USER'S MANUAL FOR

SHAKE91

A Computer Program for Conducting Equivalent Linear
Seismic Response Analyses of Horizontally Layered Soil Deposits

Program Modified based on the Original ***SHAKE*** program published in
December 1972 by Schnabel, Lysmer & Seed

Modifications by

I. M IDRISS
JOSEPH I. SUN

Sponsored by

Structures Division
Building and Fire Research Laboratory
National Institute of Standards and Technology
Gaithersburg, Maryland

Center for Geotechnical Modeling
Department of Civil & Environmental Engineering
University of California
Davis, California

August 1992

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

USER'S MANUAL FOR

SHAKE91

A Computer Program for Conducting Equivalent Linear
Seismic Response Analyses of Horizontally Layered Soil Deposits

Program Modified based on the Original *SHAKE* program published in
December 1972 by Schnabel, Lysmer & Seed

Modifications by

I. M Idriss[1] and Joseph I. Sun[2]

INTRODUCTION

The computer program **SHAKE** was written in 1970-71 by Dr. Per Schnabel and Professor John Lysmer and was published in December 1972 by Dr. Per Schnabel and Professors John Lysmer and H. Bolton Seed in report No. UCB/EERC 72/12, issued by the Earthquake Engineering Research Center at the University of California in Berkeley. This has been by far the most widely used program for computing the seismic response of horizontally layered soil deposits.

The program computes the response of a semi-infinite horizontally layered soil deposit overlying a uniform half-space subjected to vertically propagating shear waves. The analysis is done in the frequency domain, and, therefore, for any set of properties it is a linear analysis. An iterative procedure is used to account for the nonlinear behavior of the soils as summarized below.

The object motion (ie, the motion that is considered to be known) can be specified at the top of any sublayer within the soil profile or at the corresponding outcrop.

The program **SHAKE** was originally written for a main frame computer. It was converted for use on a personal computer by Dr. S. S. Lai in 1985; almost everything else remained identical to the original computer program. While there have been many modifications and several editions of the program **SHAKE** have been referenced in recent publications, the version included herein constitutes the most extensive modifications to

---

[1]Department of Civil Engineering, University of California, Davis
[2]Woodward-Clyde Consultants, Oakland, California

the original program. The intent of the modifications was to make the program more convenient for use with a personal computer.

MODIFICATIONS IMPLEMENTED IN SHAKE91

The main modifications incorporated in *SHAKE91* include the following:

- The number of sublayers was increased from 20 to 50; this should permit a more accurate representation of deeper and/or softer soil deposits.

- Removed all built-in modulus reduction and damping relationships. These relationships are now specified by the user; up to 13 different relations of modulus reduction, G/G_{max}, versus shear strain and damping ratio, λ, versus shear strain can be specified as part of the input file. A number of published variations of G/G_{max} and λ with shear strain are available in the literature (eg, Hardin and Drnevich, 1970; Seed and Idriss, 1970; Seed et al, 1986; Sun et al, 1988; Vucetic and Dobry, 1991).

- The maximum shear velocity or the maximum modulus are now specified for each sublayer; again these are part of the input and therefore the program no longer calculates modulus values as a function of either confining pressure or shear strength. The user specifies the maximum values, which are derived by the user.

- Object motion is now read from a separate file; the number of header lines and format are specified by the user.

- Other clean-up included: renumbering of options, elimination of infrequently used options, user specified periods for calculating spectral ordinates ... etc.

DESCRIPTION OF THE PROGRAM

The soil profile is idealized as a system of homogeneous, visco-elastic sublayers of infinite horizontal extent; the idealized soil profile is shown in Fig. 1. The response of this system is calculated considering vertically propagating shear waves. The algorithm in the original program **SHAKE** (Schnabel et al, 1972) is based on the continuous solution to the wave equation (Kanai, 1951; Matthiesen et al, 1964; Roesset and Whitman, 1969; Lysmer et al 1971), which was adapted for transient motions using the Fast Fourier Transform techniques of Cooley and Tukey (1965). The program *SHAKE91* retains this feature of the original program. Details pertinent to the derivation of the applicable equations of motion and solution of these equations are summarized in the original **SHAKE** manual, in the aforementioned references and in most textbooks on wave propagation.

An equivalent linear procedure (Idriss and Seed, 1968; Seed and Idriss, 1970) is used to account for the nonlinearity of the soil using an iterative procedure to obtain values for modulus and damping that are compatible with the equivalent uniform strain induced in each sublayer. Thus, at the outset, a set of properties (shear modulus, damping and total unit weight) is assigned to each sublayer of the soil deposit. The analysis is conducted using these properties and the shear strains induced in each sublayer is calculated. The shear modulus and the damping ratio for each sublayer are then modified based on the applicable relationship relating these two properties to shear strain. The analysis is repeated until strain-compatible modulus and damping values are arrived at. Starting with the maximum shear modulus for each sublayer and a low value of damping, essentially (ie, difference less than one percent) strain-compatible properties are obtained in 5 to 8 iterations for most soil profiles.

The following assumptions are incorporated in the analysis (Schnabel et al, 1972):

- Each sublayer, m, is completely defined by its shear modulus, G_m, damping ratio, λ_m, total unit weight, γ_{tm} (or corresponding mass density, ρ_m) and thickness, h_m; these properties are independent of frequency.

- The responses in the soil profile are caused by the upward propagation of shear waves from the underlying rock half-space.

- The shear waves are specified as acceleration ordinates at equally spaced time intervals. (Cyclic repetition of the acceleration time history is implied in the solution).

- The strain dependence of the shear modulus and damping in each sublayer is accounted for by an equivalent linear procedure based on an equivalent uniform strain computed in that sublayer. The ratio of this equivalent uniform shear strain divided by the calculated maximum strain is specified by the user (see Option 5 below) and is assumed to be the same for all sublayers.

Available Options

The options incorporated into ***SHAKE91*** are as follows:

Option Number	Description
1	dynamic soil properties
2	data for soil profile
3	input (object) motion
4	assignment of object motion to the top of a specified sublayer
5	number of iterations specified & ratio of uniform strain to max strain
6	sublayers at top of which peak accelerations & time histories are computed and saved

7	sublayer at top of which time history of shear stress or strain is computed and saved
8	save time history of object motion
9	compute response spectrum
10	compute amplification spectrum
11	compute Fourier amplitudes

Note that the original program **SHAKE** included 16 options and that the modified program includes only 11; the five options eliminated pertain mostly to plotting and to adjusting the time increment all of which can best be done in auxiliary programs.

INPUT DATA

The input data are provided in an input file that is specified directly from the key board at the time of program execution; a sample input is presented in Table 1. As can be noted in the table, each option starts with the following two lines:

Line No. 1 (Format: A80)

columns 1 - 80 Identification information for this option (this line cannot be blank)

Line No. 2 (Format: I5)

column 1 - 5 Option Number

The specific inputs for each option are presented below.

__Option 1 -- Dynamic Soil Properties__

- first line after option number (Format: I5)

column 1 - 5 Number of materials included (maximum is 13)

then, for each material, the following input should be supplied:

first line (Format: I5, 11A6)

column 1 - 5 number of strain values to be read (maximum is 20)
column 6 - 71 identification for this set of modulus reduction values

second & consecutive lines (Format: 8F10.0) column 1 - 80 strain values, in percent, beginning with the lowest value. Eight entries per line (maximum is 20)

consecutive lines (Format: 8F10.0)

column 1 - 80 values of modulus reduction (G/G_{max}) each corresponding to the shear strain provided in the previous lines; these values should be in decimal not in percent.

the second set for the same material will consist of identical information except that values of damping (in percent) are provided as illustrated in Table 1.

After the last set is completed, the following information is to be provided (Format: 16I5):

column 1 - 5	number, N, of materials to be used in this analysis
column 6 - 10	first material number which will be used
column 11 - 15	second material number to be used
column 16 - 20	third material number to be used
.	....
.	....
.	etc until all N materials are identified.

Values of G/G_{max} and λ versus strain for these N materials will then be saved in output file No. 1 (see section on OUTPUT below) so that only the material properties used in this analysis are saved in this file. This feature was added for the convenience of the user who can include up to 13 sets of material properties in the input file but for any one analysis uses fewer than 13. This feature also provides a check that the intended material properties were utilized in the analysis.

Option 2 -- Soil Profile

- first line after option number (Format: 2I5, 5X, 6A6)

column 1 - 5	soil deposit number; may be left blank
column 11 - 10	number of sublayers, including the half-space
column 16 - 51	identification for soil profile

- second and subsequent lines; one line for each sublayer, including the half-space (Format: 2I5, 5X, 5F10.0)

column 1 - 5	sublayer number
column 11 - 10	soil type (corresponding to numbers assigned to each material in Option 1). [Note that if this material type is given as 0 (zero) for *all* sublayers, then the calculations are conducted for only one iteration using the

	properties (modulus, or shear wave velocity, and damping) specified in this input].
column 16 - 25	thickness of sublayer, in feet
column 26 - 35	maximum shear modulus for the sublayer, in ksf (leave blank if maximum shear wave velocity for the sublayer is given)
column 36 - 45	initial estimate of damping (decimal)
column 46 - 55	total unit weight, in ksf
column 56 - 65	maximum shear wave velocity for the sublayer, in ft/sec (leave blank if maximum shear modulus for the sublayer is given)

For the half-space, leave columns 16 to 25 blank; ie, no thickness should be specified for the half-space.

Option 3 – Input (Object) Motion

- first line after option number (Format: 2I5, F10.3, A30, A12)

column 1 - 5	number, NV, of acceleration values to be read for input motion
column 6 - 10	number, MA, of values for use in Fourier Transform; MA should be a power of 2 (typically, this number is 1024, 2048 or 4096). Note that MA should always be greater than NV. The following may be used as a guide: for NV ≤ 800, MA can be 1024, for NV ≤ 1800, MA can be 2048 and for NV ≤ 3800, MA can be 4096. The current program is limited to a maximum value of 4096 for MA. For those rare occasions when MA = 8196 is needed, the size of the COMMON block and the length of the variable MAMAX in the MAIN Module (see Appendix A) should be changed to 51220 and 8196, respectively.
column 11 - 20	time interval between acceleration values, in seconds
column 21 - 50	name of file for input (object) motion
column 51 - 62	format for reading acceleration values

- second line after option number (Format: 3F10.0, 2I5)

column 1 - 10	multiplication factor for adjusting acceleration values; use only if columns 11 - 20 are left blank
column 11 - 20	maximum acceleration to be used, in g's; the acceleration values read-in will be scaled to provide the maximum acceleration specified in these columns; leave columns 11 - 20 blank if a multiplication factor is specified in columns 1 - 10.
column 21 - 30	maximum frequency (ie, frequency cut-off) to be used in the analysis
column 31 - 35	number of header lines in file containing object motion
column 36 - 40	number of acceleration values per line in file containing object motion

Option 4 -- Assignment of Object Motion to a Specific Sublayer

- first line after option number (Format: 2I5)

column 1 - 5	number of sublayer at the top of which the object motion is assigned
column 11 - 10	use 0 (zero) if the object motion is to be assigned as outcrop motion, otherwise use 1 (one) if the object motion is applied within the soil profile at the top of the assigned sublayer

Option 5 -- Number of Iterations & Ratio of Equivalent Uniform Strain to Maximum Strain

- first line after option number (Format: 2I5, F10.0)

column 1 - 5	parameter used to specify whether the strain-compatible soil properties are saved after the final iteration; set = 1 if these properties are to be saved; otherwise leave columns 1 - 5 blank
column 1 - 10	number of iterations
column 11 - 20	ratio of equivalent uniform strain divided by maximum strain; typically this ratio ranges from 0.4 to 0.75 depending on the input motion and which magnitude earthquake it is intended to represent. The following equation may be used to estimate this ratio: [ratio = (M - 1)/10] in which M is the magnitude of the earthquake. Thus, for M = 5, the ratio would be 0.4, for M = 7.5, the ratio would be 0.65 ... etc.

Option 6 -- Computation of Acceleration at Top of Specified Sublayers

can specify a maximum of fifteen sublayers; if accelerations for more than 15 sublayers are desired, then repeat Option 6 as many times as needed

- first line after option number (Format: 15I5)

column 1 - 75	array indicating the numbers of the sublayers at the top of which the acceleration is to be calculated

- second line after option number (Format: 15I5)

column 1 - 75	array specifying types of above sublayer: 0 (zero) for outcropping or 1 (one) for within the soil profile

- third line after option number (Format: 15I5)

column 1 - 75	array to specify the mode of output for the computed accelerations: 0 (zero) if only maximum acceleration is desired or 1 (one) if both the maximum acceleration and the time history of acceleration are to be calculated and saved

Option 7 -- Computation of Shear Stress or Strain Time History at Top of Specified Sublayers

can specify a maximum of two sublayers; if stress or strain time histories for more than two sublayers are desired, then repeat Option 7 as many times as needed

- first line after option number (Format: 5I5, F10.0, 5A6)

column 1 - 5	number of sublayer
column 11 - 10	set equal to 0 (zero) for strain or 1 (one) for stress
column 11 - 15	set equal to one to save time history of strain or stress
column 16 - 20	leave blank
column 21 - 25	number of values to be saved; typically this should be equal to the number NV (see Option 3 above)
column 26 - 35	leave blank
column 36 - 65	identification information

- second line after option number (Format: 5I5, F10.0, 5A6)

same as the above line for the second sublayer

Note that the time histories of shear stresses or strains are calculated at the top of the specified sublayer. Thus, if the time history is needed at a specific depth within the soil profile, that depth should be made the top of a sublayer. The time history of stresses or strains is saved in second Output file.

This options should be specified after Option 6 as shown in Table 1 and in Table B-1.

Option 8 -- Save Time History of Object Motion

Although this option was retained, its purpose is most easily accomplished in Option 6.

Option 9 -- Response Spectrum

- first line after option number (Format: 2I5)

column 1 - 5	sublayer number
column 6 - 10	set equal to 0 (zero) for outcropping or equal to 1 (one) for within

- second line after option number (Format: 2I5, F10.0)

column 1 - 5	number of damping ratios to be used
column 6 - 10	set equal to 0 (zero)
column 11 -20	acceleration of gravity

- third line after option number (Format: 6F10.0)

column 1 - 60	array for damping ratios (in decimal)

Option 10 -- Amplification Spectrum

- first line after option number (Format: 4I5, F10.0, 8A6)

column 1 - 5	number of first sublayer
column 6 - 10	set equal to 0 (zero) for outcropping or equal to 1 (one) for within
column 11 -15	number of second sublayer
column 16 - 20	set equal to 0 (zero) for outcropping or equal to 1 (one) for within
column 21 - 30	frequency step (in cycles per second); the amplification spectrum is calculated for 200 frequencies using this frequency step and starting with 0
column 31 - 78	identification information

[The amplification spectrum is the ratio of the amplitude of motion at the top of the second sublayer divided by that at the top of the first sublayer].

If the amplification spectrum is desired for two other sublayers, Option 10 can be repeated as many times as needed.

