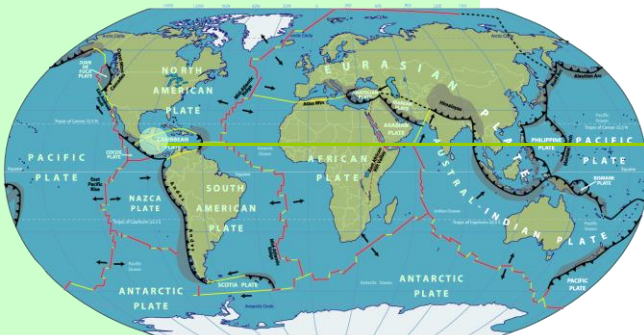
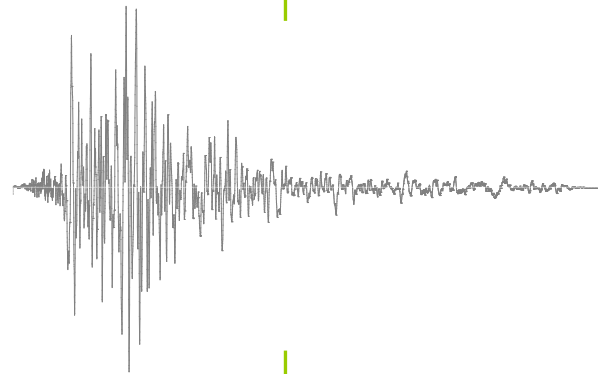
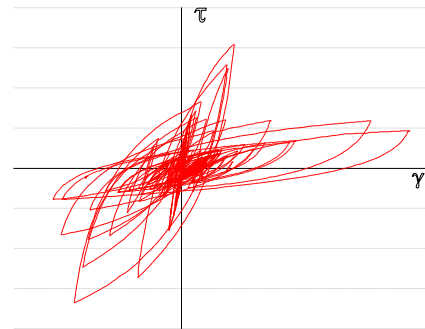
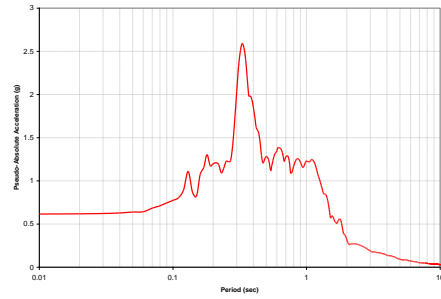


D-MOD2000

A Computer Program for
Seismic Response Analysis
of Horizontally Layered
Soil Deposits, Earthfill
Dams and Solid Waste
Landfills

User's Manual

Neven Matasović
Gustavo A. Ordóñez



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D-MOD2000

***A Computer Program Package for Seismic Response Analysis
of Horizontally Layered Soil Deposits, Earthfill Dams and
Solid Waste Landfills***

By

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Gustavo A. Ordóñez
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September 2011 - Revision

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D-MOD2000
User's Manual

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D-MOD2000

Genesis

The computer program package D-MOD2000 is an interactive, Windows™-based platform built by GeoMotions, LLC around D-MOD_2. D-MOD_2 is an enhanced version of D-MOD which was developed by Matasovic (1993). D-MOD combined a *dynamic response model* of DRAIN-2D¹ as implemented in computer program DESRA-2² with the *nonlinear stress-strain model* developed by Matasovic and Vucetic (1993), Dobry et al. (1985) *porewater pressure generation model for sand* with modification made by Vucetic and Dobry (1988) to simulate quasi two-directional pore water pressure response³, and a *porewater pressure generation/cyclic degradation model for clay* developed by Matasovic and Vucetic (1995a).

In D-MOD_2, modifications have been made with respect to stress-strain constitutive model employed (*reference strain* has been introduced to facilitate evaluation of the nonlinear stress-strain model material parameters⁴) and dynamic equation of motion solver (Wilson's θ algorithm used in earlier versions of the program was replaced by the Newmark β algorithm). D-MOD_2 further allowed for modeling of soil profile with up to 200 soil layers and 200 material parameter sets (as opposed to 15 layers/materials in D-MOD) and for up to 2,000 nodes for calculation of pore water pressure dissipation (100 in early versions of the program). D-MOD_2 was further modified to allow for use of the extended Rayleigh damping formulation (matching of target damping ratio at up to four frequencies), and for direct calculation of average acceleration of sliding mass within the profile (for use in Newmark-type seismic deformation analysis).

Other notable improvements with respect to the previous version of the program include adjustments for dissipation of negative (suction) pore water pressure (negative pore water pressures occur in overconsolidated clays subjected to cyclic straining and, when in composite soil profile, may reduce positive porewater pressures in liquefiable layers), an extension of the nonlinear stress-strain model to simulate seismically-induced "slip" along the composite landfill liner interfaces, and introduction of an option for "quasi" 2-D site response analysis of earthfill dams, levees and slopes. The latest version of the program (V9.3.1) incorporates routines for the processing and error checking of output data, and for displaying that output in a form familiar to geotechnical engineers and users of SHAKE2000.

The development of D-MOD2000 is a work in progress. We would appreciate receiving suggestions about new features that users would like included in the program, information on modifications that are recommended to make the program easier to use, and information on any bug in the source code that needs to be fixed. D-MOD2000 will be continuously updated/upgraded based on input from users and developments in geotechnical earthquake engineering practice.

¹ Computer program DRAIN-2D (Kannan and Powell, 1975) is a classical program for calculation of in-elastic (bi-linear) structural response in time domain.

² The computer programs DESRA/DESRA-2 were written in 1977-78 by Michael K. W. Lee and W. D. Liam Finn at the University of British Columbia (UBC) Department of Civil Engineering.

³ The modified Dobry et al. (1985) porewater pressure model was first implemented in DESRA-2 by Vucetic (1986). Version of DESRA-2 with implemented Dobry et al. (1985) model is called DESRAMOD.

⁴ In the previous versions of the program, material parameters were evaluated by fitting the initial loading stress-strain curve, while in the current version, the parameters are evaluated by fitting modulus reduction and damping curves, hence a need to introduce reference strain into the model.

Architecture

The D-MOD2000 package is essentially an interactive graphical platform built around D-MOD_2. Besides D-MOD_2 site response calculation engine, the platform integrates a suite of auxiliary programs (options) that either facilitate development of a site response model or enable processing of input/output time histories. The following options are presently in D-MOD2000:

- An option to use numerous attenuation relationships, i.e., empirical models for calculation of Peak Horizontal Ground Acceleration (PHGA) and Peak Ground Velocity (PGV) in bedrock at the site. Several of these attenuation relationships can also be used to calculate pseudo acceleration and pseudo velocity spectra for both rock and soil conditions.
- An option to generate design spectra based upon NEHRP, IBC 2003, UBC 1997, EuroCode and AASHTO codes. Acceleration response spectra of input motions and spectra calculated from time histories calculated by D-MOD2000 can be plotted against code-derived spectra and spectra generated by empirical attenuation relationships.
- An option for calculation of permanent seismic displacements by Newmark's permanent seismic displacement method.
- An option to evaluate PHGA for any latitude and longitude in the United States based upon the 1996/2006 USGS National Seismic Hazard Maps.
- An option to compute the response spectra of any ground motion.
- An option to printing output results in a table, for inclusion in reports, storage or other uses.

As can be inferred from the list of options above, special attention has been devoted to graphic capabilities of the package. For example, in addition to displaying the input data and calculation results, current version of the package plots peak values of time histories along the profile, marks liquefied layers, and can be used to plot attenuation of input ground motions with distance (in both linear and logarithmic scales). The program-generated graphs can be imported into another application such as a word processing program and/or spreadsheet and thus facilitate preparation of presentations and/or reports.

Execution

To run D-MOD2000, the user either needs to create a new working file or to edit an existing input file. This is done through the options of the main menu form (Figure 1). A tutorial, enclosed in Appendix A, is provided to guide a novice user through the file creation/program execution process. In general, the process starts with use of the **Edit** button to generate (or edit) the option data. The **Add** button is used to select options user wants to employ in the analysis. The **D-MOD** button is used to start the analysis. Upon termination of the analysis (DOS window disappears shortly), the **Process** button is used to retrieve and process relevant results from the output files generated by site response calculation. These relevant results can be graphed by use of the **Plot Options**.

A number of auxiliary programs included in D-MOD2000 package can be used independently (e.g., ground motion attenuation relationships, processing and scaling of ground motion records to compare them to a target response spectrum, conversion of ground motion records to a format compatible with D-MOD2000, Newmark's permanent seismic displacement method, ratio or response spectrum, and USGS seismic hazard data). These programs are invoked by pressing the "Earthquake Engineering Analyses & Utilities" button in the main menu form. The results generated by these auxiliary programs can be, within the same graphic platform, compared to D-MOD2000 input/output data/results.

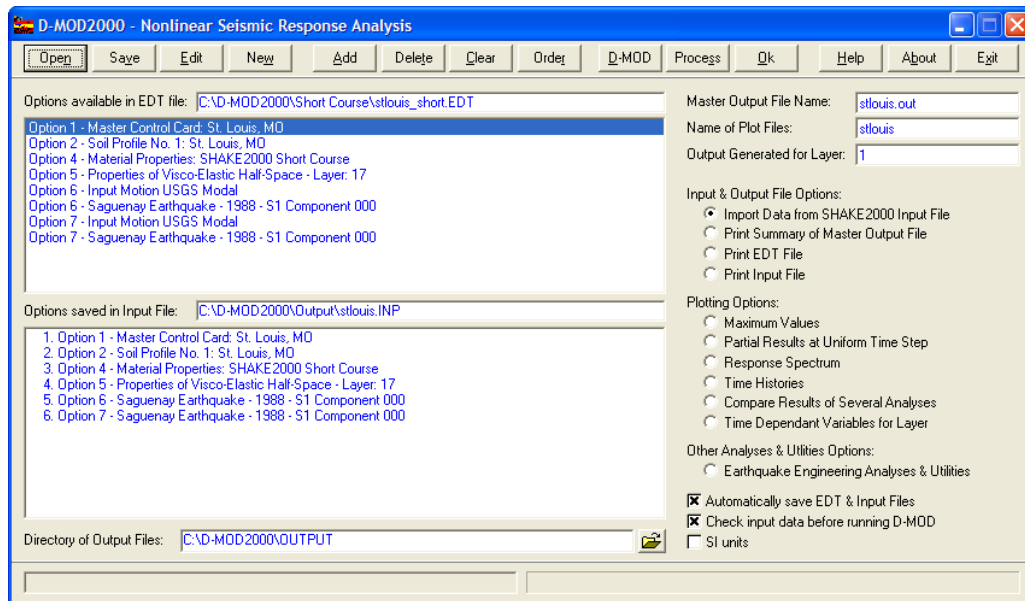


Figure 1: D-MOD2000 Main Menu Form.

EDT File

The “EDT” file (i.e., file identified by the *.EDT extension) is the main working file of D-MOD2000. This file stores data required for coordination of other input files required for execution of various D-MOD2000 options. No limit is imposed on the number of data sets for each option in this file. However, a total number of all of the options combined is limited to 32,000. Upon selecting options from EDT file, the D-MOD2000 *.INP input file is created by pressing the **Save** button.

The difference between an *.EDT file and other input files is that D-MOD2000 options are saved sequentially, beginning with option 1, and so on. For example, an *.EDT file for D-MOD2000 could be composed by the options shown in Figure 2.

```

Option 1 - Master Control Card
:
Option 2 - Soil Profile
:
Option 4 - Material Properties - Case SHA
:
Option 4 - Material Properties - Case SHB
:
Option 5 - Properties of Visco-Elastic Half-Space
:
Option 6 - Dynamic Analysis Solution - Loma Prieta
:
Option 6 - Dynamic Analysis Solution - Northridge
:
Option 7 - Input Ground Motion - Loma Prieta
:
Option 7 - Input Ground Motion - Northridge

```

Figure 2: Sample *.EDT File for D-MOD2000

The Sample “EDT” file shown in Figure 2 contains 1 set of options 1, 2 and 5 data; and, 2 sets of options 4, 6 and 7 data. By selecting specific options from this database, you could create different input files for D-MOD2000. For example, you could create two different input files, as shown on Figure 3, wherein the same soil profile is analyzed using two different object motions. Notice the difference in the way the options are ordered in Figures 2 and 3. The options in Figure 2 are ordered sequentially, beginning with option 1. Those on Figure 3 are ordered in a way that tells D-MOD2000 to conduct an analysis using the data provided.

```
Option 1 - Master Control Card
:
Option 2 - Soil Profile
:
Option 4 - Material Properties - Case SHA
:
Option 6 - Dynamic Analysis Solution - Loma Prieta
:
Option 7 - Input Ground Motion - Loma Prieta
```

(a)

```
Option 1 - Master Control Card
:
Option 2 - Soil Profile
:
Option 4 - Material Properties - Case SHA
:
Option 6 - Dynamic Analysis Solution - Northridge
:
Option 7 - Input Ground Motion - Northridge
```

(b)

Figure 3: Sample input files.

To create an *.EDT file, you have two options. First, you may start from scratch by creating new options using the **New** command button. Or, second, you can edit an existing file by opening a file using the **Open** command button. The former will create a set of each option, and use default values for each. You will have to enter your project's specific data for each option using the editing forms provided with D-MOD2000. The latter allows you to simply modify existing data without the need to retype data that is similar to each project, like the dynamic material properties. Once you have edited the data for each option, you can create an input file for the program engine.

To differentiate the input file from the database file, you should give it a different name and extension. The file does not need to have the EDT extension; however, by default, when opening an existing file, D-MOD2000 will present you with a list of files that end with this extension.

Processing of Output Files

After a successful “run” of D-MOD2000, depending on the output option selected in the input file, The engine will generate a *master output file* and zero, two, or eleven *auxiliary output files*. The *master output file* echoes the input information, provides information on the initial stress state in the profile, lists the peak values of time-dependent variables (for all layers in the profile), and defines the content (file names, variable and units) of the *auxiliary output files*. The *auxiliary output files* contain time-dependent

variables calculated for a specified layer. Depending upon selection, one of the two *auxiliary output files* sets will be generated.

Set 1 (alternative with two auxiliary files):

File Name	Contents	Units
i-plot1.prn	Time axis	(sec)
	Acceleration in layer “i”	(g)
	Shear strain in layer “i”	(%)
	Normalized shear stress in layer “i”	(-)
	Normalized Pore water pressure in layer “i”	(-)
	Degradation index in layer “i” (clay only)	(-)
i-plot2.prn	Time axis	(sec)
	(Scaled) base (input) acceleration	(g)
	Surface acceleration (same as in layer i = 1)	(g)
	Velocity in layer “i”	(ft/sec)
	Displacement in layer “i”	(ft)
	Shear stress in layer “i”	(psf)

Set 2 (alternative with eleven auxiliary files):

File Name	Contents	Units
i-time.prn	Time axis	(sec)
i-baccel.prn	(Scaled) base (input) acceleration	(g)
i-saccel.prn	Surface acceleration (same as in layer i = 1)	(g)
i-accel.prn	Acceleration in layer “i”	(g)
i-veloc.prn	Velocity in layer “i”	(ft/sec)
i-displ.prn	Displacement in layer “i”	(ft)
i-gamma%.prn	Shear strain in layer “i”	(%)
i-tau.prn	Shear stress in layer “i”	(psf)
i-ustar.prn	Normalized pore water pressure in layer “i”	(-)
i-dindex.prn	Degradation index in layer “i” (clay only)	(-)
i-taustr.prn	Normalized shear stress in layer “i”	(-)

The use⁵ for the *master* and *auxiliary output files* is limited as D-MOD2000 processes them and creates graphical output. The processing results in creation of another set of auxiliary files used with various plot options, as follows.

