NODE N.   ,
     *   7X,8H IN SITU  ,
     *  9X,10H AFTER EQ.   ,
     *  7X,7H EXCESS  )
 2011 FORMAT(2X,I5,3X,E15.6,3X,E15.6,10H       0.0      )
 2012 FORMAT(2X,I5,3X,E15.6,3X,E15.6,3X,E15.6)
      END
```

```
      SUBROUTINE TRIA (A,MB,NEQ,M)
C
      DIMENSION A(1),MB(1)
C
      NE=NEQ-1
      MN=M-1
      MM=MN*NEQ
      MK=NEQ-MN
      DO 300 N=1,NE
      NT=N-MK
      IF(NT.GT.0) MM=MM-NEQ
      MB(N)=0
      IF(A(N).EQ.0.0) GO TO 300
      L=N
      IL=N+NEQ
      IH=N+MM
      JB=0
      IB=0
      DO 200 I=IL,IH,NEQ
      L=L+1
      J=L
      IB=IB+1
      C=A(I)/A(N)
      IF(C.EQ.0.0) GO TO 200
      DO 100 K=I,IH,NEQ
      A(J)=A(J)-C*A(K)
  100 J=J+NEQ
      A(I)=C
      JB=IB
  200 CONTINUE
      MB(N)=JB
  300 CONTINUE
      MB(NEQ)=0
      RETURN
      END
```

```
      SUBROUTINE BACKS (A,B,MB,NN,MM)
C
      DIMENSION  A(1),B(1),MB(1)
C
      MMM=MM-1
      N=0
  270 N=N+1
      C=B(N)
      IF (A(N).NE.0.0) B(N)=B(N)/A(N)
      IF(N.EQ.NN) GO TO 300
      IL=N+1
      IH=N+MB(N)
      M=N
      DO 285 I=IL,IH
      M=M+NN
  285 B(I)=B(I)-A(M)*C
      GO TO 270
C
  300 IL=N
      N=N-1
      IF (N.EQ.0) RETURN
      IH=N+MB(N)
      M=N
      C=B(N)
      DO 400 I=IL,IH
      M=M+NN
  400 C=C-A(M)*B(I)
      B(N)=C
      GO TO 300
C
      END
```

```
      SUBROUTINE PROFIL(A,MB,NEQ,MBAND)
C
      DIMENSION A(1),MB(1)
C
      NN=NEQ*MBAND
      DO 300 N=1,NEQ
      NI=0
      NJ=0
      L=0
      IL=N+NEQ
      DO 100 I=IL,NN,NEQ
      L=L+1
      IF (A(I).NE.0.0) NI=I
      IF(N-L) 100,100,80
   80 IF(A(I-L).NE.0.0) NJ=I-L
  100 CONTINUE
      MB(N)=NI
      MB(N+NEQ)=NJ
  300 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE MLTPLY(A,B,BO,MB,NEQ)
C
      DIMENSION A(1),B(1),BO(1),MB(1)
C
      MM=NEQ-1
      DO 300 N=1,NEQ
      BB=A(N)*BO(N)
      L=N
      IL=N+NEQ
      IH=MB(N)
      IF(IH) 120,120,50
   50 DO 100 I=IL,IH,NEQ
      L=L+1
  100 BB=BB+A(I)*BO(L)
  120 L=N
      IF(L.EQ.1) GO TO 250
      IL=N+MM
      IH=MB(N+NEQ)
      IF(IH) 250,250,150
  150 DO 200 I=IL,IH,MM
      L=L-1
  200 BB=BB+A(I)*BO(L)
  250 B(N)=B(N)+BB
  300 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE SCAL(CX,DIST,SCA1,SCA2)
C
      DX=CX*2.
      A=10.E+11
      DO 1 I=1,20
      A=A/10.
      B=A/10.
      IF(DX.LT.A.AND.DX.GE.B) GO TO 2
    1 CONTINUE
      SCA1=-DX/2.
      SCA2=DX/DIST
      RETURN
    2 ID=INT((DX/B)+0.99)
      SCA1=-(FLOAT(ID)/2.)*B
      SCA2=-2.*SCA1/DIST
      RETURN
      END
```

```
      SUBROUTINE SZERO (A,NTLLL)
C
      DIMENSION  A(NTLLL)
C
      DO 100 I=1,NTLLL
  100 A(I)=0.0
      RETURN
      END
```

APPENDIX D

EXAMPLE INPUT AND OUTPUT

EXAMPLE INPUT

```
       EXAMPLE PROBLEM, 100 FT. UNIFORM LAYER
    1    1   10    0    0 1000     0.005
    1    1
  500    0  500    1


  60.0
1200.00      20    1
  8000.     3000.     7.50       3000.0     7.500 10000000.    0.108   0.0001873
.0000974   1.00      .6667       .001       0.95       0.80       0.1       0.5
  EL CENTRO (X-COMP) DT=0.005
   1.0       1.0      1000    1    1
 ( S00E COMPONENT OF EL CENTRO EARTHQUAKE (MAY 1940) DATA
   CODED BY 8F9.0, 250 CARDS )
  EL CENTRO (Y-COMP) DT=0.005
   1.0       1.0      1000    1    1
 ( S90W COMPONENT OF EL CENTRO EARTHQUAKE (MAY 1940) DATA
   CODED BY 8F9.0, 250 CARDS )
```