Option 11 -- Fourier Spectrum

- first line after option number (Format: 5I5)

column 1 - 5	number of the sublayer
column 6 - 10	set equal to 0 (zero) for outcropping or equal to 1 (one) for within
column 11 -15	set equal to 2 (two) if spectrum is to be saved to file
column 16 - 20	number of times the spectrum is to be smoothed
column 21 - 25	number of values to be saved

The following expression (Schnabel et al, 1972) is used to smooth the Fourier spectrum:

$$A_i = \frac{A_{i-1} + 2A_i + A_{i+1}}{4}$$

in which A_i is the amplitude of the spectrum for the i^{th} frequency.

A second line is always needed when using Option 11. Thus, either provide a second line for another sublayer or repeat the information provided in the first line in a second line.

It may be noted that calculation of Fourier amplitudes for a specific accelerogram is best accomplished in an auxiliary program.

Program Termination

For program termination, provide a line that contains information that execution will terminate when the number is encountered as an option number; the line following this information should have 0 (zero) with a format of I5. Execution will then terminate.

OUTPUT

The output of the program is contained in two files. The first file echoes much of the input information and contains the results of each iteration, the listing of calculated maximum shear stresses and strains, maximum acceleration, response spectrum, Fourier spectrum and amplification spectrum, as appropriate. The second file contains all the time histories requested. The name of each file is specified by the user at the time of program execution directly from the key-board.

COMPUTER LISTING

The FORTRAN listing of program *SHAKE91* is given in Appendix A.

SAMPLE PROBLEM

The results for a sample problem are given in Appendix B.

CONCLUDING REMARKS

The computer program SHAKE has been widely used throughout the United States and in many parts of the world for conducting ground response studies. Its use in recent studies involving recordings obtained at several sites from the 1989 Loma Prieta earthquake (eg, Idriss, 1990; Dickenson et al, 1991; Idriss, 1991; Rollins et al, 1992; Yokel, 1992) have indicated that the calculated surface motions are in reasonably good agreement with the recorded values when the appropriate soil properties and input rock motions are used. Therefore, this program remains a convenient tool for conducting such analyses at many sites and for a variety of applications.

ACKNOWLEDGMENTS

The modification of the original SHAKE program was completed as part of a research study regarding earthquake ground motions being completed at the University of California at Davis. The study is being supported by a research grant from the National

Institute of Standards and Technology (NIST); Dr. Felix Y. Yokel of NIST is the Contract monitor for this study. The writers gratefully acknowledge this support and thank Dr. Yokel for his timely input and support during this study.

Mr. Peter Dirrim, formerly with Caltrans in Sacramento, provided valuable input during the early stages of the modifications and the writers are grateful for this assistance.

REFERENCES

Cooley, J. W. and Tukey, J. W. (1965) "An Algorithm for the Machine Calculations of Complex Fourier Series," Mathematics of Computation, Vol. 19, No. 90.

Dickenson, S. E. and Seed, R. B. (1991) "Correlations of Shear Wave Velocity and Engineering Properties for Soft Soil Deposits in the San Francisco Bay Region", Report No. UCB/EERC-91/, Earthquake Engineering Research Center, University of California, Berkeley, 110p..

Dickenson, S. E., Seed, R. B., Lysmer, J and Mok, C. M. (1991) "Response of Soft Soils during the 1989 Loma Prieta Earthquake and Implications for Seismic Design Criteria", Proceedings, Pacific Conference on Earthquake Engineering, Auckland, New Zealand, November.

Hardin, B. O. and Drnevich, V. P. (1970) "Shear Modulus and Damping in Soils: I. Measurement and Parameter Effects, II. Design Equations and Curves," Technical Reports UKY 27-70-CE 2 and 3, College of Engineering, University of Kentucky, Lexington, Kentucky, July. [These reports were later published by the authors in the Journal of Soil Mechanics and Foundation Division, ASCE, Vol. 98, No. 6, pp 603-624 and No. 7, pp 667-691, in June and July, 1972].

Idriss, I. M. (1990) "Response of Soft Soil Sites during Earthquakes", Proceedings, Memorial Symposium to honor Professor Harry Bolton Seed, Berkeley, California, Vol. II, May.

Idriss, I. M. (1991) "Earthquake Ground Motions at Soft Soil Sites", proceedings, Second International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics, St. Louis, Missouri, Vol. III, March.

Idriss, I. M. and Seed, H. Bolton (1968) "Seismic Response of Horizontal Soil Layers," Journal of the Soil Mechanics and Foundations Division, ASCE, Vol. 94, No. SM4, July.

Kanai, K. (1951) "Relation Between the Nature of Surface Layer and the Amplitude of Earthquake Motions," Bulletin, Tokyo Earthquake Research Institute.

Lysmer, J., Seed, H. Bolton and Schnabel, P. B. (1971) "Influence of Base -Rock Characteristics on Ground Response," Bulletin of the Seismological Society of America, Vol. 61, No. 5, October, pp 1213-1232.

Matthiesen, R. B., Duke, C. M., Leeds, D. J. and Fraser, J. C. (1964) "Site Characteristics of Southern California Strong-Motion Earthquake Stations, Part Two," Report No. 64-15, Department of Engineering, University of California, Los Angeles, August.

Roesset, J. M. and Whitman, R. V. (1969) "Theoretical Background for Amplification Studies," Research Report No. R69-15, Soils Publications No. 231, Massachusetts Institute of Technology, Cambridge.

Rollins, K. M., Hryciw, R. D., McHood, M., Homolka, M. and Shewbridge, S. E. (1992) "Soil Amplification at Treasure Island during the Loma Prieta Earthquake," Paper prepared for Inclusion in the NEHRP Report to Congress on the Loma Prieta Earthquake.

Schnabel, P. B., Lysmer, J. and Seed, H. Bolton (1972) "SHAKE: A Computer Program for Earthquake Response Analysis of Horizontally Layered Sites", Report No. UCB/EERC-72/12, Earthquake Engineering Research Center, University of California, Berkeley, December, 102p.

Seed, H. Bolton and Idriss, I. M. (1970) "Soil Moduli and Damping Factors for Dynamic Response Analysis", Report No. UCB/EERC-70/10, Earthquake Engineering Research Center, University of California, Berkeley, December, 48p.

H. B. Seed, Wong, R. T., Idriss, I. M. and Tokimatsu, K. (1986) "Moduli and Damping factors for Dynamic Analyses of Cohesionless Soils," Journal of the Geotechnical Engineering Division, ASCE, Vol. 112, No. GT11, November, pp 1016-1032.

Sun, J. I., Golesorkhi, R. and Seed, H. Bolton (1988) "Dynamic Moduli and Damping Ratios for Cohesive Soils," Report No. UCB/EERC-88/15, Earthquake Engineering Research Center, University of California, Berkeley, 42p.

Yokel, F. Y. (1992) " Effects of Subsurface Conditions on earthquake Ground Motions", Report No. NISTIR 4769, Building and Fire Research Laboratory, National Institute of Standards and Technology, Gaithersburg, Maryland, 85p .

Vucetic, M. and Dobry, R. (1991) "Effect of Soil Plasticity on Cyclic Response," Journal of the Geotechnical Engineering Division, ASCE, Vol. 111, No. 1, January, pp 89-107.

Table 1
Sample Input

```
option 1 - dynamic soil properties - (max is thirteen):
   1
   3
  11     #1 modulus reduction for clay (Sun et al, 1988) upper range
0.0001   0.0003   0.001    0.003    0.01     0.03     0.1      0.3
1.       3.       10.
1.000    1.000    1.000    0.981    0.941    0.847    0.656    0.438
0.238    0.144    0.110
  11     damping for clay (Idriss 1990) -
0.0001   0.0003   0.001    0.003    0.01     0.03     0.1      0.3
1.       3.16     10.
0.24     0.42     0.8      1.4      2.8      5.1      9.8      15.5
21.      25.      28.
  11     #2 modulus reduction for sand (seed & idriss 1970) - upper Range
0.0001   0.0003   0.001    0.003    0.01     0.03     0.1      0.3
1.       3.       10.
1.000    1.000    0.990    0.960    0.850    0.640    0.370    0.180
0.080    0.050    0.035
  11     damping for sand (Idriss 1990) - (LRng from seed & idriss) 1970)
0.0001   0.0003   0.001    0.003    0.01     0.03     0.1      0.3
1.       3.       10.
0.24     0.42     0.8      1.4      2.8      5.1      9.8      15.5
21.      25.      28.
   8     #3 modulus for rock half space (Schnabel et al, 1972)
 .0001    0.0003   0.001    0.003    0.01     0.03     0.1      1.0
 1.000    1.000    0.9875   0.9525   0.900    0.810    0.725    0.550
   5     Damping in Rock (Schnabel et al, 1972)
 .0001    0.001    0.01     0.1      1.
  0.4     0.8      1.5      3.0      4.6
   2   1   3
option 2 -- soil profile:
   2
   1   9          EXAMPLE SITE
   1   1           7.00  1500.    0.05    0.120
   2   1          13.00  1000.    0.05    0.100
   3   1          10.00  1800.    0.05    0.100
   4   1          12.00  2000.    0.05    0.100
   5   1          20.00  2500.    0.05    0.125
   6   1          18.00  3000.    0.05    0.125
   7   1          20.00  4000.    0.05    0.125
   8   1          20.00  5000.    0.05    0.125
   9   3                          0.01    0.150    3000.
option 3 -- input motion:
   3
  800 2048   .02    PAS.acc                       (8f9.6)
             .1     25.        1   8
option 4 -- sublayer where input motion is applied (within or outcropping):
   4
   9   0
option 5 -- number of iterations & ratio of avg. strain to max strain:
   5
   1   7    0.65
option 6 -- sublayers for which accn. time histories are to computed & saved:
   6
   1   2   3   4   5   6   7   8   9   9
   1   1   1   1   1   1   1   1   1   0
   1   0   0   0   0   0   0   0   1   0

option 7 -- sublayer for which shear stresses or strains are computed & saved:
   7
   4   1   1     809          -- stress in level 4
```

Table 1
Sample Input

```
    4    0    1       809            -- strain in level 4
option 9 -- compute & save response spectrum:
    9
    1    0
    1    0      981.0
   0.05
option 10 -- compute & save amplification spectrum:
   10
    9    0    1    0    0.125
option 11 -- compute & save Fourier spectrum:
   11
    1    0    1    1 1000
    1    0    1    3 1000
execution will stop when program encounters 0
    0
```

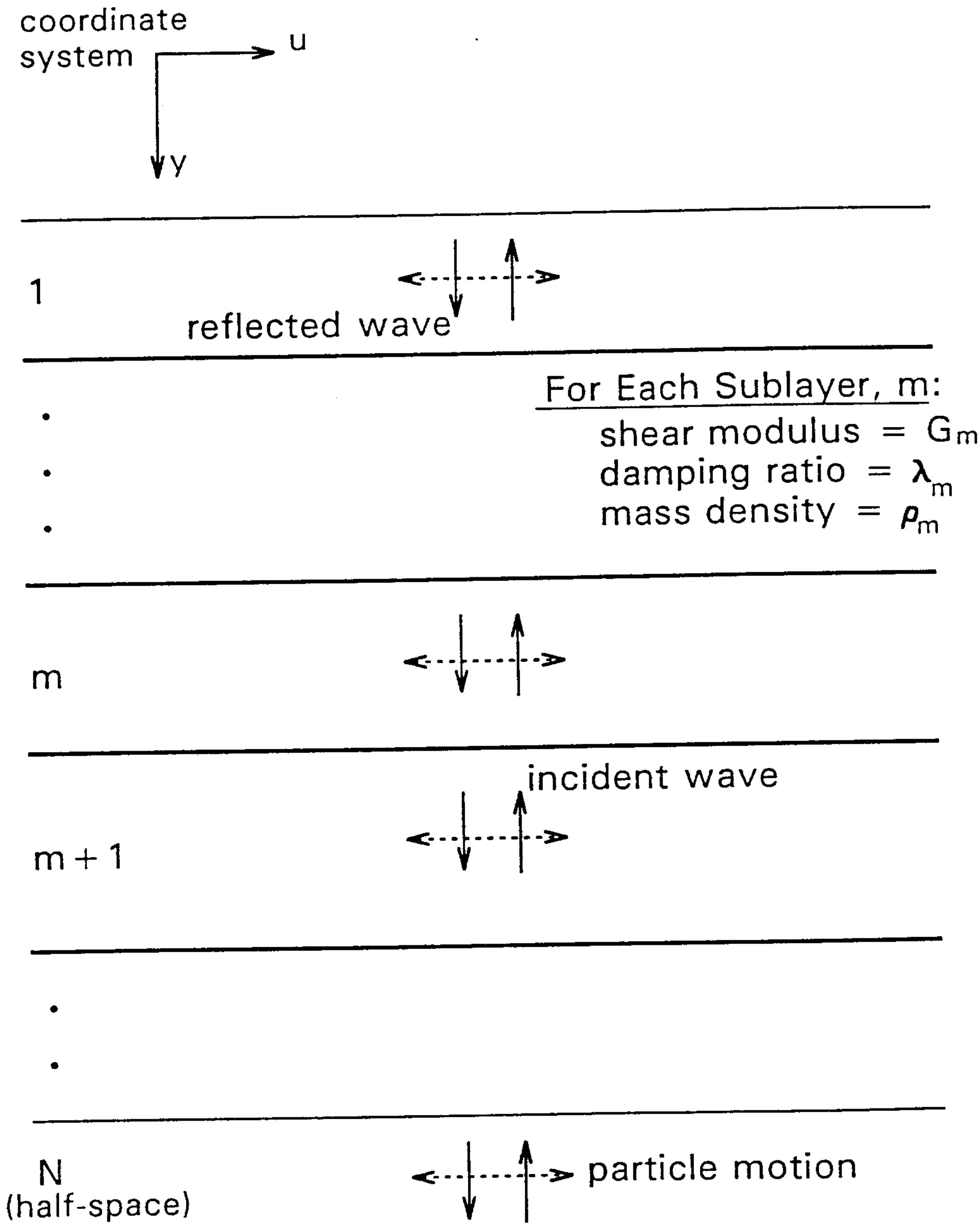


Fig. 1 One-Dimensional Idealization of a Horizontally-Layered Soil Deposit Over a Uniform Half-Space

APPENDIX B

SAMPLE PROBLEM

A 150-ft soil profile consisting of clay and sand overlying a half-space was used for this sample problem; the input is summarized in Table B-1. The response was calculated using as object (or input) motion the earthquake time history which had been recorded at Diamond Heights (EW component) during the 1989 Loma Prieta earthquake as an outcrop to the half-space underlying the soil profile. This motion was normalized to a peak acceleration of 0.1g.

The maximum shear wave velocities used for this sample problem are shown in Fig. B-1. The modulus reduction and the damping values as functions of strain are presented in Fig. B-2. The time history of the object motion, normalized to a peak acceleration of 0.1 g, and its response spectrum are shown in Fig. B-3.