The first file created, identified with the extension *.ACC, contains acceleration time histories for the different layers in the profile. The next file, identified with the *.DPL extension, contains the displacement time history computed for the layers. Maximum values of acceleration, strain, normalized stress and normalized pore water pressure are saved in the file with the extension *.MAX. The normalized shear stress time histories are saved in the file with the extension *.NTS. Pore water pressure

⁵ We describe these output files as some Federal agencies (e.g., United States Department of Energy) require this level of documentation of calculations. For most users, graphical presentation of the results will suffice.

ratio vs. time histories are saved in the file with the extension *.PWP. Strain and stress time histories for soil profile layers are stored in the files with the extensions *.STN and *.STS, respectively. The file with the extension *.VEL contains the velocity time history data. All these files are ASCII text files, thus, they can be used with other software (e.g., Microsoft® Excel™, etc.), to plot the results.

While advanced users and researchers prefer manipulation of the individual output files, the majority of the users prefer D-MOD2000 graphing options. The best way to learn these options (and the program) is to follow the step by step tutorial saved in the Manual folder.

If you require additional help with running the program, you may e-mail to:

support@geomotions.com

It is recommended to attach the *.EDT and input ground motion files to any e-mails when requesting technical support. This will help us to identify the cause of any problems and/or to better understand the questions.

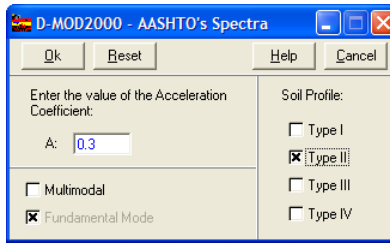
Free updates of the program can be downloaded from our web site at:

<http://www.geomotions.com>

The student version of the program is limited to 20 layers and 10 materials. Other limitations include: the Newmark Analysis and Ratio of Response Spectrum features are disabled. Also, graphs or tables can be printed, but not copied to the Clipboard. Further, the effective-stress analysis with pore water pressure dissipation and redistribution option is disabled. When printing results, a “Student Version” string of characters is also printed. The main purpose of the student version is to help the student learn about seismic site response analysis.

D-MOD2000 Package Forms

AASHTO's Response Spectra



This form is used to define the coefficients to compute the AASHTO response spectra based on the following equations (AASHTO, 1994):

$$C_s = \frac{1.2 A S}{T^{2/3}}$$

$$C_{sm} = \frac{1.2 A S}{T_m^{2/3}}$$

Where: C_s = elastic seismic response coefficient for single mode analysis
 C_{sm} = elastic seismic response coefficient for multimodal analysis
 A = Acceleration coefficient from Article 3.2
 S = Dimensionless coefficient for the soil profile characteristics of the site (Article 3.5).
 T = Period
 T_m = Period of the m^{th} mode of vibration.

D-MOD2000 uses the value of Acceleration Coefficient, A , to compute the spectra for a number of periods using the above equation. For single mode or multimodal analysis, the value of C_s will be $> 2.5 A$; and, for soil profiles type III or type IV in areas where $A \geq 0.3$, C_s will not exceed $2.0 A$.

The spectra for multimodal analysis are obtained by selecting the **Multimodal** option. An **x** will appear in the check box when multimodal analysis is used by D-MOD2000. Further, the **Fundamental Mode** option will be enabled when the **Multimodal** option is selected. If the **Fundamental Mode** option is not selected, then for soil profiles types III and IV and for periods less than 0.3 seconds, D-MOD2000 will use the following formula to determine C_{sm} :

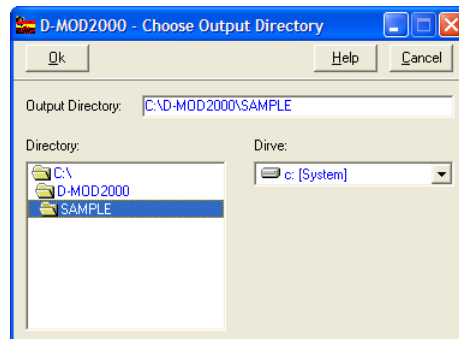
$$C_{sm} = A(0.8 + 4T_m)$$

Further, for multimodal analysis, when T_m exceeds 4.0 seconds the value of C_{sm} for that mode will be determined with the following formula:

$$C_{sm} = \frac{3 A S}{T_m^{4/3}}$$

The user needs to enter the value for **A**, and select the site classes. To select a site class, click on the check box next to the class. An **x** will appear in the box when the class is selected. You can select all of the classes. Once you enter a value for **A** and select at least one class, the **Ok** command button is enabled. You can click on **Ok** to return to the previous form.

Choose Output Directory



This form is used to select the directory where the output files generated by D-MOD2000 will be stored. There is a directory list box that shows the directories of the current drive, and a drive list box that can be used to change drives. To select a folder, double-click on it. The folder path will be shown on the text box next to the **Output Directory** label. Once you have selected a directory, click on the **Ok** button to return to the **Main Menu** or the **Earthquake Response Analysis** form. The output directory will be shown on the output directory cell.

Company & Project Information

No.	Label	Information	X left (in)	Y left (in)	Center
1	Project:	SHAKE2000 Site	5.05	9.575	<input type="checkbox"/>
2	File No.:	Example 1	5.05	9.775	<input type="checkbox"/>
3	Subject:	Seismic Analysis	5.05	9.975	<input type="checkbox"/>
4	Date:	January 2000	5.05	10.17	<input type="checkbox"/>
5					<input type="checkbox"/>
6					<input type="checkbox"/>
7					<input type="checkbox"/>
8					<input type="checkbox"/>
9					<input type="checkbox"/>
10					<input type="checkbox"/>

Font: Tahoma Style: Regular Size: 9

☐ Show logo:

X left (in): Y left (in): X right (in): Y right (in):

This form is used to enter textual information about your company and/or project that will be printed together with your graph and form.

The information that can be entered on this form is divided into two groups: 1) information that is constant such as your company name, address, etc.; and, 2) information that changes from project to project such as project number, dates, etc.

When you create your own forms, you can enter a description for the form on the text box next to the **Description** label. This description can be up to 80 characters long, and will not be shown on the form.

To enter information on the form, first type in the information in the **Label** column. This label is expected to be constant, e.g. "Project No.:". Then enter the information that changes in the text box for the **Information** column, e.g. "99-1035". Then enter the X and Y coordinates where the text will be printed on the paper. The origin of coordinates, i.e. $X = 0$ & $Y = 0$, is the upper left corner of the paper sheet. The string of text formed by the information on the **Label** and **Information** columns will be printed starting at the point defined by X and Y. If you want to print the string centered at this point, then click on the check box of the **Center** column to select it (an **x** is shown on the check box when this option is selected). The string will be vertically centered with respect to the Y coordinate.

To change the font type, size, or style of a string, click on the **Font** command button to display the font dialog form. Select a different font, size, or style and then click on **Ok** to return to the form. The information for the string's font will be displayed on the **Font**, **Style**, and **Size** text boxes. Every time you move the cursor to a text box on the **Label** or **Information** columns, the characteristics of the font for the string will be displayed on the respective text boxes.

You can also display a logo on the page at a specific location. The position of the logo is determined by the coordinates for the upper-left and bottom-right corners of a rectangle as entered in the coordinate text boxes at the bottom of the form. This logo should be a bitmap, metafile or an icon type file. To select a

logo, click on the **Logo** command button to display the file dialog window, select a file, and then click on the **Open** command button. Then, enter the coordinates for the box where in the logo will be displayed.

The example described in the following paragraph is for a letter size paper (8.5" x 11") and portrait orientation. To change paper type or orientation, click on the **Printer** command button to display the printer dialog window. For this example, first place the cursor on the text box next to the **Description** label. Type in a description for the information, e.g. "D-MOD2000 standard form". Press the *Tab* key to move the cursor to the text box on the **Label** column for string No. 1, and enter **Project**. Next, press the *Tab* key twice to move the cursor to the text box on the **X left** column and enter 6.05. Press the *Tab* key once, and enter 9.575 on the **Y left** column. Note that the string is now shown on the bottom right corner of the form. Next, follow the same procedure to enter the following:

Label	X left	Y left
File No.:	6.05	9.775
Date:	6.05	9.975
Initials:	6.05	10.17

The coordinates in this example are such that the text will print on the bottom right corner of the form created in the example of the **Report Form Development** section of this manual.

After you have entered the information, click on the **Save** command button to save the data on an ASCII text file. The data can be retrieved for future use using the **Open** command button.

Each time you place the cursor on either the **Label** or **Information** columns the **Add** and **Delete** command buttons are enabled. If you want to add data for a new line, place the cursor on the line where the new line will be located, and click on the **Add** button. A new line will be created, and the coordinates and thickness for the new line will be the same as those for the line immediately below. Now, you need to modify the information for the coordinates and thickness for the new line. The **Delete** button is used to delete a line from the form. Place the cursor on either the **Label** or **Information** columns, and then click on the **Delete** button. The data for the line will be removed from the form, and the information for the other lines updated accordingly. The **Reset** command button will delete the information for all of the lines.

Comparison of Results

Results:	Variable:	File:	Description:
<input checked="" type="radio"/> Maximum Values	<input checked="" type="radio"/> Acceleration	<input checked="" type="checkbox"/> C:\D-MOD2000\Sample\wildshaux.max	Wildlife Site - SHA
<input type="radio"/> Partial Results	<input type="radio"/> Velocity	<input checked="" type="checkbox"/> C:\D-MOD2000\Sample\wildshbaux.max	Wildlife Site - SHB
<input type="radio"/> Response Spectrum	<input type="radio"/> Displacement	<input checked="" type="checkbox"/> C:\D-MOD2000\Sample\wildSHCaux.max	Wildlife Site - SHC
	<input type="radio"/> Shear Strain	<input type="checkbox"/> Click Open to select a data file	
	<input type="radio"/> Shear Stress	<input type="checkbox"/> Click Open to select a data file	
	<input type="radio"/> Normalized Shear Stress	<input type="checkbox"/> Click Open to select a data file	
	<input type="radio"/> PWP Ratio	<input type="checkbox"/> Click Open to select a data file	

This form is used to select a number of result files in order to compare the results from different analyses.

To compare results, first choose one of the **Results** and one of the **Variable** options. Depending on the **Results** option selected, the appropriate **Variable** options will be enabled. Then, select the output files using the **Open** command button. The file name and path will be shown on the **File** section of the form. You can select up to 6 output files. After selecting the files, click on the **Read** command button. The program will check that the number of layers and the thickness and depth to the middle of the layer are the same for each file. Those files with the same layering, will be selected and an **x** will be shown on their check boxes. The data from the files will be read and stored in the computer's memory for plotting. Only those files which are selected (i.e. an **x** is shown on the check box next to the file name) will be read. The other files will be ignored.

If you would like to remove a file from the list of files, click on the file and then on the **Delete** command button.

You can enter a description for the results in the **Description** text boxes. The label entered in this box will be used to identify the curve when plotting.

To plot the results, click on the **Plot** command button.

Conversion of Ground Motion File

Source File Type	No. Values	Time Step	No. Header Lines	Values per Line	No. Digits	Number of Columns	Acceleration Column	Format for Output
Other	19398	0.005	7	10	8			(6F15.8)

Source Units	Output Units	Multiplier	Other Units	Database Header Line	Lines from Source File header to be included in header of Converted File	Hard Rock	Match Sa	Free Format
cm/sec ²	g's	.001019		1	1-7	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Converted Ground Motion File: C:\D-MOD2000\Sample\328n15IV_W0a.eq

This form is used to convert ground motion files to a format compatible with D-MOD_2; or to a format and units compatible with other software applications. The ground motion file used as input in D-MOD_2 is usually formed by a series of acceleration values in g's saved in a formatted way that is compatible with the Format statement used in the FORTRAN programming language. Today, the user can obtain ground motion records from a wide number of sources. However, these files are not uniform in their formatting or processing. For example, ground motion files can be downloaded through the Internet that are saved in units other than g's such as cm/sec². Other records may include values for acceleration, velocity and displacement in the same file, each as a column of data. Thus, the main purpose of this form is to extract the acceleration data from the file, convert them to g's and save them to a formatted text file that can be used by D-MOD_2.

This form has two other functions. First, it can be used to enter information about a new ground motion file and then add the information to the database of ground motion files used by D-MOD2000. Second, the user can access the form used to edit information about a ground motion file in the database.

Conversion of a ground motion file involves the following steps: 1) opening the original or source ground motion file; 2) defining the way the data in the source file are to be read; and, 3) defining the way the data will be written to the new converted ground motion file.

For the first step, use the **Open** command button to display the **Open Source Ground Motion File** dialog form, change to a different folder and/or subdirectory if necessary, and click on the file that needs to be converted to select it. This file needs to be a text or ASCII file. Then click on the **Open** command button of the dialog form to open it. After a few seconds, the first few lines of the file (up to 99 lines) will be displayed on the top list box of the form.

The first three characters displayed in red are the numbers of each row of data in the file followed by a “|”. These characters are not part of the source file and are only shown to number the rows. After the row numbers, the alphanumeric characters that constitute the information saved in the file for each row are shown. Note that the characters are displayed as blue on a white background, and that every tenth character is displayed in red. However, if the tenth character is a “blank space” then the character is not shown. This is done to guide the user when defining the order of the data in the file.

During the second step, you need to define the way the data in the source file are to be read. To this end, there are seven options available in SHAKE2000: **Other**, **PEER**, **USGS**, ***.HEA file**, ***.AHL file**, ***.AVD file** and **RSPMATCH**, **PEER AT2** and **PEER ACC**. The first option is used to manually define the way the data are to be read. The **PEER** and **USGS** options are used to automatically convert files downloaded from the respective web sites; and, the ***.HEA file**, ***.AHL file** and ***.AVD file** options are used to convert specific files created by D-MOD2000. The **RSPMATCH** option is used to convert files created by the RSPMATCH program. To select one of these options, click on the down-arrow of the **Source File Type** list to display the list of options, and select the option that applies to your file.

The **PEER** option is used to convert files downloaded from the PEER Strong Motion Database at:

<http://peer.berkeley.edu/smdat/search.html>

The **PEER AT2** option is used to convert files downloaded from the PEER Strong Motion Databases at:

<http://peer.berkeley.edu/nga/search.html>
http://peer2.berkeley.edu/peer_ground_motion_database/site

The **PEER ACC** option is used to convert files downloaded from the PEER Ground Motion Database at:

http://peer2.berkeley.edu/peer_ground_motion_database/site

The **USGS** option is used to convert files created with the Interactive Deaggregation feature of the United States Geological Survey (USGS) web site at:

<http://eqint.cr.usgs.gov/eq-men/html/deaggint2002-06.html>

The files downloaded from either web site, **PEER** or **USGS**, should be saved as Text files. This is done by first, selecting the **Save As...** option of the **File** menu in your web browser. And second, by selecting the **Text File (*.txt)** option of the **Save as type** option list.

