

**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 IDRISI
JOSEPH I. SUN

Sponsored by

Structures Division
Building and Fire Research Laboratory
National Institute of Standards and Technology
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Modifications by

I. M Idriss¹ and Joseph I. Sun²

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

¹Department of Civil Engineering, University of California, Davis

²Woodward-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.
- All built-in modulus reduction and damping relationships were removed. 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 include: 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. Therefore, they are not repeated in this user's manual.

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 strain-compatible properties (ie, difference less than about one percent) 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); the same value of this ratio is used 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 or to the corresponding outcrop
5	number of iterations specified & ratio of uniform strain to maximum 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	time history of object motion
9	response spectrum
10	amplification spectrum
11	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. Such operations can best be done in auxiliary programs.

INPUT DATA

The input data are provided in an input file; the name and location of this input file 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)

columns 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)

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

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

first line (Format: I5, 11A6)

columns 1 - 5 number of strain values to be read (maximum is 20)

columns 6 - 71 identification for this set of modulus reduction values
 second & consecutive lines (Format: 8F10.0)

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

columns 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):

columns 1 - 5	number, N, of materials to be used in this analysis
columns 6 - 10	first material number which will be used
columns 11 - 15	second material number to be used
columns 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)
- | | |
|-----------------|---|
| columns 1 - 5 | soil deposit number; may be left blank |
| columns 11 - 10 | number of sublayers, including the half-space |
| columns 16 - 51 | identification for soil profile |
- second and subsequent lines; one line for each sublayer, including the half-space (Format: 2I5, 5X, 5F10.0)

columns 1 - 5	sublayer number
columns 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 <i>all</i> sublayers, then the calculations are conducted for only one iteration using the properties (modulus, or shear wave velocity, and damping) specified in this input].
columns 16 - 25	thickness of sublayer, in feet
columns 26 - 35	maximum shear modulus for the sublayer, in ksf (leave blank if maximum shear wave velocity for the sublayer is given)
columns 36 - 45	initial estimate of damping (decimal)
columns 46 - 55	total unit weight, in ksf
columns 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)

columns 1 - 5	number, NV, of acceleration values to be read for input motion
columns 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.
columns 11 - 20	time interval between acceleration values, in seconds

columns 21 - 50	name of file for input (object) motion
columns 51 - 62	format for reading acceleration values

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

columns 1 - 10	multiplication factor for adjusting acceleration values; use only if columns 11 - 20 are left blank
columns 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.
columns 21 - 30	maximum frequency (ie, frequency cut-off) to be used in the analysis

columns 31 - 35 number of header lines in file containing object motion
columns 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)

columns 1 - 5 number of sublayer at the top of which the object motion is assigned
columns 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)

columns 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
columns 1 - 10 number of iterations
columns 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

(Note that a maximum of fifteen sublayers can be specified at a time; if accelerations for more than 15 sublayers are desired, then Option 6 can be repeated as many times as needed).

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

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

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

columns 1 - 75	array to specify type of each sublayer: 0 (zero) for outcropping or 1 (one) for within the soil profile
• third line after option number (Format: 15I5)	
columns 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

(Note that a maximum of two sublayers can be specified; if stress or strain time histories for more than two sublayers are desired, then Option 7 can be repeated as many times as needed).

• first line after option number (Format: 5I5, F10.0, 5A6)	
columns 1 - 5	number of sublayer
columns 11 - 10	set equal to 0 (zero) for strain or 1 (one) for stress
columns 11 - 15	set equal to one to save time history of strain or stress
columns 16 - 20	leave blank
columns 21 - 25	number of values to be saved; typically this should be equal to the number NV (see Option 3 above)
columns 26 - 35	leave blank
columns 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 the second Output file.

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

Option 8 -- 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)

columns 1 - 5 sublayer number
columns 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)

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

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

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

Option 10 – Amplification Spectrum

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

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

columns 1 - 5 number of the sublayer
columns 6 - 10 set equal to 0 (zero) for outcropping or equal to 1 (one) for within
columns 11 - 15 set equal to 2 (two) if spectrum is to be saved to file
columns 16 - 20 number of times the spectrum is to be smoothed
columns 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, the user should 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, the user should 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 the support of NIST 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.

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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					

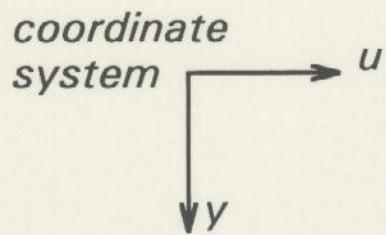
option 6 -- sublayers for which accn. time histories are to computed & saved:

6							
1	2	3	4	5	6	7	8
1	1	1	1	1	1	1	1
1	0	0	0	0	0	0	0



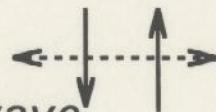
Table 1
Sample Input

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



1

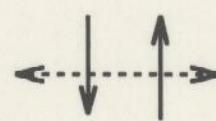
reflected wave



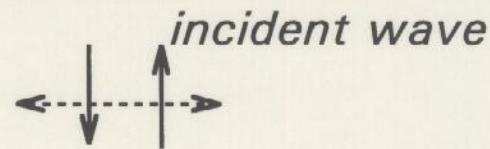
For Each Sublayer, m :

shear modulus = G_m
damping ratio = λ_m
mass density = ρ_m

m



$m + 1$



N
(half-space)

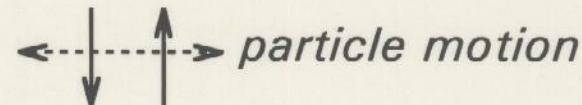


Fig. 1 One-Dimensional Idealization of a Horizontally-Layered Soil Deposit Over a Uniform Half-Space

APPENDIX A
COMPUTER LISTING

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 and Joseph I. Sun

November 1992

APPENDIX A

COMPUTER LISTING

The FORTRAN listing of the program **SHAKE91** is included in this Appendix. The program consists of the following four modules:

- MAIN
- A1
- B1
- C1

Each module contains several subroutines as follows:

MODULE	SUBROUTINE
MAIN	EARTHQ
A-1	CURVEG
	STEPG
	RESP
	DRCTSP
	CMPMAX
	FFT
	RFFT
	RFSN
	XMX
B-1	AMP
	UTPR
	REDUCE
	INCR
	MOTION
	CXSOIL
	STRAIN
C-1	SHAKIT
	STRT
	SOILIN
	CG

The program has been compiled in DOS using FORTRAN 5.1 and under Windows 3.1; the latter offers the opportunity to run the program concurrently with other applications if desired.

Listings of the above modules are included in the remaining pages of this Appendix.

MODULE: MAIN

MODULE: MAIN

PROGRAM: SHAKE91

MODULE: MAIN

```

C .....WRITE(6,2012) FINPQ, NV, MA, NHEAD, NPL, DT, FMAT
C .....WRITE (*,2026) FINPBQ, FMAT
C .....OPEN(8,FILE=FINPQ,STATUS='OLD')
C .....WRITE (6,2021)
DO 4 I=1,NHEAD
READ (8,2022) HEAD
4 WRITE (6,2022) HEAD
NPA = NV + NV/10
IF (NPA.GT.NA) NPA=NA
MA2 = MA + 2
MFOLD = MA2/2
MFOLD = MFOLD + 1
DF = 1./ (MA*DT)
FMA = FLOAT(MA)
MX = (ALOG10 (FMA) / ALOG10 (2.)) - 1
NMX = 2** (NM+1)
IF (MA .LE. NMX) GO TO 11
MX = MX + 1
GO TO 1
11 NCARDS = (NM-1)/NPL + 1
N = NV +
N = 0
LC = 0
NCARDS = (NM-1)/NPL + 1
NV = NV +
N = NV +
IF (I .NE. NCARDS) GO TO 6
IF (I.EQ.0) GO TO 6
JL=NPL+1-JL
DO 5 J=JL,NPL
LC = LC + 1
READ (8,FMAT) (XR(J), J=1,NPL)
IF (I.LE.5 .OR. ICHECK .LT. 5) WRITE(6,2008) I, (XR(J), J=1,NPL)
IF (I.EQ.10) WRITE (6,2009)
2009 FORMAT(1X,'..... INPUT MOTION READ NOT ECHOED .....')
C ERDIF
6 ICHECK = NCARDS - I
IF (I.LE.5 .OR. ICHECK .LT. 5) WRITE(6,2008) I, (XR(J), J=1,NPL)
IF (I.EQ.10) WRITE (6,2009)
2009 FORMAT(1X,'..... INPUT MOTION READ NOT ECHOED .....')
C FIND MAX. INPUT ACC. (XMAX)
C .....311 DO 311 J = 1,NPL,2
N = N + 1
X(N) = CMPLX (XR(J),XR(J+1))
311 CONTINUE
CLOSE (8)
N = N + 1
DO 312 I = N, MFOLD
312 X(I) = 0.
CALL XMK(X,MA,XM,NMAX)
IP (XMAX,LT,.000001) GO TO 300
IP = XMAX/XM
300 DO 30 I = 1, N
30 X(I) = X(I)*XF
XMAX = XM*XP
XM = FLCAT (NMAX-1)*DT
WRITE (6,2014) XM,TMAX,XF,XMAX
C CALL RFPT(X, MX, INV, S, IFERR, 1)
C ..... REMOVE FREQUENCIES ABOVE FNAX AND FIND MAX. ACC. OF NEW MOTION
C .....SFREQ = 0.
SXX = 0.
SFX = 0.
NCUT=0
DO 313 I = 1, MFOLD
IF (FRQ.LB.FNMAX) GO TO 34
NCUT=NCUT+1
X (I) = 0.0
314 CONTINUE
XA = CABS(X(I))
SXX = SXX + XA*XA
SFX = SFX + FRQ*X*A*YA
AX(1,I) = X(I)
FRQ = FRQ + DF
313 CONTINUE
SFX = SFX/SXX
NCUT=MFOLD-NCUT
N2ER0=NCUT+1
WRITE (6,2005) SFX
IF (FNAX.GT.FRQ) RETURN
CALL RFSN(X,MX,INV,S,IFERR,-2)
72 X (I) = AX(1,I)
WRITE (6,2001) XM, FNMAX
C .....1001 FORMAT(2I5, F10.3, A30, A12)
1002 FORMAT(8F5.17)
1003 FORMAT(8F10.0)
1004 FORMAT(3F10.0,2I5)
2001 FORMAT(2I1H MAX ACCELERATION = F10.5, 22H FOR FREQUENCIES REMOV
19HD ABOVE F10.2, 7H C/SEC.)
2003 FORMAT(17H ACC. CARD NO. 14.16H OUT OF SEQUNCB )
2005 FORMAT(2SH MEAN SQUARE FREQUENCY = F10.2, 7H C/SEC. )
C2008 FORMAT(2X, 15, 5X, 8F15.6)
2008 FORMAT(1X,15,1X, 8F9.6)
2012 FORMAT(1X, ' FILE NAME FOR INPUT MOTION = ', A30, /
1X, ' NO. OF INPUT ACC. POINTS = ', I5, /
1X, ' NO. OF POINTS USED IN PFT = ', I5, /
1X, ' NO. OF HEADING LINES = ', I5, /
1X, ' NO. OF POINTS PER LINE = ', I5, /
1X, ' TIME STEP FOR INPUT MOTION = ', F6.4/
1X, ' FORMAT FOR OF TIME HISTORY = ', A12, '/')
2014 FORMAT( /2H MAXIMUM ACCELERATION = F9.5/
1 23H AT TIME = F6.2, 4H SEC/
1 44H THE VALUES WILL BE MULTIPLIED BY A FACTOR = F7.3/
3 44H TO GIVE NEW MAXIMUM ACCELERATION = F9.5 )
2021 FORMAT ('/1X, **** H E A D E R ')
2022 FORMAT (A80)
2023 FORMAT (1X, ****)
1 ***** FIRST & LAST 5 LINES OF INPUT MOTION **** */
2024 FORMAT (' *** FIRST & LAST 5 LINES OF INPUT MOTION **** ')
2025 FORMAT (' **** ')
2026 FORMAT ('/1X, READING INPUT MOTION FROM ----> ', A30/
+ 1X, ' FORMAT OF INPUT MOTION USED ----> ', A12)
RETURN
END