```
**********************************************************
*                                                        *
*  LL      AAAAA   SSSSSS   SSSSSS    IIIII IIIII IIIII  *
*  LL     AA   AA SS       SS           I     I     I    *
*  LL     AA   AA SSSSSS   SSSSSS       I     I     I    *
*  LL     AAAAAAA  SSSSSS   SSSSSS ***  I     I     I    *
*  LL     AA   AA     SS       SS       I     I     I    *
*  LLLLLL AA   AA SSSSSS   SSSSSS     IIIII IIIII IIIII  *
*                                                        *
*   PROGRAM FOR SEISMIC RESPONSE AND LIQUEFACTION OF     *
*    LAYERED GROUND UNDER MULTI-DIRECTIONAL SHAKING      *
*                                                        *
*                     DEVELOPED BY                       *
*                                                        *
*         JAMSHID GHABOUSSI AND UMIT DIKMEN              *
*     UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN         *
*                     JANUARY 1979                       *
*                                                        *
**********************************************************


      EXAMPLE PROBLEM, 100 FT. UNIFORM LAYER


NUMBER OF LAYERS ............    =     1

NUMBER OF MATERIALS .........    =     1

MAX. NO. OF SUBINC. PER
PLASTIC STEP ................    =    10

NUMBER OF CYCLES ............    =  1000

TIME STEP (DT) ..............    = .5000E-02
ACCELARATION IN X-DIRECTION=           1
                Y-DIRECTION=           1
                Z-DIRECTION=           0
( YES=1, NO=0 )


PRINT INTERVAL  .............    =   500

INTERVAL FOR SAVING RESPONSE     =     0

STEP FOR STARTING PRINT ....     =   500

STIFFNESS UPDATE CYCLE .....     =     1



DEPTH OF WATER TABLE ........    =    60.000

GRAVITY  ....................    =   386.200
```

```
---------- PROPERTIES OF LAYERS -----------

   LAYER             DEPTH          NUMBER OF          MATERIAL
   NUMBER                            ELEMENTS            NUMBER

        1         1200.000                 20                 1
```

```
----------- MATERIAL PROPERTIES ------------

MAT. NO.  CONS. MOD.   SHEAR MOD.   SH. MOD. CHGE. IN. PL. SH. MOD.   PL. MOD. CHGE.   BULK MOD.(FL.) PERMEABILITY   MASS DEN.(TOTAL
   1     .800000E+04   .300000E+04   .750000E+01   .300000E+04   .750000E+01   .100000E+08   .108000E+00   .187300E-03

MAT. NO.  MASS DEN.(FL.)   S(MAX)     1./LAMBDA      TLBMC        ALPHA          THETA          RES. EFF. STRS. VOID RAT.
   1     .974000E-04   .100000E+01   .666700E+00   .100000E-02   .950000E+00   .800000E+00   .100000E+00   .500000E+00
```

```
 EL CENTRO (Y-COMP) DT=0.005
TIME SCALE -------------   =    1.0000
AMPLITUDE SCALE --------   =    1.0000

OUTPUT OF BASE MOTION INPUT IS SUPPRESSED DUE TO USER REQUEST
```

```
 EL CENTRO (Y-COMP) DT=0.005

TIME SCALE -------------   =    1.0000

AMPLITUDE SCALE --------   =    1.0000


OUTPUT OF BASE MOTION INPUT IS SUPPRESSED DUE TO USER REQUEST


STORAGE INFORMATION

CORE SPACE AVAILABLE=  40000 CORE SPACE REQUESTED=   5479


 ----- INSITU STRESS CONDITION -----
  ELEMENT     EFFECTIVE      PORE
  NUMBER      PRESSURE       PRESSURE


       1          -.2170E+01     0.
       2          -.5382E+01     -.1128E+01
       3          -.7465E+01     -.3385E+01
       4          -.9548E+01     -.5642E+01
       5          -.1163E+02     -.7899E+01
       6          -.1371E+02     -.1016E+02
       7          -.1580E+02     -.1241E+02
       8          -.1788E+02     -.1467E+02
       9          -.1996E+02     -.1693E+02
      10          -.2205E+02     -.1918E+02
      11          -.2413E+02     -.2144E+02
      12          -.2621E+02     -.2370E+02
      13          -.2830E+02     -.2595E+02
      14          -.3038E+02     -.2821E+02
      15          -.3246E+02     -.3047E+02
      16          -.3455E+02     -.3273E+02
      17          -.3663E+02     -.3498E+02
      18          -.3871E+02     -.3724E+02
      19          -.4080E+02     -.3950E+02
      20          -.4288E+02     -.4175E+02
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---------- RESPONSE AT TIME -----   =    2.50000

 N        DX         DY         DZ         DW            VX         VY         VZ         VW            AX         AY         AZ         AW