When using the **PEER** or **USGS** option, some basic information needed to read the source file is displayed on some of the text boxes. For PEER files, it is assumed that the first 4 lines in the file are the header, and that the acceleration values in the file are in g's. Further, the program will assume that the fourth line of the header section includes the number of acceleration values and the time interval between acceleration values. Hence, the program will use the value next to the NPTS= string for the number of acceleration values, and the value next to the DT= string for the time interval. For example, in the section of the ground motion file shown below, it is assumed that there are 11800 acceleration values and that the time interval is 0.005 seconds.

```
PEER STRONG MOTION DATABASE RECORD. PROCESSING BY PACIFIC ENGINEERING.
CHI-CHI 09/20/99, ALS, E (CWB)
ACCELERATION TIME HISTORY IN UNITS OF G. FILTER POINTS: HP=0.1 Hz LP=30.0 Hz
NPTS= 11800, DT= .00500 SEC
.9029319E-05 .9034156E-05 .9026870E-05 .9016792E-05 .9034652E-05
```

If the formatting or the information in the file do not match these assumptions, then it is recommended to use the **Other** option as explained below.

The **USGS** option is similar to the **PEER** option in that specific information is searched to determine the number of acceleration values and the time interval. However, the USGS files do not have a fixed number of header lines. Accordingly, USGS files are first read to determine the number of header lines, and at the same time, determine the number of acceleration values and time interval. To this end, the program will first search for the “**npw2, dt, total duration =**” string. For example:

```
npw2, dt, total duration = 16384 0.00500 81.9
```

When this string is found, it is assumed that the time interval is the second value, e.g. 0.005 sec for the string above. The program will then search for the “**Begin Scaled Accelerogram Data**” string and assume that the acceleration values start one line after this position. The program will count the number of lines of data until it finds the “**END OF AGRAM DATA**” string. It is also assumed that the acceleration values are in cm/sec^2 units. Once the number of header lines, acceleration values and time interval are determined, the program will proceed to convert the ground motion file.

Please note that the USGS files contain data for 6 seismograms. For example:

```
am0, am0b_m0fa= 1.642E+25 0.000E+00
npw2, dt, total duration = 16384 0.00500 81.9

*** Begin Scaled Accelerogram Data ***
T      A1 (cm/s2)      A2      A3      A4      A5      A6
0.0000  8.2623E-04  2.9951E-04  3.0377E-04  2.8430E-04 -3.0169E-04  4.7918E-04
```

In the above section of a USGS file, the first column corresponds to the time for the acceleration value, and the A1 through A6 columns each correspond to a different seismogram. By default, the program will read the acceleration values for the first column of acceleration data, i.e. the A1 column. If you wish to obtain the data for any of the other acceleration columns, change the value on the **Acceleration Column** text box as explained below. Another option that applies to the USGS files is **Match Sa**. The motions downloaded from the USGS web site are no longer scaled to the probabilistic motion. For example, for the 1996 synthetic seismogram option, if the probabilistic 2-second spectral acceleration for the 2% probability of exceedance in 50 years was 0.1 g, then each seismogram was scaled so that its 2-second spectral acceleration, with 5% damping, was 0.1 g. This is no longer the case for the 2002 synthetic seismogram option. The **Match Sa** option can be used to scale the synthetic motions to the probabilistic value. The USGS file includes the following information that is used by D-MOD2000 to scale the motions:

```
Fractional oscillator damping = 0.050 period= 1.000
**Agrams not scaled to PSHA SA level. Avg SA (cm/s/s) = 102.44
**Avg factor needed to match target probabilistic SA 3.5127
**PSHA MODAL r(km), amag, PSHA sa or pga(cm/s2)= 0.138E+03 0.900E+01 0.360E+03
```

On the first line above, the damping value and period for the S_a are shown. If this line is not found on the file, then it is assumed that the seismogram is for PGA. The second line indicates that the motion was not scaled, and that an average value of S_a of 102.44 cm/sec^2 was obtained for the 1-second period from the synthetic motions generated without scaling. The third line notes that the ground motion values will need to be scaled by an average value of 3.5127 to obtain a motion with the corresponding probabilistic value of S_a . On the fourth line, the last value corresponds to the probabilistic value of S_a or PGA (S_a in the above example) that was obtained for your site. Hence, if the synthetic motions were scaled by a factor of 3.5127, their probabilistic value of S_a at 1-second would be 360 cm/sec^2 . To match the spectra value,

D-MOD2000 will use the probabilistic S_a or PGA value from the fourth line (i.e. 360 for the above example), compute the response spectrum for the synthetic motion, and then use the computed value of S_a for the period of interest (i.e. 1 second for the above example) to obtain a scaling factor by dividing the probabilistic S_a by the computed S_a . The acceleration values for the motion will be multiplied by this factor to obtain the modified ground motion.

The **Hard Rock** option is only enabled when processing USGS ground motion files. When this option is selected, the USGS B/C boundary type motion will be transformed to a hard rock, i.e. rock type A, motion. The motions are converted using the deamplification function presented by Park (2003).

The ***.AHL file** option is used to convert files with the AHL extension (for **A**cceleration **H**istory at **L**ayer), i.e. files created by D-MOD2000. Similarly, the ***.HEA file** option is used to convert files with the HEA extension (for **H**orizontal **E**quivalent **A**cceleration), i.e. files created by D-MOD2000 from the shear stress time histories. For more information about these files, refer to the **Non-Linear Earthquake Response Analysis** section of this manual. The ***.AVD file** option will convert files with the AVD extension (for **A**cceleration **V**elocity **D**isplacement), i.e. files created using the **Save to file** option of the **Plot Object Motion** form. In this last option, by default, the acceleration data in column 2 of the file will be converted. If you would like to use the baseline-corrected acceleration values instead, change the number in the **Acceleration Column** text box to **5**. For any other type of file, it is recommended to use the **Other** option.

The third option used to convert files is **Other**. With this option, you can choose one of two alternatives: 1) Free Format Data: The data are separated by blank spaces and can be read sequentially one after another or by using a specific sequence; or, 2) Formatted Data: The data can be obtained by reading a specific number of characters (with or without blank spaces) sequentially or by using a specific sequence. Please note that if the data are separated by characters other than blank spaces, such as “,” or “tabs”, then the data may not be read properly.

- **Free Format Data:** If the data are separated by at least one, or more blank spaces, then select the **Free Format** option. Next, enter the number of acceleration values that are to be read from the file in the text box below the **No. Values** label. Then, enter the time interval between acceleration values in the text box below the **Time Step** label. This value is used when plotting the converted motion and when adding the information about the source or converted files to the database. Usually the first few lines in the source file provide information about the motion such as earthquake magnitude, station, etc.; these lines are considered herein as the “header” lines. Also, this is the number of lines that need to be skipped before reaching the section of the file where the acceleration values are located. Enter the number of header lines in the text box below the **No. Header Lines** label.

If you selected the **Free Format** option, skip the next two text boxes and place the cursor on the text box below the **Number of Columns** label. When reading the acceleration values in free format, the values should be ordered in one of two ways. Either each row of data is formed only by values of acceleration; or, on each row of data, there are also other values. For the second type, each row of data may have a column for period, acceleration, velocity, and displacement. For example, in the section of the ground motion file below, each row of data is formed only by acceleration values. There are 10 values of acceleration (in cm/sec²) in each row:

```
SAMPLES/SEC=100 FILTER TYPE=BUTTERWORTH CORNER= 0.10 ORDER=3 DATA TYPE=AC
NO OF POINTS= 6228, UNITS=CM/SEC**2
-0.16 -0.16 -0.16 -0.16 -0.17 -0.18 -0.20 -0.20 -0.20 -0.22
-0.25 -0.27 -0.28 -0.27 -0.27 -0.29 -0.32 -0.35 -0.38 -0.39
```

If your source file is of the above type, skip the **Number of Columns** and **Acceleration Column** boxes, and place the cursor on the text box below the **Format** label. On the other hand, each row of data on the file below has one value for time, acceleration, velocity and displacement:

```
m0444r01  8.0 25.6 147.6 75.9 0.65
          sec    cm/sec**2  cm/sec    cm
          0.00  -0.1934E+00  0.0000E+00  0.0000E+00
          0.01  -0.1938E+00 -0.1900E-02  0.0000E+00
```

If the source file is of this second type, enter the total number of columns of data on each row. For example, for the above example you would enter a **4**. Next, place the cursor on the text box below the **Acceleration Column**. In this text box, you enter the number of the column that forms the acceleration value. In the above example this is the second column, thus you would enter a **2**. Then place the cursor on the **Format** text box.

- **Formatted Data:** If you did not select the **Free Format** option, then you need to provide either the number of values per row and the length as number of characters of the values; or, the number of data columns per row, the number of the column with the acceleration values and the length as number of characters of the columns.

For the first alternative, you need to define the way the values are separated in each row by indicating the number of values per row and the number of characters that form each value. The number of characters should be the same for every value. For example:

4 values per row, each value is 15 characters long including blank spaces and exponent:

```
-.1059027E-04  -.1461820E-04  -.1690261E-04  -.1506594E-04
```

8 values per row, each value is 9 characters long including blank spaces:

```
0.00000  -0.00434  0.00860  0.00540  -0.00565  -0.00944  -0.00369  -0.00669
```

8 values per row, each value is 9 characters long:

```
-0.000001-0.000002-0.000001-0.000001 0.000000 0.000001 0.000000-0.000001
```

After you have entered the data for number of values, time step, and number of header lines, place the cursor on the text box below the **Values per Line** label, and enter the number of values that are included in each line of data (for the above examples: **4**, or **8**, or **8**, respectively). Next, place the cursor on the text box below the **No. Digits** label and enter the number of characters that form each value (for the above examples: **15**, or **9**, or **9**, respectively). Then enter the rest of the information as described previously.

For the second alternative, you need to provide the number of data columns on each row, the number of the acceleration column, and the number of characters that form each column. For example:

```
m0444r01  8.0 25.6 147.6 75.9 0.65
          sec    cm/sec**2  cm/sec    cm
          0.00  -0.1934E+00  0.0000E+00  0.0000E+00
          0.01  -0.1938E+00 -0.1900E-02  0.0000E+00
```

In the above section of a ground motion file, there are 4 columns of data per row (one each for time, acceleration, velocity and displacement), the second column is the acceleration value, and each value is 12 characters long including blank spaces and exponent. Thus, after entering data for number of values, time step, and number of header lines, place the cursor on the text box below the **No. Digits** label and enter the number of characters that form each value (e.g. **12**). Then, place the cursor on the text box below the **Number of Columns** label and enter the total number of columns of data on each

row. For the above example, you would enter a **4**. Next, place the cursor on the text box below the **Acceleration Column**. In this text box, you enter the number of the column that forms the acceleration value. In the above example this is the second column, thus you would enter a **2**. To continue with the conversion of the file, enter the rest of the information as described previously.

In the third step, you will define how the data will be written to the converted file. First, define the format, i.e. the way the data are written to the file, of the acceleration values. This is based on the syntax used in the Format statement of the FORTRAN computer language. In this statement edit descriptors specify how the values are read. In this feature of D-MOD2000 the only two edit descriptors supported by D-MOD2000 are:

Fw.d Real values
Ew.d [Ee] Real values with exponents

In these descriptors, the field is *w* characters wide, with a fractional part *d* decimal digits wide, and an optional exponent width of *e*. Remember that the field *w* also includes any blank spaces. You can also indicate that a given data format is repeated a number of times. For example, 8F9.6 repeats a nine-character real value with six decimal digits descriptor eight times. The first character on the format field should be a “(” and the last character a “)”, e.g. (8F9.6). Examples of data saved in the ground motion files included with D-MOD2000 and the format used to define them follow:

Format: (4E15.8E2) or (4E15.8):

```
-.10590270E-04 -.14618200E-04 -.16902610E-04 -.15065940E-04
```

Format: (8F9.5):

```
0.00000 -0.00434 0.00860 0.00540 -0.00565 -0.00944 -0.00369 -0.00669
```

Format: (8F10.6):

```
-0.000001 -0.000001 -0.000001 -0.000001 0.000000 0.000000 0.000000 0.000001
```

If you use the “E” descriptor and do not provide a value for exponent width, “e”, D-MOD2000 will use a default value of 2.

Depending on the number of decimal figures used for the acceleration values in the converted file, the velocity or displacement time histories obtained by double integration of the converted acceleration time history may not be correct, e.g. they may increase or decrease without bounds. Accordingly, it is recommended to use as many decimal figures as possible when converting the file. However, due to the nature of the programming language used to create D-MOD_2, the acceleration time history values are limited to a maximum of 8 decimal figures.

Next, you need to select a factor to convert the acceleration values in the source file to units compatible with D-MOD_2, i.e. fractions of acceleration of gravity (g’s) or in ft/sec², if necessary; or, to other units if you wish to use the converted data as input for another software application. This can be done by selecting a factor that represents the units of the acceleration data in the source file from the list of options shown on the **Source Units** list box; and, by selecting the units of the converted file from the list of options shown on the **Output Units** list. After selecting the units, a multiplication factor will be displayed on the **Multiplier** box. This is the multiplication factor that will be used to convert the values from the units shown on the **Source Units** list box to the units shown on the **Output Units** list box. For example, to convert values of acceleration from cm/sec² to g’s, you need to divide each value by 980.665 cm/sec²; which is equivalent to multiplying each value by 1/980.665 = 0.00102. In the program, this is

done by selecting the **cm/sec²** option of the **Source Units** list and the **g's** option of the **Output Units** list, respectively.

If the accelerations in the source file are in units that are not shown in the list, select the **Other** option of the **Source Units** list, and then enter a multiplication factor in the **Multiplier** text box. This multiplication factor should be appropriate to convert the source acceleration data to the units shown on the **Output Units** list. For example:

```

WESTERN WASHINGTON EARTHQUAKE   APR 13, 1949 - 1156 PST           55
EPICENTER  47 06 00N,122 42 00W           31
INSTR PERIOD  0.0770 SEC  DAMPING  0.574           42
NO. OF POINTS  1094  DURATION  89.16 SEC           42
UNITS ARE SEC AND G/10.           23
RMS ACCLN OF COMPLETE RECORD  0.2455 G/10.           43
ACCELEROGRAM IS BAND-PASS FILTERED BETWEEN  0.070  AND  25.000  CYC/SEC
4454 INSTRUMENT AND BASELINE CORRECTED DATA
AT EQUALLY-SPACED INTERVALS OF  0.02  SEC.
PEAK ACCELERATION  161.63023  CMS/SEC/SEC AT  10.9400 SEC
-152      29      -51      -309      -364      -125      134      111      17
-176     -147     -49       86       88       -69     -103     -75     -65
-234     -176      27       86       26       42       26     -185    -181

```

The fifth line of the header section indicates that the units are seconds and G/10, and from the tenth line you can see that the acceleration values are given in cm/sec². Thus, to convert the values to g's, you need first to divide each value by 10, and then divide the result by 980.665. For example for the first value of -152:

$$\frac{\left(\frac{-152}{10}\right)}{980.665} = -0.015500$$

However, this is equivalent to multiplying each value by a factor of (1 / 9806.65) or 0.000102. Thus, you would enter a value of 0.000102 in the **Multiplier** text box.

If you select the **Other** option of the **Output Units** list, you can enter a description of the other units (e.g. *gals*) in the **Other Units** text box.

The **RspMatch** option of the **Output Units** list is used to convert files to a format compatible with the RspMatch computer program.