The results for this sample problem are presented in Table B-2 and in Figs. B-3 through B-8. Table B-2 includes the properties used, the strain-compatible damping and modulus values obtained for each sublayer, the maximum strains, maximum shear stresses and maximum accelerations calculated throughout the soil profile. Also presented in Table B-2 are the spectral ordinates for the motions calculated at the ground surface of the soil profile and the amplification spectrum (ground surface/rock outcrop).

The calculated maximum shear strains and the strain-compatible damping and shear wave velocities obtained for this soil profile are shown in Fig. B-4. The calculated maximum accelerations and the maximum shear stresses are plotted in Fig. B-5. Figure B-6 shows the acceleration time history and spectral ordinates for the motion computed at the ground surface. The amplification spectrum (for frequencies up to 25 Hz) is presented in Fig. B-7. Time histories of shear strains and stresses calculated at depths of 20 and 60 ft are presented in Fig. B-8.

Table B-1
Input Data for Sample Problem

```
option 1 - dynamic soil properties - (max is thirteen):
    1
    3
   11      #1 modulus for clay (seed & sun 1989) upper range
0.0001     0.0003    0.001     0.003     0.01      0.03      0.1       0.3
1.         3.        10.
1.000      1.000     1.000     0.981     0.941     0.847     0.656     0.438
0.238      0.144     0.110
   11        damping for clay (Idriss 1990) -
0.0001     0.0003    0.001     0.003     0.01      0.03      0.1       0.3
1.         3.16      10.
0.24       0.42      0.8       1.4       2.8       5.1       9.8       15.5
21.        25.       28.
   11      #2 modulus for sand (seed & idriss 1970) - upper Range
0.0001     0.0003    0.001     0.003     0.01      0.03      0.1       0.3
1.         3.        10.
1.000      1.000     0.990     0.960     0.850     0.640     0.370     0.180
0.080      0.050     0.035
   11        damping for sand (Idriss 1990) - (about LRng from SI 1970)
0.0001     0.0003    0.001     0.003     0.01      0.03      0.1       0.3
1.         3.        10.
0.24       0.42      0.8       1.4       2.8       5.1       9.8       15.5
21.        25.       28.
    8       #3 ATTENUATION OF  ROCK  AVERAGE
 .0001      0.0003    0.001     0.003     0.01      0.03      0.1       1.0
 1.000      1.000     0.9875    0.9525    0.900     0.810     0.725     0.550
    5       DAMPING IN ROCK
 .0001      0.001     0.01      0.1       1.
  0.4       0.8       1.5       3.0       4.6
    3    1    2    3
Option 2 -- Soil Profile
    2
    1    17       Example -- 150-ft layer; input:Diam @ .1g
    1    2             5.00                 .050      .125      1000.
    2    2             5.00                 .050      .125       900.
    3    2            10.00                 .050      .125       900.
    4    2            10.00                 .050      .125       950.
    5    1            10.00                 .050      .125      1000.
    6    1            10.00                 .050      .125      1000.
    7    1            10.00                 .050      .125      1100.
    8    1            10.00                 .050      .125      1100.
    9    2            10.00                 .050      .130      1300.
   10    2            10.00                 .050      .130      1300.
   11    2            10.00                 .050      .130      1400.
   12    2            10.00                 .050      .130      1400.
   13    2            10.00                 .050      .130      1500.
   14    2            10.00                 .050      .130      1500.
   15    2            10.00                 .050      .130      1600.
   16    2            10.00                 .050      .130      1800.
   17    3                                  .010      .140      4000.
Option 3 -- input motion:
    3
 1900 4096    .02      diam.acc                       (8f10.6)
              .10      25.        3    8
Option 4 -- sublayer for input motion (within (1) or outcropping (0):
    4
   17    0
```

Table B-1
Input Data for Sample Problem

```
Option 5 -- number of iterations & ratio of avg strain to max strain
    5
    0    8    0.50
Option 6 -- sublayers for which accn time histories are computed & saved:
    6
    1    2    3    4    5    6    7    8    9   10   11   12   13   14   15
    0    1    1    1    1    1    1    1    1    1    1    1    1    1    1
    1    0    0    0    0    0    0    0    0    0    0    0    0    0    0
Option 6 -- sublayers for which accn time histories are computed & saved:
    6
   16   17   17
    1    1    0
    0    1    0
option 7 -- sublayer for which shear stress or strain are computed & saved:
    7
    4    1    1    0 1800           -- stress in level 4
    4    0    1    0 1800           -- strain in level 4
option 7 -- sublayer for which shear stress or strain are computed & saved:
    7
    8    1    1    0 1800           -- stress in level 8
    8    0    1    0 1800           -- strain in level 8
option 9 -- compute & save response spectrum:
    9
    1    0
    1    0     981.0
   0.05
option 10 -- compute & save amplification spectrum:
   10
   17    0    1    0       0.125      - surface/rock outcrop
execution will stop when program encounters 0
    0
```

Table B-2
Results for Sample Problem

```
*****************************************************
* SHAKE  --    A COMPUTER PROGRAM FOR EARTHQUAKE RESPONSE  *
*              ANALYSIS OF HORIZONTALLY LAYERED SITES      *
*              by: Per B. Schnabel & John Lysmer -- 1970   *
* ------------------------------------------------------- *
* shake85      IBM-PC version of SHAKE                     *
*              by: S.S. (Willie) Lai, January 1985         *
* ------------------------------------------------------- *
* shake88    : New modulus reduction curves for clays added*
*              using results from Sun et al (1988)         *
*              by: J. I. Sun & Ramin Golesorkhi            *
*              February 26, 1988                           *
* ------------------------------------------------------- *
* SHAKE90/91: Adjust last iteration; Input now is either   *
*              Gmax or max Vs; up to 13 material types can *
*              be specified by user; up to 50 Layers can   *
*              be specified; object motion can be read in  *
*              from a separate file and can have user      *
*              specified format; Different periods for     *
*              response spectral calculations; options     *
*              are renumbered; and general cleanup         *
*              by: J. I. Sun, I. M. Idriss & P. Dirrim     *
*              June 1990 - February 1991                   *
* ------------------------------------------------------- *
* SHAKE91    : General cleanup and finalization of input/  *
*              output format ... etc                       *
*              by: I. M. Idriss                            *
*              December 1991                               *
***********************************************************
MAX. NUMBER OF TERMS IN FOURIER TRANSFORM =       4096
NECESSARY LENGTH OF BLANK COMMON X        =      25619

1******   OPTION  1  ***  READ RELATION BETWEEN SOIL PROPERTIES AND STRAIN

**********************
MATERIAL TYPE NO. 1
**********************

CURVE NO.  1:      #1 modulus for clay (seed & sun 1989) upper range
```

Table B-2
Results for Sample Problem

CURVE NO. 2: damping for clay (Idriss 1990) -

CURVE NO. 1		CURVE NO. 2	
STRAIN	G/Gmax	STRAIN	DAMPING
.0001	1.000	.0001	.24
.0003	1.000	.0003	.42
.0010	1.000	.0010	.80
.0030	.981	.0030	1.40
.0100	.941	.0100	2.80
.0300	.847	.0300	5.10
.1000	.656	.1000	9.80
.3000	.438	.3000	15.50
1.0000	.238	1.0000	21.00
3.0000	.144	3.1600	25.00
10.0000	.110	10.0000	28.00

****
MATERIAL TYPE NO. 2
****

CURVE NO. 3: #2 modulus for sand (seed & idriss 1970) - upper Range
CURVE NO. 4: damping for sand (Idriss 1990) - (about LRng from SI

CURVE NO. 3		CURVE NO. 4	
STRAIN	G/Gmax	STRAIN	DAMPING
.0001	1.000	.0001	.24
.0003	1.000	.0003	.42
.0010	.990	.0010	.80
.0030	.960	.0030	1.40
.0100	.850	.0100	2.80
.0300	.640	.0300	5.10
.1000	.370	.1000	9.80
.3000	.180	.3000	15.50

```
  1.0000       .080         1.0000      21.00
  3.0000       .050         3.0000      25.00
 10.0000       .035        10.0000      28.00

**********************
 MATERIAL TYPE NO. 5
**********************

CURVE NO.  9:        #5 ATTENUATION OF  ROCK  AVERAGE
CURVE NO. 10:        DAMPING IN ROCK


    CURVE NO. 9              CURVE NO.10
 ===================      =================
  STRAIN    G/Gmax         STRAIN   DAMPING
 --------   -------       --------  --------
   .0001     1.000          .0001       .40
   .0003     1.000          .0010       .80
   .0010      .988          .0100      1.50
   .0030      .952          .1000      3.00
   .0100      .900         1.0000      4.60
   .0300      .810          .0000       .00
   .1000      .725          .0000       .00
  1.0000      .550          .0000       .00

1******   OPTION  2  ***  READ SOIL PROFILE
 NEW SOIL PROFILE NO.   1      IDENTIFICATION   Example -- 150-ft layer; input:Diam
 NUMBER OF LAYERS                   17         DEPTH TO BEDROCK        150.00

  NO. TYPE  THICKNESS   DEPTH  Tot. PRESS.  MODULUS  DAMPING   UNIT WT.  SHEAR VEL
               (ft)      (ft)     (ksf)       (ksf)              (kcf)     (fps)
   1    2      5.00      2.50       .31      3882.     .050      .125     1000.0
   2    2      5.00      7.50       .78      3144.     .050      .125      900.0
   3    2     10.00     15.00      1.25      3144.     .050      .125      900.0
   4    2     10.00     25.00      1.88      3503.     .050      .125      950.0
   5    1     10.00     35.00      2.50      3882.     .050      .125     1000.0
   6    1     10.00     45.00      3.13      3882.     .050      .125     1000.0
   7    1     10.00     55.00      3.75      4697.     .050      .125     1100.0
   8    1     10.00     65.00      4.38      4697.     .050      .125     1100.0
```

Table B-2
Results for Sample Problem

```
  9   2      10.00      75.00       5.03       6823.    .050     .130    1300.0
 10   2      10.00      85.00       5.71       6823.    .050     .130    1300.0
 11   2      10.00      95.00       6.38       7913.    .050     .130    1400.0
 12   2      10.00     105.00       7.06       7913.    .050     .130    1400.0
 13   2      10.00     115.00       7.74       9084.    .050     .130    1500.0
 14   2      10.00     125.00       8.41       9084.    .050     .130    1500.0
 15   2      10.00     135.00       9.09      10335.    .050     .130    1600.0
 16   2      10.00     145.00       9.76      13081.    .050     .130    1800.0
 17  BASE                                   69565.    .010     .140    4000.0

 PERIOD =  .48 FROM AVERAGE SHEAR VELOCITY =   1253.


 FREQUENCY    AMPLITUDE
MAXIMUM AMPLIFICATION =  13.80
FOR FREQUENCY         =   2.32 C/SEC.
    PERIOD            =    .43 SEC.

1******    OPTION  3  ***   READ INPUT MOTION

  FILE NAME FOR INPUT MOTION =  diam.acc
    NO. OF INPUT ACC. POINTS =  1900
   NO. OF POINTS USED IN FFT =  4096
        NO. OF HEADING LINES =     3
      NO. OF POINTS PER LINE =     8
  TIME STEP FOR INPUT MOTION =  .0200
  FORMAT FOR OF TIME HISTORY = (8f10.6)


 ***** H E A D E R
"Loma P. Eqk","Diamond Hts","H1_90","init. vel:"," .307 c/s","disp: -0.016 cm"
"Total No. of Points :",2000,"@ DT =",.02
"Peak Acceleration (g) =",.1128945,"@ Time (sec) :",10.92
 **   FIRST & LAST 5 LINES OF INPUT MOTION *****
      1  -.001694 -.001668 -.000086 -.001356 -.000678  .000700 -.001209 -.000604
      2   .000730  .000737  .002496  .004583  .001644  .001377  .002408 -.000352
      3  -.001073 -.000359 -.000486  .000344  .000767 -.002507 -.003164 -.002890
      4  -.004086  .000143  .004340  .003943  .002350 -.001087 -.002345  .001716
      5  -.001943 -.007436 -.004493  .000827  .002915  .003241  .003055  .002658
```

```
 ........ INPUT MOTION READ NOT ECHOED...........
  234  -.000885 -.000806 -.001026 -.000795 -.001049 -.000340 -.000016 -.000647
  235  -.000515  .000588 -.000315 -.000794 -.001081 -.000293  .001415  .001959
  236   .000800 -.000751  .000743  .000708  .000867 -.000101 -.000805 -.001058
  237  -.001011 -.001037 -.001032 -.000992  .001206  .001623  .001755  .000918
  238  -.000949 -.000830 -.001072 -.000940  .000000  .000000  .000000  .000000
MAXIMUM ACCELERATION =    .11289
AT TIME               = 10.92 SEC
THE VALUES WILL BE MULTIPLIED BY A FACTOR =   .886
TO GIVE NEW MAXIMUM ACCELERATION          =   .10000
MEAN SQUARE FREQUENCY =        2.52 C/SEC.
 MAX ACCELERATION =      .09997 FOR FREQUENCIES REMOVED ABOVE      25.00 C/SEC.
1******    OPTION  4  ***  READ WHERE OBJECT MOTION IS GIVEN
  OBJECT MOTION IN LAYER NUMBER  17 OUTCROPPING

1******    OPTION  5  ***  OBTAIN STRAIN COMPATIBLE SOIL PROPERTIES
  MAXIMUM NUMBER OF ITERATIONS                =      8
  FACTOR FOR UNIFORM STRAIN IN TIME DOMAIN    =    .50

     EARTHQUAKE    -  diam.acc
     SOIL PROFILE  -  Example -- 150-ft layer; input:Diam

  ITERATION NUMBER  8

  VALUES IN TIME DOMAIN
```

NO	TYPE	DEPTH (FT)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS -----> NEW	USED	ERROR	G/Go RATIO
1	2	2.5	.00077	.007	.007	.0	3851.5	3851.5	.0	.992
2	2	7.5	.00295	.014	.014	.0	3020.0	3020.0	.0	.960
3	2	15.0	.00634	.023	.023	.0	2803.8	2803.8	.0	.892
4	2	25.0	.00976	.028	.028	.0	2985.8	2985.8	.0	.852
5	1	35.0	.01099	.030	.030	.0	3621.7	3621.7	.0	.933
6	1	45.0	.01403	.035	.035	.0	3540.5	3540.5	.0	.912
7	1	55.0	.01362	.034	.034	.0	4296.0	4296.0	.0	.915
8	1	65.0	.01566	.037	.037	.0	4239.8	4239.8	.0	.903
9	2	75.0	.01356	.034	.034	.0	5402.8	5402.8	.0	.792
10	2	85.0	.01505	.037	.037	.0	5266.1	5266.2	.0	.772

11	2	95.0	.01336	.034	.034	.0	6288.3	6288.4	.0	.795
12	2	105.0	.01413	.035	.035	.0	6203.6	6203.6	.0	.784
13	2	115.0	.01233	.032	.032	.0	7357.0	7357.0	.0	.810
14	2	125.0	.01282	.033	.033	.0	7290.6	7290.6	.0	.803
15	2	135.0	.01115	.030	.030	.0	8570.2	8570.1	.0	.829
16	2	145.0	.00865	.026	.026	.0	11292.4	11292.4	.0	.863