```

MODULE: MAIN

PROGRAM: SHAKE91

```

      SUBROUTINE CURVGS(NC, NV, K1, A, B, NR, TSTEP, NT, T, V, X, Y, NSTEP)
      C THE PROGRAM GENERATES NEW POINTS ON A CURVE BY LINEAR INTERPOLATION
      C USING AN ARITHMETIC OR A HALFLOGARITHMIC SCALE
      C
      C RV(I) = NUMBER OF VALUES ON CURVE I
      C NC = NUMBER OF CURVES
      C K1 = SWITCH K1 = 1 ARITHMETIC SCALE
      C K1 = 2 HALFLOGARITHMIC SCALE
      C
      C A,B = PARAMETERS FOR CALCULATING NEW VALUES
      C Y = A*X + B
      C X,Y = KNOWN POINTS ON CURVE
      C T = VALUES ON ABSISSA WHERE NEW POINTS ARE GENERATED
      C V = NEW ORDINATE VALUES
      C
      C ARITHMETIC SCALE K1 = 1
      C NN = NUMBER OF INTERVALS
      C TSTEP = LARGEST VALUE IN EACH INTERVAL
      C NT = NUMBER OF STEPS IN EACH INTERVAL
      C
      C HALFLOGARITHMIC SCALE
      C NN = NUMBER OF VALUES IN EACH LOG10
      C
      C DIMENSION X(27,20),Y(27,20),A(27,20),B(27,20),NV(27),TSTEP(27)
      C DIMENSION NT(27), T(200), V(27,200)
      C
      C XMIN = 100000000.
      C XMAX = 0.
      DO 1 L= 1,NC
      M = NV(L)
      IF (XMAX .LT. X(L,M)) XMAX = X(L,M)
      IF (XMIN .GT. X(L,1)) XMIN = X(L,1)
      M = M - 1
      DO 1 I = 1,M
      X1 = X(L,I)
      X2 = X(L,I+1)
      IP (K1 .EQ. 2) X1 = ALOG10(X1)
      IP (K1 .EQ. 2) X2 = ALOG10(X2)
      X(L,I) = X(L,I+1)
      A(L,I) = (Y(L,I+1) - Y(L,I))/(X2 - X1)
      1 B(L,I) = -A(L,I)*X1 + Y(L,I)
      CALL STEPG(K1, NN, TSTEP, NT, XMIN, XMAX, T, NSTEP)
      3 CONTINUE
      J = M
      DO 2 L = 1,NC
      M = NV(L) - 1
      DO 2 I = 1,NSTEP
      DO 3 J = 1,M
      IP (T(I) .LT. X(L,J)) GO TO 31
      21 CONTINUE
      TA = TA*10.
      GO TO 211
      212 NSTEP = K
      RETURN
      END

      SUBROUTINE STEPG(KK, NN, TSTEP, NT, T1, TN, T, NSTEP)
      C THE ROUTINE GENERATES STEPS IN LINEAR OR LOGARITHMIC INCREMENT
      C
      C KK = SWITCH KK = 1 STEP INCREASE OF VALUES
      C KK = 2 LOGARITHMIC INCREASE OF VALUES
      C NN = NUMBER OF STEPS OR NUMBER OF VALUES IN EACH 10
      C TSTEP = LARGEST VALUE IN EACH STEP
      C NT = NUMBER OF VALUES IN EACH STEP
      C T1 = FIRST VALUE IN LOG-STEP
      C TN = LAST VALUE IN LOG-STEP
      C T = VALUES GENERATED
      C NSTEP = NUMBER OF VALUES
      C
      C CODED PER B SCHNABEL SEPT. 1970
      C
      C DIMENSION T(200), TSTEP(27), NT(27)
      C
      C GO TO (1, 2), KK
      1 K = 1
      T(K) = 0.
      SAVE = 0.
      DO 11 N = 1,NN
      M = NT(N)
      STEP = (TSTEP(N) - SAVE)/FLOAT(M)
      SAVE = TSTEP(N)
      DO 11 I = 1,M
      K = K + 1
      11 T(K) = T(K-1) + STEP
      NSTEP = K
      RETURN
      2 NST = ALOG10(T1)
      21 IP (T1.LT. 1.) NST = NST - 1
      STEP = 1./NN
      K = 1
      TA = 10.*FLOAT(NST)
      T(1) = TA
      DO 22 J = 2,NN
      K = K + 1
      T(K) = TA*10.**(STEP*FLOAT(J))
      IP (T(K).GT. T1) GO TO 221
      22 CONTINUE
      221 TA = T(K-1)
      211 DO 21 J = 1,NN
      K = K + 1
      T(K) = TA*10.**(STEP*FLOAT(J))
      IP (T(K).GT.TN) GO TO 212
      21 CONTINUE
      TA = TA*10.
      GO TO 211
      212 NSTEP = K
      RETURN
      END

      SUBROUTINE RESPUN(LS, NN, X, AX, A, S, TN)
      C
      C TT = T(I)
      IF (K1 .EQ. 2) TT = ALOG10(TT)
      IF (K1 .EQ. 1) TT = T(I)
      END

```

MODULE: A-1

```

C * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C THIS PROGRAM READS DATA FOR RESPONSE SPECTRUM ANALYSIS
C NECESSARY SUBROUTINES DRCDSP, CMPPMAX
C
C NN = RESPONSE SPECTRUM NUMBER
C ND = NUMBER OF DAMPING VALUES
C X = FOURIER TRANSFORM OF OBJECT MOTION
C AX = FOURIER TRANSFORM OF COMPUTED MOTIONS
C T = PERIODS FOR WHICH RESPONSE IS TO BE COMPUTED
C
C CODED PER B SCHNABEL DEC. 1970
C New Sets of Periods -- included in February 1991
C
C * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C CHARACTER*6 TITLE, ID, IBLANK, IDNT
CHARACTER*60 ABSFS
CHARACTER*32 PERIOD
CHARACTER*32 headerD
CHARACTER*30 headerR
COMPLEX X, AX
C
C DIMENSION X(64), AX(3, 64), A(2, 64), S(10), INV(10)
C D-MEMORY ID(27,11)
C
C COMMON /SOILA/ IDNT(6), BL(51), GL(51), FACT(51), H(51), R(51), BF(51)
COMMON /EQ/ MFOLD, MA2, TITLE(5), DT, MA, MMA, DF, MX
COMMON /RVAL/ NND(27), ZLD(6), T(200), SA(5,200), SV(5,200)
C
C IBLANK =
ABSIS = ' PERIOD IN SEC.'
C
READ(5,4) ND, KPER, GGT
4 FORMAT(2I5, F10.2)
READ(5,5) (ZLD(I), I = 1, ND)
5 FORMAT(FP10.3)
WRITE(6,9001) LN, (ZLD(I), I = 1, ND)
C
C IF KPER = 0: Periods from 0.03 to 10 sec are included in data block
C otherwise, periods are specified by user (maximum is 200 periods)
C
IF (KPER.EQ.0) GO TO 99
READ(5,'(A32)') FPERIOD
WRITE(6,60) FPERIOD
60 FORMAT(' File from which periods were read: ', A32)
OPEN(8,FILE=FPERIOD,STATUS='OLD')
READ(8,4) NLLINES, NRM
DO 10 I = 1, NLLINES
READ(B,*), headerD
WRITE(6,*), headerD
10 CONTINUE
READ(8,*), (T(I), I=1, NRM)
CLOSE(8)
GO TO 101
C
C default periods for calculating response spectra
C
99 NRM=152
T(1) = .01
data (t(i), i=2,152)/
1   0.03,    0.04,    0.05,    0.06,    0.07,    0.08,    0.09,

```

MODULE: A-1

PROGRAM: SHAKE91

```

C THIS ROUTINE COMPUTES RESPONSE SPECTRA BY THE STEP BY STEP METHOD
C
C   NN    = RESPONSE SPECTRUM CURVE NUMBER USED (Cancelled)
C   KG    = NUMBER OF ACCELERATION VALUES
C   DT    = TIME STEP BETWEEN EACH ACCELERATION VALUE
C   M    = NUMBER OF PERIODS FOR WHICH RESPONSE IS TO BE COMPUTED
C   T    = ARRAY WITH THE PERIODS
C   A    = ACCELERATION VALUES
C   D    = CRITICAL DAMPING RATIO
C   ID   = IDENTIFICATION
C   GGT  = Acceleration of gravity - cm/sec/sec., or in/sec/sec
C          or ft/sec/sec
C
C   CODED BY I. M. IDRISS 1967
C   * * * * *
C   CHARACTER*6 ID
C   DIMENSION A(1)
C   COMMON /EVAL/ NND(27), ZLD(6), T(200), SA(5,200), SV(5,200)
C   DIMENSION PRV(200), PAA(200), RD(200)
C   DIMENSION ID(27,11)
C
C   zmax=0
DO 10 K = 1, KG
IF(zmax.GT. ABS(A(K))) GO TO 9
zmax = ABS(A(K))
9 A(K) = GGT*A(K)
10 CONTINUE
PIW = 6.283185307
SV(NN,1) = zmax*GGT*T(1)/PIW
SA(NN,1) = zmax
KUG = KG-1
RD(1) = zmax*GGT*T(1)*T(1)/(PIW*PIW)
PRV(1) = zmax*GGT*T(1)/PIW
PAR(1) = zmax
WRITE(6,112) D
N = 1
YY = SQRT(1.-D*D)
DO 200 LOOP = 2, M
  W = 6.283185307*T(N)
  WD = YY*W
  W2 = W*W
  W3 = W2*W
  CALL CMPLX(KUG,T(N),W,W2,W3,WD,D,DT,ZD,ZV,ZA,A)
  SV(NN,N) = ZV
  SA(NN,N) = ZA/GGT
  RD(N) = ZD
  PRV(N) = W*ZD
  PAA(N) = W2*ZD/GGT
  200 N = N + 1
  WRITE(6,312) GGT, (ID(NN,I), I = 1,10), D
  SUMSV = 0.
  SUMSA = 0.
  SUMT = 0.
  SUMV = 0.
  SUMAX = 0.
  TT1 = .1
  TT2 = 0.
  DO 320 N = 1, M
    IF (T(N).LT. .0999 .OR. TT2.GT.2.4999) GO TO 320
    IF (T(N).LT. .0999 .OR. TT1.GT.2.4999) GO TO 320
    TT1 = TT2
    IF (SUMSV.LT. SV(NN,N)) SUMAX = SV(NN,N)
    IF (SUMSA.LT. SA(NN,N)) SUMAX = SA(NN,N)
    IF (SUMT.LT. TA(NN,N)) SUMAX = TA(NN,N)
    IF (SUMV.LT. PV(N)) SUMAX = PV(N)
    SUMSV = SUMSV+SV(NN,N)
    SUMSA = SUMSA+SA(NN,N)
    SUMT = SUMT+TA(NN,N)
    SUMV = SUMV+PV(N)
    WRITB(6,322) N, T(N), RD(N), SV(NN,N), PRV(N), SA(NN,N), PAA(N), FREKV
    WRITB(6,202) SUMSA, SUMSV, SUMAX, SYMAX
    DO 11 K = 1, KG
11 A(K) = A(K)/GGT
  RETURN
C
C   112 FORMAT(15X,41HTIMES AT WHICH MAX. SPECTRAL VALUES OCCUR /
C          1 10X,33HDT = TIME FOR MAX. RELATIVE DISD. /
C          2 10X,33HVT = TIME FOR MAX. RELATIVE VEL. /
C          3 10X,33HTA = TIME FOR MAX. ABSOLUTE ACC. /
C          4 5X,15HDFTA = TIME FOR MAX. ABSOLUTE ACC. /
C          312 FORMAT(15X, ' SPECTRAL VALUES --' / 15X, ' ACCELERATION OF GRAVITY USED = ' F8.2 ' ] ' /
C          21046,2X,15HDAMPING RATIO =
C          3 P5,2/5X,3HRO,4X,6HPERTOD,5X,9HREL. VEL.,3X,
C          4 12HPSU,REL. VEL.,6X,9HABS. ACC.,3X,5HREQ.)
C
  322 FORMAT(18,F10.2,5F15.5, F10.2)
  402 FORMAT(18,F10.2,5F15.5, F10.2)
  412 FORMAT(15,25H ACC. RESPONSE VALUES FOR , 8A6)
  413 FORMAT(15,25H VEL. RESPONSE VALUES FOR , 8A6)
  2002 FORMAT(10X,40HVALUES IN PERIOD RANGE .1 TO 2.5 SEC.
  11543 SHARE OF ACC. RESPONSE SPECTRUM = F10.3/
  21543 SHARE OF VEL. RESPONSE SPECTRUM = F10.3/
  31543 SHARE OF ACCELERATION RESPONSE VALUE = F10.3/
  41543 SHARE OF VELOCITY RESPONSE VALUE = F10.3)
  END
C *****
C   SUBROUTINE CMPLX(KUG,PP,W,W2,W3,WD,D,DT,ZD,ZV,ZA)
C   *****
C   THIS ROUTINE COMPUTES RESPONSE VALUES FOR ONE SINGLE DEGREE OF
C   FREEDOM SYSTEM USING STEP BY STEP METHOD
C   EXPLANATIONS TO PARAMETERS GIVEN IN DRCTSP
C
C   CODDED BY I. M. IDRISS 1967
C
C   DIMENSION XD(2), XV(2), T(3)
C   DIMENSION UG(1)
C
C   ZA = 0.
C   ZD = 0.
C   ZV = 0.
C   XD(1) = 0.
C   XV(1) = 0.
C   F1 = 2.*D/(W3*DT)
C   F2 = 1./W2
C   F3 = D*W
C   F4 = 1./WD
C   F5 = F3*F4
C   F6 = 2.*F3

```

```

B = EXP(-F3*DT)
S = SIN(WD*DT)
C= COS(WD*DT)
G1 = E*S
G2 = E*C
H1 = WD*G2 - F3*G1
H2 = WD*G1 + F3*G2
DO 100 K = 1, KUG
Y = K_1
DUG = UG(K+1) - UG(K)
Z1 = F2*DUG
Z2 = F2*UG(K)
Z3 = F1*DUG
Z4 = Z1/DT
B = XD(1) + Z2 - Z3
A = F4*XV(1) + F5*B + F4*Z4
XD(2) = A*G1 + B*G2 + Z3 - Z2 - Z4
XV(2) = A*H1 - B*H2 - Z4
XD(1) = XD(2)
XV(1) = XV(2)
AA = -F6*XV(1) - W2*XD(1)
F = ABS(XD(1))
G = ABS(XV(1))
H = ABS(AA)
IF(F .LE. 2D) GO TO 75
T(1) = Y
2D = F
75 IF(G .LE. 2V) GO TO 85
T(2) = Y
ZV = G
85 IF(H .LE. ZA) GO TO 100
T(3) = Y
ZA = H
100 CONTINUE
DO 110 L = 1, 3
110 T(L) = DT*T(L)
WRITE(6,112) PR, (T(L),L=1,3)
112 FORMAT(5X,5PR, = F5.2,5X,15HTIMES FOR MAXIMA -- ,3X,
14HTD = F8.4,3X,4HTV = F8.4,3X,4HTA = F8.4)
RETURN
END
C **** SUBROUTINE FFT (A,M,INV,S,IFFT,IERR)
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
DIMENSION A(1),INV(1),N(3),M(3),W(3),W(2),W(2),W(3)
EQUIVALENCE (N1,N(1)), (N2,N(2)), (N3,N(3))
C
M1=M(1)
M2=M(2)
M3=M(3)
MTT=M1-2
MT-MAC(2,MTT)
NTL=2**MTT
10 IF (IABS(IFFST)-1) 610,610,20
610 MT-MAC(M(1),M(2),M(3))-2
MT-MAC(2,MTT)
IF (MT-20) 630,630,620
620 IFFR=1
GO TO 600
630 IFFR=0
NT=2**MTT