After selecting the multiplication factor, place the cursor on the text box below the **Database Header Line** label (or **Option 7 Set ID – Line** label, if converting a file for use in Option 7 of D-MOD_2). Here you would enter a value that represents the line from the header section that will be used to identify the converted file in the database of ground motion files or in the set identification of Option 7. For example, for the above record, you could use the first line to be included in the database, thus you would enter a **1**.

The last information needed before you convert the file is the number of the lines from the header section in the source file that you would like to include in the converted file. To do this, place the cursor on the first text box below the **Lines from Source Header to be included in Converted Ground Motion File** label. Here you can select a specific line, or select a range of lines. To select one line, just enter the number of the line in the text box. For example to select the first line from the above file enter a **1**. To select a range of lines, enter the number of the first line in the range followed by a “-” and then the number of the last line in the range. For example, if you would like to select the first five lines of the

above header you would enter **1-5** in the text box. There are 3 text boxes in this section that you can use to select different lines from the header section. By default, the first four lines in the header of the converted file will be created by D-MOD2000. The lines will include the name and path of the source file, the units of the acceleration values, the number of acceleration values in the converted file (which may be slightly different from the original number in the source file), the time step of the acceleration time history, and the format string used to write the data to the file. These four lines will provide valuable information if the file is used with a different software application.

After you have entered the above information, you need to enter the name and path of the converted file. A default file name and path are shown on the box next to the **Converted Ground Motion File** label. If you would like to select a different file, first click on the **Save** command button to display the **Save Converted Ground Motion File** dialog form. Enter the name of the file on the text box next to the **File name** label, or use the mouse to select a file by highlighting it. Then click on the **Save** command button to return to the conversion form. Now, click on the **Convert** command button to convert the source file to the units and format you selected. After a few seconds, the first few lines (up to 99) of the converted file will be shown on the bottom list box.

After you have converted the file, you can plot the resulting motion using the **Plot** command button. You can also add information about this motion in the database of ground motions using the **Dbase** command button. Refer to the **Edit/Add Ground Motion File Information** section of this manual for further information.

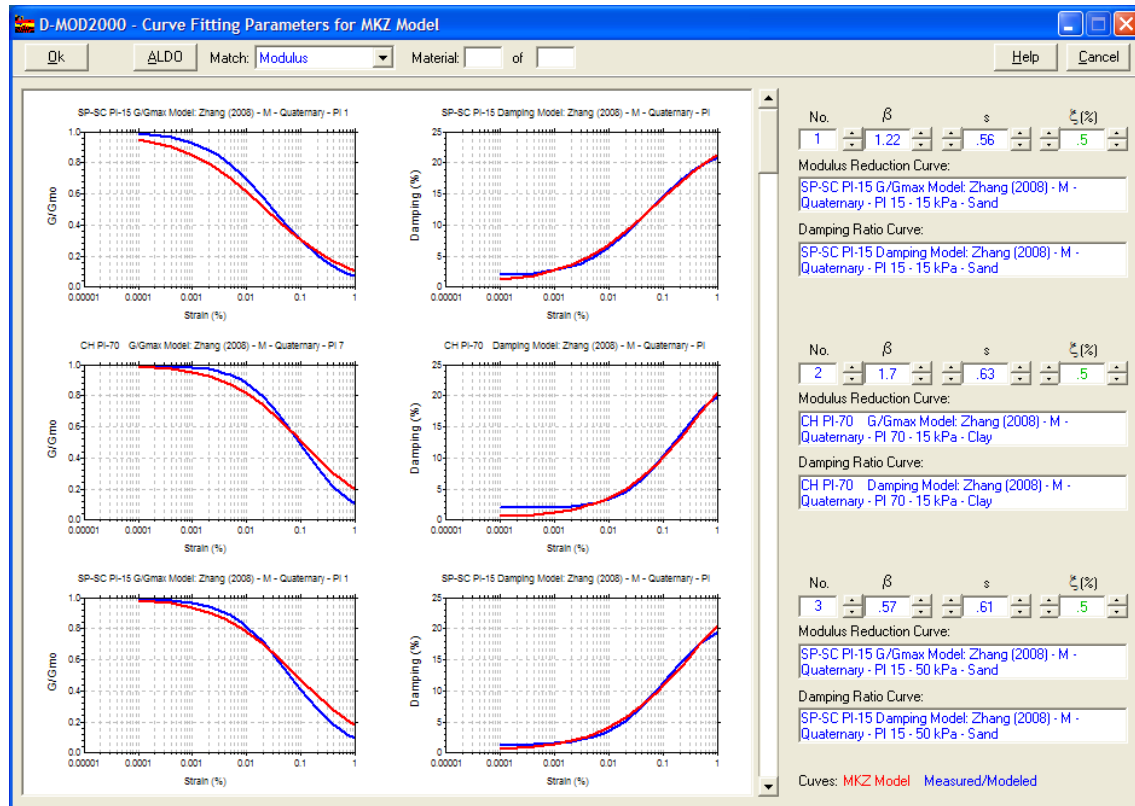
The **Spectra** command button is used to display the **Response Spectra for Ground Motion** form. This form can be used to compute the response spectra for the converted ground motion.

Adding Information about a Ground Motion File to the Database: To do this, first click on the **Ground Motion File Utilities: Conversion & Database** option of the Main Menu form to select it. Then, click on the **Ok** button to display the conversion form. Next, click on the **Open** command button to display the **Open Source Ground Motion File** dialog form. Change to the folder and subdirectory where the file is located if necessary, click on the file to highlight it, and then use the **Open** button to open the file and return to the conversion form. After a few seconds, the first few lines of the file (up to 99 lines) will be shown on the top list box of the form.

Once the file is opened, you need to enter as a minimum the information requested in the **No. Values**, **Time Step**, **No. Header Lines**, **Values per Line**, **Format** and **Database Header Line** text boxes as described in the previous section. Note that in this case, the information that you enter in the **Format** text box refers to the file that you want to add to the database. If you do not enter a value for “Values per Line”, this information will be obtained from the data entered in the format text box. After entering this information, click on the **Dbase** command button to display the **Edit/Add Ground Motion File Information** form. Refer to that section on this manual for further information.

Editing the Database of Ground Motion Files: This form also allows you to access the form used to edit the information available in the database of ground motion files. For more information about the database, refer to the **Database of Earthquake Records** section of this manual. To access the editor form, click on the **Dbase** command button to display the **Edit/Add Ground Motion File Information** form. Refer to that section of this manual for more information about editing the database. Please note that to access the database form, you should not open a file first.

Curve Fitting Parameters for MKZ Model



This form is used to find the MKZ model parameters β and s for more than one material at a time by either modifying the values by trial and error; or, by using an automatic optimization routine.

After you have selected the modulus reduction and damping ratio curves for the materials in Option 4 set, the **Curve Fitting Parameters for MKZ Model** form can be used to speed up the process of matching β and s . This form is only available after every material has been assigned both modulus reduction and damping ratio curves and when there are at least 3 materials in the Option 4 set.

For a trial and error search, enter the values of β , s and ξ in the respective text box; or, use the up/down arrows to increase/reduce the values by 0.05 units (right side) or 0.01 units (left side). The curves will be automatically updated to show the effects of changing the values.

An automatic linear data optimization (**ALDO**) routine is also included that will speed up the process of matching the curves. There are three options for this optimization: **Modulus** (match modulus reduction curves only); **Modulus/Damping** (match both modulus reduction and damping curves); and **Damping** (match damping ratio curves only). Select one of these options using the down arrow and then click on the **ALDO** command button to optimize the matching process.

D-MOD Option 1 – Master Control Card

TITLE	Up to 75 alphanumeric characters to describe the analysis
NPTYPE	<p>Analysis type control number:</p> <p>1 – <i>Total-Stress Analysis</i> (no cyclic degradation of soil properties during shaking, i.e., dynamic response with neither pore water pressure generation nor cyclic degradation via the generalized degradation index).</p> <p>2 – <i>Effective-Stress Analysis</i> (cyclic degradation of soil properties, but without hydraulic interaction between layers, i.e., dynamic response with pore water pressure generation and/or cyclic degradation, but with no pore water pressure dissipation).</p> <p>3 – <i>Effective-Stress Analysis</i> (cyclic degradation of material properties with hydraulic interaction between layers, i.e., dynamic response + pore water pressure generation + pore water pressure dissipation and redistribution).</p>
NLAYER	Number of material (soil) layers in the profile [min = 2, max = 50 (student version) or max = 200 (full version)]. Note: Single degree-of-freedom system can be analyzed by specifying NLAYER = 1.
NMAT	Number of material (soil) property sets specified [min = 2, max = 50 (student version) or max = 200 (full version)].
ITMBY	<p>Half-space control number:</p> <p>0 – Half-space is infinitely stiff⁴ (omit Option 5 in this case).</p> <p>1 – Half-space is visco-elastic⁵.</p> <p>⁴ Setting ITMBY = 0 simulates an “infinitely” stiff half-space. Use this option to specify an “in-hole” (i.e. “within”) motion.</p> <p>⁵ Setting ITMBY = 1 introduces a fictitious layer (transmitting boundary) at the base of the profile. Use this option to simulate the “outcropping” motion. Note that, for this fictitious layer, only the absolute velocity is printed in the master output file.</p>
NUNIT	System of units to be used in the master input and master output files:

0 – lb-ft-sec system (U.S.) except acceleration which is in “g”.
1 – metric

NLINEL Stress-Strain model control number (applies to all layers in the profile):
0 – Linear-elastic model is used (i.e., $\tau = G_{mo} \gamma$).
1 – Non-linear hysteretic model is used (choice between two non-linear hysteretic models is offered in Option 4).

NDAMP Viscous damping⁶ control number:
1 – Coefficients of the viscous damping matrix [C] are read from input cards as force per unit velocity values (not recommended).
2 – Rayleigh damping coefficients α_R and β_R are read from the input cards⁷. The viscous damping matrix [C] is calculated by the program as: $[C] = \alpha_R[M] + \beta_R[K]_{t=0}$, where $t=0$ denotes the initial conditions, i.e., conditions before stiffness degradation by the seismically-induced PWP buildup.

⁶ Viscous damping is required to maintain numerical stability of the solution. Note that, as viscous damping is additive to the hysteretic (material) damping, it also compensates for lack of material damping in small strain range.

⁷ Recommended option.

NBT Top hydraulic boundary condition number⁸:
0 – Sets zero pore water pressure (PWP) at the top hydraulic boundary (PWP = 0 at the top of the NFIRST layer; see explanation for NLAST of this card).
1 – Sets zero flow at the top hydraulic boundary (flow = 0 at the top of NFIRST layer).

⁸ Note that NBT and NBB are used by the program only when NPTYPE = 3.

NBB Bottom hydraulic boundary condition control number⁸:
0 – Sets zero pore water pressure at the bottom hydraulic boundary (PWP = 0 at the bottom of the NLAST layer; see explanation for NLAST of this card).
1 – Sets zero flow at the bottom hydraulic boundary (flow = 0 at the bottom of NLAST layer).

⁸ Note that NBT and NBB are used by the program only when NPTYPE = 3.

ITERRV The “irregular stress-strain behavior” accuracy control number No. 1:
0 – Do not recalculate all time-dependant variables with two smaller time steps each time when reversal in stress-strain loop occurs (this option speeds up calculation).
1 – Recalculate all time-dependant variables with two smaller time steps each time when reversal in stress-strain loop occurs (recommended).

ICKFB The “irregular stress-strain behavior” accuracy control number No. 2:
0 – Do not apply correction forces for the departure of the stress-point from the stress strain-curve (this option speeds up calculation).
1 – Apply correction forces for the departure of the stress-point from the stress strain curve (recommended).

NFIRST Number of the top saturated soil layer considered for pore water pressure generation and dissipation calculation.

NLAST Number of the bottom saturated soil layer considered for pore water pressure generation and dissipation calculation (Note that saturated soil lies between NFIRST and NLAST layer including these two layers).

D-MOD Option 2 – Layer Description Card

Layer No.	Material Type	Number of Subdivisions	Thickness (ft)	Width (ft)	GW/T Control Number	PWP Control Number	Material Description
1	1	4	5	1	1	0	Silt 1
2	2	4	3.3	1	0	1	Silt 2
3	3	4	3.3	1	0	1	Sand (WSA)
4	4	4	3.3	1	0	1	Sand (WSB)
5	5	4	3.3	1	0	1	Sand (WSB)
6	6	4	4.25	1	0	1	Sand (WSB)
7	7	4	2.3	1	0	1	Sand (WSB)
8							
9							
10							

As many cards as there are layers, i.e., NLAYER cards.

MATYP(I) Material type identification number corresponding to the “i”-th layer. Note that layers in the input file are not numbered, but it is assumed that the layer at the soil surface (or at the crest of a dam) is layer number 1. Uses XLBL (optional) to number the material sets.

NSUBD(I) Number of subdivisions of the “i”-th layer for pore water pressure redistribution and/or dissipation calculation⁹ (min \equiv default value = 2; max = 10).

⁹ PWP redistribution and/or dissipation are calculated using an explicit finite difference (FD) scheme. The mesh for FD calculation should be denser than the one for site response calculation, hence NSUBD(I) default value is 2.

h_i Thickness of the “i”-th layer¹⁰, h_i , [decimal]; [ft].

¹⁰ Note that the maximum frequency of a layer (f_{\max}) is the highest frequency that the layer can propagate. The f_{\max} is calculated as: $f_{\max} = V_s/4H$, where V_s and H are the shear wave velocity and thickness of the layer, respectively. If a layer is too thick, the maximum frequency that a layer can propagate is small. For example, the most commonly used f_{\max} to calculate an adequate thickness of a layer for site response analysis is 25 Hz, hence layer thickness can be calculated as $h_i = (V_s)_i/100$.

b_i Width of the “i”-th layer, b_i , [decimal]; [ft].

ITWT(I) Ground water table control number:
0 – Layer is below the ground water table.
1 – Layer is above the ground water table.

MOTYP(I) Pore water pressure/cyclic degradation model control number:
0 – No pore water pressure/cyclic degradation model is activated.
1 – Dobry et al. (1985); Vucetic and Dobry (1988) pore water pressure model for sand is activated.

2 – Generalized degradation-pore water pressure generation model for clay by Matasovic and Vucetic (1995a) is activated.

XLBL Up to 10 alphanumeric characters to describe (number) the material set (optional).

Use the **Add** command button to add a new layer at the cursor position. By default, the same data for the current layer will be assigned to the new layer. To delete a layer from the soil column, use the **Remove** command button. If you want to create more than one layer at a time, place the cursor on the soil layer that you want to copy and then click on the **Layers** command button. This will display the **Soil Column Layers** form. Use this new form to enter the data that will be used for the new layers.

The **Profile** command button is used to display a plot of the soil column and other material properties vs. depth. The properties displayed will be for the first set of Option 4 for which there is a number of materials greater or equal than the maximum number entered in the **Material Type** column. A different set of Option 4 can be chosen on the form where the graphs are displayed.