VALUES IN TIME DOMAIN

LAYER	TYPE	THICKNESS FT	DEPTH FT	MAX STRAIN PRCNT	MAX STRESS PSF	TIME SEC
1	2	5.0	2.5	.00154	59.43	11.30
2	2	5.0	7.5	.00591	178.41	11.30
3	2	10.0	15.0	.01267	355.31	11.30
4	2	10.0	25.0	.01952	582.73	11.30
5	1	10.0	35.0	.02197	795.85	11.30
6	1	10.0	45.0	.02806	993.46	11.30
7	1	10.0	55.0	.02723	1169.83	11.30
8	1	10.0	65.0	.03132	1327.93	11.30
9	2	10.0	75.0	.02711	1464.73	11.30
10	2	10.0	85.0	.03011	1585.43	11.30
11	2	10.0	95.0	.02671	1679.79	11.30
12	2	10.0	105.0	.02825	1752.67	11.30
13	2	10.0	115.0	.02467	1814.84	11.52
14	2	10.0	125.0	.02563	1868.58	11.52
15	2	10.0	135.0	.02230	1911.02	11.52
16	2	10.0	145.0	.01729	1952.92	11.54

```
PERIOD =  .52 FROM AVERAGE SHEAR VELOCITY =   1153.

 FREQUENCY    AMPLITUDE
MAXIMUM AMPLIFICATION =  20.47
FOR FREQUENCY         =   2.11 C/SEC.
    PERIOD            =    .47 SEC.

1******   OPTION  6  ***  COMPUTE MOTION IN NEW SUBLAYERS

  EARTHQUAKE - diam.acc
  SOIL DEPOSIT -  Example -- 150-ft layer; input:Diam
    LAYER          DEPTH       MAX. ACC.        TIME      MEAN SQ. FR.       ACC. RATIO      TH SAVED
```

```
                 FT          G           SEC        C/SEC          QUIET ZONE    ACC. RECORD
 OUTCR.           .0      .19037        11.28        2.42            .000            512
 WITHIN          5.0      .19006        11.28        2.40            .000              0
 WITHIN         10.0      .18876        11.28        2.35            .000              0
 WITHIN         20.0      .18258        11.28        2.23            .000              0
 WITHIN         30.0      .17208        11.28        2.19            .000              0
 WITHIN         40.0      .15947        11.28        2.19            .000              0
 WITHIN         50.0      .14288        11.28        2.17            .000              0
 WITHIN         60.0      .12652        11.28        2.13            .000              0
 WITHIN         70.0      .11050        11.52        2.12            .000              0
 WITHIN         80.0      .09840        11.54        2.14            .000              0
 WITHIN         90.0      .08999        11.56        2.19            .001              0
 WITHIN        100.0      .08268        11.56        2.24            .001              0
 WITHIN        110.0      .08559        10.94        2.32            .000              0
 WITHIN        120.0      .08547        10.94        2.39            .001              0
 WITHIN        130.0      .08198        10.94        2.45            .001              0

1******    OPTION  6  ***  COMPUTE MOTION IN NEW SUBLAYERS

  EARTHQUAKE - diam.acc
 SOIL DEPOSIT -  Example -- 150-ft layer; input:Diam
   LAYER          DEPTH     MAX. ACC.      TIME     MEAN SQ. FR.     ACC. RATIO     TH SAVED
                   FT          G            SEC        C/SEC         QUIET ZONE     ACC. RECORD
  WITHIN         140.0      .07769        10.92        2.48            .001              0
  WITHIN         150.0      .07617        10.92        2.48            .001            512
  OUTCR.         150.0      .10000        10.92        2.52            .000              0

1******    OPTION  7  ***  COMPUTE STRESS/STRAIN HISTORY

  COMPUTE STRESS OR STRAIN HISTORY AT THE TOP OF  LAYER    4
  SCALE FOR PLOTTING      .0000
 IDENTIFICATION -  -- stress in level 4

  COMPUTE STRESS OR STRAIN HISTORY AT THE TOP OF  LAYER    4
  SCALE FOR PLOTTING      .0000
 IDENTIFICATION -  -- strain in level 4

1******    OPTION  7  ***  COMPUTE STRESS/STRAIN HISTORY

  COMPUTE STRESS OR STRAIN HISTORY AT THE TOP OF  LAYER    8
  SCALE FOR PLOTTING      .0000
 IDENTIFICATION -  -- stress in level 8
```

```
 COMPUTE STRESS OR STRAIN HISTORY AT THE TOP OF  LAYER    8
 SCALE FOR PLOTTING      .0000
IDENTIFICATION -  -- strain in level 8

1******   OPTION  9  ***  COMPUTE RESPONSE SPECTRUM
 RESPONSE SPECTRUM ANALYSIS FOR LAYER NUMBER        1
CALCULATED FOR DAMPING          .050

    TIMES AT WHICH MAX. SPECTRAL VALUES OCCUR
         TD = TIME FOR MAX. RELATIVE DISP.
         TV = TIME FOR MAX. RELATIVE VEL.
         TA = TIME FOR MAX. ABSOLUTE ACC.
    DAMPING RATIO =  .05
    PER =  .01     TIMES FOR MAXIMA --    TD = 11.2600    TV = 11.4200    TA = 11.2600
    PER =  .03     TIMES FOR MAXIMA --    TD = 11.4800    TV = 11.1600    TA = 11.4800
    PER =  .04     TIMES FOR MAXIMA --    TD = 11.2600    TV = 11.1600    TA = 11.2600
    PER =  .05     TIMES FOR MAXIMA --    TD = 11.2800    TV = 11.1600    TA = 11.2600
    PER =  .06     TIMES FOR MAXIMA --    TD = 11.2600    TV = 11.4000    TA = 11.2600
    PER =  .07     TIMES FOR MAXIMA --    TD = 11.5000    TV = 11.1600    TA = 11.5000
    PER =  .08     TIMES FOR MAXIMA --    TD = 11.2600    TV = 12.7000    TA = 11.2600
    PER =  .09     TIMES FOR MAXIMA --    TD = 11.2800    TV = 12.7000    TA = 11.2800
    PER =  .10     TIMES FOR MAXIMA --    TD = 11.3000    TV = 12.7200    TA = 11.3000
    PER =  .11     TIMES FOR MAXIMA --    TD = 11.2200    TV = 11.1800    TA = 11.2200
    PER =  .12     TIMES FOR MAXIMA --    TD = 11.2400    TV = 11.2000    TA = 11.2400
    PER =  .13     TIMES FOR MAXIMA --    TD = 11.2400    TV = 13.9400    TA = 11.2400
    PER =  .14     TIMES FOR MAXIMA --    TD = 11.2600    TV = 13.7600    TA = 11.2600
    PER =  .15     TIMES FOR MAXIMA --    TD = 11.2600    TV = 13.7800    TA = 11.2600
    PER =  .16     TIMES FOR MAXIMA --    TD = 11.2600    TV = 13.7800    TA = 11.2600
    PER =  .17     TIMES FOR MAXIMA --    TD = 11.2800    TV = 11.8200    TA = 11.2800
    PER =  .18     TIMES FOR MAXIMA --    TD = 11.2800    TV = 12.8400    TA = 11.2800
    PER =  .19     TIMES FOR MAXIMA --    TD = 11.0600    TV = 12.8600    TA = 11.0600
    PER =  .20     TIMES FOR MAXIMA --    TD = 11.5000    TV = 12.2600    TA = 11.4800
    PER =  .21     TIMES FOR MAXIMA --    TD = 11.2600    TV = 10.3600    TA = 11.2600
    PER =  .22     TIMES FOR MAXIMA --    TD = 11.2800    TV = 10.3800    TA = 11.2800
    PER =  .23     TIMES FOR MAXIMA --    TD = 11.5000    TV = 13.0200    TA = 11.5000
    PER =  .24     TIMES FOR MAXIMA --    TD = 11.0800    TV = 13.1600    TA = 11.0800
    PER =  .25     TIMES FOR MAXIMA --    TD = 11.2600    TV = 11.1800    TA = 11.2600
    PER =  .26     TIMES FOR MAXIMA --    TD = 11.2800    TV = 11.2000    TA = 11.2600
```

Table B-2
Results for Sample Problem

```
PER =  .27    TIMES FOR MAXIMA --   TD = 11.2800   TV = 11.3600   TA = 11.2800
PER =  .28    TIMES FOR MAXIMA --   TD = 11.3000   TV = 11.3800   TA = 11.3000
PER =  .29    TIMES FOR MAXIMA --   TD = 11.5000   TV = 11.4000   TA = 11.4800
PER =  .30    TIMES FOR MAXIMA --   TD = 11.5000   TV = 11.4200   TA = 11.5000
PER =  .31    TIMES FOR MAXIMA --   TD = 11.5000   TV = 11.6000   TA = 11.5000
PER =  .32    TIMES FOR MAXIMA --   TD = 11.5000   TV = 11.4000   TA = 11.5000
PER =  .33    TIMES FOR MAXIMA --   TD = 11.5000   TV = 11.4000   TA = 11.5000
PER =  .34    TIMES FOR MAXIMA --   TD = 11.5200   TV = 11.6000   TA = 11.5000
PER =  .35    TIMES FOR MAXIMA --   TD = 11.5200   TV = 11.6200   TA = 11.5200
PER =  .36    TIMES FOR MAXIMA --   TD = 11.5200   TV = 11.6200   TA = 11.5200
PER =  .37    TIMES FOR MAXIMA --   TD = 11.5400   TV = 11.6400   TA = 11.5400
PER =  .38    TIMES FOR MAXIMA --   TD = 11.5600   TV = 11.6600   TA = 11.5400
PER =  .39    TIMES FOR MAXIMA --   TD = 11.5600   TV = 11.8800   TA = 11.5600
PER =  .40    TIMES FOR MAXIMA --   TD = 12.4200   TV = 12.3000   TA = 12.4000
PER =  .41    TIMES FOR MAXIMA --   TD = 12.4400   TV = 12.3200   TA = 12.4200
PER =  .42    TIMES FOR MAXIMA --   TD = 12.4400   TV = 12.3400   TA = 12.4400
PER =  .43    TIMES FOR MAXIMA --   TD = 12.4600   TV = 12.3600   TA = 12.4600
PER =  .44    TIMES FOR MAXIMA --   TD = 12.4800   TV = 12.3800   TA = 12.4800
PER =  .45    TIMES FOR MAXIMA --   TD = 12.2800   TV = 12.3800   TA = 12.2600
PER =  .46    TIMES FOR MAXIMA --   TD = 12.2800   TV = 12.1800   TA = 12.2800
PER =  .47    TIMES FOR MAXIMA --   TD = 12.0800   TV = 12.2000   TA = 12.0800
PER =  .48    TIMES FOR MAXIMA --   TD = 11.8600   TV = 11.9800   TA = 11.8600
PER =  .49    TIMES FOR MAXIMA --   TD = 11.8800   TV = 11.9800   TA = 11.8600
PER =  .50    TIMES FOR MAXIMA --   TD = 11.8800   TV = 12.0000   TA = 11.8800
PER =  .51    TIMES FOR MAXIMA --   TD = 11.8800   TV = 12.0000   TA = 11.8800
PER =  .52    TIMES FOR MAXIMA --   TD = 11.8800   TV = 12.0000   TA = 11.8800
PER =  .53    TIMES FOR MAXIMA --   TD = 11.9000   TV = 12.0200   TA = 11.8800
PER =  .54    TIMES FOR MAXIMA --   TD = 11.9000   TV = 11.7800   TA = 11.9000
PER =  .55    TIMES FOR MAXIMA --   TD = 11.9200   TV = 11.7800   TA = 11.9000
PER =  .56    TIMES FOR MAXIMA --   TD = 11.9200   TV = 11.8000   TA = 11.9200
PER =  .57    TIMES FOR MAXIMA --   TD = 11.9400   TV = 11.8000   TA = 11.9200
PER =  .58    TIMES FOR MAXIMA --   TD = 11.6800   TV = 11.8200   TA = 11.6800
PER =  .60    TIMES FOR MAXIMA --   TD = 11.6800   TV = 11.8200   TA = 11.6800
PER =  .62    TIMES FOR MAXIMA --   TD = 11.7000   TV = 11.8200   TA = 11.6800
PER =  .64    TIMES FOR MAXIMA --   TD = 11.7000   TV = 11.8400   TA = 11.6800
PER =  .66    TIMES FOR MAXIMA --   TD = 11.7200   TV = 11.5800   TA = 11.7000
PER =  .68    TIMES FOR MAXIMA --   TD = 11.7400   TV = 11.5800   TA = 11.7200
PER =  .70    TIMES FOR MAXIMA --   TD = 11.4600   TV = 11.6000   TA = 11.4400
PER =  .72    TIMES FOR MAXIMA --   TD = 11.4800   TV = 11.6200   TA = 11.4600
```