  1   -1.77E+00 -3.99E-01 -1.22E-03  0.             -4.06E+00  4.90E+00 -5.10E-03  0.             3.39E+01  1.06E+01  1.62E-02  0.
  2   -1.75E+00 -3.09E-01 -3.24E-03  2.76E-03       -4.50E+00  5.31E+00 -5.03E-03  4.93E-03       7.87E+01  2.12E+01  1.30E-02 -1.05E-02
  3   -1.73E+00 -2.97E-01 -1.36E-03  9.91E-04       -4.64E+00  5.42E+00 -1.96E-03  1.86E-03       8.21E+01 -2.29E+01 -1.34E-02  1.60E-02
  4   -1.58E+00 -2.94E-01 -1.45E-03  9.99E-04       -3.12E+00  6.26E+00 -2.04E-03  1.97E-03       4.52E+01  2.21E+01  7.74E-04  1.64E-03
  5   -1.36E+00 -2.81E-01 -1.22E-03  7.91E-04       -3.91E-01  6.49E+00 -1.99E-03  1.96E-03       3.31E+01  3.60E+01  5.20E-04  1.74E-03
  6   -1.17E+00 -2.03E-01 -7.01E-04  2.94E-04       -8.62E-01  6.66E+00 -9.11E-05  9.78E-05      -2.97E+02  4.17E+01  1.80E-02 -1.38E-02
  7   -1.10E+00 -1.25E-01 -7.77E-04  3.98E-04       -3.55E+00  6.41E+00 -2.96E-04  3.04E-04      -9.41E+01  2.50E+01 -6.23E-03  6.02E-03
  8   -1.04E+00 -5.66E-02 -8.18E-04  4.68E-04       -4.16E+00  6.13E+00 -1.70E-04  1.77E-04      -1.43E+02  4.06E+00  1.84E-03 -1.86E-03
  9   -9.90E-01 -1.52E-02 -7.39E-04  4.17E-04       -4.94E+00  5.60E+00  2.29E-04 -2.23E-04      -5.10E+01  6.60E-01 -6.41E-04  6.88E-04
 10   -9.28E-01  6.69E-03 -5.90E-04  2.88E-04       -5.28E+00  5.04E+00  8.65E-05 -8.03E-05      -5.76E+01 -1.53E+01  2.04E-04 -1.20E-04
 11   -8.45E-01  1.12E-02 -5.73E-04  3.10E-04       -5.32E+00  4.41E+00 -6.23E-05  6.92E-05      -1.00E+01 -2.34E+01  3.57E-04 -2.48E-04
 12   -7.57E-01  1.41E-02 -3.67E-04  1.32E-04       -5.29E+00  3.67E+00  3.00E-04 -2.95E-04       1.39E+00 -2.47E+01 -2.12E-04  3.39E-04
 13   -6.65E-01  1.22E-02 -2.76E-04  6.91E-05       -4.97E+00  2.96E+00  5.50E-05 -5.03E-05       1.91E+01 -2.37E+01  3.99E-04 -2.66E-04
 14   -5.83E-01  8.47E-03 -1.79E-04 -9.94E-07       -4.40E+00  2.32E+00  1.77E-04 -1.71E-04       3.51E+01 -2.76E+01 -3.34E-05  1.67E-04
 15   -5.06E-01  2.78E-03 -1.85E-04  3.21E-05       -3.75E+00  1.76E+00  9.99E-05 -9.63E-05       5.44E+01 -1.73E+01  2.66E-04 -1.40E-04
 16   -4.27E-01 -3.15E-03 -1.43E-04  1.65E-05       -3.09E+00  1.25E+00  2.03E-04 -2.00E-04       7.05E+01 -5.27E+00  4.73E-06  1.09E-04
 17   -3.41E-01 -8.81E-03 -1.54E-04  5.38E-05       -2.42E+00  8.26E-01  1.39E-04 -1.35E-04       7.32E+01  2.01E+00  1.69E-04 -7.25E-05
 18   -2.53E-01 -1.24E-02 -1.64E-04  9.96E-05       -1.71E+00  4.80E-01  1.37E-04 -1.36E-04       5.96E+01  3.50E+00  4.82E-06  7.12E-05
 19   -1.64E-01 -1.31E-02 -2.31E-04  1.81E-04       -1.04E+00  2.27E-01  4.21E-05 -4.11E-05       3.64E+01  2.20E+00  1.39E-04 -8.67E-05
 20   -7.91E-02 -9.47E-03 -1.42E-04  1.17E-04       -4.68E-01  7.31E-02  8.64E-05 -8.58E-05       1.58E+01  7.85E-01 -4.11E-05  6.77E-05

----- STRAINS AND STRESSES AT TIME ----- =   2.50000

ELEMENT   VOLUME        SHEAR         SHEAR          FLUID VOL      EFFECTIVE       SHEAR           SHEAR         PORE
NUMBER    STRAIN        STRN. X       STRN. Y        CHANGE         PRESSURE        STRESS          STRESS        PRESSURE