D-MOD Option 4 – Material Description Card

D-MOD2000 Option 4: Material Description

Ok New Delete MKZ Sand Clay Fit Help Cancel

Set No.: 1 Material Description - Set Identification: Material Properties: Short Course - Median

No. Materials: 29 Material: No. 1 - SP-SC PI-15

G_{mo} (kN/m ²)	τ_{mo} (kN/m ²)	β	s	v	ID
136006.8	44.0662	0.85	0.65	1	SP-SC PI-15
V_s (m/sec)	E_t (kN/m ²)	K_2	m	n	
266		0.0025	0.43	0.62	
γ_{sat} (kN/m ³)	γ_{wet} (kN/m ³)	k (m/sec)	α_R or c	β_r	
18.85	17.85	2.011704E-03	0.00000E00	6.70361E-04	
f	P	F	s	γ_{tv} (%)	OCR
2	1.04	2.6	1.7	0.02	
s_t	r	A	B	C	D

For each (different) material, up to 24 constants may be specified, depending on NPTYPE and MOTYP selected. Note that 5 cards must be used to describe each material, even though some of the constants/parameters may be omitted. There are 5(NMAT) cards for this data set.

Use the **MKZ** command button to display the **MKZ Non-Linear Stress-Strain Model** form. This form is used to calculate the modulus reduction and damping curves using the MKZ non-linear stress-strain model (Matasovic and Vucetic, 1993). It is also used to find the MKZ model parameters β and s (by trial and error), and to calculate the stiffness-proportional Rayleigh coefficients α_R and β_R . Upon returning to this form, the values for G_{mo} , τ_{mo} , β and s will be updated.

Similar to the **MKZ** button, the **Fit** command button will display the **Curve Fitting Parameters for MKZ Model** form. This form is used to find the MKZ model parameters β and s (by trial and error), but for more than one material at a time. After you have selected the modulus reduction and damping ratio curves for the materials in this set, the **Curve Fitting Parameters for MKZ Model** form can be used to speed up the process of matching β and s . The **Fit** command button is enabled after every material has been assigned both modulus reduction and damping ratio curves and when there are at least 3 materials in the set.

The **Sand** command button is used to display the **Grain Size Distribution Curve Matching** form. In this form, the user can enter the gradation curve for his/her own sand/silt soil and then compare this curve to those from other liquefiable sands and/or silts. Based on this, the user can pick a curve that approximates his/her own curve and then use generic material parameters (i.e., k , v , f , p , F , s and γ_{tv}) and curve fitting constants (i.e., γ_r , β and s) for the selected curve.

Similarly, the **Clay** command button will display the **Plasticity Chart for Cyclically Degradable Clays** form. The liquid limit and plasticity index for your clay soil can be entered in this form and compared to other clay soils for which material parameters (i.e., γ_{tv}) and curve fitting constants of the pore water pressure and degradation model (i.e., s_t , r , A , B , C , and D) are available. Upon returning to this form, the generic values will be shown on the appropriate text boxes.

To display the other materials, scroll down the **Material** list and select a material. A new material set can be created by clicking on the **New** command button. The current material set can be deleted by clicking on the **Delete** command button. After editing the data, click on the **Ok** command button to return to the Main Menu form.

Please note that for some parameters, a value of zero, i.e. 0, is considered an input value. Accordingly, if you don't want to input any value for the parameter, make sure that nothing is shown in the text box for the parameter. For example, entering a value of zero for the α_R parameter is not the same as leaving the text box blank.

Default material properties for some typical soils are presented in Appendices A and B. More detailed information about the computation of the Rayleigh damping coefficients is presented in Appendix C.

Further, the data provided in Appendices A & B can also be imported by clicking on the icons next to the row of data of interest. For example, by clicking on the icon with a sail boat, the **Material Parameters and Curve Fitting Constants** form is displayed. In this case, the form will display the data provided in Table B-3, i.e. pore water pressure dissipation model (sand and clay), typical values of k , E_r , and Martin's PWP dissipation model curve fitting constants. You can select the data for any of the materials in that form and import the data into the current material set for Option 4.

Card 4.1 – Stress-Strain Model Control Card

G_{mo}	Initial ($t = 0$), tangent shear modulus of soil, G_{mo} , [decimal]; [psf].
V_s	Shear wave velocity, [decimal]; [fps]. Either a value for G_{mo} or V_s should be provided; the other value will be computed using the value for the saturated unit weight.
τ_{mo}	Shear stress at reference strain, τ_{mo} (MKZ model), or the shear strength of soil, τ_f (KZ model ¹¹), [decimal]; [psf]. Evaluate τ_{mo} by curve-fitting the initial loading stress-strain curve or as $\tau_{mo} = G_{mo} \gamma_r$, where γ_r is reference shear strain. Generic values of γ_r are provided in Tables A-1 and A-2 in Appendix A.
β	Curve-fitting parameter of the non-linear hysteretic MKZ model [decimal]; [-]. To use the KZ model, set $\beta = 1.0$. Use spreadsheet D-MOD_2 MKZ-fit.xls or the MKZ command button to develop β from modulus reduction and damping curves; or pick generic values using the Sand or Clay command buttons; or, use generic values from Tables A-1 and A-2.
s	Curve-fitting parameter of the non-linear hysteretic MKZ model [decimal]; [-]. To use the KZ model, set $s = 1.0$. Use spreadsheet D-MOD_2 MKZ-fit.xls or the MKZ command button to develop s from modulus reduction and damping curves; or, pick generic values using the Sand or Clay command buttons; or, use generic values from Tables A-1 and A-2.
ν	Curve-fitting parameter that controls cyclic degradation of saturated sand. Set $\nu = 1.0$ for all practical applications. For research purposes, check in Matasovic and Vucetic (1993), [decimal]; [-].

¹¹ Kondner and Zelasko (1963) model, which is sometimes referred as the “hyperbolic model”.

YLBL (ID) Up to 6 alphanumeric characters to describe (e.g., to number) the material sets (optional).

Card 4.2 – The Pore Water Pressure Dissipation and Redistribution Model and Physical Properties of Soils (Part I)

E_r Unloading (rebound) modulus of soil¹², E_r , [decimal]; [psf]. Default generic values for clay is provided in Table B-3 in Appendix B. Leave blank to have the program calculate E_r from the Martin et al. (1975) model (recommended, especially for sand). Note that in sand, E_r is a function of σ'_v , K_2 , m , n where K_2 , m , n are constants defined below.

¹² Use this option only if E_r is to be evaluated from special laboratory testing (testing program described in Martin et al., 1975 paper). Otherwise, leave this column blank to have D-MOD_2 calculate E_r (recommended).

K_2 Constant used to calculate E_r from Martin et al. (1975) model, [decimal]; [-]. Generic values are provided in Table B-3.

m Constant used to calculate E_r from Martin et al. (1975) model, [decimal]; [-]. Generic values are provided in Table B-3.

Card 4.3 – The Pore Water Pressure Dissipation and Redistribution Model and Physical Properties of Soils (Part II)

n Constant used to calculate E_r from Martin et al. (1975) model, [decimal]; [-]. Generic values are provided in Table B-3.

γ_{sat} Saturated unit weight of soil, [decimal]; [pcf]. The value of G_{mo} will be re-calculated using the value for V_s when the value for saturated unit weight is changed.

γ_{wet} Wet (bulk) unit weight of soil, [decimal]; [pcf].

k Hydraulic conductivity of soil, [decimal]; [ft/sec].

α_R or c The first Rayleigh damping coefficient, α_R , or c , if NDAMP¹³ = 1, an element on the diagonal of the viscous matrix [C], [percent if NDAMP = 1; decimal if NDAMP = 2]; [units: “-“ if NDAMP = 1; force per unit velocity if NDAMP = 2].

¹³ NDAMP = the “viscous damping control number” specified in Option 1.

β_R Second Rayleigh damping coefficient¹⁴, [decimal]; [-].

¹⁴ The damping in soil is not frequency dependent. Therefore, the choice of α_R and β_R must be made that provides for damping values that have minimum variations over the range of frequencies of interest. The simplest, and for most practical applications accurate enough way to achieve that is to set $\alpha_R = 0$ and calculate β_R as $\beta_R = (c/\pi) T$, where c is the viscous damping coefficient (decimal) and T is predominant period of the soil deposit (in seconds). T can be calculated in a “dry run” of D-MOD_2. Viscous damping coefficient c is typically in the 0.5 to 5% range. The conventional procedure to evaluate α_R and β_R is presented in Appendix D. More rigorous procedure to establish α_R and β_R can be found in Hudson et al. (1994).

Card 4.4 – Pore Water Pressure (PWP) Generation Model for Sand (This model is referred to as *Model 1* in the *master output file*)

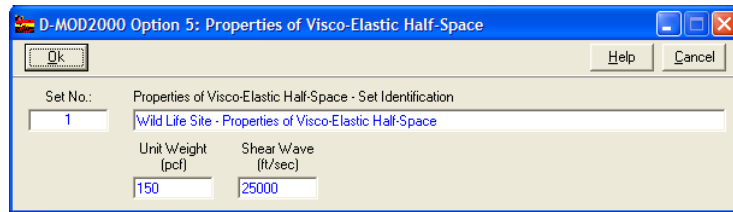
f	Factor introduced by Vucetic and Dobry (1988) to simulate quasi two-directional pore water pressure response of Dobry's PWP model, [decimal]; [-]. 1.0 – One-directional pore water pressure response. 2.0 – Quasi two-directional pore water pressure response.
P	Curve-fitting constant of Dobry's PWP model, [decimal]; [-]. Generic values are provided in Table B-1.
F	Curve-fitting constant of Dobry's PWP model, [decimal]; [-]. Generic values are provided in Table B-1.
s	Curve-fitting constant of Dobry's PWP model, [decimal]; [-]. Generic values are provided in Table B-1.
γ_{tv}	Volumetric threshold shear strain, γ_{tv} , [decimal]; [%]. Generic values are provided in Table B-1 (for Sands) and in Table B-2 (for clays). Note that γ_{tv} is a material parameter of both Dobry's and Matasovic Vucetic's models. Accordingly, it should also be included as part of the material properties for a clayey soil.
OCR	Overconsolidation ratio of soil, OCR , [decimal]; [-]. Note that this is a descriptive label, not a material parameter and therefore can be omitted.

Card 4.5 – Generalized Degradation – Pore Water Pressure (PWP) Generation Model for Clay (This model is referred to as *Model 2* in the *master output file*)

s_r	Degradation parameter fitting constant, [decimal]; [-]. Generic values are provided in Table B-2.
r	Degradation parameter fitting constant, [decimal]; [-]. Generic values are provided in Table B-2.
A	Degradation index fitting constant, [decimal]; [-]. Generic values are provided in Table B-2.
B	Degradation index fitting constant, [decimal]; [-]. Generic values are provided in Table B-2.
C	Degradation index fitting constant, [decimal]; [-]. Generic values are provided in Table B-2.
D	Degradation index fitting constant, [decimal]; [-]. Generic values are provided in Table B-2.

For clayey soils, the volumetric threshold shear strain, γ_{tv} , should also be provided in the material properties set for the soil.

D-MOD Option 5 – Properties of the Visco-Elastic Half-Space



The screenshot shows a Windows-style dialog box titled "D-MOD2000 Option 5: Properties of Visco-Elastic Half-Space". It has a blue title bar with standard window controls. Inside, there are "Ok", "Help", and "Cancel" buttons. The main area is divided into two sections. The first section, "Set No.:", has a text box containing "1" and a label "Properties of Visco-Elastic Half-Space - Set Identification". Below this is a text box containing the file path "Wild Life Site - Properties of Visco-Elastic Half-Space". The second section contains two input fields: "Unit Weight (pcf)" with the value "150" and "Shear Wave (ft/sec)" with the value "25000".

This card is used only if ITMBY = 1. Otherwise, omit this card and go directly to Option 6.

γ_E Unit weight of the visco-elastic half-space, γ_E , [decimal]; [pcf].

V_{SE} Shear wave velocity of the visco-elastic half-space, V_{SE} , [decimal]; [ft/sec].

D-MOD Option 6 – Dynamic Analysis Solution Control Card

NEQ	INTYP	NC	NCPR	NCPRM	NPLD	Time Step (sec)
1	1	19392	50	100	2	0.005

NEQ Set equal to 1 (this version of the program reads only single (horizontal) acceleration time history from the *accelerogram input file*).

INTYP Set equal to 1 (this version of the program performs step-by-step numerical integration using Newmark's "Beta" method).

NC Total number of numerical integrations to be performed by the program. Note that if NC is set as $NC = NCARD * NREC$ (recommended; see option 7), the entire accelerogram will be used to calculate the dynamic response of the deposit.

NCPR Partial number of numerical integrations to be performed prior to printing time-history values in the master output file. For example, if the time step of the numerical integration is 0.01 seconds and NCPR is 100, then values will be printed in the master output file for every second, since $100 \cdot 0.01 = 1$.

NCPRM This variable controls what will be printed in the master output file¹⁴. In other words, it is used to specify partial number of numerical integrations to be performed prior to printing peaks of the time histories in the *master output file*. For example, if the time step of numerical integration is 0.01 seconds and $NCPRM = 500$, then maximum values that occurred in intervals of 0-5, 5-10 seconds, etc. will be printed in the master output file since $500 \times 0.01 = 5$. Note that a total sum of the intervals can be larger than the duration of the earthquake record.

¹⁴ Also note that the values of acceleration used in the computation of the spectrum will depend on the number of values saved to the output file defined with the NCPR and NCPRM variables. Thus, when computing the spectrum, a value of 1 should be used for NCPR and NCPRM. This will lengthen the time necessary to process the output file, but it will provide acceleration values for each time step.

NPLD Auxiliary output file(s) control number:
 0 – No auxiliary output file(s) containing time histories will be created by the program.
 1 – Time-dependant variables for layer "i"¹⁵ will be stored in eleven single-column files (each variable in its own file). All eleven files have descriptive names and extension "prn". More detailed description of file contents (and units) is provided in the *master output file*.
 2 – Time-dependant variables for layer "i"¹⁵ will be stored in two files with extension "dat". More detailed description of file contents (and units¹⁶) is provided in the *master output file*.

¹⁵ Layer "i" is specified from console.

¹⁶ Note: in program versions prior to β9_03, surface acceleration is printed in the "imperial units".

Δt Time step for numerical integration, Δt . (min = 0.0001; max = 0.1); [decimal]; [sec].
Note that Δt typically coincides with the time step of the earthquake record.

D-MOD Option 7 – Earthquake Record (Accelerogram) Control Card

NCARD Number of earthquake record (accelerogram) data cards¹.

NREC Number of digitized acceleration values per data card (min = 1; max = 10)¹.

¹D-MOD2000 accepts up to 32,000 values for the accelerogram file. Accordingly, the result of NCARD x NREC should be less than or equal to 32,000.

NFTS Input Acceleration unit control number:
0 – Input acceleration values are in g-units.
1 – Input acceleration values are in ft/sec².

RDFR Accelerogram scaling constant. Input acceleration values will be multiplied by this constant before execution of the step-by-step numerical integration. (RDFR = 1.0 by default).

Time Step Time step of earthquake record in seconds.

FINPEQ Name of the *accelerogram input file* (e.g. taftN21E.sar). Any 1-, 2-, and/or 3-letter file extension is allowed. A maximum of 68 characters is allowed for this variable.

NHEAD Number of the header lines at the top of the *accelerogram input file* [min = 0; max = 200].

The Accelerogram Input File:

Card 1.0 – Headers (Accelerogram Description Card(s)). There are NHEAD cards to describe the accelerogram.