```

```

80    IDIF=NP(ID)
      KBIT=NP(ID)
      MBY=2*(MI/2)
      IF (MI .EQ. MEV) 120,120,90
      KBIT=KBIT/2
      KLYKBIT=2
      DO 100 I=1,ILL,1DIF
      KLAST=KL+I
      DO 100 K=1,KLAST,2
      KD=K+KBIT
      T=A(KD)
      A(KD)=A(K)-T
      A(K)=A(K)+T
      T=A(KD+1)
      A(KD+1)=A(K+1)-T
      100  IF (MI-1) 330,330,110
      110  LPFIRST=3
      JLAST=1
      GO TO 130
      120  LPFIRST=2
      JLAST=0
      130  DO 320 L=LPFIRST,MI,2
      JJDIF=KBIT/4
      KLYKBIT=2
      DO 140 K=1,KLAST,2
      KLAST=T+KL
      K1=K+KBIT
      K2=K1+KBIT
      K3=K2+KBIT
      T=A(K2)
      A(K2)=A(K)-T
      A(K)=A(K)+T
      T=A(K2+1)
      A(K2+1)=A(K+1)-T
      A(K+1)=A(K+1)+T
      T=A(K3)
      A(K3)=A(K1)-T
      A(K1)=A(K1)+T
      T=A(K3+1)
      A(K3+1)=A(K+1)-T
      A(K+1)=A(K+1)+T
      T=A(K4)
      A(K4)=A(K1)-T
      A(K1)=A(K1)+T
      T=A(K4+1)
      A(K4+1)=A(K+1)-T
      A(K+1)=A(K+1)+T
      R=A(K3+1)
      T=A(K3)
      A(K3)=A(KR+R)/ROOT2
      A(KR)=A(KL)-A(K1+1)
      AWR=(K1-1)*A(R(K1))
      R=A(K3)-A(K3+1)
      T=A(K3)-A(K+1)+T
      AWR=(AWR-R)/ROOT2
      A(K3)=(AWR+R)/ROOT2
      A(K1)=A(WR+R)/ROOT2
      A(K1+1)=(AWR-T)/ROOT2
      T=A(K1)
      A(K1)=A(K+1)+T
      R=A(K3+1)
      T=A(K1)
      A(K1)=A(KX)-T
      A(KX)=A(K)+T
      T=A(K3+1)
      A(K3+1)=A(K+1)-T
      A(K+1)=A(K+1)+T
      T=A(K3)
      A(K3)=A(K2+R)
      A(K2)=A(K2+R)
      A(K2+1)=A(K2+1)-T
      160  A(K2+1)=A(K2+1)+T
      170  IF (JLAST-1) 310,310,170
      DO 300 J=2,JLAST
      I=INV(J+1)
      IC=NT-I
      W(1)=S(IC)
      W(2)=S(I)
      I2=2*I
      I2C=NT-I2
      IF (I2C) 200,190,180
      180  W(1)=S(I2C)
      W(2)=S(I2)
      GO TO 210
      190  W(1)=S(
      W(2)=S(
      I2=I+2
      GO TO 210
      200  I2CC=I2C+NT
      I2C=I2C+12C
      W(1)=S(I2C)
      W(2)=S(I2)
      GO TO 280
      210  I3=I+2
      I3C=NT-I3
      IF (I3C) 240,230,220
      220  W(1)=S(I3C)
      W(2)=S(I3)
      GO TO 280
      230  W(1)=S(
      W(2)=S(
      I3=I+2
      I3C=NT-I3
      IF (I3C) 240,230,220
      240  W(1)=S(I3C)
      W(2)=S(I3)
      GO TO 280
      140  IF (JLAST) 310,310,150
      150  IF (JLAST) 310,310,150
      JJUJEIP+1
      ILAST=IL-JJ
      DO 160 I=J,ILAST,1DIF
      KLAST=KL+I

```

```

250   I3C=-13C          IF (M2MT) 380,370,370
      M3(1)=-S(I3C)
      W3(2)=S(I3C)
      GO TO 280
260   W3(1)=-1.
      W3(2)=0.
      GO TO 280
270   I3CC=NNT-13CC    N2VNT=N2/NT
      I3CC=I3CC
      M3(1)=-S(I3CC)
      W3(2)=-S(I3CC)
      DO 290 1=J,JLAST,1DIF
      KLAST=JL-J
      KLAST-KL-1
      DO 290 K=1,KLAST,2
      K1=K+RBIT
      K2=K1-RBIT
      K3=K2-RBIT
      R=A(K2)*R2(1)-A(K2+1)*W2(2)
      T=A(K2)*R2(2)+A(K2+1)*W2(1)
      A(K2)=A(K)-R
      A(K)=A(K)+R
      A(K2+1)=A(K+1)-T
      A(K+1)=A(K+1)+T
      R=A(K3)*R3(1)-A(K3+1)*W3(2)
      T=A(K3)*R3(2)+A(K3+1)*W3(1)
      AWR=A(K1)*W1(1)-A(K1+1)*W1(2)
      AWI=A(K1)*W1(2)+A(K1+1)*W1(1)
      A(K3)=AWR-R
      A(K3+1)=AWI-T
      A(K1)=AWR+R
      A(K1+1)=AWI+T
      T=A(K1)
      A(K1)*A(K)-T
      A(K)=A(K)+T
      T=A(K+1)
      A(K+1)=A(K+1)-T
      A(K+1)=A(K+1)+T
      R=-A(K3+1)
      T=A(K3)
      A(K3)=A(K2)-R
      A(K2)=A(K2+1)-T
      A(K3+1)=A(K2+1)+T
      JJJ=J+IP-J
      JLAST=J+JLAST+3
      CONTINUE
      320  CONTINUE
      330  NTSQ=N7*NT
      M3MT=M3-N7
      IP (M2MT) 350,340,340
      340  IG03=1
      N3VNT=N3/NT
      MINN3=NT
      GO TO 360
      350  IG03=2
      N3VNT=1
      NTVN3=NT/N3
      MINN3=N3
      JJD3=NTSQ/N3
      M2NT=M2-NT

```

MODULE: A-1

MONDI II E: A-1

PROGRAM: SHAKE91

```

A(2*I)=C1IM
A(K6)=CNIRE
A(K6+1)=CR1IM
SIS=SI
SIS=SC+C0*SS
50 CO=C0*SC-SIS*SS
K0=NTOT+1
DO 40 I=1,K0,2
K1=NTOT2-I+4
APR1=A(I)-A(K1+1)
APR2=( A(I-1)-A(I) )
AP1IMA(I)+A(K1+1)
AP2IMA(I+1)-A(K1)
A(I)=AP1RE
A(I+1)=AP2RE
A(K1)=AP1IM
A(K1+1)=AP2IM
NTOP=NTOT2+2
NTD0=NTOT-1
A(1)=A(NTOT2+3)
A(2)=A(NTOT2+4)
21 DO 52 I=NTD0,NTOP,2
A(1)=A(I/2)
A(1)=A(I/2)
52 A(I+1)=A(I+3)
CALL FFT(A,L,INV,S,IFSET,IFERR)
DO 20 I=1,NTOT2
20 A(I)=A(I)*FN
DO 10 I=2,NTOT2,2
10 A(I)=-A(I)
RETURN
END
C*****
C SUBROUTINE XMX(X,MX,XMAX,NMAX)
C * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C THIS ROUTINE FIND MAX. VALUE, XMAX, AND NUMBER OF MAX. VALUE, NMAX.
C OF ARRAY X WITH MX NUMBER OF VALUES
C CODED PER B SCHNABEL OCT, 1971
C * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C
DIMENSION X(1)
XMAX = 0.
DO 1 I = 1, MX
XA = ABS(X(I))
IF (XMAX.GT.XA) GO TO 1
NMAX = 1
XMAX = XA
1 CONTINUE
RETURN
END

```

```

SNODEBUG
SNODETALLS
*****
***** SUBROUTINE AMP( N1,IN,INT,LL,LT,XPL,IDAMP,NA,DF)
***** C * * * * * THIS ROUTINE COMPUTES THE AMPLIFICATION SPECTRUM BETWEEN ANY TWO
***** C LAYERS
***** C
***** C N1 = NUMBER OF SOIL LAYERS EXCLUDING ROCK
***** C IN = NUMBER OF SUBLAYER FROM WHICH AMPLIFICATION IS COMP.
***** C INT = SUBLAYER TYPE
***** C 0 - OUTCROPPING LAYER
***** C 1 - LAYER WITHIN PROFILE
***** C LL = NUMBER OF SUBLAYER TO WHICH AMPLIFICATION IS COMP.
***** C LT = SUBLAYER TYPE
***** C 0 - OUTCROPPING LAYER
***** C 1 - LAYER WITHIN PROFILE
***** C DF = FREQUENCY STEPS IN AMP. FUNCTION
***** C NA = CURVE NUMBER IN PLOTTING
***** C IDAMP = IDENTIFICATION
***** C
***** C CODED PER B SCHNABEL FEB. 1971
***** C modified to increase number of sublayers to 50
***** C February 1991
***** C * * * * * THIS ROUTINE COMPUTES THE AMPLIFICATION SPECTRUM BETWEEN ANY TWO
***** C LAYERS
***** C
***** C COMPLEX G, V, PLUS, MINUS
***** C COMPLEX E, F, EE, FF, A, EX, AIN, IP12, AA
***** C CHARACTER*6 ABSIS
***** C DIMENSION IDAMP (27,11),T(200)
***** C COMMON /T0B4/ ST(127,200)
***** C COMMON /SOILA/ IDNT(6),BL(51),GL(51),FACT(51),H(51),R(51),BF(51)
***** C COMMON /CSOIL/ G(51), V(51), PLUS(51), MINUS(51)
***** C COMMON /CG/ ID(27,11)
***** C ABSIS = CYCLES/SEC.
***** C IP12 = CMPLX(0., 6.283185307)
***** C
***** C FREQ = 0.
***** C ST(NA,1) = 1.
***** C DO 191 K = 1,200
***** C E = 1.
***** C FP = 1.
***** C FREQ = FREQ + DF
***** C A = FREQ*IP12
***** C DO 192 IF (K,NE,1) GO TO 192
***** C AIN = E + FF
***** C IF (INT,EQ,0) AIN = 2.*E
***** C 11. EX = CEXP(H(K)*A/V(K))
***** C EE = E*EX
***** C F = FF*EX
***** C E = EE*PLUS(K) + MINUS(K)*F
***** C FF = PLUS(K)*F + MINUS(K)*EE
***** C 191 CONTINUE
***** C IF (IN,NE,NA+1) GO TO 193
***** C
***** C SNODEBUG
***** C SNODETALLS
***** C
***** C AIN = B + FF
***** C IF (INT,EQ,0) AIN = 2.*E
***** C AA = E + FF
***** C IF (LT,EQ,0) AA = 2.*E
***** C 21. CONTINUE
***** C 19 ST(NA,1) = CABS(AA/AIN)
***** C DO 23 I = 1,200
***** C 23 T(I) = DF*FLOAT(I-1)
***** C AMAX = 0.
***** C WRITE(6,2)
***** C DO 22 I = 1,200
***** C 22 IF (ST(NA,I) .LT. AMAX) GO TO 22
***** C TMAX = T(I)
***** C AMAX = ST(NA,I)
***** C
***** C 22 CONTINUE
***** C IF (NA,LT,9) NA=NA+1
***** C PERIOD = 1./TMAX
***** C IF (TMAX,LT,.0001) WRITE(6,1001) AMAX, TMAX
***** C IF (TMAX,GT,.0001) WRITE(6,1001) AMAX, TMAX, PERIOD
***** C IF (KPL,EQ,0) RETURN
***** C WRITE(6,1000)
***** C N = NA-1
***** C
***** C RETURN
***** C
***** C 1 FORMAT(1X,F10.4,3X, P10.4)
***** C 2 FORMAT(/2X, FREQUENCY, AMPLITUDE')
***** C 1000 FORMAT(3H1) PLOT OF AMPLIFICATION SPECTRA /
***** C 1001 FORMAT(25H MAXIMUM AMPLIFICATION = F6.2/
***** C 1 25H FOR FREQUENCY = F6.2, 7H SEC. /
***** C 1 25H PERIOD = F6.2, 5H SEC. )
***** C
***** C END
***** C *****
***** C SUBROUTINE UTPIK, DPTH,LS,LH,X,S,INV
***** C *****
***** C THIS ROUTINE TRANSFERS THE VALUES IN AX(LL, ) INTO THE TIME DOMAIN
***** C IN X( ), TRANSFERS RESULTS TO OUTPUT FILE
***** C
***** C RK = 5 TABULATE MAX. ACC.
***** C 6 PRINT MAX ACC. SEPARATELY
***** C DPTH = DEPTH OF LAYER
***** C X(1 ) = OBJECT MOTION
***** C AX(LL, ) = COMPUTED MOTION
***** C LS = COMPUTED MOTION NUMBER
***** C 0 IF OBJECT MOTION
***** C LH = SUBLAYER NUMBER
***** C LT = SUBLAYER TYPE
***** C 0 - OUTCROPPING
***** C 1 - INSIDE
***** C S, INV SCRATCH ARRAYS
***** C
***** C CODED PER B SCHNABEL OCT. 1970
***** C MODIFIED PBS AUG. 1971
***** C modified to increase number of layers to 50
***** C
***** C CHARACTER*6 TITLE, IDNT
***** C COMPLEX SAVE
***** C COMPLEX X, AX
***** C
***** C