  1         .3518E-06   -.2385E-03    .1314E-04    -.4607E-04    -.2170E+01    -.7691E+00     .4237E-01     0.
  2        -.3132E-04   -.3262E-03   -.2058E-03     .3122E-04    -.4296E+01    -.2030E+01    -.1257E+00    -.2214E+01
  3         .1557E-05   -.2596E-02   -.4742E-04    -.1798E-05    -.5005E+01    -.3321E+01     .3736E+00    -.5801E+01
  4        -.3815E-05   -.3655E-02   -.2177E-03     .3466E-05    -.5983E+01    -.4229E+01     .2626E+00    -.9140E+01
  5        -.8727E-05   -.3091E-02   -.1310E-02     .3295E-05    -.7195E+01    -.5064E+01    -.2131E-01    -.1232E+02
  6         .1269E-05   -.1127E-02   -.1295E-02    -.1735E-05    -.9055E+01    -.1970E+01    -.3617E+00    -.1431E+02
  7         .6770E-06   -.1026E-02   -.1139E-02    -.1157E-05    -.1100E+02    -.1487E+01    -.8976E+00    -.1721E+02
  8        -.1334E-05   -.8795E-03   -.6903E-03     .8465E-06    -.1301E+02    -.1659E+00    -.5695E+00    -.1954E+02
  9        -.2629E-05   -.1039E-02   -.3650E-03     .2148E-05    -.1517E+02    -.1222E+00    -.2370E+00    -.2173E+02
 10        -.1119E-06   -.1379E-02   -.7556E-04    -.3636E-06    -.1729E+02     .1723E+00     .1035E+00    -.2394E+02
 11        -.3430E-05   -.1459E-02   -.4847E-04     .2956E-05    -.1939E+02     .9368E-01     .4306E+00    -.2614E+02
 12        -.1519E-05   -.1541E-02    .3160E-04     .1054E-05    -.2158E+02    -.3433E+00     .9122E+00    -.2834E+02
 13        -.1626E-05   -.1365E-02    .6275E-04     .1169E-05    -.2372E+02    -.9587E+00     .1420E+01    -.3053E+02
 14         .1011E-06   -.1288E-02    .9554E-04    -.5509E-06    -.2588E+02    -.1760E+01     .1937E+01    -.3271E+02
 15        -.7022E-06   -.1306E-02    .9820E-04     .2595E-06    -.2804E+02    -.2799E+01     .2260E+01    -.3490E+02
 16         .1890E-06   -.1438E-02    .9439E-04    -.6212E-06    -.3021E+02    -.4042E+01     .2459E+01    -.3706E+02
 17         .1729E-06   -.1472E-02    .5957E-04    -.5979E-06    -.3239E+02    -.5320E+01     .2573E+01    -.3923E+02
 18         .1112E-05   -.1490E-02    .1206E-04    -.1530E-05    -.3453E+02    -.6433E+01     .2679E+01    -.4142E+02
 19        -.1490E-05   -.1432E-02   -.6068E-04     .1076E-05    -.3665E+02    -.7257E+01     .2809E+01    -.4355E+02
 20        -.2360E-05   -.1302E-02   -.1578E-03     .1949E-05    -.3877E+02    -.7833E+01     .2959E+01    -.4567E+02
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---------- RESPONSE AT TIME -----   =    5.00000

 N      DX         DY         DZ         DW          VX         VY         VZ         VW          AX         AY         AZ         AW