TITLE Up to 72 alphanumeric characters to describe the accelerogram

Card 2.0 – Earthquake Record (Accelerogram) Cards. There are NCARD accelerogram cards:

AE(I,J) Acceleration values digitalized at time step Δt . The time step should be specified on Option 6. The acceleration values need to be input in accelerogram input file in either of the following FORTRAN “F” formats: 1F9.1, 1F9.2,, 1F9.8; 4F9.1,, 4F9.8; 10F9.1,, 10F9.8. The most commonly used format is 8F9.6 (i.e. eight columns, nine digits in each column, out of nine digits one is decimal point, six are decimals).

Earthquake Records: You can select an object motion listed in the earthquake records database by clicking on the **Quakes** button to display a listing of the records saved in the **D-MOD2000.EQ** file. Once the list is displayed, you can choose a record by highlighting it and clicking on the **Ok** button, or by double clicking on it.

The **New Option 6** option when selected allows you to automatically create a corresponding Option 6 for this Option 7.

If you want to use the data saved in a file that is not included in D-MOD2000.EQ, use the **Other** command button to display the **Object Motion File** dialog box to select the file. After you choose a file, the name of the file will be displayed on the text box below the **FINPEQ** label.

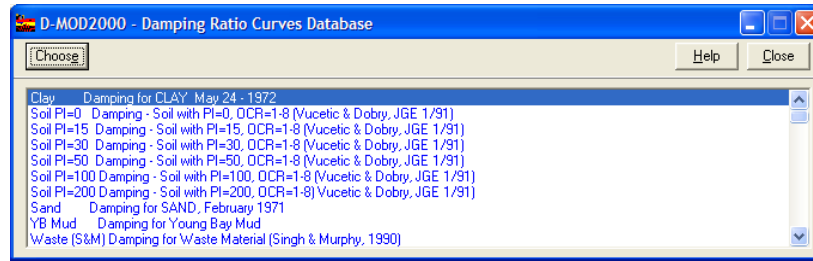
The **Convert** command button is used to display the **Conversion of Ground Motion File** form that can be used to convert ground motion files to different units and/or formatting. Further information on this feature is provided in the **Conversion of Ground Motion File** section of this manual.

The **View** command button can be used to view the contents of a ground motion file. This will help you to collect the information needed to define the formatting of the file if necessary. To do this, first select a file using the **Other** button to select other files. The first 60 lines of the file will be displayed on a form, with the first three characters displayed in red representing the numbers of each row of data in the file followed by a “[”. These characters are not part of the source file and are only shown to number the rows. After the row numbers, the alphanumeric characters that constitute the information saved in the file for each row are shown. Note that the characters are displayed as blue on a white background, and that every tenth character is displayed in red. However, if the tenth character is a “blank space” then the character is not shown. This is done to guide the user when defining the order of the data in the file.

The Plot command button is used to display a graph of the acceleration time history. The program will read the data from the file using the information on this form. A value that may cause problems is the number of characters that will be read to create a number. Basically, the program opens the file, reads NHEAD number of header lines, and then it will read the first line of data. Next, the program obtains the length of this line, i.e. the total number of characters on the line. Then, it will use the NREC number, i.e. the number of acceleration values per line, to obtain the number of characters that form each value. For example, say that the length of the data line is 72 characters and the number of values per line, NREC, is 8. Thus, each value will be formed by $72/8 = 9$ characters. Thus, the program will create an acceleration value by selecting groups of 9 characters. If there are any errors when plotting the time history, it is likely due to reading of the data. Check that the data lines are of uniform length.

A copy of the ground motion file is saved in the EDT file. If you wish to restore the file, click on the **Restore** command button. A copy of the file with the same name will be then created in the same folder where the input file is saved.

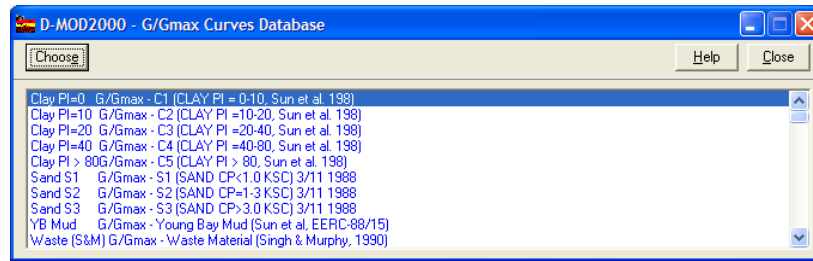
Database of Damping Ratio Curves



To select a damping curve, click on the material to highlight it, and then on the **Choose** command button. You will return to the **MKZ Non-Linear Stress-Strain Model** form. You can also double-click on the material to select it and return to the MKZ model form.

Some of the curves included with D-MOD2000 were obtained from the following references: Sukhmander Singh and Bruce J. Murphy (1990); Kavazanjian, E. Jr.; Matasovic, N.; and Caldwell, J. (1998).; Idriss, I.M.; Fiegel, Gregg; Hudson, Martin B.; Mundy, Peter K.; and Herzig, Roy (1995); Gazetas G. and Dakoulas, P. (1992); Seed, H.B.; Wong, R. T.; Idriss, I.M.; and Tokimatsu, K. (1986); Vucetic, M. and Dobry, R. (1991); Rollins, K.M.; Evans, M.D.; Diehl, N.B. and Daily, W.D. III (1998); Yegian, M.K.; Harb, J.N. and Kadakal, U. (1998); Makdisi, F.I. and Seed, H.B. (1978); Schnabel, P.B. (1973); Seed, H.B. and Idriss, I.M. (1970); Sun, J.I.; Goleosorkhi, R. and Seed, H.B. (1988), Wehling et al. (2003); Darendeli, M. (2001); EPRI (1993); Roblee and Chiou (2004); Martirosyan et al. (2003); Singh and Donovan (1977); Matasovic, N. (1993); and, Zekkos et al. (2008).

Database of G/G_{\max} Curves



To select a G/G_{\max} curve, click on the material to highlight it, and then on the **Choose** command button. You will return to the **MKZ Non-Linear Stress-Strain Model** form. You can also double-click on the material to select it and return to the MKZ model form.

Some of the curves included with D-MOD2000 were obtained from the following references:

Sukhmander Singh and Bruce J. Murphy (1990); Kavazanjian, E. Jr.; Matasovic, N.; and Caldwell, J. (1998).; Idriss, I.M.; Fiegel, Gregg; Hudson, Martin B.; Mundy, Peter K.; and Herzig, Roy (1995); Gazetas G. and Dakoulas, P. (1992); Seed, H.B.; Wong, R. T.; Idriss, I.M.; and Tokimatsu, K. (1986); Vucetic, M. and Dobry, R. (1991); Rollins, K.M.; Evans, M.D.; Diehl, N.B. and Daily, W.D. III (1998); Yegian, M.K.; Harb, J.N. and Kadakal, U. (1998); Makdisi, F.I. and Seed, H.B. (1978); Schnabel, P.B. (1973); Seed, H.B. and Idriss, I.M. (1970); Sun, J.I.; Golesorkhi, R. and Seed, H.B. (1988), Wehling et al. (2003); Darendeli, M. (2001); EPRI (1993); Roblee and Chiou (2004); Martirosyan et al. (2003); Singh and Donovan (1977); Matasovic, N. (1993); and, Zekkos et al. (2008).

Dynamic Material Properties Model

This form is used to enter the input data for the different relationships for estimating normalized shear modulus and material damping ratio of soils. The relationships included with D-MOD2000 are those developed by Darendeli, M.B. (2001); Ishibashi and Zhang (1993); and, Zhang, Andrus and Juang (Zhang et al., 2005; Andrus et al., 2003; Zhang et al., 2008).

For the **Darendeli (2001)** relationship, it is necessary to enter values for the mean effective confining stress, σ'_m , in atmospheres; the soil plasticity index as percentage; overconsolidation ratio; loading frequency; and, number of loading cycles. For the **Zhang, Andrus & Juang (2005)** relationship you need to enter a value for mean effective confining stress in kPa, select one of the **Geologic Unit** options, and enter a value for **Plasticity Index (PI)**. For each Geologic Unit option, a range of PI values is displayed on the PI label. For PI values other than those presented in Andrus et al. (2003), the coefficients will be obtained through interpolation. The effective confining stress in kN/m^2 and plasticity index values should be provided when using the **Ishibashi & Zhang (1993)** relationship.

After entering the data for the model, select the property curve, i.e. **Shear Modulus** or **Damping**, to plot and then click on the **Plot** command button to display the curve.

The mean effective confining stress, σ'_m , used in these models is computed from:

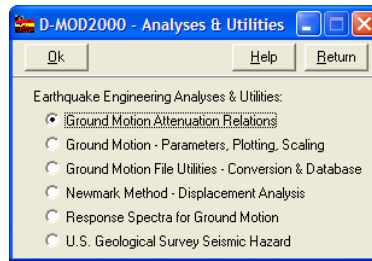
$$\sigma'_m = \sigma'_v \left(\frac{1 + 2K'_o}{3} \right)$$

Where; σ'_v = vertical effective stress
 K'_o = coefficient of effective earth stress at rest

After both graphs have been plotted the **Ok** command button will be enabled. Click on the **Ok** command button to return to the **MKZ Non-Linear Stress-Strain Model** form.

The **Mean \pm Std. Dev.** options to compute the mean \pm standard deviation curves are only enabled when the Darendeli, M.B. or Zhang, Andrus & Juang model is being used to obtain the curves.

Earthquake Engineering Analyses & Utilities



This form presents a list of different features and other utilities useful for geotechnical earthquake engineering analyses.

*To execute one of these options, first click on the option to select it and then on the **Ok** command button.*

Ground Motion Attenuation Relations: This option is used to plot attenuation relations for peak ground acceleration and peak horizontal velocity with distance, and pseudo absolute acceleration and pseudo relative velocity response spectra. Several equations are used, as described in the **Ground Motion Attenuation Relations** section of this manual.

Ground Motion – Parameters, Plotting, Scaling: This option is used to plot the acceleration time history for an earthquake record; to compute the mean response spectrum for a series of ground motion records; and, to obtain various parameters useful in characterizing ground motions. For example, you can use this option to plot the object motion that is used as input for the D-MOD_2 analysis. The **Plot Object Motion** form will be displayed to allow you to select the object motion to be plotted.

Ground Motion File Utilities: Conversion & Database: With this option the user can convert ground motion files to different units and/or formatting. Also, the information on the database of ground motion files can be edited and data about new files added.

Newmark Displacement Analysis: This option allows you to determine permanent slope displacements due to earthquake shaking, using the Newmark Method.

Response Spectra for Ground Motion: This option is used to compute the response spectra for a ground motion.

U.S. Geological Survey Seismic Hazard: This form is used to retrieve the Peak Ground Acceleration from the files of gridded points used to make the 1996 USGS National Seismic Hazard Maps (Frankel et al., 1996), for the updates (Frankel et al., 2002; U.S. Geological Survey, 2003a and 2003b, 2008, 2010); and also, to plot the results of the seismic hazard deaggregation for a site in the conterminous states of the United States.

Earthquake Records Database

CHI-CHI 09/20/89, TCU070, W (CWB)

CHI-CHI 09/20/89, TCU070, N (CWB)

COALINGA 07/22/83 0239, SKUNK HOLLOW, 360 (USGS STATION 1605)

COALINGA 07/22/83 0239, SKUNK HOLLOW, 270 (USGS STATION 1605)

LOMA PRIETA 10/18/89 00 05, ANDERSON DAM DOWNSTREAM, 360 (USGS STATION 1652)

LOMA PRIETA 10/18/89 00 05, ANDERSON DAM DOWNSTREAM, 270 (USGS STATION 1652)

PALM SPRINGS 07/08/86 0920, N PALM SPR P.O., 300 (USGS STATION 5070)

PALM SPRINGS 07/08/86 0920, N PALM SPR P.O., 210 (USGS STATION 5070)

NAHANNI, CANADA 12/23/85, SITE 2, 330

Ground Motion File	No. Values	Time Step	Max. Acc.	No. Header	Values/Line	Format
Crusta\TCU070-W_AT2.eq	18000	0.005		8	8	(8F9.6)

Source File: Chi Chi\TCU070-W_AT2.txt
D-MOD2000 Conversion: 18000 .005 8 8 9 (8F9.6)
Acceleration Units: (g's) - No. Values: 18000 - Time Step: .005 (secs)
Data Format: (8F9.6) - No. Header Lines: 8
PEER STRONG MOTION DATABASE RECORD. PROCESSING BY PACIFIC ENGINEERING.

☒ Path to Earthquake Files: C:\D-MOD2000\Quakes

This form is used to display a listing of earthquake records available in your system. Basic information for each record is saved in the **D-MOD2000.EQ** database file located in the same directory where D-MOD2000 is installed. This file is an ASCII text file that can be modified either manually or through the **Edit Database of Ground Motion Files** form to include new information about new records, or to edit current information.

To select an earthquake record, click on it to highlight it, and then click on the **Choose** button. You will return to either, the Option 7 editor where the data will be displayed on the corresponding cells; or, to the **Plot Object Motion** form, where the data will be displayed on the bottom section of the form.

Use the **Directory** command button to choose the path to the directory where the earthquake motion files are stored. After clicking on this button, the **Path to Earthquake Files** form will be displayed. Use the mouse to select the drive and directory, and then click on the **Ok** button. The directory will be displayed on the text box next to the **Path to Earthquake Files** label.

The following web sites provide ground motion records for download. Please note that the following Internet addresses were valid at the time this User's Manual was written.

1. PEER Strong Motion Databases: These databases contains over 1000 records from 140 earthquakes from tectonically active regions.

<http://peer.berkeley.edu/smcat/>

<http://peer.berkeley.edu/nga/search.html>

2. Cosmos Virtual Data Center

<http://db.cosmos-eq.org/scripts/earthquakes.plx>

It is highly recommended that you use the above web sites to search for records given specific characteristics (e.g. mechanism, soil classification, magnitude, etc.). When downloading a file from an internet site, you need to save the file as a text file. Once you have an appropriate record for your

analysis, you may need to transform the record to a format compatible with D-MOD2000. You can use the **Ground Motion File Utilities: Conversion & Database** option of the Main Menu to convert the file.

Edit/Add Ground Motion File Information

D-MOD2000 - Edit/Add Ground Motion File Information

Buttons:

List of Ground Motion Files:

- CHI-CHI 09/20/99, TCU070, W (CWB)
- CHI-CHI 09/20/99, TCU070, N (CWB)
- COALINGA 07/22/83 0239, SKUNK HOLLOW, 360 (USGS STATION 1605)
- COALINGA 07/22/83 0239, SKUNK HOLLOW, 270 (USGS STATION 1605)
- LOMA PRIETA 10/18/89 00:05, ANDERSON DAM DOWNSTREAM, 360 (USGS STATION 1652)
- LOMA PRIETA 10/18/89 00:05, ANDERSON DAM DOWNSTREAM, 270 (USGS STATION 1652)
- PALM SPRINGS 07/08/86 0920, N PALM SPR P.O., 300 (USGS STATION 5070)
- PALM SPRINGS 07/08/86 0920, N PALM SPR P.O., 210 (USGS STATION 5070)
- NAHANNI, CANADA 12/23/85, SITE 2, 330

Description of Ground Motion File used in Database:

LOMA PRIETA 10/18/89 00:05, SANTA CRUZ UCSC LICK OBS, 090 (CDMG STATION 58135)

Ground Motion File	No. Values	Time Step	Max. Acc.	No. Header	Values/Line	Format
LOB090_AT2.eq	7984	.005		8	8	(8F9.6)

☒ Path to Earthquake Files: C:\D-MOD2000\Quakes

This form is used to edit the database of ground motion files used by D-MOD2000. The information about the files (e.g. file name, number of values, etc.) is saved in the D-MOD2000.EQ file and can be accessed by different features of D-MOD2000 to get the information for the ground motion. For example, this database can be accessed from the Option 7 editor form to select a ground motion file used in the D-MOD_2 analysis; or, from the response spectra form to select a ground motion for which the response spectra is computed.