```

MODULE: B-1

```

DIMENSION XR(8)
DIMENSION X(300),AX(3,270),S(70),INV(10)
COMMON /SOILA/TINT(6),BL(51),GL(51),FACT(51),H(51),R(51),SF(51)
COMMON /BQ/MFOLD,MAD,TITLE(5),DT,MA,MMA,DP,MX
C
FREQ = 0.
SFX = 0.
SXX = 0.
C TRANSFORM VALUES IN X OR IN AX INTO THE TIME DOMAIN
DO 24 I = 1, MFOLD
 1P (LS, EQ, 0) GO TO 241
  SAVE = X(I)
  X(I) = AX(ILS, I)
  AX(ILS, I) = SAVE
  AXA = CABS(X(I))
  SXX = SXX + XA*XAXA
  SFX = SFX + XA*FREQ*XAXA
  FREQ = FREQ + DF
24 CONTINUE
  SFX = SFX/SXX
  CALL RPSN(X,MX,INV,S,IFERR,2)
  CALL XK(X,MA,XMAX,NMAX)
  TMAX = DT*FLOAT(NMAX-1)
  XEND = 0.
  N = MA/20
  NN = 8*N
  DO 25 I = N,NN
    XABS = REAL(X(I))
    XABS = ABS(XABS)
    IF (XABS.GT.XEND) XEND = XABS
    XABS = AINAG(X(I))
    XABS = ABS(XABS)
    IF (XABS.GT.XEND) XEND = XABS
25 CONTINUE
  XEND = XEND/XMAX
  SAVE OUTPUT
  NN = 4
  NCARDS=MA/8
  NC = NCARDS
  IF (K2 EQ 0) NC = 0
  IF (KK.EQ.5) GO TO 252
  IF (KK.EQ.6) GO TO 253
  IF (LT.EQ.0) WRITE(6,2000) LH,(IDNT(I),I=1,6)
  IF (LT.EQ.1) WRITE(6,2002) LH,(IDNT(I),I=1,6)
  IF (LT.EQ.6) WRITE(6,2005) SFX
  WRITE(6,2003) XMAX,TMAX
  WRITE(6,2001) DPTH,XMAX,TMAX,SFX,XEND,NC
252 IF (KK.EQ.6.AND.LT.EQ.0) WRITE(6,2010) DPTH,XMAX,TMAX,SFX,XEND,NC
  IF (K2 EQ 6) GO TO 262
  WRITE(7,2006) XMAX,(TITLE(I),I=1,5)
  IF (LT.EQ.1) WRITE(7,2002) LH,(IDNT(I),I=1,6)
  IF (LT.EQ.0) WRITE(7,2000) LH,(IDNT(I),I=1,6)
  DO 26 I = 1,NCARDS
    K = 0
    DO 261 J = N,NN
      XR(K) = REAL(X(J))
      K = K + 1
      XR(K) = AIMAG(X(J))
      XR(K) = ATIMAG(X(J))
      WRITE(7,2609) (XR(J),J=1,8),I
      IF (K2 .EQ. 2) WRITE(6,2019) (XR(J),J = 1,8),I
      IF (K2 .EQ. 0) RETURN
      NN = 4 + NN
      N = N + 4
26 CONTINUE
262 CALL RFFTK(MX,INV,S,IFERR,2)
      IF (LS, EQ, 0) RETURN
      DO 27 I = 1, MFOLD
        SAVE = AX(ILS, I)
        AX(ILS, I) = X(I)
        X(I) = SAVE
27 RETURN
C
C 2000 FORMAT(43H ACCELERATION VALUES AT OUTCROPPING LAYER 13,3H - 6A6)
C 2001 FORMAT(5X,6HOUTCR, F15.1,F15.5,2F15.2,F20.3,I20)
C 2010 FORMAT(5X,6HITIN F15.1,F15.5,2F15.2,F20.3,I20)
C 2002 FORMAT(42H ACCELERATION VALUES AT THE TOP OF LAYER 13,3H - 6A6)
C 2003 FORMAT(1/15H MAX. ACC. = F9.6,11H AT TIME = F6.3, 5H SEC. /)
C 2005 FORMAT(1/26H MEAN SQUARE FREQUENCY = F10.2/)
C
C **** END ****
C
C ***** SUBROUTINE REDUCE(IFR,X,AX,LL)
C * * * * * THIS ROUTINE INCREASES TIME INTERVAL AND REDUCES NUMBER OF VALUES
C * * * * *
C
C 1FR = DIVIDING FACTOR ON LENGTH OF RECORD
C C   MULTIPLICATION FACTOR ON TIME STEP
C C   MUST BE A POWER OF 2.
C C   DT = TIMESTEP IN SEC.
C C   DF = FREQUENCY STEP IN C/SBC.
C C   MA = NUMBER OF POINTS USED IN FOURIER TRANSFORM
C C   X = FOURIER TRANSFORM OF OBJECT MOTION
C C   AX = FOURIER TRANSFORM OF COMPUTED MOTIONS
C
C C
C C CODED BY PER B. SCHNABEL DEC. 1970.
C C MODIFIED SEPT. 1971
C C
C C   CHARACTERISTICS
C C   DT = TIMESTEP IN SEC.
C C   DF = FREQUENCY STEP IN C/SBC.
C C   MA = NUMBER OF POINTS USED IN FOURIER TRANSFORM
C C   X = FOURIER TRANSFORM OF OBJECT MOTION
C C   AX = FOURIER TRANSFORM OF COMPUTED MOTIONS
C
C C
C C DIMENSION X( 68 ), AX( 3, 64 ), LL( 3 )
C C COMMON /BQ/ MFOLD,MA2,TITLE(5),DT,MA,MMA,DF,MX
C C COMMON//PRCUT// NCUT, NZERO
C
C F1 = .5/DT
C FR = FLOAT(IFR)
C DT = ID*FR
C MA = MMA/IFR
C MMA = MMA/IFR
C MA2 = MA + 2
C MFOLD = MA2/2
C
C

```

MODI II E: B-1

PROGRAM: SHAKE91

MODULE: B-1

MODUL E: B-1

PROGBAM: SHAKE91

```

192 DO 11 L = 1,3
  IF (K.NE.LL(L)) GO TO 11
  C AMPLIFICATION FACTOR FOR SUBLAYER WITHIN PROFILE
  C AA(L) = E + FF
  C AMPLIFICATION FACTOR FOR OUTCROPPING SUBLAYER
  IF (LT(L).EQ.0) AA(L) = 2.*E
11 CONTINUE
  EX = CEXP(H(K)*A/V(K))
  BE = S*EX
  P = FF/EX
  E = BE+PLUS(K) + MINDS(K)*P
  FF = PLUS(K)*F + MINDS(K)*EE
191 CONTINUE
  IF (IN.NE.N1+1) GO TO 193
  AIN = E + FF
  IF (INT.BG.0) AIN = 2.*E
193 DO 21 L = 1,3
  IF (LL(L).NE.N1+1) GO TO 21
  AA(L) = E + FF
  IF (LT(L).EQ.0) AA(L) = 2.*E
21 CONTINUE
  DO 23 L = 1,3
  IF (LL(L).GT.0) AX(L,I) = X(I)*AA(L)/AIN
23 CONTINUE
19 CONTINUE
  RETURN
END
C*****SUBROUTINE CSOIL(N1)
C*****CHARACTER*6 TITLE, IDNT, ID
C THIS ROUTINE CALCULATES THE COMPLEX SOIL PROPERTIES AND TRANSFER
C FUNCTIONS FOR THE LAYERS
C
C N    = NUMBER OF SOIL LAYERS
C BL   = RATIO OF CRITICAL DAMPING
C GL   = SHEAR MODULUS
C R    = DENSITY
C G    = COMPLEX SHEAR MODULUS
C V    = COMPLEX WAVE VELOCITY
C PLUS = COMPLEX TRANSFER FUNCTION
C MINDS = COMPLEX TRANSFER FUNCTION
C
C COMPLEX G, V, PLUS, MINUS
C COMPLEX E, F, BE, A, AH, IP12, AB, AF, EX, AI
C
C DIMENSION AE(2), AP(2)
C DIMENSION X(1), AX(2,1), S(1), INV(1)
C DIMENSION LL(2), LGS(2), LPCH(2), LNV(2)
C
C COMMON /SOILA/ IDNT(6),BL(51),GL(51),FACT(51),H(51),R(51),BF(51)
C COMMON /SOILB/ FAC(51),ML(51),TP(51),DEPTH(51),WEIGHT(51)
C COMMON /CSOIL/ G(51), V(51), PLDS(51), MINUS(51)
C COMMON /EQ/ MFOLD,MA2,TITLE(5),DT, MA , MMA, DF, MX
C COMMON /COG/ ID127,11
C COMMON /FCUT/ NCUT, NZERO
C COMMON /TIME/ T(9)
C
C ABSIS = TIME IN SEC
C IP12 = CMPLX(0.,6.283185307)
C GT = 32.2
C AX(2,1) = 0.
C AX(3,1) = 0.
C
C STARTING AT THE SURFACE THE STRAIN IS COMPUTED SUCCESSIVELY DOWNWARDS
C FOR EACH FREQUENCY
C DO 1 I=2,NCUT
C   E = AX(1,I)/2.
C   F = E
C
C
194 DO 11 I = 1,N
  G1=BL(1)*GL(1)*SQT(1.-BL(1)*BL(1))
  GREAL=G1*(1.-2.*BL(1)*BL(1))
  G1=CQRT(GREAL,GIMAG)
  V(1)=CQRT(G(1))/R(1)
11 CONTINUE
  DO 2 I = 1,N1
    J = I + 1

```

```

FREQ = FREQ + DF
AH = AI/FREQ
A = FREQ*IP12
DO 11 K = 1, N1
DO 12 L = 1, 2
  IF (K, NE, LL(L)) GO TO 12
  AB(L) = E/V(K)
  AF(L) = F/V(K)
12 CONTINUE
EX = CEXP(H(K)*A/V(K))
E = EX-EX
F = F-EX
EB = E*PLUS(X) + MINUS(X)*F
F = F*PLUS(X) + MINUS(X)*E
E = EB
11 CONTINUE
DO 13 L = 1, 2
  IF (LL(L), NE, N1+1) GO TO 13
  AB(L) = E/V(N1+1)
  AF(L) = F/V(N1+1)
13 CONTINUE
DO 14 L = 1, 2
  IF (LL(L), GT, 0) AX(LL+1, L) = (AB(L) - AF(L))*AH
14 CONTINUE
1 CONTINUE
DO 2 I = 1, MFOLD
  2 AX(1, I) = X(1)
  DO 3 L = 1, 2
    IF (LL(L), EQ, 0) GO TO 3
    X(I) = 0.
    DO 31 I=2, NCUT
      31 X(I) = AX(LL+1, I)
      IF (NCUT, EQ, MFOLD) GO TO 33
      DO 34 I=1-NZERO, MFOLD
        X(I) = COMPLEX(0., 0.)
34 CONTINUE
33 CONTINUE
CALL RFSN(X, MX, INV, S, IFERR, -2)
DO 32 I = 1, MFOLD
  AA(I, 2*I-1) = REAL(X(I)) * 1.00
  32 AA(LL, 2*I) = AIMAG(X(I)) * 1.00
3 CONTINUE
C
DO 4 I = 1, MFOLD
  4 X(I) = AX(1, I)
  COMPUTE STRESS IF WANTED AND SAVE COMPUTED RESPONSES
  DO 5 L = 1, 2
    IF (LL(L), EQ, 0) GO TO 5
    NVAL = INV(L)
    IF (INV, LE, 0) NVAL = MNRA
    IF (INV, GT, MA) NVAL = MA
    IF (INV, GT, 2049) NVAL = 2049
    DO 51 I = 1, 5
      51 ID(L, I) = TITLE(I)
      N = LL(L)
      ID(L, 6) = 'STRAIN'
      IF (LGS(L), EQ, 0) GO TO 53
      ID(L, 6) = 'STRESS'
      DO 52 I = 1, NVAL
        52 AA(L, I) = GI(N)*AA(L, I)/100
      53 IF (LPCH(L), EQ, 0) GO TO 54