Table B-2
Results for Sample Problem

```
PER =  .74    TIMES FOR MAXIMA --   TD = 11.4800   TV = 11.3400   TA = 11.4800
PER =  .76    TIMES FOR MAXIMA --   TD = 11.5000   TV = 11.3600   TA = 11.4800
PER =  .78    TIMES FOR MAXIMA --   TD = 11.5000   TV = 11.3600   TA = 11.4800
PER =  .80    TIMES FOR MAXIMA --   TD = 11.5000   TV = 11.3600   TA = 11.4800
PER =  .82    TIMES FOR MAXIMA --   TD = 11.5000   TV = 11.3600   TA = 11.4800
PER =  .84    TIMES FOR MAXIMA --   TD = 11.5000   TV = 11.3600   TA = 11.5000
PER =  .86    TIMES FOR MAXIMA --   TD = 11.5200   TV = 11.3600   TA = 11.5000
PER =  .88    TIMES FOR MAXIMA --   TD = 11.2200   TV = 11.3600   TA = 11.2000
PER =  .90    TIMES FOR MAXIMA --   TD = 11.2200   TV = 11.3800   TA = 11.2000
PER =  .92    TIMES FOR MAXIMA --   TD = 11.2200   TV = 11.3800   TA = 11.2000
PER =  .94    TIMES FOR MAXIMA --   TD = 11.2200   TV = 11.3800   TA = 11.2200
PER =  .96    TIMES FOR MAXIMA --   TD = 11.2400   TV = 11.3800   TA = 11.2200
PER =  .98    TIMES FOR MAXIMA --   TD = 11.2400   TV = 11.3800   TA = 11.2200
PER = 1.00    TIMES FOR MAXIMA --   TD = 11.2400   TV = 11.3800   TA = 11.2200
PER = 1.05    TIMES FOR MAXIMA --   TD = 11.2400   TV = 11.4000   TA = 11.2400
PER = 1.10    TIMES FOR MAXIMA --   TD = 11.2600   TV = 11.4000   TA = 11.2400
PER = 1.15    TIMES FOR MAXIMA --   TD = 11.2600   TV = 11.1200   TA = 11.2400
PER = 1.20    TIMES FOR MAXIMA --   TD = 11.2800   TV = 11.1200   TA = 11.2600
PER = 1.25    TIMES FOR MAXIMA --   TD = 11.3000   TV = 11.1400   TA = 11.2800
PER = 1.30    TIMES FOR MAXIMA --   TD = 11.3000   TV = 11.1400   TA = 11.2800
PER = 1.35    TIMES FOR MAXIMA --   TD = 11.3200   TV = 11.1400   TA = 11.3000
PER = 1.40    TIMES FOR MAXIMA --   TD = 12.3000   TV = 11.1400   TA = 12.2800
PER = 1.45    TIMES FOR MAXIMA --   TD = 12.3200   TV = 11.1600   TA = 12.3000
PER = 1.50    TIMES FOR MAXIMA --   TD = 12.3600   TV = 11.1600   TA = 12.3200
PER = 1.55    TIMES FOR MAXIMA --   TD = 11.7000   TV = 11.1600   TA = 11.6800
PER = 1.60    TIMES FOR MAXIMA --   TD = 11.7200   TV = 11.1600   TA = 11.7000
PER = 1.65    TIMES FOR MAXIMA --   TD = 11.7200   TV = 11.1600   TA = 11.7000
PER = 1.70    TIMES FOR MAXIMA --   TD = 11.7400   TV = 11.1600   TA = 11.7000
PER = 1.75    TIMES FOR MAXIMA --   TD = 11.7400   TV = 11.1600   TA = 11.7200
PER = 1.80    TIMES FOR MAXIMA --   TD = 11.7400   TV = 11.1600   TA = 11.7200
PER = 1.85    TIMES FOR MAXIMA --   TD = 11.7400   TV = 11.1600   TA = 11.7200
PER = 1.90    TIMES FOR MAXIMA --   TD = 11.7600   TV = 11.1600   TA = 11.7200
PER = 1.95    TIMES FOR MAXIMA --   TD = 11.7600   TV = 11.1600   TA = 11.7400
PER = 2.00    TIMES FOR MAXIMA --   TD = 11.7800   TV = 11.1600   TA = 11.7400
PER = 2.05    TIMES FOR MAXIMA --   TD = 11.7800   TV = 11.1600   TA = 11.7400
PER = 2.10    TIMES FOR MAXIMA --   TD = 11.7800   TV = 11.1600   TA = 11.7600
PER = 2.15    TIMES FOR MAXIMA --   TD = 11.8000   TV = 11.1600   TA = 11.7600
PER = 2.20    TIMES FOR MAXIMA --   TD = 11.8200   TV = 11.1600   TA = 11.7600
PER = 2.25    TIMES FOR MAXIMA --   TD = 12.0600   TV = 11.1600   TA = 12.0400
```

Table B-2
Results for Sample Problem

```
PER = 2.30   TIMES FOR MAXIMA --   TD = 12.0800   TV = 11.6000   TA = 12.0600
PER = 2.35   TIMES FOR MAXIMA --   TD = 12.1000   TV = 11.6200   TA = 12.0600
PER = 2.40   TIMES FOR MAXIMA --   TD = 12.1200   TV = 11.6200   TA = 12.0800
PER = 2.50   TIMES FOR MAXIMA --   TD = 12.1400   TV = 11.6200   TA = 12.1000
PER = 2.60   TIMES FOR MAXIMA --   TD = 11.0200   TV = 11.6200   TA = 10.9800
PER = 2.70   TIMES FOR MAXIMA --   TD = 11.0200   TV = 11.6400   TA = 11.0000
PER = 2.80   TIMES FOR MAXIMA --   TD = 11.0400   TV = 11.6400   TA = 11.0000
PER = 2.90   TIMES FOR MAXIMA --   TD = 16.9600   TV = 11.6400   TA = 16.9200
PER = 3.00   TIMES FOR MAXIMA --   TD = 17.0400   TV = 11.6400   TA = 17.0000
PER = 3.10   TIMES FOR MAXIMA --   TD = 17.1600   TV = 11.6400   TA = 17.1000
PER = 3.20   TIMES FOR MAXIMA --   TD = 14.4000   TV = 11.6400   TA = 11.0000
PER = 3.30   TIMES FOR MAXIMA --   TD = 14.5200   TV = 11.6400   TA = 14.4800
PER = 3.40   TIMES FOR MAXIMA --   TD = 14.5800   TV = 11.6400   TA = 14.5200
PER = 3.50   TIMES FOR MAXIMA --   TD = 14.6200   TV = 11.6400   TA = 14.5800
PER = 3.60   TIMES FOR MAXIMA --   TD = 14.6600   TV = 11.6400   TA = 14.6200
PER = 3.70   TIMES FOR MAXIMA --   TD = 11.4800   TV = 10.7600   TA = 11.4200
PER = 3.80   TIMES FOR MAXIMA --   TD = 11.4800   TV = 10.7600   TA = 11.4400
PER = 3.90   TIMES FOR MAXIMA --   TD = 11.4800   TV = 10.7600   TA = 11.4400
PER = 4.00   TIMES FOR MAXIMA --   TD = 11.4800   TV = 10.7600   TA = 11.4400
PER = 4.10   TIMES FOR MAXIMA --   TD = 11.5000   TV = 10.7600   TA = 11.4400
PER = 4.20   TIMES FOR MAXIMA --   TD = 11.5000   TV = 10.7600   TA = 11.4400
PER = 4.30   TIMES FOR MAXIMA --   TD = 11.5000   TV = 10.7600   TA = 11.4400
PER = 4.40   TIMES FOR MAXIMA --   TD = 11.5000   TV = 10.7600   TA = 11.4400
PER = 4.50   TIMES FOR MAXIMA --   TD = 13.7600   TV = 10.7600   TA = 11.4400
PER = 4.60   TIMES FOR MAXIMA --   TD = 13.7600   TV = 10.7600   TA = 11.4400
PER = 4.70   TIMES FOR MAXIMA --   TD = 13.7600   TV = 11.3800   TA = 11.4400
PER = 4.80   TIMES FOR MAXIMA --   TD = 13.7800   TV = 11.3800   TA = 11.4400
PER = 4.90   TIMES FOR MAXIMA --   TD = 13.7800   TV = 11.3800   TA = 13.7400
PER = 5.00   TIMES FOR MAXIMA --   TD = 19.2000   TV = 11.3800   TA = 19.1600
PER = 5.10   TIMES FOR MAXIMA --   TD = 19.2200   TV = 11.3800   TA = 19.1600
PER = 5.20   TIMES FOR MAXIMA --   TD = 19.2600   TV = 11.3800   TA = 19.1800
PER = 5.40   TIMES FOR MAXIMA --   TD = 19.4400   TV = 11.3800   TA = 19.3800
PER = 5.60   TIMES FOR MAXIMA --   TD = 19.6600   TV = 11.3800   TA = 19.6000
PER = 5.80   TIMES FOR MAXIMA --   TD = 19.7400   TV = 11.3800   TA = 19.6600
PER = 6.00   TIMES FOR MAXIMA --   TD = 23.3000   TV = 11.3800   TA = 23.1400
PER = 6.20   TIMES FOR MAXIMA --   TD = 23.5200   TV = 11.3800   TA = 23.4400
PER = 6.40   TIMES FOR MAXIMA --   TD = 23.7000   TV = 11.3800   TA = 23.6400
PER = 6.60   TIMES FOR MAXIMA --   TD = 24.0600   TV = 11.3800   TA = 23.9800
PER = 6.80   TIMES FOR MAXIMA --   TD = 24.3200   TV = 11.3800   TA = 24.1200
```

Table B-2
Results for Sample Problem

```
PER = 7.00      TIMES FOR MAXIMA --   TD = 31.6600   TV = 11.3800   TA = 31.5200
PER = 7.20      TIMES FOR MAXIMA --   TD = 31.9600   TV = 11.3800   TA = 31.9000
PER = 7.40      TIMES FOR MAXIMA --   TD = 36.1200   TV = 11.3800   TA = 36.0000
PER = 7.60      TIMES FOR MAXIMA --   TD = 36.3800   TV = 11.3800   TA = 36.2600
PER = 7.80      TIMES FOR MAXIMA --   TD = 36.6000   TV = 11.3800   TA = 36.4800
PER = 8.00      TIMES FOR MAXIMA --   TD = 36.7600   TV = 11.3800   TA = 36.6800
PER = 8.50      TIMES FOR MAXIMA --   TD = 29.6600   TV = 11.3800   TA = 29.5400
PER = 9.00      TIMES FOR MAXIMA --   TD = 29.9600   TV = 11.3800   TA = 29.6600
PER = 9.50      TIMES FOR MAXIMA --   TD = 21.9600   TV = 11.3800   TA = 11.4200
  SPECTRAL VALUES --
  [Acceleration of gravity used =  981.00]
Example -- 150-ft layer; inpu  DAMPING RATIO =  .05
```

NO.	PERIOD	REL. DISP.	REL. VEL.	PSU.REL.VEL.	ABS. ACC.	PSU.ABS.ACC.	FREQ.
1	.01	.00047	.00684	.29693	.19037	.19018	100.00
2	.03	.00425	.07850	.89043	.19031	.19010	33.33
3	.04	.00756	.14085	1.18806	.19039	.19023	25.00
4	.05	.01186	.23305	1.49033	.19087	.19091	20.00
5	.06	.01748	.30826	1.83048	.19560	.19540	16.67
6	.07	.02376	.52652	2.13235	.19481	.19511	14.29
7	.08	.03356	.94085	2.63549	.21245	.21100	12.50
8	.09	.04361	1.42912	3.04484	.21564	.21669	11.11
9	.10	.05845	2.12048	3.67262	.23270	.23523	10.00
10	.11	.08046	2.88215	4.59567	.26599	.26759	9.09
11	.12	.09893	2.81971	5.17978	.27345	.27647	8.33
12	.13	.10994	2.51611	5.31379	.26394	.26180	7.69
13	.14	.13246	2.82865	5.94489	.26939	.27197	7.14
14	.15	.15087	3.13740	6.31982	.27164	.26985	6.67
15	.16	.16229	3.69704	6.37320	.25763	.25512	6.25
16	.17	.19682	3.67960	7.27453	.27186	.27407	5.88
17	.18	.20656	4.13247	7.21035	.25854	.25656	5.56
18	.19	.24045	4.43719	7.95147	.27022	.26804	5.26
19	.20	.27096	5.34143	8.51233	.27243	.27260	5.00
20	.21	.30133	5.42470	9.01591	.27629	.27498	4.76
21	.22	.32854	7.42915	9.38296	.27393	.27317	4.55
22	.23	.39262	8.81153	10.72563	.29800	.29868	4.35
23	.24	.46524	8.82002	12.17987	.32335	.32504	4.17
24	.25	.58569	10.35311	14.72011	.37574	.37712	4.00
25	.26	.71646	11.92771	17.31394	.42720	.42651	3.85
26	.27	.80710	13.18311	18.78213	.44940	.44555	3.70

Table B-2
Results for Sample Problem

27	.28	.85566	14.83589	19.20102	.43859	.43922	3.57
28	.29	.95665	15.40618	20.72692	.45945	.45777	3.45
29	.30	1.03481	15.21398	21.67311	.46372	.46271	3.33
30	.31	1.07387	15.69132	21.76550	.45266	.44969	3.23
31	.32	1.21292	17.41235	23.81566	.47826	.47668	3.13
32	.33	1.47749	21.59001	28.13139	.54989	.54599	3.03
33	.34	1.73803	25.66905	32.11880	.60466	.60505	2.94
34	.35	1.98084	29.38892	35.55995	.65218	.65073	2.86
35	.36	2.24836	33.67574	39.24122	.70692	.69815	2.78
36	.37	2.60084	38.58868	44.16632	.76362	.76454	2.70
37	.38	2.85827	42.37081	47.26068	.80456	.79658	2.63
38	.39	3.05160	45.57609	49.16344	.81210	.80740	2.56
39	.40	3.24531	49.06948	50.97717	.82289	.81626	2.50
40	.41	3.50397	52.28638	53.69781	.84813	.83885	2.44
41	.42	3.62443	53.71510	54.22134	.83751	.82686	2.38
42	.43	3.70872	54.28742	54.19210	.81135	.80719	2.33
43	.44	3.79692	54.88032	54.21991	.78616	.78925	2.27
44	.45	3.91915	56.62024	54.72164	.77958	.77886	2.22
45	.46	4.00330	57.53357	54.68151	.77246	.76137	2.17
46	.47	4.06850	57.33379	54.38968	.74336	.74119	2.13
47	.48	4.02679	55.10962	52.71060	.70836	.70334	2.08
48	.49	3.87891	51.83490	49.73859	.65350	.65014	2.04
49	.50	3.74462	49.39650	47.05623	.60240	.60278	2.00
50	.51	3.72759	48.35779	45.92381	.57870	.57674	1.96
51	.52	3.88346	49.14880	46.92408	.58229	.57797	1.92
52	.53	4.14360	50.92344	49.12262	.60008	.59363	1.89
53	.54	4.42542	52.88392	51.49211	.61087	.61074	1.85
54	.55	4.53606	54.75008	51.81978	.61043	.60345	1.82
55	.56	4.55299	55.19758	51.08447	.58584	.58427	1.79
56	.57	4.40068	53.97779	48.50931	.55022	.54508	1.75
57	.58	4.27420	51.43185	46.30275	.51172	.51132	1.72
58	.60	4.04669	47.84361	42.37680	.45704	.45236	1.67
59	.62	4.20111	47.73764	42.57476	.44473	.43982	1.61
60	.64	4.72033	49.91222	46.34174	.46448	.46377	1.56
61	.66	5.15662	51.80372	49.09091	.48011	.47640	1.52
62	.68	5.25111	54.20516	48.52016	.46100	.45701	1.47
63	.70	5.05053	52.84882	45.33343	.41675	.41479	1.43
64	.72	4.89465	48.66660	42.71386	.38392	.37997	1.39
65	.74	4.55493	45.56124	38.67494	.33676	.33474	1.35