The editing functions that can be performed with this form are twofold. First, you can edit the data for an existing ground motion file, or you can remove a file from the database. Second, you can add the information about a new file in the database.

Edit Information about a Ground Motion File:

To display this form, you need to first select the **Ground Motion File Utilities: Conversion & Database** option of the **Analyses & Utilities** form and then click on the **Ok** command button. This will display the **Conversion of Ground Motion File** form. In this second form click on the **Dbase** command button to display the editing form. Once this form is displayed, you can edit the information by entering the new values in their respective text boxes.

In the text box below the **Description of Ground Motion File used in Database** enter a string up to 128 characters long that describes the motion and that is displayed in the list box. For example, the first ground motion in the database shown above is identified as **Alaska (7/3072) – Sitka Record, M: 7.5, Dis: 48 km, Amax: 0.091g, Rock outcrop.**

The name of the file and a path are entered in the text box below the **Ground Motion File** text box. The information in this text box can be added to the information shown on the **Path to Earthquake Files** text box to define the path to the file. For example, when executing D-MOD2000 the path to the first ground motion will be specified as **c:\D-MOD2000\quakes\alaska.eq** when the path option is selected. You can also enter the name and a path if you saved the files in different subdirectories. For example, you can enter **quakes\alaska.eq** if the file is saved in the **quakes** subdirectory, and then on the path option you would select the **c:\D-MOD2000** folder as the path where the file is located. Use the **Directory** command button to choose the path to the directory where the earthquake motion files are stored. After

clicking on this button, the **Path to Earthquake Files** form will be displayed. Use the mouse to select the drive and directory, and then click on the **Ok** button. The directory will be displayed on the text box next to the **Path to Earthquake Files** label.

The total number of acceleration values that form the object motion file is entered in the text box below the **No. Values** label. For the above example, there are 2048 values in the file.

In the text box below the **Time Step** label, enter the time interval between each acceleration value. For this example, it is 0.02 seconds.

The peak acceleration value of the ground motion can be entered in the text box below the **Max. Acc.** label. Entering this value is optional.

In the text box below the **No. Header** label enter the number of lines at the beginning of the file that are used to describe the object motion. In the above example, the first three lines are the header lines.

In the text box below the **Values/Line** label, enter the number of acceleration values on each line of the file. For the above example, there are 8 values on each line. The number entered in this box is used with the information entered in the **Format** text box to determine how many values are to be read from each row of data in the file. Other examples of the information entered in this box are:

In the line below there are 4 values separated by blank spaces:

-.1059027E-04 -.1461820E-04 -.1690261E-04 -.1506594E-04

In the line below there are 8 values. Note that there are no blank spaces separating the values when a negative sign is included:

-0.000001-0.000001-0.000001-0.000001 0.000000 0.000000 0.000000 0.000001

In the line below, there are 8 values, and there are blank spaces separating the values. The last number (e.g. 1) only identifies the row number. Thus, you would enter an 8 in this cell for this specific example:

0.000000 -0.00434 0.00860 0.00540 -0.00565 -0.00944 -0.00369 -0.00669 1

The last information needed for the file is the **Format** value. The format string tells D-MOD2000 how to read the ground motion values from the file. This string is based on the syntax used in the Format statement of the FORTRAN computer language. In this statement edit descriptors specify how the values are read. The edit descriptors supported by D-MOD2000 in this feature are:

Fw.d	Real values
EW.d [Ee]	Real values with exponents
Gw.d	Real values, extended range
Dw.d	Double-precision real values
Iw	Integer values

In these descriptors, the field is *w* characters wide, with a fractional part *d* decimal digits wide, and an optional exponent width of *e*. Remember that the field *w* also includes any blank spaces and the sign. You can also indicate that a given data format is repeated a number of times. For example, 8F9.6 repeats a nine-character real value with six decimal digits descriptor eight times. The first character on the format field should be a "(" and the last character a ")", e.g. (8F9.6). Examples of data saved in the ground motion files included with D-MOD2000 and the format used to define them follow:

Format:(4E15.7):

-.1059027E-04 -.1461820E-04 -.1690261E-04 -.1506594E-04

Format: (8F9.6):

-0.000001-0.000001-0.000001-0.000001 0.000000 0.000000 0.000000 0.000001

From the format string, D-MOD2000 gets the number of digits that form each value, and combines this number with the value entered in the **Values/Line** box to determine the length of each value and the number of values to read from a ground motion file. For more information on format types, please refer to a FORTRAN Programming Language book.

After you have modified the information, click on the **Edit** command button to include the new information on the database file. You will be asked if you want to proceed with the changes. However, even if you accept, the information on the d-mod2000.eq file will not be changed until after you leave this form using the **Ok** command button. Thus, even if you have changed the information on several of the files, but ultimately elect not to modify the information in the d-mod2000.eq file, click on the **Cancel** command button to cancel all of the changes.

To remove a file from the database, click on the **Delete** command button. You will be asked if you want to proceed with removal of the file's information or not.

Add Information about a New Ground Motion File:

To add information about a new file to the database of ground motion files, you first need to use the **Conversion of Ground Motion File** form to open the file and enter the information described previously. To do this, first click on the **Ground Motion File Utilities: Conversion & Database** option of the **Analyses & Utilities** form to select it. Then, click on the **Ok** button to display the conversion form. Next, click on the **Open** command button to display the **Open Source Ground Motion File** dialog form. Change to the folder and subdirectory where the file is located if necessary, click on the file to highlight it, and then use the **Open** button to select the file and return to the conversion form. After a few seconds, the first few lines of the file (up to 99 lines) will be shown on the top list box of the form.

Once the file is opened, you need to enter as a minimum the information requested in the **No. Values**, **Time Step**, **No. Header Lines**, **Values per Line**, **Format** and **Database Header Line** text boxes of the conversion form as discussed in the **Conversion of Ground Motion File** section of this manual. After entering this information, click on the **Dbase** command button to display the **Edit/Add Ground Motion File Information** form.

When you are adding information about a new file, the **Edit** and **Delete** command buttons are not displayed. Instead, the **Add** command button is the only button displayed. Click on this button to include the information on the database, and then on the **Ok** command button to modify the d-mod2000.eq file. If you are adding data for a file converted using the **Conversion of Ground Motion File** form, then the text boxes where the information are displayed will not be enabled, i.e. you will not be able to modify the information. These boxes are enabled if you are adding information about a file that has not been converted with the conversion form.

Edit the D-MOD2000.EQ File with a Text Processor:

The database file can be modified manually using a text processor. Please remember that the formatting in the file (i.e. the way the information is saved in columns) should not be modified. If you choose to do this, the following section explains the way the information is saved in the file which will help you edit the file manually.

Earthquake Records File – D-MOD2000.EQ Format:

D-MOD2000 ".EQ" File
Earthquake Database
Number of Earthquake Records: 2363

Identification	Path	No. Acc	Time Step	Mx. Acc.	Header	Values	Format
Alaska (7/30/72) - Sitka Record, M: 7.5, Dis: 48 km, Amax: 0.091g, Rock outcrop	alaska.eq	2048	0.02		3	8	(8F9.6)
Apeel 7 - crystal spr, pulgas 0 deg	pulgas0.eq	2000	0.02		1	8	(8F9.6)
Apeel 7 - upper crystal spr. pulgas 90 deg	pulgas90.eq	2000	0.02		1	8	(8F9.6)
ANZA 02/25/80 1047, ANZA FIRE STATION, 225 (USGS STATION 5160) - PEER Database	azf225.eq	2058	0.0050		4	6	(6E15.7)

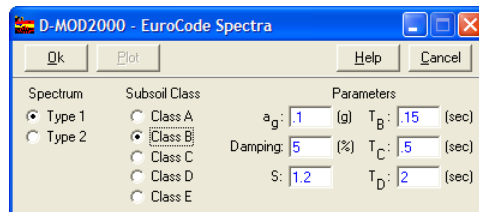
The first two lines in the file (i.e. *D-MOD2000 ".EQ" File & Earthquake Database*) should not be modified. The third line (*Number of Earthquake Records: 2363*) is the number of records listed in the file. Every time you add or delete a record, this number should be modified accordingly. For the above example there is information listed for 2363 different records. The next line is a **blank line**, followed by two lines that limit the fields for the information necessary for each record. The next line is a **blank line**. Each record is described by two lines. The first line (*/Identification*) describes the record (e.g. *Alaska (7/30/72) - Sitka Record, M: 7.5, Dis: 48 km, Amax: 0.091g, Rock outcrop*). This line can contain as many as 128 characters. The following line, i.e.:

Path	No. Acc	Time Step	Mx. Acc.	Header	Values	Format
------	---------	-----------	----------	--------	--------	--------

gives information about the record that is used in Option 7 of D-MOD2000, and also to plot the object motion. The first field (i.e. */Path*) is 30 characters long, from columns 1 through 30, and describes the path in your hard drive where the file is stored or the file name only. For the above example, the first record is saved as a file named *alaska.eq* and assumed to be saved in the *quakes* directory of the hard drive. You could also only include the name without the subdirectory. The */No. Acc* field from columns 36 through 45 is the number of acceleration values in the object motion. The time interval between acceleration values is entered in the */Time Step* field, from columns 46 through 55. The next field *|Mx. Acc.*, from columns 56 through 65, is used to enter the maximum acceleration value to be used. If this field is left blank, a value of zero will be assigned. The number of header lines in the file containing the object motion is entered in the */Header* field, from columns 66 through 75. The number of acceleration values per line in the object motion file is entered in the */Values* field, from columns 76 through 85. The format for reading the acceleration values is entered in the */Format* field, from columns 86 through 95.

After modifying the file, don't forget to update the number of earthquake records in the *Number of Earthquake Records* line. The file should be saved as a text file, with no special formatting using a text processor.

EuroCode 8 Response Spectrum

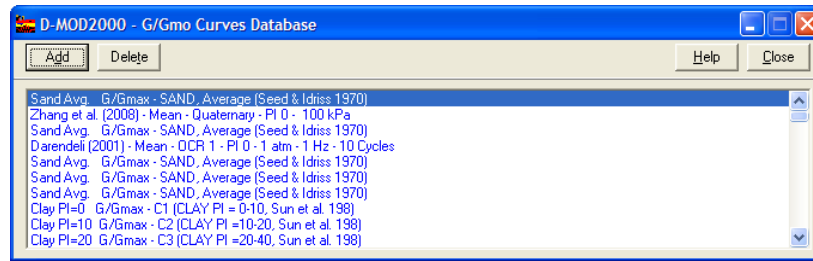


This form is used to select the options and/or enter the data necessary to plot a design response spectrum in accordance with Part 1 of the EuroCode 8 (European Committee for Standardization, 2000).

To select a spectrum, first, choose one of the **Spectrum Type** options. Then, select a subsoil class from the **Subsoil Class** options to determine the soil parameter, S . Next, enter a value for the design ground acceleration in the text box adjacent to the a_g label. Then, click on the **Ok** button to return to the **Response Spectrum Plot Menu** form. The value of damping shown is the first value selected in the **Response Spectrum Plot Menu** form.

The value for the soil parameter, S , can be changed to 1.4 for the special case “...when the subsoil includes an alluvial surface layer with thickness varying between 5 and 20 m, underlain by much stiffer materials of class A” (European Committee for Standardization, 2000). To do this, place the cursor on the text box adjacent to the S label and enter 1.4. Please note that this is only allowed when **Class B** of the **Subsoil Class** options is selected. If a different value is entered, the program will set the default value for the soil parameter based on the type of spectrum selected.

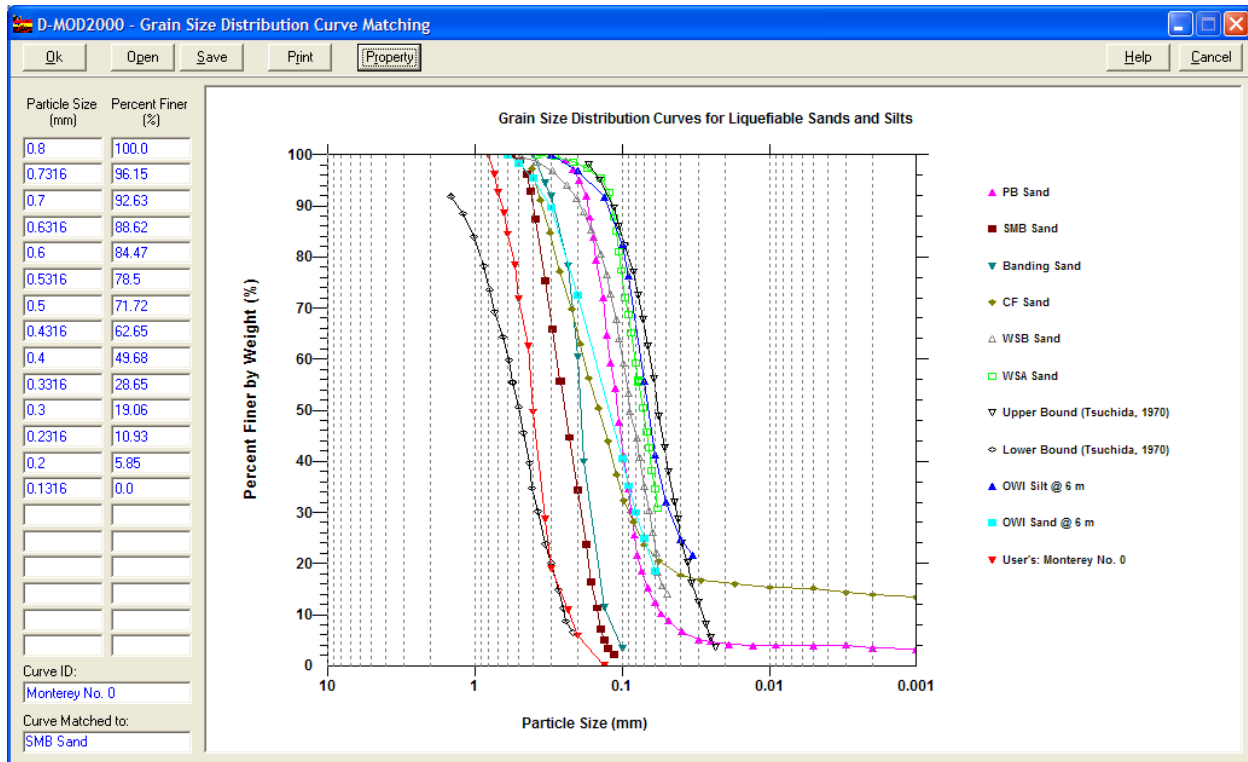
G/G_{mo} & Damping Ratio Curves Database



The current damping data entered in the **MKZ nonlinear Stress-Strain Model** form can be added to the database of material properties. First click on the **Dbase** command button on the MKZ form. Then, click on the **Add** command button. You will be asked if you would like to add the data to the position highlighted in the list of materials.