```

```

SNOFLOATCALLS
SNODEBUG
C ..... SUBROUTINE SHAKTI(X,AX,AA,S,INV)
C ..... INTEGER TP
CHARACTER*6 TITLE, ID, IDNT, IDAMP, IBLANK
CHARACTER*60 ASSIS, ABSPR, ABSCL
CHARACTER*80 OHEAD
CHARACTER*30 FINPQ
COMPLEX X, AX
COMPLEX G, V, PLUS, MINUS

C DIMENSION LL(3), LT(3), LNSW(3)
C DIMENSION LL(2), LLOG(2), LLFL(2), LNV(2), S(2)
DIMENSION X(3,0), AX(3,270), AA(2,550), S(70), INV(70)
DIMENSION LL(15), LTS(15), LPS(15), LP(3)
DIMENSION TDAMP(27,11), MM4(3)

C COMMON /EQ/ MFOLD, MA2, TITLE(5), DT, MA, MMA, DF, MX
COMMON /SOILA/ IDNT(6), BL(51), GL(51), FACT(51), H(51), R(51), BF(51)
COMMON /SOILB/ FAC(51), WL(51), TP(51), DEPTH(51), WEIGHT(51)
COMMON /SOILC/ MSOIL, MWL
COMMON /CG/ CG(51), V(51), PLUS(51), MINUS(51)
COMMON /JSLCK/ JSL, FINPQ
COMMON /PCUT/ NCUT, NZERO
COMMON /TIME/ T(19)
C originally coded by Per Scinabel in 1970-71
C modified by Sun, Dirrim & Idriss in 1990-91 to
C increase number of layers to 50;
C renumber the Options & other cleanup
C

IBLANK = '
ABSIN = 'TIME IN SECONDS'
ABSCL = 'CYCLES/SEC'
ABSPR = 'PERIOD IN SEC.'

C * * * * *
C DO 102 I = 1, 3
LL(I) = 0
102 LT(I) = 0
DO 103 L = 1, 9
DO 103 I = 1, 11
ID(L,I) = IBLANK
NP = 0
NR=0
NP=0
NA = 1

C * * * * *
C New Option 5 -- # of iterations & ratio of unif. strain/max strain
C..... 4 WRITE(6,4007) KK
KK = -1
C..... READ(5,4000) KS, ITMAX, PRMUL
ITMAX(6,4001) ITMAX, PRMUL
LL(1) = 1
LT(1) = 0
JIS = 0
WRITE(*,2029)
2029 FORMAT(/)
DO 41 L = 1, ITMAX
IF (KK .EQ. 0) STOP
IF (KK .EQ. 1) AND. KK.LE.11) WRITE(*, 24) KK
READ(5, 1000, END=999) KK
IF (KK .EQ. 0) STOP

C ***** Options *****
WRITE(*,23) KK
IF (KK .EQ. 1) GO TO 8
IF (KK .EQ. 2) GO TO 2
IF (KK .EQ. 3) GO TO 1
IF (KK .EQ. 4) GO TO 3
IF (KK .EQ. 5) GO TO 4
IF (KK .EQ. 6) GO TO 5
IF (KK .EQ. 7) GO TO 16
IF (KK .EQ. 8) GO TO 6
IF (KK .EQ. 9) GO TO 9
IF (KK .EQ. 10) GO TO 15
IF (KK .EQ. 11) GO TO 13
C * * * * *
C New Option 3 -- input motion
C..... 1 WRITE(6,1002) KK
NSN = 0
GO TO 101
C * * * * *
C New Option 2 -- data for Soil Profile
C..... 2 WRITE(6,2002) KK
CALL SOILLIN(NL)
NSN = 1

C FIND FUNDAMENTAL PERIOD OF DEPOSIT FROM AVERAGE SHEAR WAVE VELOCITY
C AND FROM THE PERIOD WHICH GIVE MAXIMUM AMPLIFICATION
SH = 0.
N = N1 + 1
SHV = 0.
DO 21 I = 1, N1
SH = SH + H(I)
21 SHV = SHV + H(I)*SQRT(GL(I)/R(I))
VSAV = SHV/SH
TT = 4.*SH/VSAV
WRITE(6,4006) TT, VSAV
DFA = .01/TT
CALL AMP(IN,N,1,1,0,0, IDAMP, 9, DFA)
GO TO 101
C * * * * *
C New Option 4 -- sublayer for input motion
C..... 3 WRITE(6,3002) KK
READ(5,1000) IN, INT
IF (INT .EQ. 0) WRITE(6,3001) IN
IF (INT .NE. 0) WRITE(6,3002) IN
GO TO 101
C * * * * *
C New Option 5 -- # of iterations & ratio of unif. strain/max strain
C..... 4 WRITE(6,4007) KK
READ(5,4000) KS, ITMAX, PRMUL
ITMAX(6,4001) ITMAX, PRMUL
LL(1) = 1
LT(1) = 0
JIS = 0
WRITE(*,2029)
DO 41 L = 1, ITMAX
IF (KK .EQ. 1) AND. KK.LE.11) WRITE(*, 24) KK
READ(5, 1000, END=999) KK
IF (KK .EQ. 0) STOP
IF (KK .EQ. 1) AND. KK.LE.11) WRITE(*, 24) KK
READ(5, 1000, END=999) KK
IF (KK .EQ. 0) STOP

```

```

      WRITE(*,202B) L          ITERATION NUMBER , I2
2028 FORMAT(1H-,12X,19H)
      IF (IN.EQ.1) GO TO 412
      CALL MOTION(N1,IN, INT, LL, LT, X, AX)
      IF (L .EQ. ITMAX) JIS = 1
      412 CALL STRT(L, N1, DGNM, PRNU, X, AX, AA, S, INV)
      C   IF (IDMAX.LT.100) GO TO 411
      411 CONTINUE
      C
      C FIND FUNDAMENTAL PERIOD OF DEPOSIT FROM AVERAGE SHEAR WAVE VELOCITY
      C AND FROM THE PERIOD WHICH GIVE MAXIMUM AMPLIFICATION
      C
      411 SH = 0.
      N = N1 + 1
      SHV = 0.
      DO 43 I = 1, N1
      SH = SH + H(I)
      43 SHV = SHV + H(I)*SQR(GL(I)/R(I))
      VSAY = SHV/SAY
      TT = 4.*SH/VSAY
      WRITE(6,4006) TT, VSAY
      DFA = .01/TT
      CALL AMP(NL,N ,1,1,0,0, IDAMP, 9, DFA)
      C
      IF (KS .EQ. 0) GO TO 101
      C SAVE NEW SET OF SOIL DATA BASED ON NEW PROPERTIES
      WRITE(7,4003) MSOIL,N,MFLD,(IDNT(I),I=1,6),(TITLE(I),I=1,4)
      DO 44 I = 1,N1
      44 WRITE(7,4004) I,TP(I), H(I), GL(I), BL(I), WL(I), FAC(I), BF(I)
      WRITE(7,4005) N,GL(N),BL(N),WL(N)
      WRITE(7,4006) N,GL(N),BL(N),WL(N)
      GO TO 101
      C * * * * * sublayers for which acceleration TH are calculated
      C New Option 6 -- sublayers for which acceleration TH are calculated
      C
      5 WRITE(6,5003) KK
      READ(5,1000) (LL(L),L=1,15)
      READ(5,1000) (LT5(L),L=1,15)
      READ(5,1000) (LP5(L),L=1,15)
      WRITE(6,5002) FINPEQ,(IDNT(I),I=1,6)
      I = 0
      DO 51 LOOP = 1,5
      DO 511 L = 1,3
      511 I = I + 1
      LL(L) = LL5(I)
      LT(L) = LT5(I)
      LP(L) = LP5(I)
      C
      IF (LL(I).EQ.0) GO TO 101
      511 CONTINUE
      C
      CALL MOTION(N1,IN, INT, LL, LT, X, AX)
      DO 512 L = 1,3
      N = LL(L)
      K = L
      IF (N.EQ.0) GO TO 101
      IF (N.LE.N1) DPTH = DEPTH(NU) - H(N)/2.
      IF (N.GT.N1) DPTH = DEPTH(N-1) + H(N-1)/2.
      CALL UTPR(KK,DPTH,K,LP(L),LL(L),LT(L),X,AX,S,INV)
      512 CONTINUE
      C
      GO TO 101
      C New Option 8 -- save time history of object motion
      C
      6 WRITE(6,6002) XK
      READ(5,1000) K2
      LS = 0
      LN = IN
      IF (K2.EQ.3) WRITE(6,6000) LN
      IF (K2.EQ.1) WRITE(6,6001) LN
      62 CALL UTPR(KK,DPTH,LS,K2,LN,INT ,X,AX,S,INV)
      GO TO 101
      C * * * * *
      C Option not used
      C
      7 WRITE(6,7002) XK
      READ(5,7001) LL1,LT1,XP,DTNEW
      IF (DTNEW.LT..001) DTNEW=DT
      IF (LL1 .EQ. 0) GO TO 71
      C CHECK IF MOTION IN SUBLAYER LL1 IS IN AX()
      DO 72 I = 1,3
      IF (LL1.NE.LL(I)) .OR. LT1.NE.LT(I) GO TO 72
      L = I
      GO TO 720
      72 CONTINUE
      LL1(I) = LL1
      LT1(I) = LT1
      L = 1
      CALL MOTION(NL,IN, INT, LL, LT, X, AX)
      720 DO 75 I = 1,MFOLD
      75 X(I) = AX(LL,I)*XF
      NEW = LL(L)
      INT = LT(L)
      GO TO 73
      71 DO 74 I = 1,MFOLD
      74 X(I) = X(I)*XF
      NEW = IN
      73 IN = NEW
      WRITE(6,7000) NEW , XF,DT, DTNEW
      IF (IN.NE.1) GO TO 76
      DO 77 II=1,MFOLD
      AX(1,II)=X(1)*XF
      77 CONTINUE
      76 CONTINUE
      DT = DTNEW
      DF = 1./ (MA*DT)
      GO TO 101
      C * * * * *
      C New Option 1 -- dynamic soil properties
      C
      8 WRITE(6,8001) XK
      CALL CG
      GO TO 101
      C * * * * *
      C New Option 9 -- response spectrum
      C
      9 WRITE(6,9002) XK
      READ(5,1000) LL1, LT1
      IF (LL1.NE.0) GO TO 171
      WRITE(6,9001)
      LS = 0
      LN = IN
      GO TO 173
      171 DO 170 I = 1,3

```

MODULE: C-1

MODUL E: C-1

PROGRAM: *SHAKE91*

```

T(N) = FLOAT(1-1)*DT
136 CONTINUE
N = 0
M = NN/2
DO 130 I = 1,M
N = N + 1
AA(INP,N) = REAL(X(I))
N = N + 1
AA(INP,N) = AIMAG(X(I))
130 CONTINUE
IF (NSKIP.EQ.1) GO TO 135
N = 0
DO 134 I = 1,NN ,NSKIP
N = N + 1
AA(INP,N) = AA(INP,I)
134 CONTINUE
135 CALL RFFT(X,MX,INV,S,IFERR,2)
DO 131 I = 1,5
131 ID(NP,I) = TITLE(I)
DO 132 I = 6,11
ID(NP,I) = IDNT(I-5)
IF (NSIN.EQ.0) ID(NP,I) = 1BLANK
132 CONTINUE
IF (NSW.EQ.1) GO TO 101
NP = 0
GO TO 101
C * * * * *
C New Option 10 -- amplification spectrum
C..... .
15 WRITE(6,1502) KK
READ(5,1400) LIN, LINT, LOUT, LOTP, DFA, (IDAMP(NA,I), I=1,8)
KP = 2
WRITE(6,1401) LIN, LOUT
IF (LOUT.EQ.0) WRITE(6,1403)
CALL AMP(N1, LIN, LINT, LOUT, LOTP, KP, IDAMP, NA, DFA)
GO TO 101
C * * * * *
C Option not used
C..... .
15 WRITE(6,1501) KK
DO 151 L = 1,2
READ(5,1500) LLL(L), LGGS(L), LLPC(L), LLPL(L), LNVL(L), SK(L),
  1 (ID(L,I), I=1,11)
IF (LLL(L).GT.0) WRITE(6,1501) LLL(L), SK(L), (ID(L,I), I=7,11)
151 CONTINUE
DO 152 L = 1,3
152 LT(L) = 0
LL(3) = 0
LL(2) = 0
LL(1) = 1
CALL MOTION(N1, IN, INT, LL, LT, X, AX)
CALL STRAIN(LL, LGGS, LLPC, LLPL, LNVL, X, AA, NL, S, INV)
DO 153 I = 1,3
153 LL(I) = 0
GO TO 101
C * * * * *
C 23 FORMAT(5X,'option NO. ',I5,
  24 FORMAT(5X,'option NO. ',I5,
1000 FORMAT(15I5)

```

```

1 6H LAYER IS /21H SCALE FOR PLOTTING F10.4/ 15H IDENTIFICATION
2 3H - 5A6.6X1)
1502 FORMAT(1/16H1**** OPTION I3,
1 5BH *** COMPUTE AMPLIFICATION FUNCTION
1601 FORMAT(1/16H1**** OPTION I3,
1 5BH *** COMPUTE STRESS/STRAIN HISTORY
) END
999 STOP
C*****
SUBROUTINE START (IT,NL,DGMAX,PNU1,X,AX,AA,SF,INV)
C THIS ROUTINE CALCULATES STRAIN IN THE MIDDLE OF EACH LAYER AND FIND
C NEW SOIL PROPERTIES COMPATIBLE WITH THE STRAINS
C
C IT      = ITERATION NUMBER
C NL     = NUMBER OF LAYERS EXCLUDING ROCK
C DGMAX  = MAX ERROR IN SOIL PARAMETERS B OR G IN PERCENT
C X      = OBJECT MOTION
C AX(1, ) = ACCELERATION VALUES AT THE SURFACE
C AX(2, ) = INCIDENT WAVE-COMPONENT
C AX(3, ) = REFLECTED WAVE-COMPONENT
C PRMUL  = RATIO EPP. STRAIN/MAX. STRAIN
C CODED FOR B SCHNAEBEL OCT. 1970
C MODIFIED PBS SEPT. 1971
C
C * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C INTEGER ITP
CHARACTER*6 TITLE, IDNT
CHARACTER*30 FINPQ
COMPLEX IP12, EX, E, EE, FF
COMPLEX X, AX
COMPLEX G, V, PLUS, MINUS
C
DIMENSION TMX(51), ENMAX(51), STR(51)
DIMENSION X(68), AX(3, 64), SF(10), INV(10), ratic(51)
COMMON /EG/ MFOLD, MA2, TTITLE(5), DT, MA , MM, DF, MK
COMMON /SOIL/ IDNT(6), BE(51), GL(51), PACT(51), H(51), R(51), BF(51)
COMMON /SOILB/ PAC(51), WL(51), TP(51), DEPTH(51), WEIGHT(51)
COMMON /SOILC/ MSOTL, MM
COMMON /SOILDG/ S(27,20), AS(27,20), BS(27,20), NV(27)
COMMON /CSOTL/ G(51), V(51), PLUS(51), MINUS(51)
COMMON /TSICK/ JIS, FINPQ
COMMON/FRCTU/ NCUT, NZERO
C
DO 43 I = 1, MFOLD
  AA(1, I) = REAL(X(1))
  43 AA(2, I) = AIMAG(X(1))
  DO 1 I = 1, MFOLD
    AX(2, I) = AX(1, I)/2.
    1 AX(3, I) = AX(2, I)
    PT2=6.283185307
    IP12=CMPLX(0., PI2)
    GT = 32.2
    DO 2 K = 1, NL
      2 WRITE(*,2029) K
      FREQ = 0.
      X(1) = 0.