Table B-2
Results for Sample Problem

66	.76	4.13750	42.97388	34.20619	.29162	.28827	1.32
67	.78	3.82844	40.37681	30.83945	.25542	.25323	1.28
68	.80	3.67983	38.76699	28.90131	.23310	.23139	1.25
69	.82	3.66395	38.35685	28.07475	.22056	.21929	1.22
70	.84	3.69431	38.70220	27.63338	.21235	.21070	1.19
71	.86	3.71415	39.30625	27.13572	.20470	.20209	1.16
72	.88	3.84822	39.83454	27.47620	.20222	.19998	1.14
73	.90	4.09697	40.24345	28.60228	.20540	.20355	1.11
74	.92	4.30977	40.25241	29.43375	.20633	.20491	1.09
75	.94	4.45795	39.67930	29.79804	.20443	.20303	1.06
76	.96	4.55043	38.67976	29.78248	.20100	.19870	1.04
77	.98	4.62792	37.47019	29.67151	.19583	.19392	1.02
78	1.00	4.67738	36.18348	29.38882	.18984	.18823	1.00
79	1.05	4.73255	33.28045	28.31949	.17482	.17275	.95
80	1.10	4.90167	31.18437	27.99828	.16482	.16302	.91
81	1.15	5.20612	30.80259	28.44436	.16003	.15842	.87
82	1.20	5.41307	33.29761	28.34277	.15301	.15128	.83
83	1.25	5.36657	35.29150	26.97535	.13984	.13822	.80
84	1.30	5.16057	36.34209	24.94218	.12445	.12289	.77
85	1.35	4.80471	36.54964	22.36215	.10740	.10609	.74
86	1.40	4.35563	35.92714	19.54803	.09011	.08943	.71
87	1.45	4.67242	34.80191	20.24666	.09033	.08943	.69
88	1.50	4.73927	33.32431	19.85180	.08567	.08477	.67
89	1.55	4.76907	31.81178	19.33223	.08093	.07988	.65
90	1.60	4.87031	30.50349	19.12565	.07755	.07656	.63
91	1.65	4.93355	29.50518	18.78690	.07403	.07293	.61
92	1.70	5.01718	28.84906	18.54346	.07092	.06986	.59
93	1.75	5.15063	28.51006	18.49277	.06859	.06768	.57
94	1.80	5.32670	28.40165	18.59368	.06716	.06616	.56
95	1.85	5.52526	28.39789	18.76553	.06608	.06497	.54
96	1.90	5.73485	28.38183	18.96481	.06493	.06393	.53
97	1.95	5.91006	28.28673	19.04307	.06346	.06255	.51
98	2.00	6.04045	28.10522	18.97664	.06178	.06077	.50
99	2.05	6.14567	27.86805	18.83629	.05974	.05885	.49
100	2.10	6.21285	27.61086	18.58880	.05759	.05669	.48
101	2.15	6.27354	27.34814	18.33388	.05544	.05462	.47
102	2.20	6.30506	27.06419	18.00720	.05316	.05242	.45
103	2.25	6.52208	26.72009	18.21309	.05213	.05185	.44
104	2.30	6.88092	27.43525	18.79742	.05272	.05235	.43

Table B-2
Results for Sample Problem

105	2.35	7.19801	28.25056	19.24530	.05293	.05245	.43
106	2.40	7.44478	28.94049	19.49039	.05263	.05201	.42
107	2.50	7.68117	29.69735	19.30488	.05015	.04946	.40
108	2.60	7.64037	29.51208	18.46380	.04632	.04548	.38
109	2.70	7.55907	28.63302	17.59076	.04267	.04173	.37
110	2.80	7.34251	27.35924	16.47655	.03864	.03769	.36
111	2.90	7.40356	25.99282	16.04067	.03564	.03543	.34
112	3.00	7.33440	24.75301	15.36114	.03307	.03280	.33
113	3.10	6.90874	23.70815	14.00287	.02914	.02893	.32
114	3.20	6.69154	22.82216	13.13881	.02649	.02630	.31
115	3.30	6.93608	22.01781	13.20627	.02581	.02563	.30
116	3.40	7.07192	21.22453	13.06889	.02484	.02462	.29
117	3.50	7.06097	20.40245	12.67582	.02340	.02320	.29
118	3.60	6.87835	19.54568	12.00498	.02160	.02136	.28
119	3.70	6.58408	18.93469	11.18081	.02022	.01935	.27
120	3.80	6.57905	18.82632	10.87827	.01921	.01834	.26
121	3.90	6.50822	18.64308	10.48522	.01812	.01722	.26
122	4.00	6.38349	18.39234	10.02716	.01697	.01606	.25
123	4.10	6.22252	18.08896	9.53591	.01583	.01490	.24
124	4.20	6.04851	17.75249	9.04854	.01472	.01380	.24
125	4.30	5.87038	17.40266	8.57783	.01369	.01278	.23
126	4.40	5.70269	17.05731	8.14342	.01276	.01185	.23
127	4.50	5.59763	16.73195	7.81577	.01194	.01112	.22
128	4.60	5.61628	16.43721	7.67133	.01124	.01068	.22
129	4.70	5.64406	16.19898	7.54525	.01064	.01028	.21
130	4.80	5.69020	16.15076	7.44846	.01014	.00994	.21
131	4.90	5.75300	16.10726	7.37697	.00984	.00964	.20
132	5.00	5.95341	16.07610	7.48128	.00966	.00958	.20
133	5.10	6.32624	16.06371	7.79392	.00990	.00979	.20
134	5.20	6.63000	16.07323	8.01106	.01001	.00987	.19
135	5.40	7.12878	16.15708	8.29471	.00990	.00984	.19
136	5.60	7.57136	16.31950	8.49505	.00979	.00972	.18
137	5.80	7.70553	16.53658	8.34746	.00933	.00922	.17
138	6.00	7.80380	16.78193	8.17212	.00878	.00872	.17
139	6.20	8.17594	17.03147	8.28564	.00864	.00856	.16
140	6.40	8.16293	17.26567	8.01394	.00807	.00802	.16
141	6.60	8.07805	17.47293	7.69028	.00750	.00746	.15
142	6.80	7.90916	17.64408	7.30804	.00692	.00688	.15
143	7.00	8.03692	17.77664	7.21392	.00666	.00660	.14

Table B-2
Results for Sample Problem

144	7.20	8.02899	17.87166	7.00661	.00627	.00623	.14
145	7.40	7.95074	17.92966	6.75081	.00588	.00584	.14
146	7.60	7.90449	17.95683	6.53492	.00554	.00551	.13
147	7.80	7.59536	17.95699	6.11834	.00506	.00502	.13
148	8.00	7.08281	17.93492	5.56283	.00449	.00445	.13
149	8.50	6.54809	17.81199	4.84034	.00369	.00365	.12
150	9.00	5.75483	17.64195	4.01763	.00289	.00286	.11
151	9.50	5.00736	17.46322	3.31181	.00231	.00223	.11
152	10.00	.00000	.00000	.00000	.00000	.00000	.10

```
VALUES IN PERIOD RANGE .1 TO 2.5 SEC.
    AREA OF ACC. RESPONSE SPECTRUM    =      .510
    AREA OF VEL. RESPONSE SPECTRUM    =    78.102
    MAX. ACCELERATION RESPONSE VALUE =      .848
    MAX. VELOCITY      RESPONSE VALUE =    57.534
```

Table B-2
Results for Sample Problem

```
1******    OPTION 10   ***
COMPUTE AMPLIFICATION FUNCTION

    AMPLIFICATION SPECTRUM
BETWEEN LAYER    17 AND    1
  OUTPUT LAYER OUTCROPPING
  INPUT LAYER OUTCROPPING
```

FREQUENCY	AMPLITUDE				
.0000	1.0000	3.0000	1.7386	6.9000	1.3642
.1000	1.0025	3.1000	1.6402	7.0000	1.3246
.2000	1.0104	3.2000	1.5605	7.1000	1.2935
.3000	1.0239	3.3000	1.4967	7.2000	1.2704
.4000	1.0434	3.4000	1.4466	7.3000	1.2546
.5000	1.0692	3.5000	1.4083	7.4000	1.2459
.6000	1.1022	3.6000	1.3807	7.5000	1.2439
.7000	1.1431	3.7000	1.3627	7.6000	1.2487
.8000	1.1932	3.8000	1.3538	7.7000	1.2601
.9000	1.2538	3.9000	1.3537	7.8000	1.2785
1.0000	1.3270	4.0000	1.3622	7.9000	1.3041
1.1000	1.4152	4.1000	1.3794	8.0000	1.3372
1.2000	1.5216	4.2000	1.4056	8.1000	1.3785
1.3000	1.6500	4.3000	1.4415	8.2000	1.4283
1.4000	1.8052	4.4000	1.4878	8.3000	1.4874
1.5000	1.9925	4.5000	1.5454	8.4000	1.5562
1.6000	2.2170	4.6000	1.6155	8.5000	1.6349
1.7000	2.4805	4.7000	1.6995	8.6000	1.7232
1.8000	2.7753	4.8000	1.7986	8.7000	1.8198
1.9000	3.0737	4.9000	1.9138	8.8000	1.9217
2.0000	3.3181	5.0000	2.0450	8.9000	2.0237
2.1000	3.4342	5.1000	2.1901	9.0000	2.1179
2.2000	3.3806	5.2000	2.3432	9.1000	2.1940
2.3000	3.1863	5.3000	2.4929	9.2000	2.2413
2.4000	2.9220	5.4000	2.6213	9.3000	2.2518
2.5000	2.6491	5.5000	2.7063	9.4000	2.2234
2.6000	2.4001	5.6000	2.7290	9.5000	2.1609
2.7000	2.1860	5.7000	2.6834	9.6000	2.0738
2.8000	2.0070	5.8000	2.5796	9.7000	1.9728
2.9000	1.8595	5.9000	2.4380	9.8000	1.8676
		6.0000	2.2805	9.9000	1.7649
		6.1000	2.1233	10.0000	1.6690
		6.2000	1.9766	10.1000	1.5821
		6.3000	1.8447	10.2000	1.5051
		6.4000	1.7292	10.3000	1.4379
		6.5000	1.6296	10.4000	1.3801
		6.6000	1.5447	10.5000	1.3311
		6.7000	1.4731	10.6000	1.2903
		6.8000	1.4134	10.7000	1.2571

Table B-2
Results for Sample Problem

10.8000	1.2309
10.9000	1.2112
11.0000	1.1977
11.1000	1.1902
11.2000	1.1884
11.3000	1.1923
11.4000	1.2018
11.5000	1.2170
11.6000	1.2379
11.7000	1.2646
11.8000	1.2973
11.9000	1.3360
12.0000	1.3805
12.1000	1.4307
12.2000	1.4856
12.3000	1.5441
12.4000	1.6040
12.5000	1.6624
12.6000	1.7153
12.7000	1.7579
12.8000	1.7857
12.9000	1.7952
13.0000	1.7846
13.1000	1.7548
13.2000	1.7091
13.3000	1.6518
13.4000	1.5878
13.5000	1.5213
13.6000	1.4556
13.7000	1.3931
13.8000	1.3352
13.9000	1.2828
14.0000	1.2361
14.1000	1.1952
14.2000	1.1600
14.3000	1.1303
14.4000	1.1058
14.5000	1.0864
14.6000	1.0716
14.7000	1.0615
14.8000	1.0559
14.9000	1.0545
15.0000	1.0575
15.1000	1.0647
15.2000	1.0762
15.3000	1.0919
15.4000	1.1119
15.5000	1.1361
15.6000	1.1645
15.7000	1.1970
15.8000	1.2331
15.9000	1.2723
16.0000	1.3137
16.1000	1.3559
16.2000	1.3972
16.3000	1.4352
16.4000	1.4674
16.5000	1.4911
16.6000	1.5040
16.7000	1.5047
16.8000	1.4930
16.9000	1.4698
17.0000	1.4372
17.1000	1.3976
17.2000	1.3538
17.3000	1.3083
17.4000	1.2629
17.5000	1.2193
17.6000	1.1784
17.7000	1.1409
17.8000	1.1073
17.9000	1.0776
18.0000	1.0519
18.1000	1.0302
18.2000	1.0124
18.3000	.9984
18.4000	.9880
18.5000	.9813
18.6000	.9780
18.7000	.9782
18.8000	.9817
18.9000	.9886
19.0000	.9988
19.1000	1.0122
19.2000	1.0288
19.3000	1.0484
19.4000	1.0709
19.5000	1.0959
19.6000	1.1232
19.7000	1.1521
19.8000	1.1818
19.9000	1.2113

```
 MAXIMUM AMPLIFICATION =
3.43
 FOR FREQUENCY         =
2.10 C/SEC.
      PERIOD           =
.48 SEC.
1  PLOT OF AMPLIFICATION
SPECTRA
```