  1  -2.23E+00 -1.22E+00 -1.68E-02  0.          1.94E+01  1.79E+01 -1.54E-02  0.         -8.01E+01 -6.50E+01 -2.05E-01  0.
  2  -2.23E+00 -1.23E+00 -1.69E-02  1.57E-02    1.81E+01  1.75E+01 -1.76E-02  1.83E-02   -6.71E+01  1.05E+01 -4.67E-01  1.12E-01
  3  -2.08E+00 -8.26E-01 -1.09E-02  9.74E-03    1.47E+01  1.77E+01 -3.99E-04  1.37E-03   -1.55E+02  2.73E+02 -6.25E-01  2.82E-01
  4  -1.94E+00 -7.64E-01 -8.88E-03  7.77E-03    9.56E+00  2.03E+01 -2.81E-03  4.64E-03    6.37E+01 -4.09E+01 -5.91E-02 -3.39E-01
  5  -1.64E+00 -6.61E-01 -3.79E-03  2.73E-03    1.28E+01  1.39E+01  4.17E-04  1.95E-03   -7.40E+01  1.20E+02 -5.44E-01  2.44E-01
  6  -8.22E-01 -7.26E-01 -3.53E-03  2.54E-03    6.92E+00  1.56E+01 -5.95E-03  9.04E-03   -2.13E+02  8.81E+01  6.61E-02 -2.54E-01
  7  -1.05E+00 -2.66E-01 -3.02E-03  2.10E-03    6.80E+00  1.12E+01  3.65E-03 -6.27E-04   -1.61E+02 -9.04E+01  1.74E-01 -3.04E-01
  8  -7.58E-01 -2.35E-01 -1.32E-03  4.93E-04    2.54E+00  1.14E+01  5.20E-03 -3.02E-03   -2.02E+02  1.53E+01 -3.07E-01  2.16E-01
  9  -7.41E-01 -1.29E-01 -2.34E-03  1.59E-03    1.80E+00  9.57E+00  4.56E-04  1.36E-03   -1.94E+02  5.63E+01  1.36E-01 -2.64E-01
 10  -6.37E-01 -1.88E-01 -2.99E-03  2.32E-03    4.19E-01  6.81E+00 -7.26E-03  8.12E-03   -5.78E+01  5.92E+01 -3.04E-01  2.08E-01
 11  -5.75E-01 -9.64E-02  1.31E-03 -1.88E-03   -1.10E+00  4.56E+00  1.45E-02 -1.42E-02   -5.80E+01 -8.95E+00 -3.09E-01  1.95E-01
 12  -5.69E-01 -6.39E-02 -9.26E-04  4.17E-04   -1.32E+00  3.50E+00 -1.19E-03  1.52E-03   -1.47E+01  1.52E+02 -4.18E-02 -6.03E-02
 13  -5.29E-01 -6.14E-02  1.40E-04 -5.86E-04   -1.20E+00  2.85E-01  1.25E-03 -9.53E-04   -9.38E+00  1.82E+02 -1.07E-01  1.65E-02
 14  -4.96E-01 -3.73E-02 -3.42E-04 -4.20E-05   -1.09E+00 -1.13E+00  9.73E-04 -7.03E-04    8.52E+01  2.06E+01 -7.38E-02 -5.14E-03
 15  -4.50E-01 -5.34E-03 -4.03E-04  7.73E-05   -1.52E+00 -9.59E-01  1.10E-03 -8.62E-04    1.54E+02 -9.42E+01 -6.81E-02  5.99E-04
 16  -3.69E-01  4.88E-03 -6.55E-05 -2.04E-04   -1.50E+00 -7.65E-01  1.40E-03 -1.20E-03    8.99E+01 -8.72E+01 -5.62E-02  5.67E-05
 17  -2.62E-01  9.95E-04 -4.16E-04  1.99E-04   -7.24E-01 -1.13E+00  7.60E-05  8.63E-05   -5.25E+01  3.34E+00 -4.43E-02 -5.46E-04
 18  -1.83E-01 -1.96E-03 -8.42E-04  6.77E-04    2.51E-01 -1.68E+00 -5.44E-04  6.67E-04   -1.82E+02  1.04E+02 -3.31E-02 -5.27E-04
 19  -1.14E-01 -3.40E-03 -1.44E-03  1.33E-03    7.99E-01 -1.78E+00 -1.32E-04  2.15E-04   -2.24E+02  1.45E+02 -2.23E-02 -7.18E-05
 20  -5.33E-02  3.19E-04 -7.53E-04  6.99E-04    6.54E-01 -1.13E+00  1.97E-04 -1.55E-04   -1.49E+02  1.00E+02 -1.13E-02  1.03E-04

----- STRAINS AND STRESSES AT TIME ----- =   5.00000

ELEMENT   VOLUME         SHEAR        SHEAR          FLUID VOL      EFFECTIVE      SHEAR          SHEAR         PORE
NUMBER    STRAIN         STRN. X      STRN. Y        CHANGE         PRESSURE       STRESS         STRESS        PRESSURE


  1        .1070E-05     .4412E-04     .1740E-03    -.2623E-03    -.2170E+01     .1423E+00     .5610E+00    0.
  2       -.1004E-03    -.2575E-02    -.6740E-02     .1000E-03    -.1280E+01     .2565E+00     .8263E+00    -.4638E+01
  3       -.3330E-04    -.2265E-02    -.1037E-02     .3268E-04    -.1661E+01     .1578E+01    -.2311E+01    -.9620E+01
  4       -.8488E-04    -.5054E-02    -.1723E-02     .8408E-04    -.3784E+00     .2359E+00    -.1487E+01    -.1365E+02
  5       -.4212E-05    -.1356E-01     .1080E-02     .3207E-05    -.2453E+00     .2330E+00    -.2483E+01    -.1795E+02
  6       -.8632E-05     .3870E-02    -.7658E-02     .7283E-05    -.1000E+00     .2393E+01    -.3539E+01    -.2365E+02
  7       -.2820E-04    -.4940E-02    -.5165E-03     .2679E-04    -.3551E+01     .3374E+01    -.1852E+01    -.2642E+02
  8        .1694E-04    -.2923E-03    -.1764E-02    -.1822E-04    -.5533E+01     .5256E+01    -.1899E+01    -.2745E+02
  9        .1077E-04    -.1732E-02     .9879E-03    -.1216E-04    -.7311E+01     .6945E+01    -.2346E+01    -.3079E+02
 10       -.7157E-04    -.1019E-02    -.1535E-02     .6999E-04    -.7202E+01     .6842E+01    -.2803E+01    -.3493E+02
 11        .3722E-04    -.1094E-03    -.5408E-03    -.3836E-04    -.1274E+02     .7007E+01    -.2054E+01    -.3278E+02
 12       -.1777E-04    -.6616E-03    -.4267E-04     .1672E-04    -.1566E+02     .6567E+01    -.3913E+01    -.3420E+02
 13        .8039E-05    -.5492E-03    -.4004E-03    -.9061E-05    -.1802E+02     .6235E+01    -.5925E+01    -.3619E+02
 14        .1008E-05    -.7768E-03    -.5332E-03    -.1988E-05    -.2053E+02     .4576E+01    -.5745E+01    -.3801E+02
 15       -.5618E-05    -.1337E-02    -.1705E-03     .4688E-05    -.2311E+02     .2011E+01    -.4204E+01    -.3977E+02
 16        .5838E-05    -.1785E-02     .6483E-04    -.6717E-05    -.2571E+02     .2845E+00    -.2933E+01    -.4152E+02
 17        .7095E-05    -.1323E-02     .4921E-04    -.7973E-05    -.2781E+02     .3378E+00    -.2614E+01    -.4376E+02
 18        .1902E-04    -.1156E-02     .2401E-04    -.1093E-04    -.2962E+02     .2018E+01    -.3652E+01    -.4629E+02
 19       -.1149E-04    -.1004E-02    -.6196E-04     .1057E-04    -.3157E+02     .4239E+01    -.5212E+01    -.4867E+02
 20       -.1256E-04    -.8889E-03     .5316E-05     .1164E-04    -.3369E+02     .5533E+01    -.6211E+01    -.5089E+02
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------- MAXIMUM RESPONSE --------