```

MODULE: C-1

MODULE C-1

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MODULE: C-1

```

      H(J) = HL/MLN
      TP(I) = TYPE
14   R(J) = W/GT
      NL = J - 1

C   CALCULATE AVERAGE DEPTH AND TOTAL PRESSURE IN EACH LAYER
C
      W1 = WL(1)
      IF (MWL .EQ. 1) W1 = WL(1) - WW
      DEPTH(1) = H(1)/2.
      WEIGHT(1) = H(1)*W1/2.
      SMEAN(1) = WEIGHT(1)*1.*W1/3.
      IF (NL .EQ. 1) GO TO 151
      DO 15 I = 2, NL
      W2 = MWL(I)
      IF (MWL .LT. I+1) W2 = WL(I) - WW
      DEPTH(I) = DEPTH(I-1) + H(I)/2. + H(I-1)/2.
      WEIGHT(I) = WEIGHT(I-1) + H(I)*W2/2. + H(I-1)*W1/2.
      SMEAN(I) = WEIGHT(I)*1.+2.*SKO/3.
15   W1 = W2
      TD = DEPTH(NL) * H(NL)/2.
      IF (MWL .LT. NL-1) WD = DEPTH(MWL) - H(MWL)/2.
      IF (MWL .EQ. NL-1) WD = DEPTH(MWL-1) + H(MWL-1)/2.

C   CALCULATE FACTOR FOR SHEAR MODULUS
      DO 16 I = 1, NL
      IF (TP(I) .EQ. 0) GO TO 16
      IF (BF(I) LT. .01) BF(I) = 2.53 - .45*ALOGIC (WEIGHT(I)*1000.)
      NTP = TP(I)

C-----A total of 13 Gmax material types can be used
C-----FACT(I) = FACT(I)
      FACT(I) = FACT(I) * 1000. * FACT(I)

C-----CONTINUE
      I = NL + 1
      VS = SORTI(GL(I)/R(I))
      WRITE(6,2105) I, GL(I), R(I)
      17 CONTINUE
      I = NL + 1
      VS = SORTI(GL(I)/R(I))
      WRITE(6,2105) I, GL(I), R(I)
      CALL CXSOIL(NL)
1003  FORMAT(1TS, 6A6)
1004  FORMAT(1TS, 6F10.0,F5.0)
2004  FORMAT(1TH, 1X, SOIL CARD NO. 14.17H CUT OF SEQUENCE )
2020  FORMAT(22H NEW SOIL PROFILE NO. I3,5X,1TH IDENTIFICATION 6A6)
2021  FORMAT(1TH NUMBER OF LAYERS ,I20.10X,16HDDEPTH TO BEDROCK, F14.2)
2015  FORMAT( 1 NO. TYPE THICKNESS DEPTH ','
3     ' 1' TOE. PRESS. MODULUS DAMPING UNIT WT. SHEAR VEL' /
4     ' 3' ' (ft) (ft) (kcf) (lbsf) '
4     ' 4' ' (kcf) (lbsf) '
2005  FORMAT(14.15, F10.2, F10.2, F12.0, F8.3, F9.3, F10.1)
2105  FORMAT( 14, 3X, 4IBASE 25X, F15.0, F8.3, F9.3, F10.1)
      RETURN
      END
      $NOFLOATCALLS

```

MODULE: C-1

PROGRAM: SHAKE91

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```
1001 FORMAT(15,F10.2, 11A6)
1002 FORMAT(8F10.3)
1003 FORMAT ('/*****'
     * MATERIAL TYPE NO. ,12,'/
     * *****')
1004 FORMAT(12IX, 'CURVE NO. ',12,':', 10a6/) )
1005 FORMAT(12IX, 'CURVE NO. ',12,':', 10a6/) )
1006 FORMAT(1X, F9.4,4X, F6.3,5X,1X, F9.4,4X, F6.2,5X)
1007 FORMAT(16I5)
2001 FORMAT(15, 11A6)
2002 FORMAT(12F10.4)
3000 FORMAT(53H MODULUS AND DAMPING VALUES ARE SCALED FOR PLOTTING
      3001 FORMAT(55H CURVES FOR RELATION STRAIN VERSUS SHEAR MODULUS AND
      1 BH DAMPING /)
      RETURN
      END
```

APPENDIX B
SAMPLE PROBLEM

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 and Joseph I. Sun

November 1992

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 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. This motion was normalized to a peak acceleration of 0.1g.

The soil types considered for this profile and 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 input data for this sample problem are listed in Table B-1. 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.

Selected results for this sample problem are presented in Table B-2 and in Figs. B-4 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.

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 ratios (for frequencies up to 25 Hz) for the motions calculated at the ground surface divided by those at the base of the soil profile and by those at the rock outcrop are 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 Using Diamond Heights Record as Input Motion

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 @ .lg					
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

Table B-1
Input Data for Sample Problem Using Diamond Heights Record as Input Motion

```

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
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
        1     0     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
Selected Results for Sample Problem Using Diamond Heights as Input Motion

***** 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
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

Table B-2
Selected Results for Sample Problem Using Diamond Heights as Input Motion

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

Table B-2
Selected Results for Sample Problem Using Diamond Heights as Input Motion

1*****		OPTION 2	***	READ SOIL PROFILE	IDENTIFICATION	DEPTH TO BEDROCK	Example -- 150-ft layer; input:Diam 150.00					
NEW SOIL PROFILE NO.	NUMBER OF LAYERS	1	17				DEPTH	TOT. PRESS.	MODULUS	DAMPING	UNIT WT.	SHEAR VEL.
		(ft)	(ft)	(ksf)	(ksf)	(kcf)	(ft)	(ksf)	(kcf)	(kcf)	(fps)	(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				
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.

Table B-2
Selected Results for Sample Problem Using Diamond Heights as Input Motion

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

2 .000730 .000737 .002496 .004583 .001644

3 -.001073 -.000359 -.000486 .000344 .000767

4 -.004086 .000143 .004340 .003943 .002350

5 -.001943 -.007436 -.004493 .000827 .002915

..... INPUT MOTION READ NOT ECHOED.....

234 -.000885 -.000806 -.001026 -.000795 -.001049

235 -.000515 .000588 -.000315 -.000794 -.001081

236 .000800 -.000751 .000743 .000708 .000867

237 -.001011 -.001037 -.001032 -.000992 .001206

238 -.000949 -.000830 -.001072 -.000940 .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

Table B-2

Selected Results for Sample Problem Using Diamond Heights as Input Motion

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

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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 ---->		<---- SHEAR MODULUS ---->		G/Go RATIO
				NEW	USED	ERROR	NEW	
1	2	2.5	.00077	.007	.007	.0	3851.5	.992
2	2	7.5	.00295	.014	.014	.0	3020.0	.960
3	2	15.0	.00634	.023	.023	.0	2803.8	.892
4	2	25.0	.00976	.028	.028	.0	2985.8	.852
5	1	35.0	.01099	.030	.030	.0	3621.7	.933
6	1	45.0	.01403	.035	.035	.0	3540.5	.912
7	1	55.0	.01362	.034	.034	.0	4296.0	.915
8	1	65.0	.01566	.037	.037	.0	4239.8	.903
9	2	75.0	.01356	.034	.034	.0	5402.8	.792
10	2	85.0	.01505	.037	.037	.0	5266.2	.772
11	2	95.0	.01336	.034	.034	.0	6288.4	.795
12	2	105.0	.01413	.035	.035	.0	6203.6	.784
13	2	115.0	.01233	.032	.032	.0	7357.0	.810
14	2	125.0	.01282	.033	.033	.0	7290.6	.803
15	2	135.0	.01115	.030	.030	.0	8570.2	.829
16	2	145.0	.00865	.026	.026	.0	11292.4	.863

Table B-2
Selected Results for Sample Problem Using Diamond Heights as Input Motion

VALUES IN TIME DOMAIN				DEPTH FT	MAX STRAIN PRCNT	MAX STRESS PSF	TIME SEC
LAYER	TYPE	THICKNESS FT					
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.

Table B-2
Selected Results for Sample Problem Using Diamond Heights as Input Motion

EARTHQUAKE - diam.acc						
SOIL DEPOSIT - Example -- 150-ft layer; input:Diam						
LAYER	DEPTH	MAX. ACC.	TIME	MEAN SQ. C/SEC.	FR.	TH SAVED ACC. RECORD
	FT	G	SEC			
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
***** 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. C/SEC.	FR.	TH SAVED ACC. RECORD
	FT	G	SEC			
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