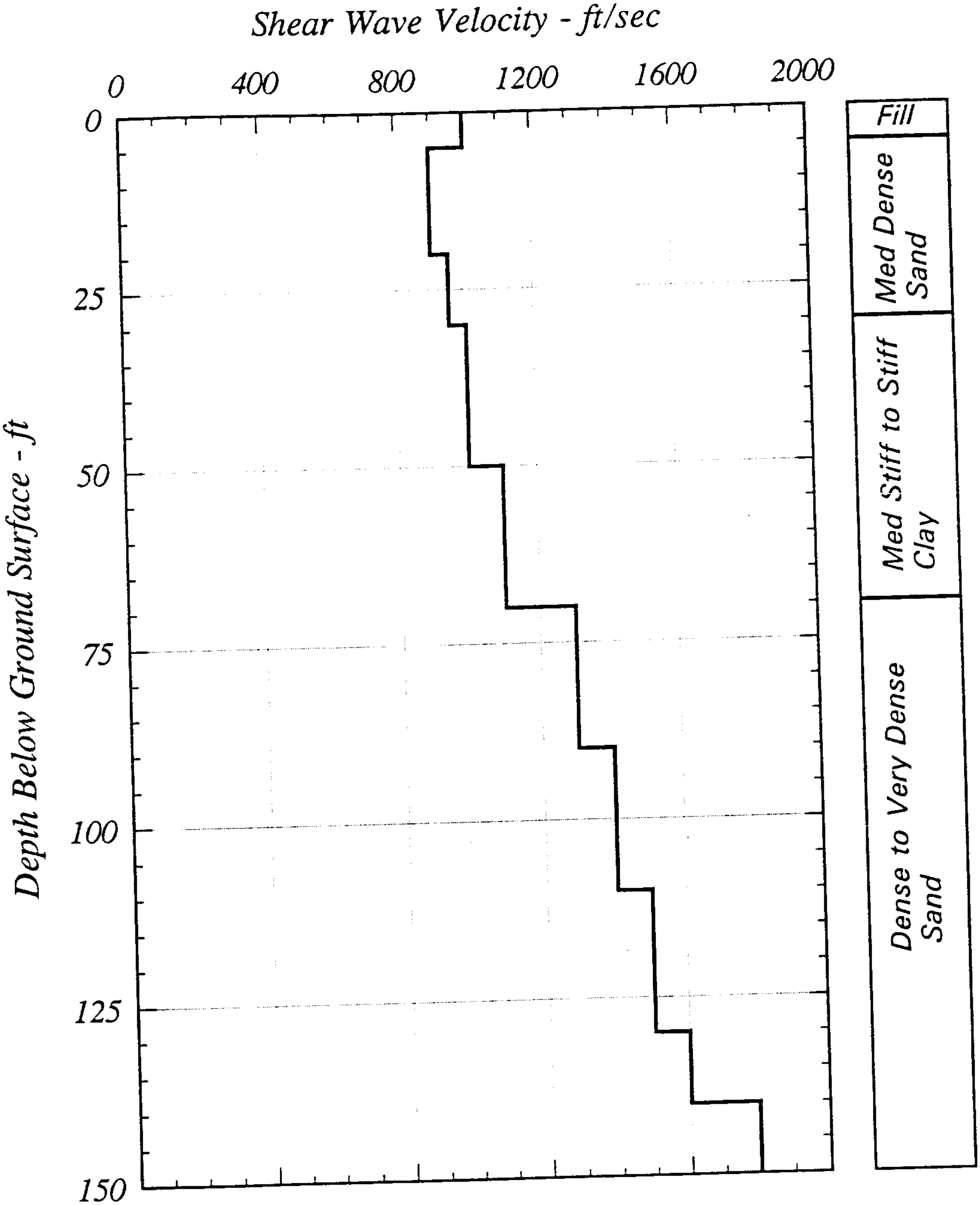


Fig. B-1 Shear Wave Velocities Used for Sample Problem

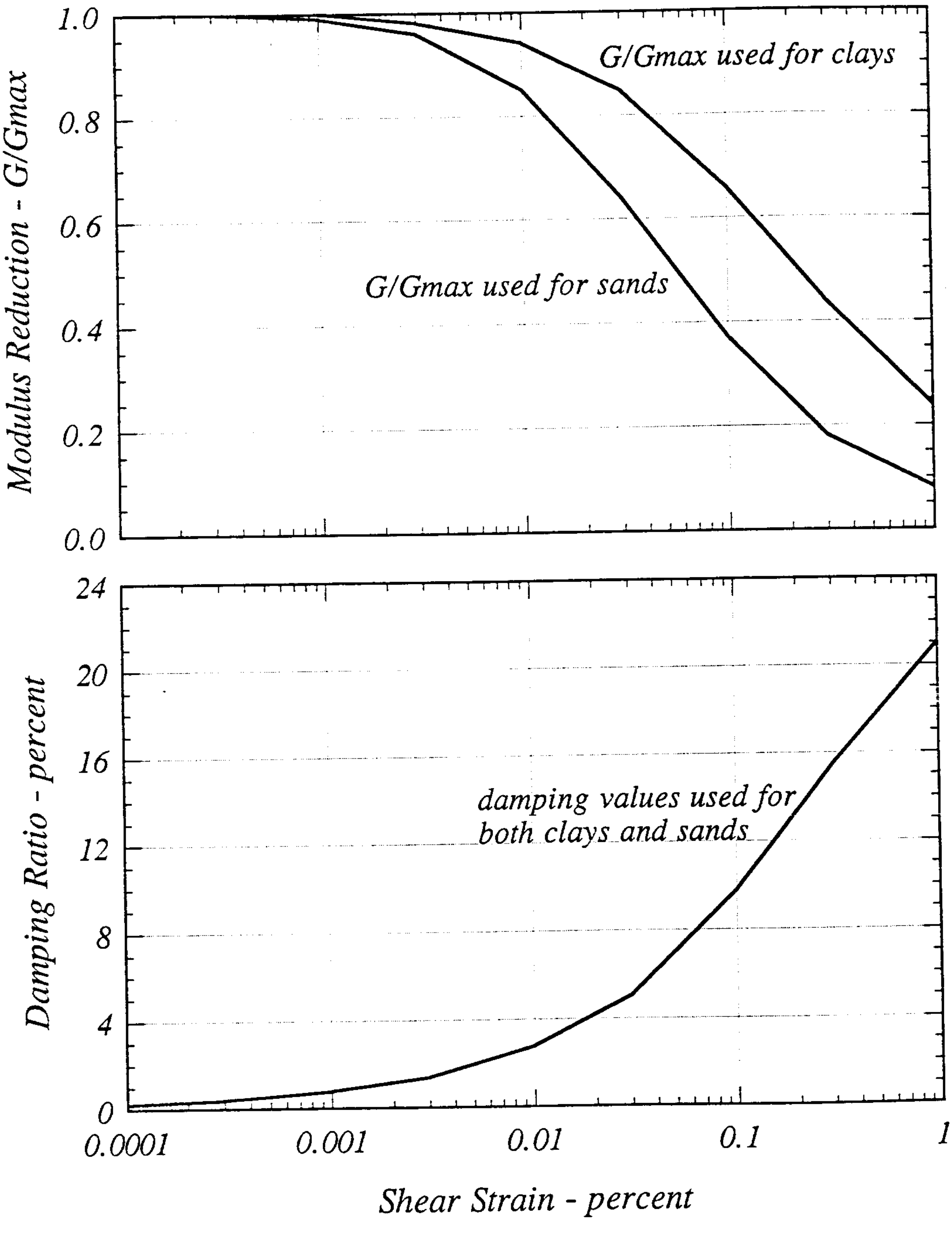


Fig. B-2 Moduius Reduction and Damping Values Used for Sample Problem

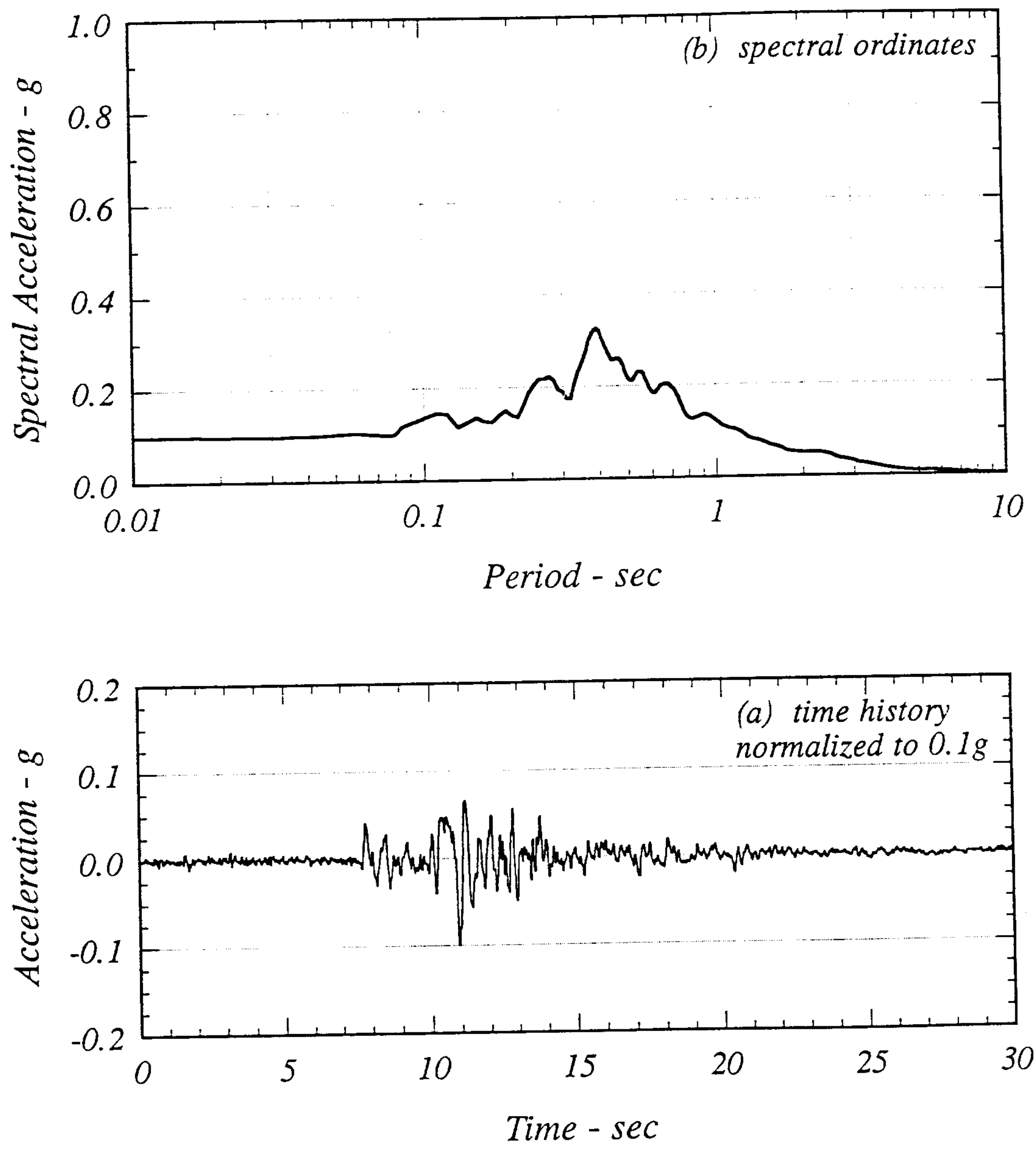


Fig. B-3 Acceleration Time History and Spectral Ordinates for EW Component Recorded at Diamond Heights

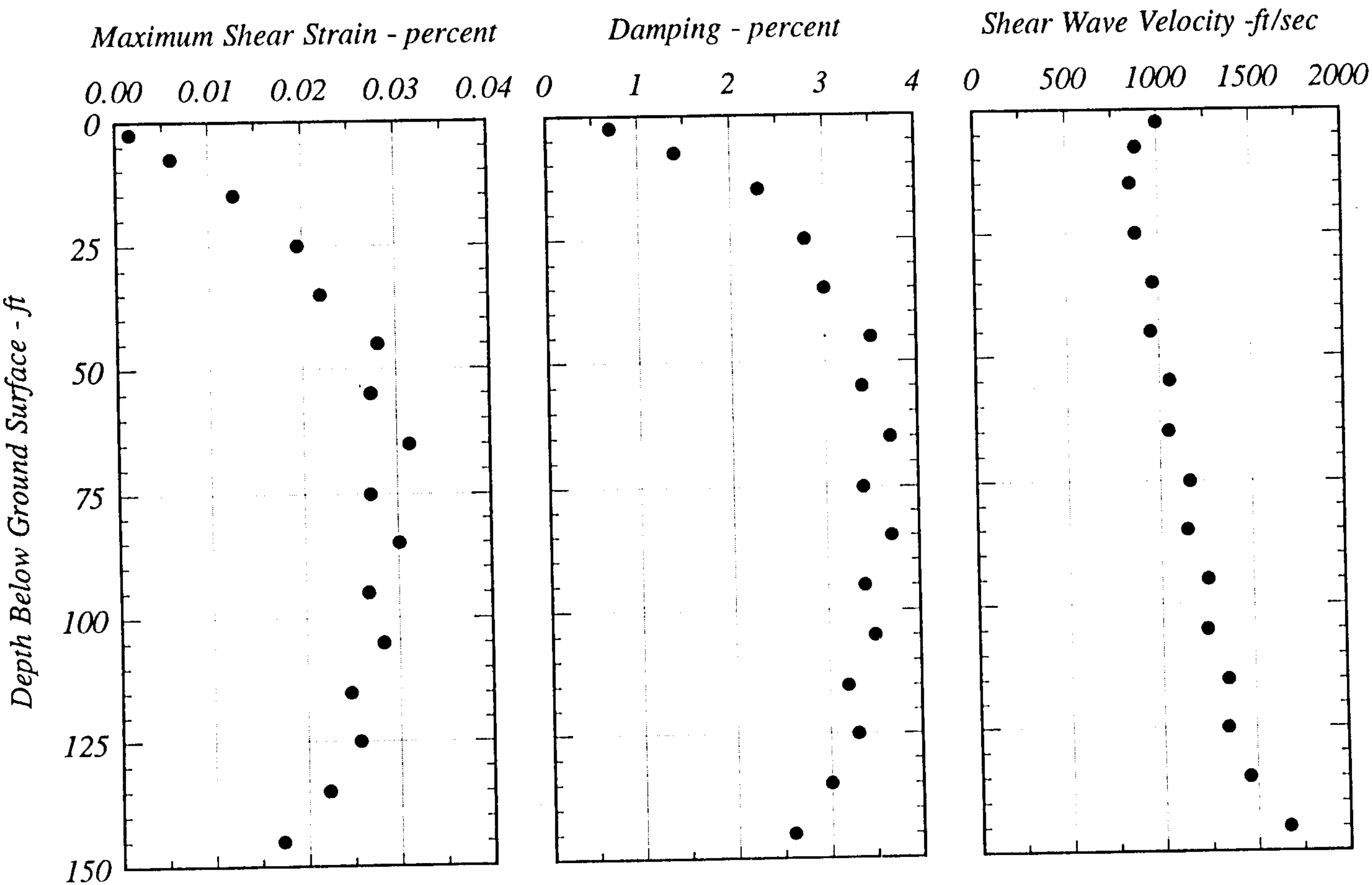


Fig. B-4 Calculated Shear Strains and Strain-Compatible Damping and Shear Wave Velocities for Sample Problem Using Diamond Heights Record as Input Motion