------ X-DIRECTION ----

  N   MAX. DISP.      TIME      MAX. VEL.      TIME     MAX. ACC.     TIME

  1   -.4433E+01    4.87000   -.2252E+02    4.63500   -.2383E+03   2.60000
  2   -.4410E+01    4.81500   -.2191E+02    4.63000    .2101E+03   4.80500
  3   -.4410E+01    4.81500   -.2090E+02    4.61000    .2237E+03   3.84000
  4   -.4146E+01    4.81000   -.1961E+02    1.88000    .3225E+03   4.78000
  5   -.3763E+01    4.79000    .1983E+02    4.93000    .3897E+03   4.77500
  6   -.3034E+01    3.74000    .1869E+02    4.90500    .4967E+03   4.77000
  7   -.2952E+01    4.80500   -.1661E+02    1.88500    .7779E+03   4.80500
  8   -.2690E+01    3.73500   -.1549E+02    1.88500    .5951E+03   4.83500
  9   -.2505E+01    3.72500   -.1438E+02    1.87500    .4366E+03   4.92500
 10   -.2279E+01    3.72000   -.1319E+02    1.87500    .3046E+03   4.96500
 11   -.2041E+01    3.71000   -.1211E+02    1.87000   -.3587E+03   4.82500
 12   -.1798E+01    3.70500   -.1107E+02    1.86500   -.3511E+03   2.03000
 13   -.1554E+01    3.69500   -.9857E+01    1.86000   -.3333E+03   2.01500
 14   -.1319E+01    3.68500   -.8513E+01    1.84000   -.3008E+03   2.00000
 15   -.1098E+01    4.70000   -.7524E+01    1.81000   -.2543E+03   1.98500
 16   -.9181E+00    4.69000   -.6484E+01    1.79000   -.2329E+03   4.89500
 17   -.7281E+00    4.68500   -.5529E+01    1.77500   -.1942E+03   4.90000
 18   -.5461E+00    4.66000   -.4302E+01    1.77000    .2232E+03   4.96000
 19   -.3787E+00    2.73500   -.3091E+01    1.75500    .2656E+03   4.96500
 20   -.1931E+00    2.73500    .1934E+01    4.98500    .1999E+03   4.96500

------ Y-DIRECTION ----

  N   MAX. DISP.      TIME      MAX. VEL.      TIME     MAX. ACC.     TIME

  1   -.2595E+01    4.87500   -.1833E+02    4.75500    .2789E+03   4.85500
  2   -.2580E+01    4.88000   -.1798E+02    4.76500    .2504E+03   4.82500
  3   -.2364E+01    4.85500    .1770E+02    5.00000    .2989E+03   4.85500
  4   -.2170E+01    4.86000    .2026E+02    5.00000    .3913E+03   4.97500
  5   -.2068E+01    1.66500   -.1603E+02    4.71500    .4289E+03   4.88000
  6   -.1994E+01    1.66500    .1560E+02    5.00000    .5362E+03   4.73500
  7   -.1898E+01    1.66500    .1402E+02    4.97500   -.8446E+03   4.73500
  8   -.1779E+01    1.66500    .1142E+02    5.00000    .4176E+03   4.80000
  9   -.1649E+01    1.66500    .9567E+01    5.00000    .6210E+03   4.80500
 10   -.1506E+01    1.66000    .8765E+01    1.85500   -.4590E+03   4.86000
 11   -.1348E+01    1.66500    .9138E+01    1.85500   -.2145E+03   4.87500
 12   -.1185E+01    1.65500   -.9096E+01    4.60500   -.2212E+03   4.89000
 13   -.1032E+01    1.63000   -.7705E+01    4.60000   -.1979E+03   4.90000
 14   -.8925E+00    1.61500   -.7202E+01    4.59500   -.1880E+03   4.91500
 15   -.7579E+00    1.60000   -.6429E+01    4.59500   -.1939E+03   4.92500
 16   -.6287E+00    1.58500   -.5412E+01    4.58500   -.1849E+03   4.93500
 17   -.5046E+00    1.56500   -.4620E+01    4.57500   -.1545E+03   4.94500
 18   -.3812E+00    1.56000   -.3645E+01    4.57500   -.1566E+03   4.96500
 19   -.2559E+00    1.55000   -.2698E+01    4.99000   -.1891E+03   4.97000
 20   -.1290E+00    1.54500   -.1745E+01    4.59000   -.1368E+03   4.97000