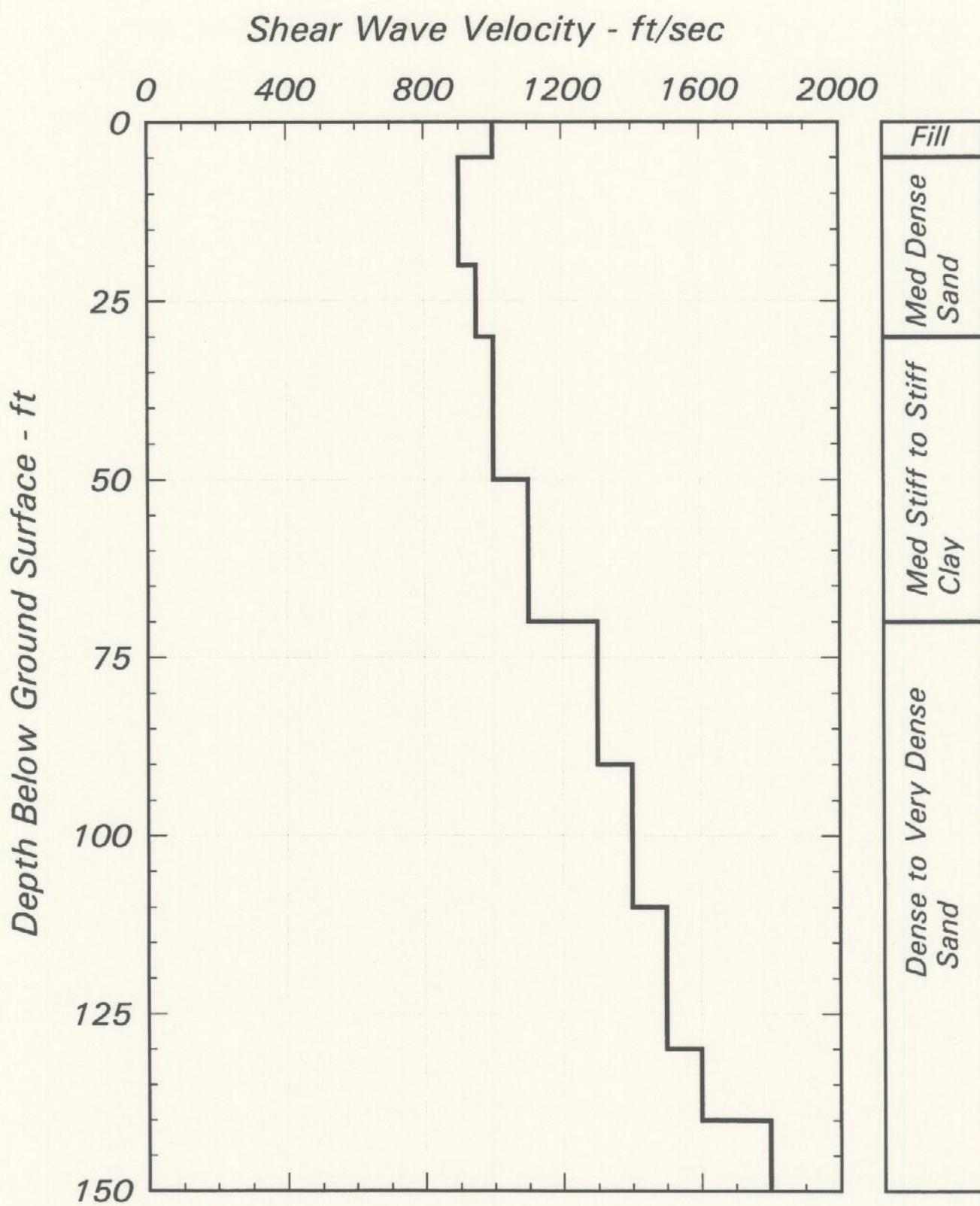


Fig. B-1 Shear Wave Velocities Used for Sample Problem

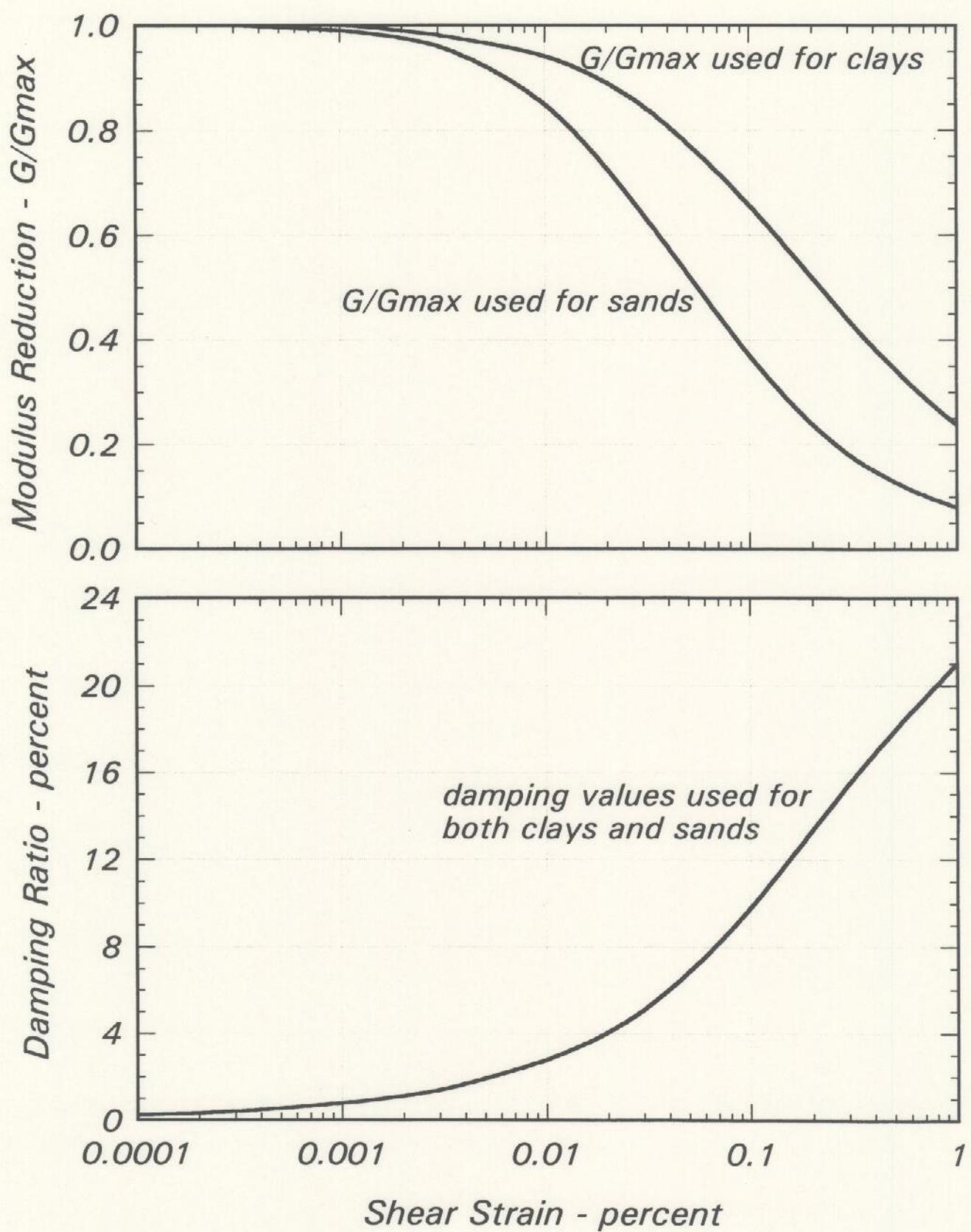
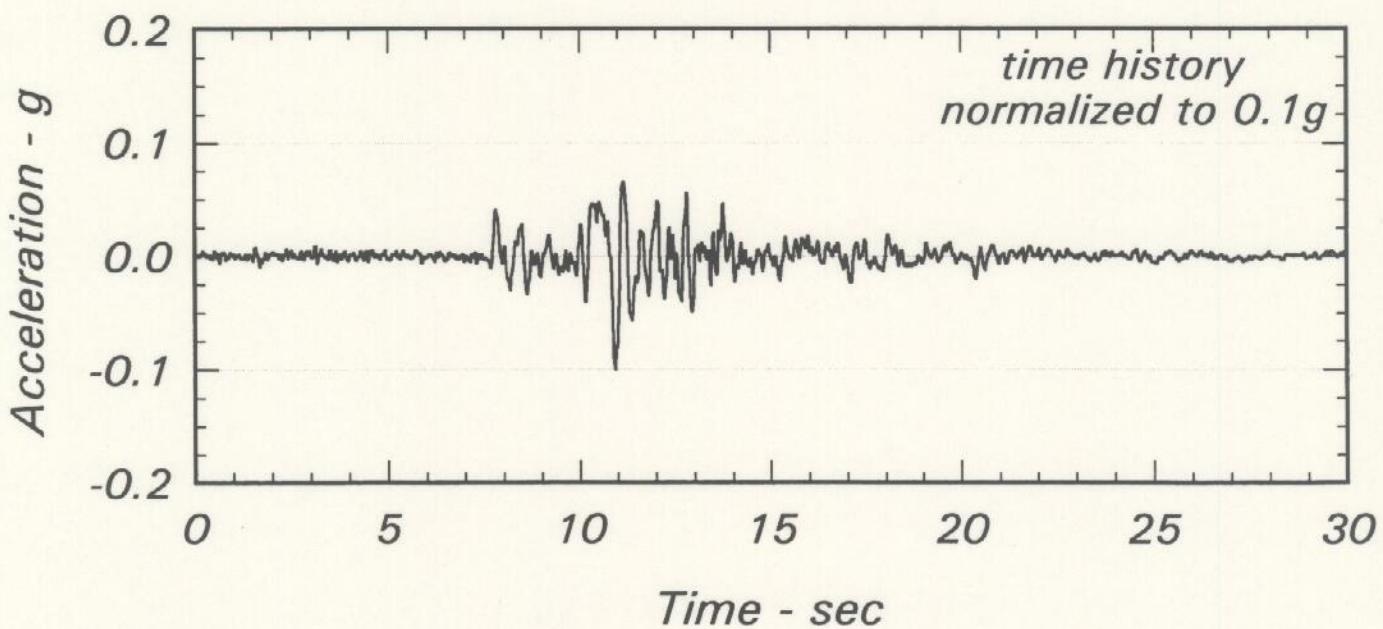
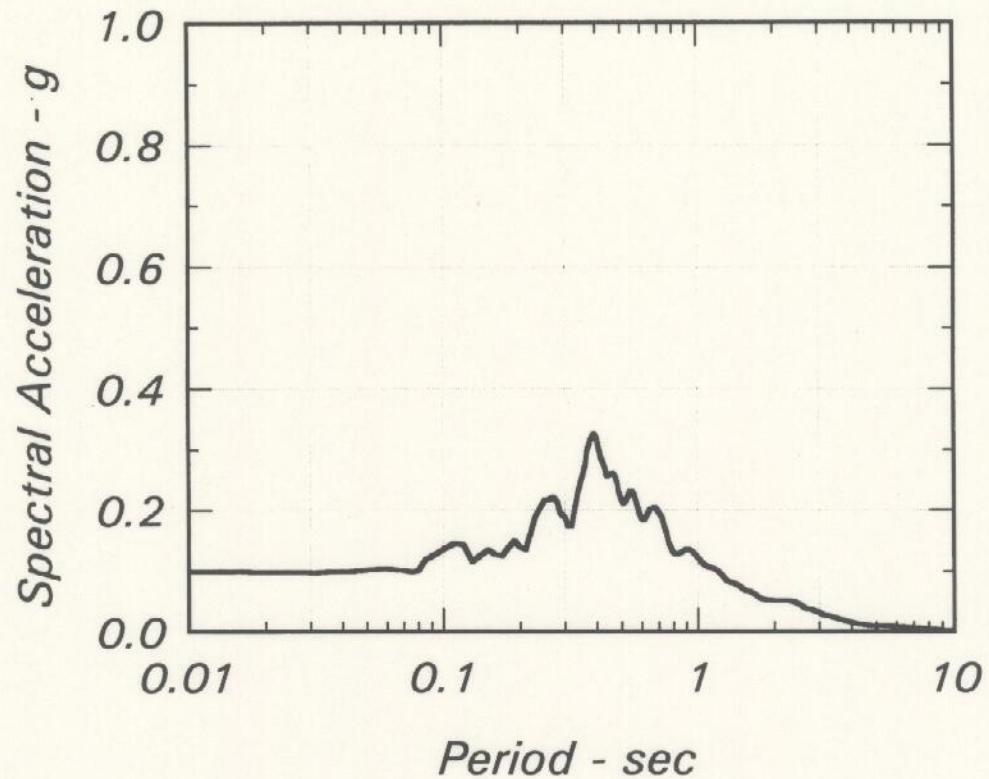


Fig. B-2 Modulus Reduction and Damping Values Used for Sample Problem



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

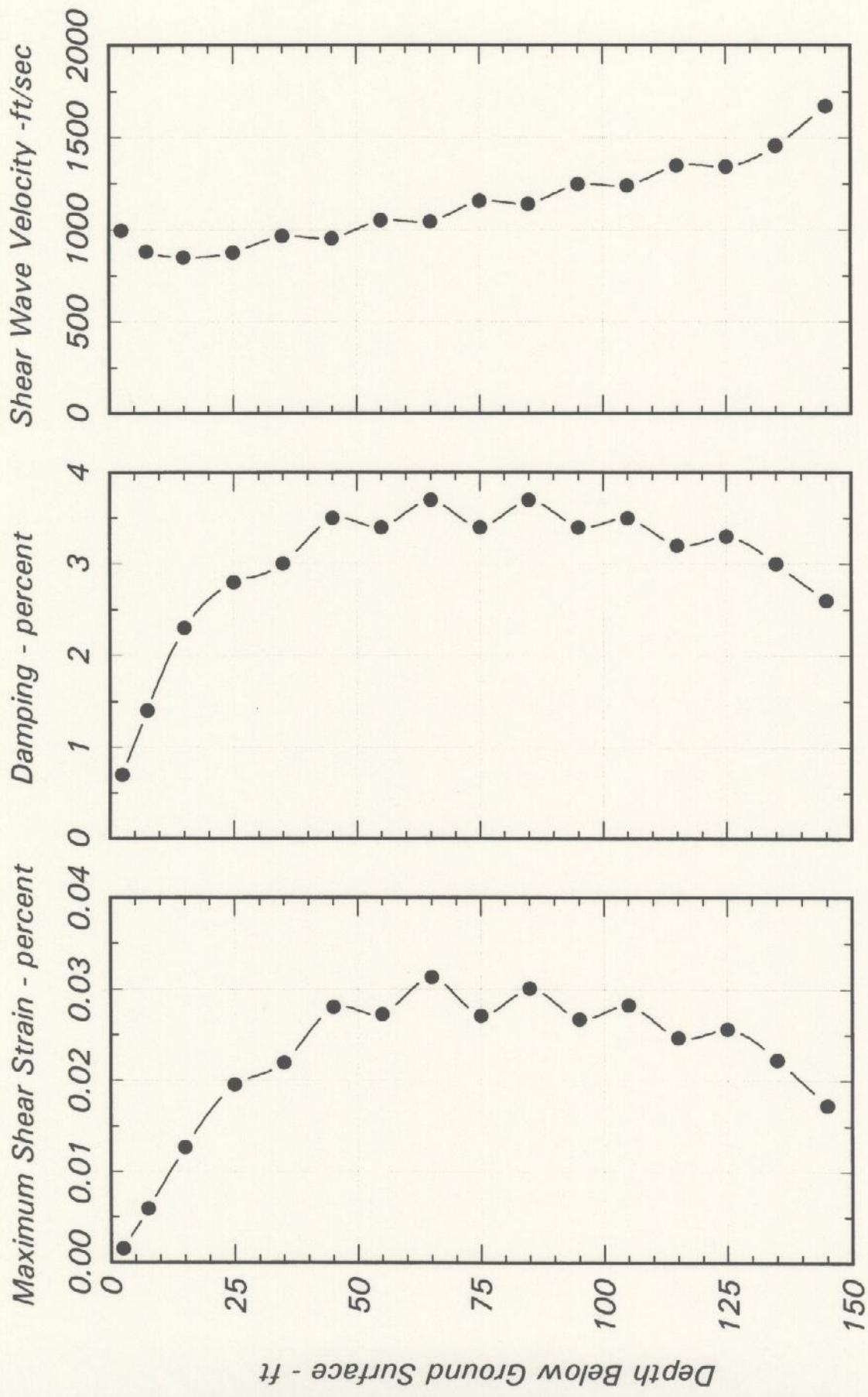


Fig. B-4 Calculated Shear Strains and Strain-Compatible Damping and Shear Wave Velocities for Sample Problem Using Diamond Heights Record as Input Motion

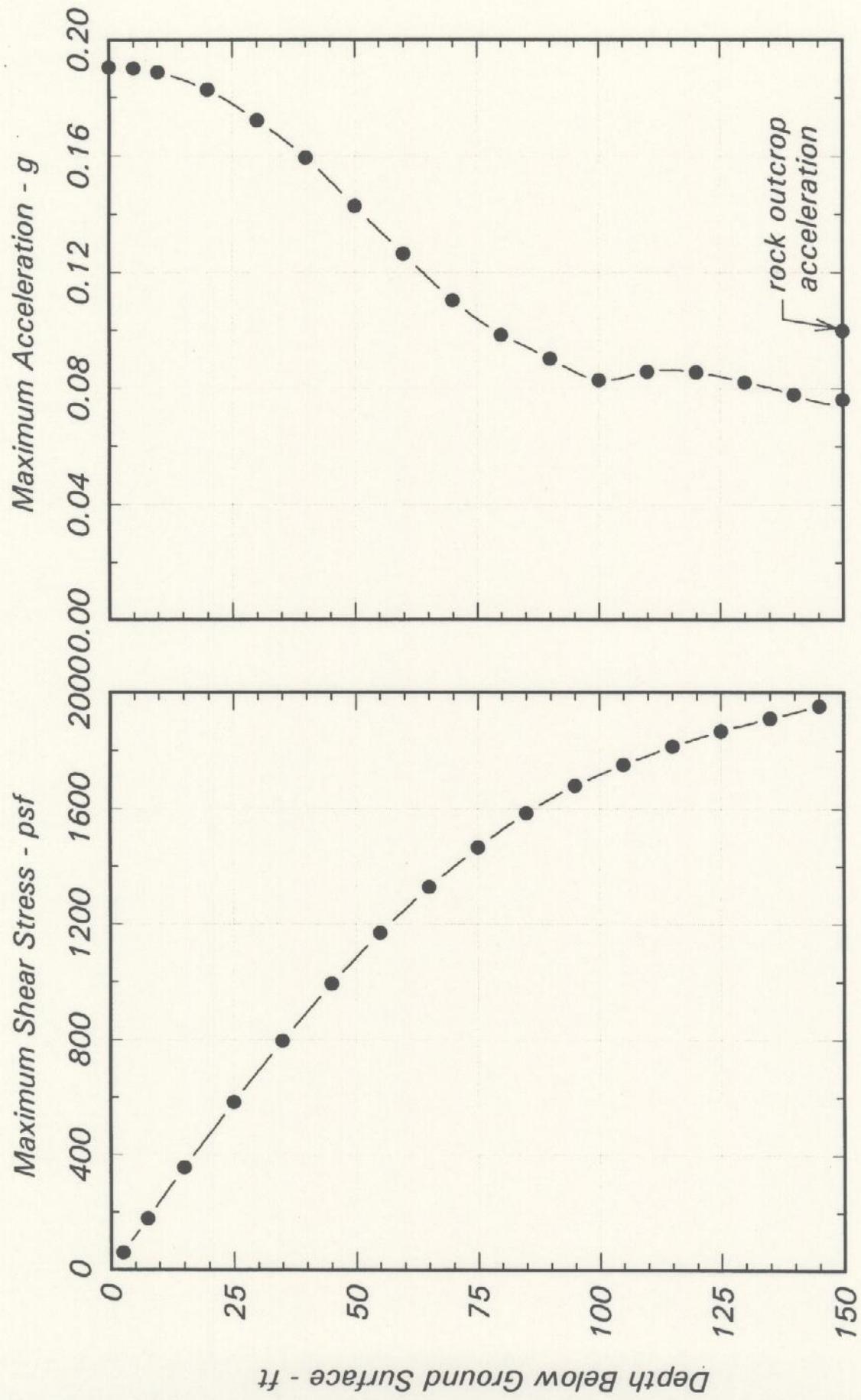


Fig. B-5 Calculated Shear Stresses and Accelerations for Sample Problem Using Diamond Heights Record as Input Motion