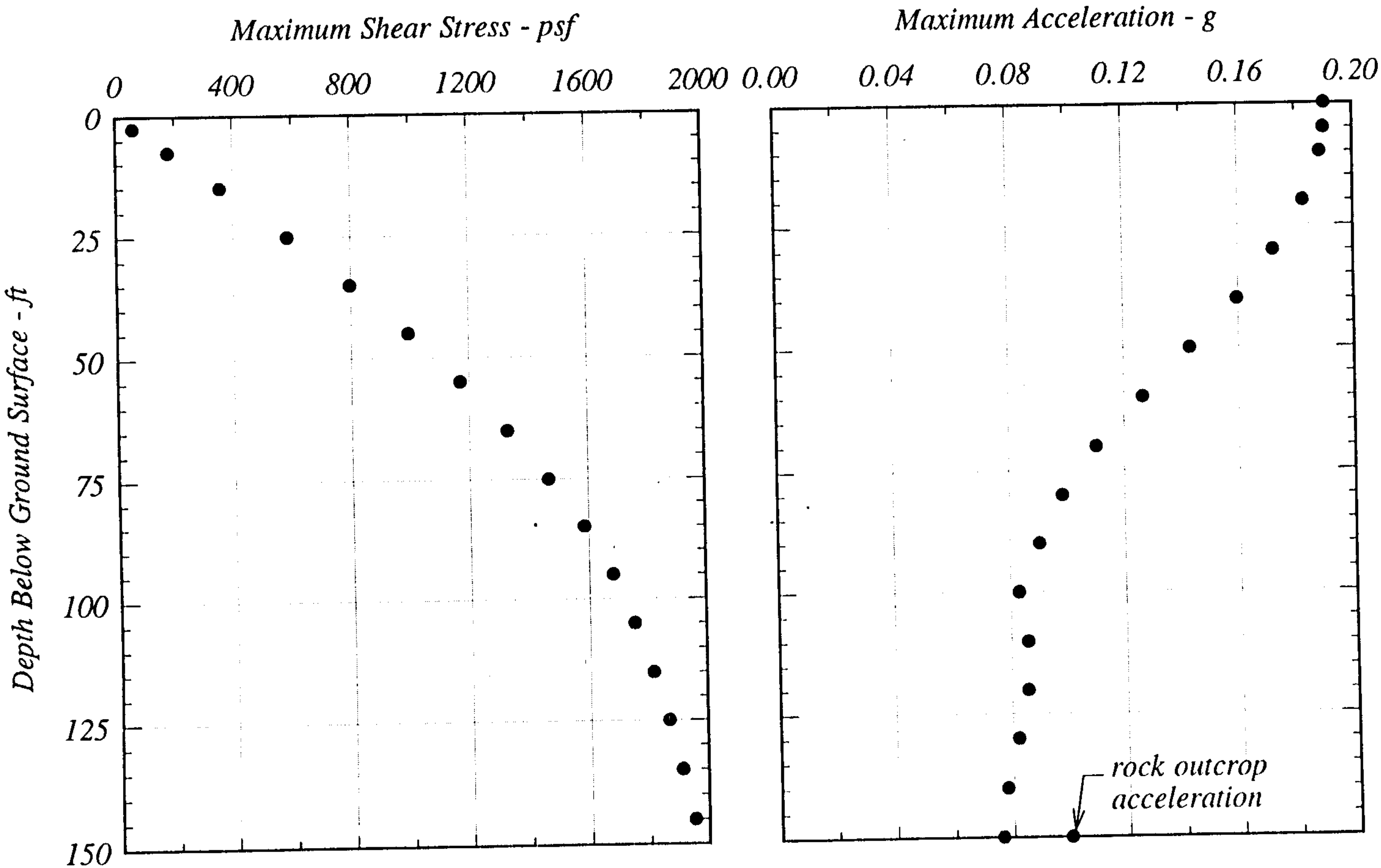
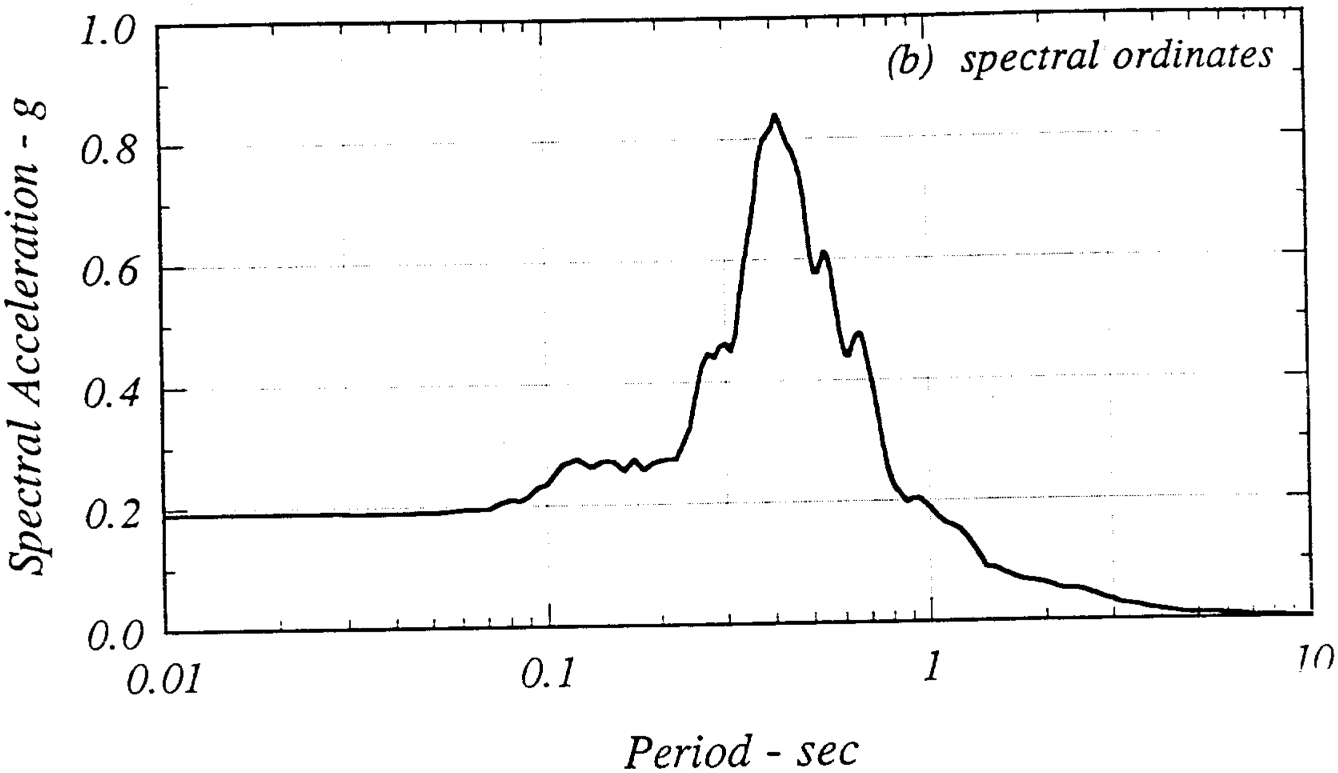


Fig. B-5 Calculated Shear Stresses and Accelerations for Sample Problem Using Diamond Heights Record as Input Motion



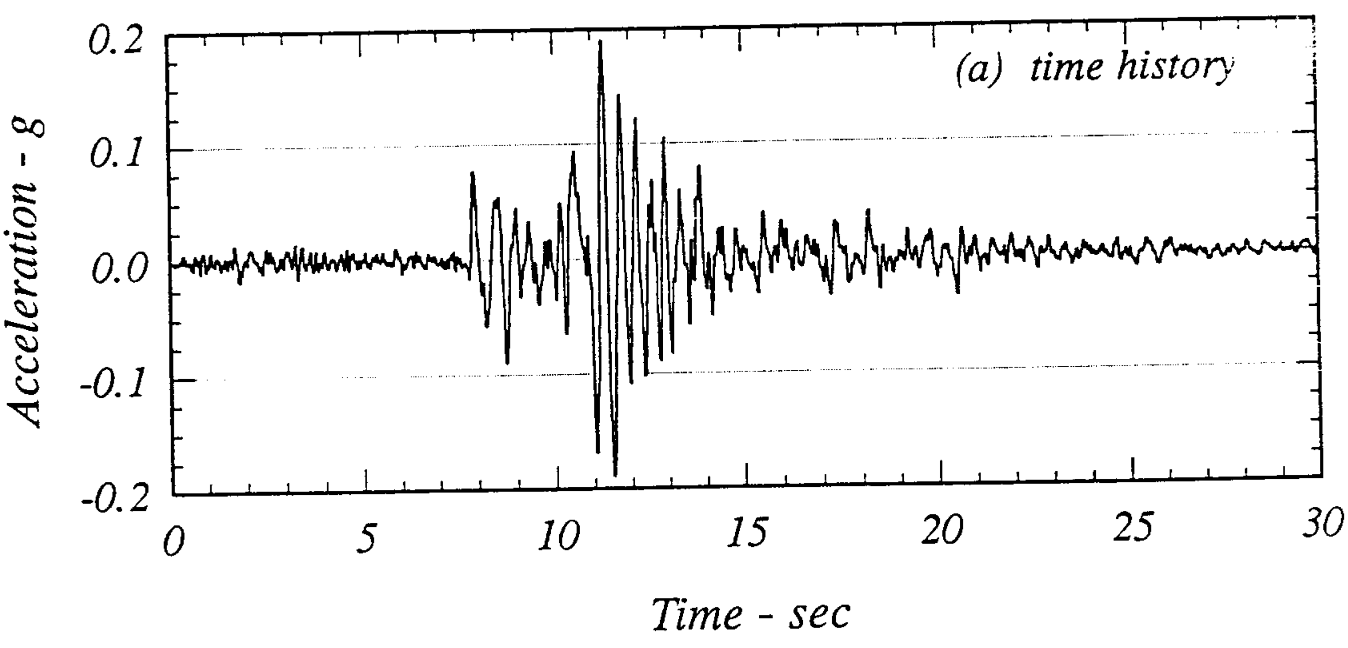


Fig. B-6 Acceleration Time History and Spectral Ordinates for Computed Motion at the Ground Surface Using Diamond Heights Record as Input Motion

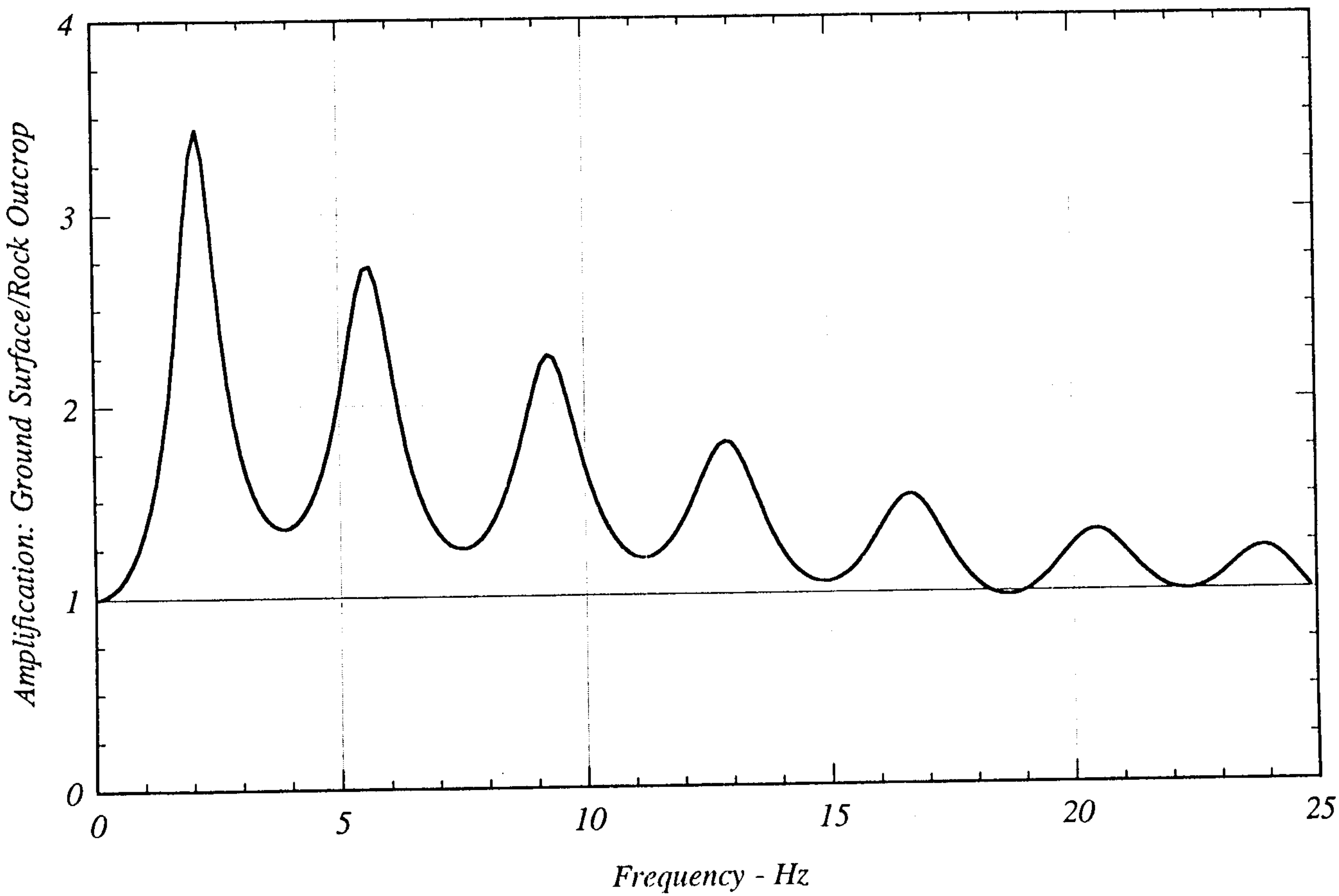


Fig. B-7 Calculated Amplification Spectrum for Sample Problem Using Diamond Heights Record as Input Motion

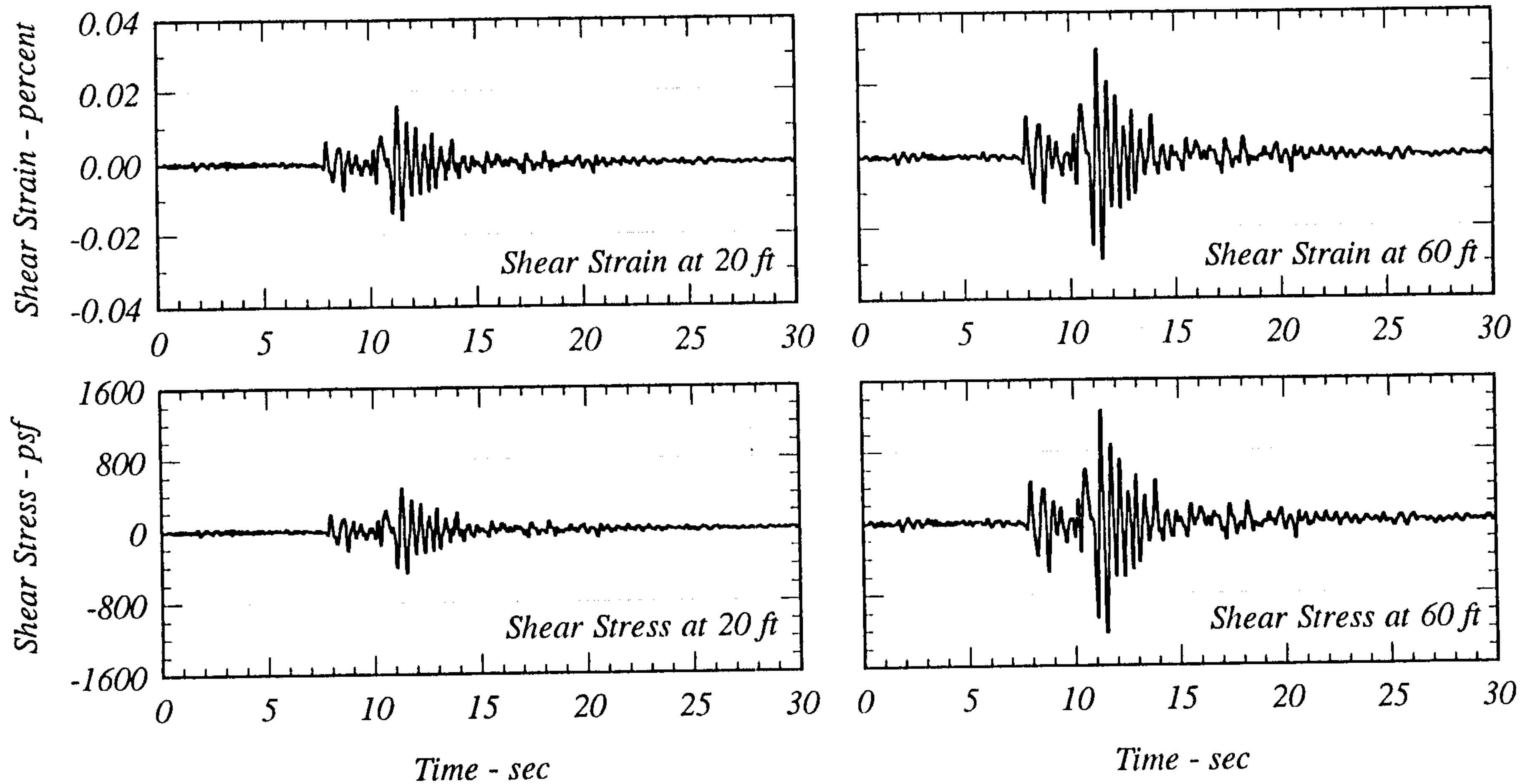


Fig. B-8 Time Histories of Shear Strains and Stresses Calculated at Depths of 20 and 60 ft for Sample Problem Using Diamond Heights Record as Input Motion