------ Z-DIRECTION ----
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```
  #   MAX. DISP.     TIME     MAX. VEL.     TIME     MAX. ACC.     TIME

  1   -.1684E-01    5.00000   -.2007E-01   4.87500    .1015E+01   4.77000
  2   -.1690E-01    5.00000   -.1970E-01   4.86500    .2370E+01   4.76500
  3   -.1098E-01    4.97500   -.1172E-01   4.79500    .2320E+01   4.76500
  4   -.8879E-02    5.00000   -.1178E-01   4.98000    .2589E+01   4.76500
  5   -.3826E-02    4.98500   -.4809E-01   4.95500   -.1632E+01   4.82000
  6   -.3534E-02    5.00000    .4996E-01   4.77500    .7112E+01   4.76500
  7   -.3052E-02    4.98500   -.5138E-01   4.77500   -.4617E+01   4.76500
  8   -.1470E-02    4.96000   -.2216E-01   4.88000   -.2727E+01   4.78500
  9   -.2341E-02    4.99500    .1577E-01   4.83500   -.2208E+01   4.78500
 10   -.2987E-02    5.00000   -.2341E-01   4.84000   -.1546E+01   4.82500
 11    .1307E-02    5.00000    .1978E-01   4.97000   -.8466E+00   4.78500
 12   -.9261E-03    5.00000   -.3356E-02   4.97500    .6248E+00   4.77500
 13   -.3578E-03    3.29000    .2761E-02   4.78000    .4890E+00   4.77500
 14   -.5029E-03    4.74500    .2579E-02   4.79000    .4290E+00   4.77500
 15   -.6233E-03    4.74000    .2381E-02   4.78000    .3742E+00   4.77500
 16   -.4792E-03    4.05000    .2713E-02   4.79000    .3127E+00   4.77500
 17   -.4171E-03    4.99000   -.1858E-02   4.67000    .2526E+00   4.77500
 18   -.9416E-03    5.00000   -.1601E-02   4.66500    .1901E+00   4.77500
 19   -.1443E-02    5.00000   -.1639E-02   4.65000    .1268E+00   4.77500
 20   -.8128E-03    4.68000   -.1330E-02   4.34000   -.7362E-01   4.63500

------ WATER      ----

  #   MAX. DISP.     TIME     MAX. VEL.     TIME     MAX. ACC.     TIME

  1   0.            5.00000   0.           5.00000   0.           5.00000
  2    .1574E-01    5.00000    .1833E-01   5.00000    .6119E+00   4.85500
  3    .9820E-02    4.91000    .6595E-02   4.79500   -.8734E+00   4.80000
  4    .7775E-02    5.00000    .1192E-01   4.98500    .9083E+00   4.80000
  5    .2730E-02    5.00000    .1636E-01   4.96000    .1372E+01   4.92000
  6    .2538E-02    5.00000   -.4296E-01   4.77500   -.4591E+01   4.76500
  7    .2135E-02    4.92500    .5504E-01   4.77500    .4900E+01   4.76500
  8    .6157E-03    3.81000    .2162E-01   4.88000   -.2302E+01   4.83500
  9    .1586E-02    5.00000   -.1493E-01   4.83500   -.1968E+01   4.82000
 10    .2316E-02    5.00000    .2355E-01   4.84000    .1521E+01   4.82500
 11   -.1884E-02    5.00000   -.1572E-01   4.97000   -.1098E+01   4.79000
 12    .4175E-03    5.00000    .329[illegible]E-02   4.97000    .2606E+00   4.79000
 13   -.5857E-03    5.00000   -.1525E-02   4.90000   -.7061E-01   4.76000
 14    .1165E-03    4.74500   -.8447E-03   4.76000   -.6972E-01   4.75000
 15    .3717E-03    4.02000   -.8953E-03   4.97000   -.1002E+00   4.74000
 16    .2702E-03    4.05000   -.1597E-02   4.74000   -.1589E+00   4.72500
 17    .2264E-03    3.67000    .1192E-02   4.68500    .7664E-01   4.65500
 18    .6774E-03    5.00000    .1101E-02   2.75500    .6716E-01   4.64500
 19    .1333E-02    5.00000    .1059E-02   4.65500   -.4562E-01   4.69500
 20    .7577E-03    4.68000    .1285E-02   4.34000   -.4539E-01   4.67500
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-------- EXTREME STRESSES AND STRAINS --------