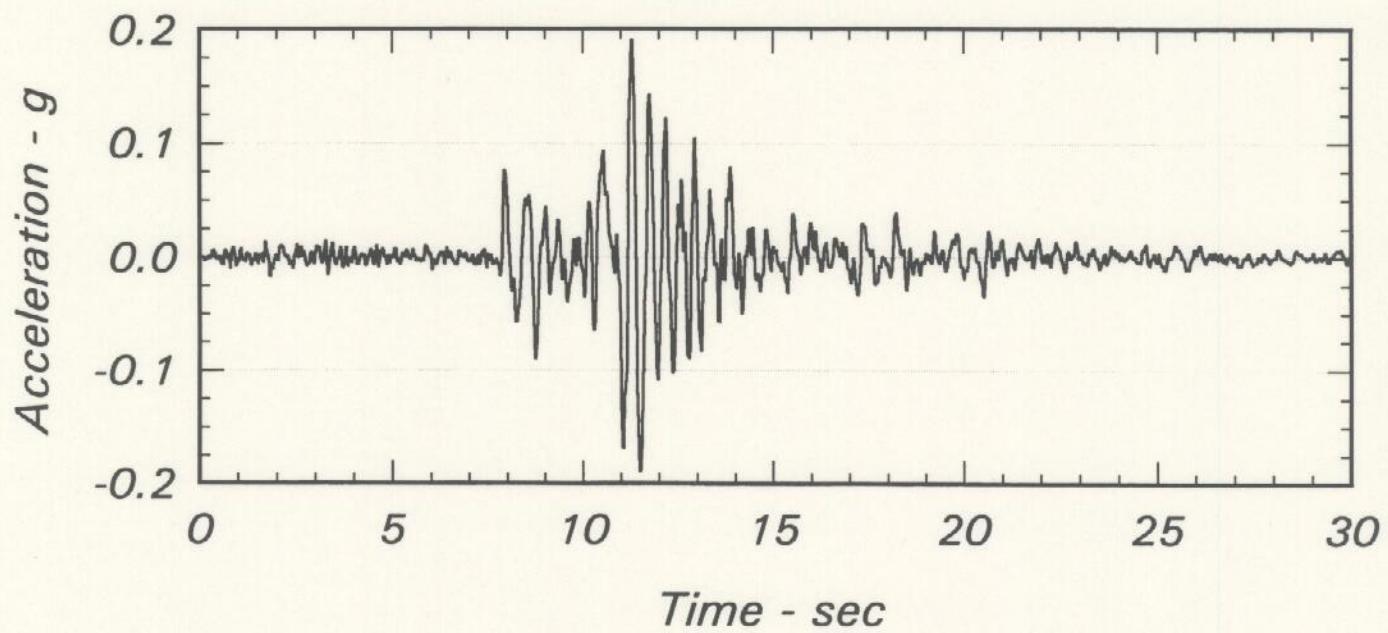
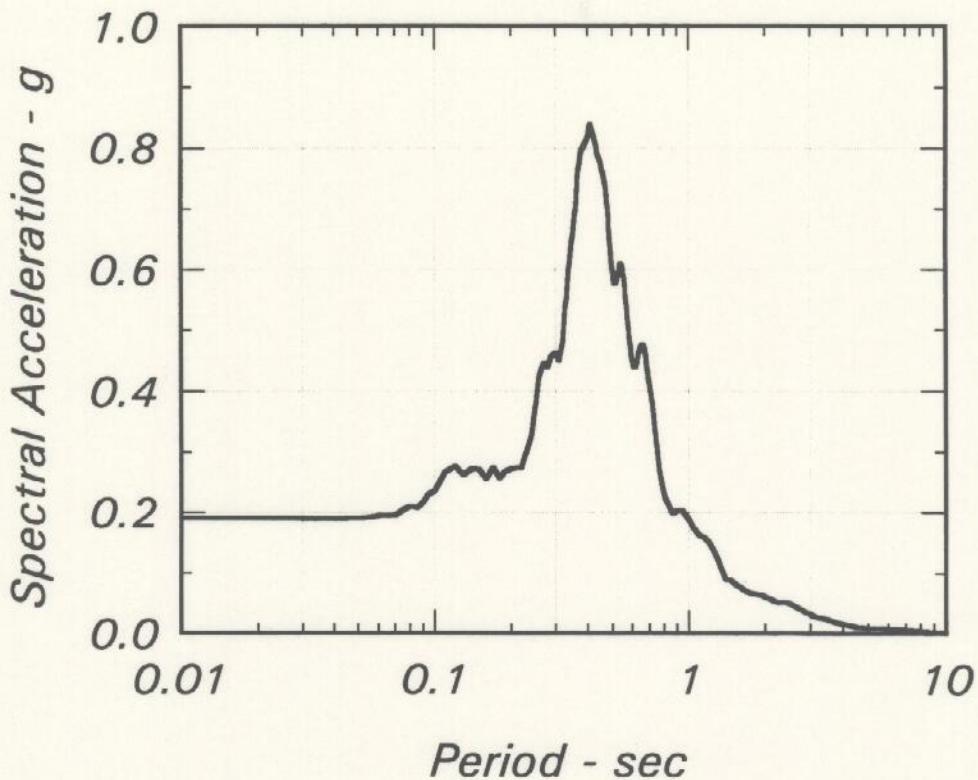


Fig. B-6 Acceleration Time History and Spectral Ordinates for Computed Motion at the Ground Surface Using Diamond Heights Record as Input Motion

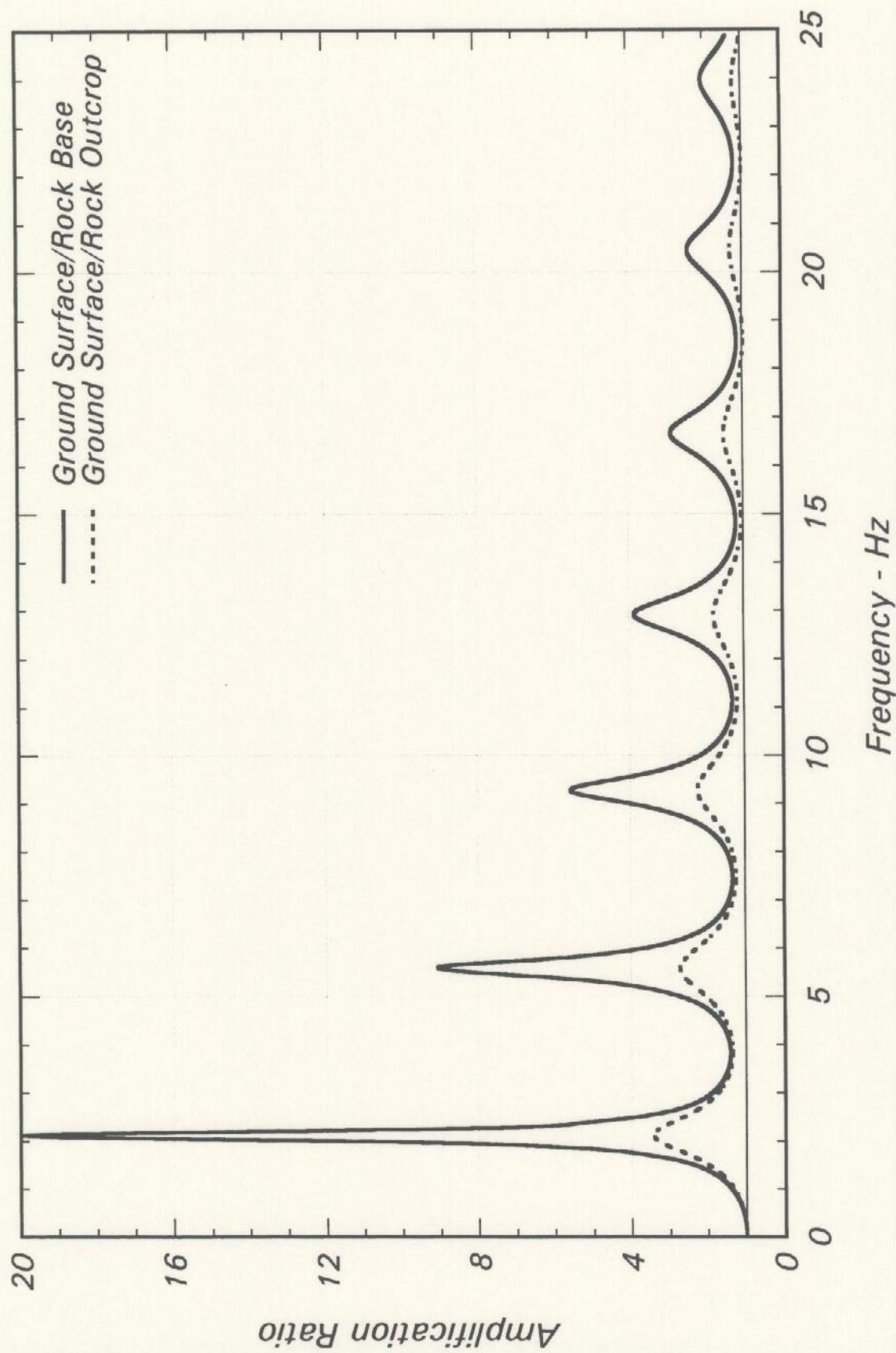


Fig. B-7 Calculated Amplification Spectra for Sample Problem Using Diamond Heights Record as Input Motion

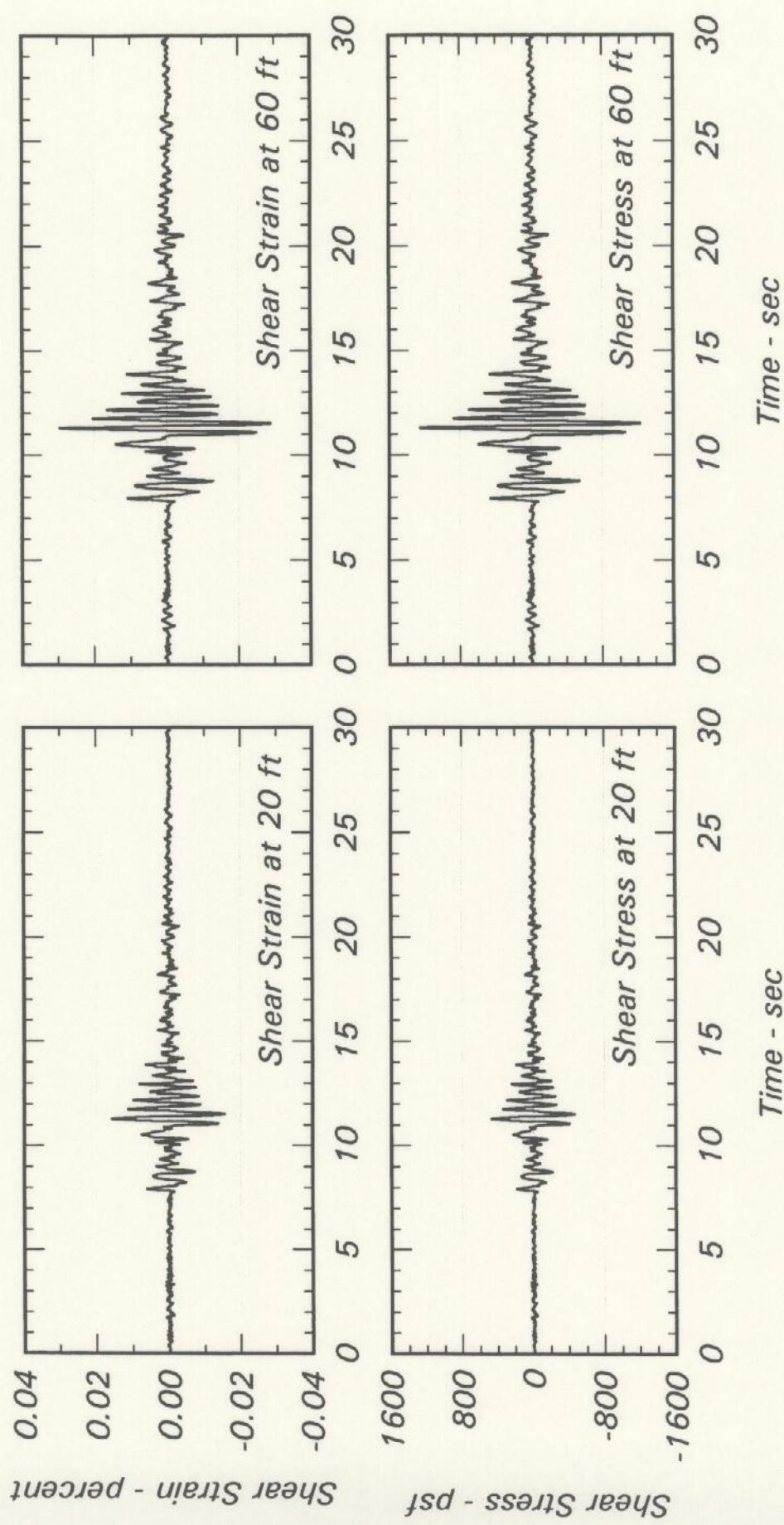


Fig. B-8 Time Histories of Shear Strains and Stresses Calculated at Depths of 20 and 60 ft for Sample Problem Using Diamond Heights Record as Input Motion