------ X-DIRECTION ----


  N   SHEAR STRS.      TIME      SHEAR STRN.      TIME

  1    .1490E+01   2.60000     .4619E-03   2.60000
  2   -.2566E+01   4.96000   -.3839E-02   4.96000
  3   -.5061E+01   4.80000   -.4745E-02   3.90500
  4   -.5625E+01   4.81500   -.8319E-02   3.89000
  5   -.7476E+01   4.79500   -.1633E-01   4.91500
  6   -.1690E+02   4.76500    .5188E-02   4.46500
  7   -.1224E+02   4.80500   -.9925E-02   4.87000
  8   -.9260E+01   4.79500   -.4568E-02   4.84000
  9   -.1280E+02   4.83000   -.7414E-02   4.83000
 10   -.9331E+01   3.72500   -.4738E-02   4.82500
 11   -.1013E+02   3.71500   -.4267E-02   3.74500
 12   -.1085E+02   3.70500   -.4240E-02   3.73000
 13   -.1144E+02   3.69500   -.4020E-02   3.71500
 14   -.1224E+02   4.68500   -.3792E-02   3.70000
 15   -.1278E+02   4.69000   -.3484E-02   3.69000
 16   -.1342E+02   4.69500   -.3369E-02   4.71500
 17   -.1393E+02   4.69500   -.3113E-02   4.69500
 18   -.1405E+02   4.68500   -.3088E-02   4.68500
 19    .1432E+02   4.31500   -.3100E-02   2.74000
 20    .1527E+02   4.33000   -.3218E-02   2.73500

------ Y-DIRECTION ----


  N   SHEAR STRS.      TIME      SHEAR STRN.      TIME

  1   -.1678E+01   4.85500   -.5204E-03   4.85500
  2   -.2958E+01   4.94000   -.7981E-02   4.95500
  3   -.6751E+01   4.85500   -.3273E-02   4.85500
  4   -.8931E+01   4.94500   -.5489E-02   4.84500
  5   -.1130E+02   4.88000   -.3053E-02   4.89000
  6   -.1335E+02   4.86000   -.1175E-01   4.85000
  7   -.1368E+02   4.83500   -.4831E-02   4.83500
  8   -.1040E+02   4.90500   -.4460E-02   4.90500
  9   -.1459E+02   4.79500   -.2524E-02   4.79500
 10   -.1142E+02   4.88500   -.3812E-02   4.89500
 11   -.1115E+02   4.89500   -.2801E-02   1.68000
 12   -.1043E+02   4.91500   -.2847E-02   1.68000
 13   -.1091E+02   4.85500   -.2644E-02   1.66500
 14   -.1059E+02   4.85500   -.2447E-02   1.65000
 15   -.1071E+02   4.82000   -.2310E-02   1.63000
 16   -.1156E+02   4.82000   -.2224E-02   1.61500
 17   -.1175E+02   4.81500   -.2124E-02   1.60000
 18   -.1214E+02   4.80000   -.2110E-02   1.57500
 19   -.1213E+02   4.80000   -.2119E-02   1.56000
 20   -.1230E+02   4.78500   -.2151E-02   1.54500
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------- EFFECTIVE STRS. AND PORE PRESS. -------
   N   PORE PRES.      TIME     EFF. STRS.

   1   0.             5.00000   -.2170E+01
   2   -.4638E+01     5.00000   -.1280E+01
   3   -.9620E+01     5.00000   -.1651E+01
   4   -.1432E+02     4.98500   -.3784E+00
   5   -.1907E+02     4.98000   -.2453E+00
   6   -.2397E+02     4.99000   -.1000E+00
   7   -.2734E+02     4.97000   -.3551E+01
   8   -.3061E+02     4.98000   -.5533E+01
   9   -.3517E+02     4.97000   -.7311E+01
  10   -.3732E+02     4.97000   -.7202E+01
  11   -.3284E+02     4.99000   -.1274E+02
  12   -.3449E+02     4.77500   -.1566E+02
  13   -.3638E+02     4.77000   -.1302E+02
  14   -.3823E+02     4.77000   -.2053E+02
  15   -.4000E+02     4.77000   -.2311E+02
  16   -.4168E+02     4.77000   -.2571E+02
  17   -.4394E+02     4.77500   -.2781E+02
  18   -.4651E+02     4.77500   -.2962E+02
  19   -.4889E+02     4.77500   -.3157E+02
  20   -.5110E+02     4.77500   -.3169E+02


ELEMENT LIQUEFACTION DATA

  EL. NO.

     1       NO LIQUEFACTION
     2       INITIAL LIQUEF. AT TIME =    4.8500 NO FINAL LIQUEF.
     3       INITIAL LIQUEF. AT TIME =    4.7900 NO FINAL LIQUEF.
     4       INITIAL LIQUEF. AT TIME =    4.5300 NO FINAL LIQUEF.
     5       INITIAL LIQUEF. AT TIME =    4.7400 NO FINAL LIQUEF.
     6       INITIAL LIQUEF. AT TIME =    4.7300 LIQUEF. AT TIME =    4.9750
     7       INITIAL LIQUEF. AT TIME =    4.7450 NO FINAL LIQUEF.
     8       INITIAL LIQUEF. AT TIME =    4.7500 NO FINAL LIQUEF.
     9       INITIAL LIQUEF. AT TIME =    4.7800 NO FINAL LIQUEF.
    10       INITIAL LIQUEF. AT TIME =    4.7850 NO FINAL LIQUEF.
    11       NO LIQUEFACTION
    12       NO LIQUEFACTION
    13       NO LIQUEFACTION
    14       NO LIQUEFACTION
    15       NO LIQUEFACTION
    16       NO LIQUEFACTION
    17       NO LIQUEFACTION
    18       NO LIQUEFACTION
    19       NO LIQUEFACTION
    20       NO LIQUEFACTION
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