Data for a specific material can be deleted from the database. To do this, highlight the material to be deleted and then click on the **Delete** command button. You will be asked if you wish to continue with deletion of this material.

Grain Size Distribution Curve Matching



In this form, the user can enter the gradation curve for his/her own material and then compare this curve to those from other liquefiable sands and/or silts (Matasovic, N., 2006). Based on this, the user can pick a curve that approximates his/her own curve and then use the generic material parameters and curve fitting constants for the selected curve.

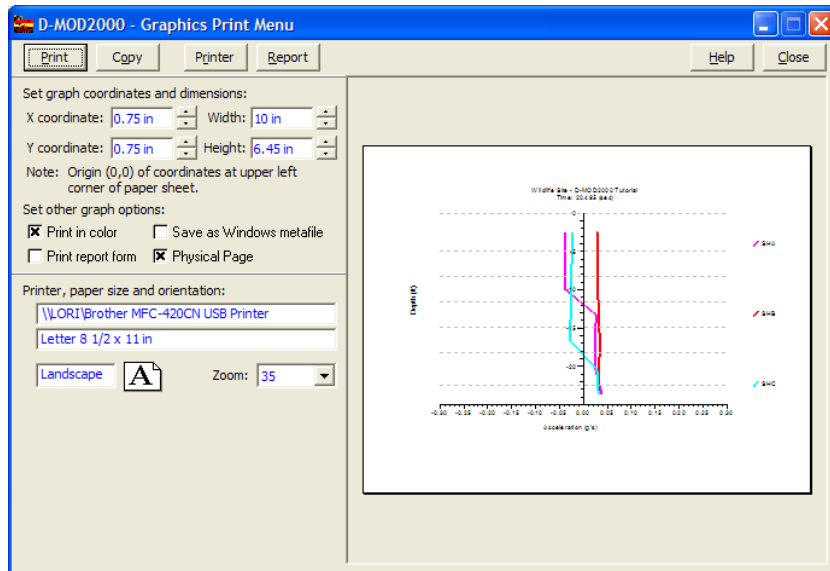
The particle size and percent finer by weight values should be entered in the appropriate text boxes. Every time a pair of values is entered, the graph will be automatically redrawn to show your curve. The label for your curve can be entered in the text box below the **Curve ID** label. This label will be shown as the last legend on the legend section of the graph. To select a “matching” curve, click on any of the symbols for the curve that best matches your own. The label for the selected curve will be shown in the text box below the **Curve Matched** label. The curves for Upper Bound and Lower Bound are only shown for reference and cannot be selected.

The data for your curve can be save to a text file using the **Save** command button. The same data can be retrieved from this file using the **Open** command button. A copy of the graph can be sent to a printer or copied to the Windows Clipboard using the **Print** command button. The **Property** command button is used to display the help pages for the graph control.

The grain size distribution curves for the sands and silts included with the program are listed below. The references listed contain more detailed material characterization information, as well as verification of curve fitting constants and material parameters on case histories.

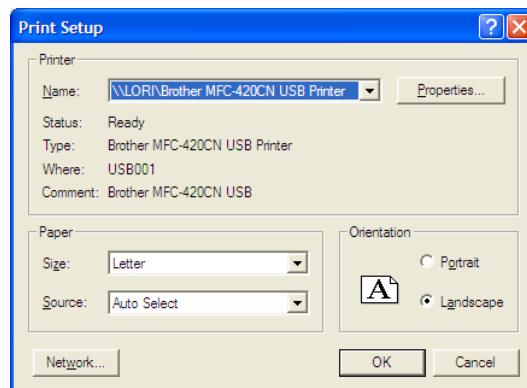
- Banding Sand (BS); poorly-graded commercially available sand; $D_r = 40\%$; $D_{50} = 0.19$; $C_c = 0.9$; $C_u = 1.4$; $\gamma_{d,min} = 90$ pcf; $\gamma_{d,max} = 106$ pcf. Reference: Dobry et al. (1985)
- Wildlife Site Sand A (WSA); void ratio 0.84 to 0.85; 37% fines; $N \approx 5$; $V_s \approx 350$ ft/sec. Reference: Vucetic and Dobry (1988); Matasovic and Vucetic (1993).
- Wildlife Site Sand B (WSB); loose silty sand that liquefied in the past; void ratio 0.74 to 0.76; $D_r = 25\%$; 25% fines; $N \approx 6$ to 13; $V_s \approx 450$ to 500 ft/sec. Reference: Vucetic and Dobry (1988); Matasovic and Vucetic (1993).
- Heber Road Site Sand CF; loose sand; void ratio 0.70; 22% fines; $D_r = 40\%$; $V_s \approx 400$ to 466 ft/sec. Reference: Vucetic et al. (1986); Matasovic and Vucetic (1993).
- Heber Road Site Sand PB; medium dense clean sand that liquefied in the past; void ratio 0.70; 15% fines; $D_r = 45\%$; $V_s \approx 500$ to 600 ft/sec. Reference: Vucetic et al. (1986); Matasovic and Vucetic (1993).
- Santa Monica Beach Sand (SMB); clean dense sand; similar to Monterey No. 0; void ratio = 0.56; zero fines; $D_r \approx 75\%$; $V_s \approx 867$ ft/sec. Reference: Matasovic, N. (1993); Matasovic and Vucetic (1993).
- Owi Island Sand at depths from 6 to 14 m b.g.s.; silty fine sand placed as hydraulic fill; 18% < fines < 35 %. Reference: Tilakaratne and Vucetic (1987); Ishihara et al. (1987).
- Owi Island Silt at depth of 6 m b.g.s.; placed as hydraulic fill; 50% < fines < 85 %. Reference: Tilakaratne and Vucetic (1987); Ishihara et al. (1987).

Graphics Print Menu



The graph can also be printed using the **System Property Page** of the graphics server. To do so, click on the toolbar at the top of the graphics window to display the property pages. Select the **System** tab. You can also use this page to save an image of the graph to a file in either metafile or bitmap format. For further information or help, click on the question mark icon.

D-MOD2000 uses the standard printer dialog form from Windows to select a printer and/or to change the properties of the printer and paper used to print the graph. This form can be displayed by clicking on the **Printer** command button.



Every time the size or position of the graph is changed, the graph is automatically redrawn on the preview window. To zoom in on the preview graph, double-click on it with the left mouse button. To zoom out, double-click on it with the right mouse button.

Use the **Copy** command button to copy the graph to the clipboard. You can use then the **Paste** or **Paste Special** commands on other Windows applications (i.e. Microsoft Word), to insert the graph into other documents.

X coordinate: This cell is used to enter the X coordinate from the top left corner of the graph. The origin of the coordinate system is at the top left corner of the paper sheet. Use the *Tab* key to move to the other data cells, and the *Delete* key to delete the contents of a cell. Once the value of this cell is modified, the margins shown will be automatically updated.

Y coordinate: This cell is used to enter the Y coordinate from the top left corner of the graph. The origin of the coordinate system is at the top left corner of the paper sheet. Use the *Tab* key to move to the other data cells, and the *Delete* key to delete the contents of a cell. Once the value of this cell is modified, the margins shown will be automatically updated.

Graph width: Set the width of the graph using the units defined by the paper size set on the window's print setup dialog. Use the *Tab* key to move to the other data cells, and the *Delete* key to delete the contents of a cell. Once the value of this cell is modified, the margins shown will be automatically updated.

Graph height: Set the height of the graph using the units defined by the paper size set on the window's print setup dialog. Use the *Tab* key to move to the other data cells, and the *Delete* key to delete the contents of a cell. Once the value of this cell is modified, the margins shown will be automatically updated.

The paper dimensions shown in the **Width** and **Height** boxes will switch to update the paper orientation to portrait or landscape. The margins shown will also be updated. Once you have entered the dimensions and position of the graph, use the **Print** button to send a copy of the graph to the printer

To create a form that can be printed together with the graph, click on the **Report** command button to display the **Company & Project Information** form, and then on the **Form** command button to display the **Report Form Development** form.

Options:

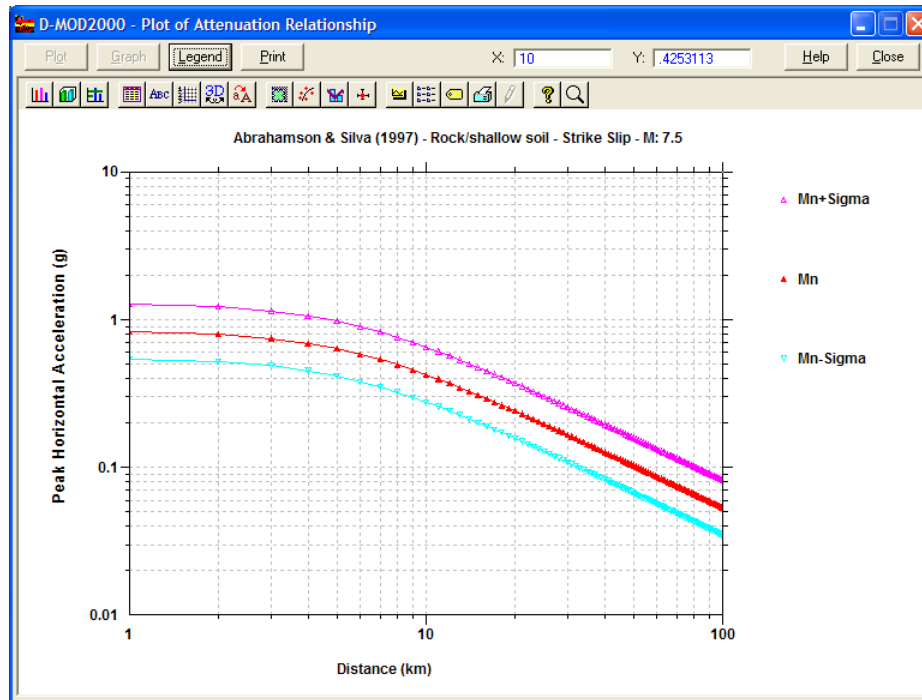
Print in color: Select this option to print the graph in color using a color printer. By default, when the **Graphics Print Menu** form is displayed, the graph is drawn in black & white. When this option is selected, an **x** will appear in the check box, and the graph will be redrawn in color.

Print as a windows metafile: Select this option if you want to create a Windows metafile of the graph. Click on **Print** to display the **Windows Metafile** dialog form. Enter the name of the file, and select a directory where the file will be saved. Then click **Save**.

Print report form: Select this option to print a form on the same sheet of paper as the graph. To create the form, click on the **Report** command button to display the **Company & Project Information** form, and then on the **Form** command button to display the **Report Form Development** form.

Physical page: This option determines whether the logical page used by the printer control should correspond to the entire physical page or only to its printable area. Most printers have a “logical” paper size that corresponds to the printer's printable area, and a “physical” paper size that corresponds to the actual page size. The physical paper size is always a little larger than the logical paper size. If this option is selected (an **x** is shown on the check box), the program will print to the physical page. This option only works when the **Print report form** option is selected.

Graphics Window



This form is used to plot a number of parameters, e.g. attenuation relations, time histories, etc.

The graphics routine includes a number of property pages that can be used for customization of the graph. For example, you could add a 3-D look to the graph, or change the colors. The property pages are accessed through the icons shown on the upper part of the graph. More help on the graph control property pages can be obtained by clicking on the **Help** command button of these pages.

To display the X and Y coordinates of a specific point on the graph, click on any point along the graph to display its coordinates in the text cells shown on the right side of the form.

A copy of the graph can be printed, or copied to the Windows Clipboard for use by other applications, by clicking on the **Print** command button. This will display the **Graphics Print Menu** form that can be used for printing.

To change the legends of the curves, click on the **Legend** command button. This will display the **Legend Text** form.

When plotting the significant duration of earthquake ground motions using either the Abrahamson & Silva (1996) or the Kempton & Stewart (2006) relation, the duration/distance pair for a user's record can be plotted on the same graph for comparison purposes. To do this, first enter the record's distance and duration in the respective text boxes and a label of up to 24 characters to describe this record; then, click on the **Plot user's event** option to select it.

Ground Motion Attenuation Relations

This section presents a number of ground motion attenuation relations that can be used to estimate the peak ground acceleration or velocity with distance, and the pseudo-absolute acceleration or pseudo-relative velocity response spectra. The reference for each attenuation relation is given, and the user is solely responsible for verifying that the attenuation relations are appropriate for his/her particular problem, and that the data required for each attenuation relation are entered in the appropriate units. It is recommended to review the references listed in this section to obtain more detailed information about these attenuation relations and their uses.

The attenuation relations available in D-MOD2000 include:

1. Abrahamson & Silva (1997). Reference: Abrahamson, N.A. and Silva, W. (1997).
2. Abrahamson & Silva (2008) – NGA. Reference: Abrahamson, N.A. and Silva, W. (2008).
3. Akkar & Bommer (2007) – Europe/Middle East. Reference: Akkar, S. and Bommer, J. (2007a, 2007b).
4. Ambraseys et al. (2005) – Europe/Middle East. Reference: Abramseys, N.N., Simpson, K.A., and Bommer, J.J. (1996); and, Ambraseys et al. (2005a, 2005b).
5. Atkinson & Boore (2006) - ENA. Reference: Atkinson, G.M. and Boore, D.M. (2006).
6. Atkinson & Boore (2003) - Subduction. Reference: Atkinson, G.M. and Boore, D.M. (1997a); Atkinson, G.M. and Boore, D.M. (2003, 2008).

7. Berge-Thierry et al. (2003) - Europe. Reference: Berge-Thierry, C., Cotton, F. and Scotti, O. (2003).
8. Boore, D. & Atkinson, G. (2008) – NGA. Reference: Boore, David and Atkinson, Gail (2008); Atkinson & Boore (2011).
9. Boore, Joyner & Fumal (1997). Reference: Joyner, W.B., Boore, D.M. and Fumal, T.E. (1997).
10. Campbell, K.W. (1997). References: Campbell, K.W. (1997) and Campbell, K.W. (2000a, 2000b).
11. Campbell, K.W. (2002) - CEUS. Reference: Campbell, K.W. (2002; 2003, personal communication; 2004).
12. Campbell & Bozorgnia (2003). References: Campbell, K.W. and Bozorgnia, Y. (2003a, 2003b, 2003c, 2004); Campbell, K.W. (2003).
13. Campbell & Bozorgnia (2008) - NGA. Reference: Campbell, K.W. and Bozorgnia, Y. (2008).
14. Campbell, Bozorgnia & Hachem (2010) – Relation for *Inelastic* response spectra. Reference: Bozorgnia et al. (2010).
15. Chiou, B. & Youngs, R. (2008) – NGA. Reference: Chiou, Brian S. and Youngs, Robert R. (2008).
16. Gregor et al. (2002) - Cascadia Subduction. Reference: Gregor et al. (2002).
17. Idriss, I.M. (2008) – NGA. Reference: Idriss, I.M. (2008).
18. Kanno et al. (2006) – Japan. Reference: Kanno et al. (2006)
19. Sabetta & Pugliese (2009) - Italy. References: Sabetta, F. and Pugliese, A. (1987, 1996, 2009).
20. Sadigh et al. (1997). Reference: Sadigh et al. (1997).
21. SEA99 - Spudich et al. (1999). Reference: Spudich, P. et al. (1996); Spudich, P. et al. (1999); and, Pankow & Pechmann (2004).
22. Stewart, Liu & Choi (2003). Reference: Stewart, Liu and Choi (2003).
23. Tavakoli & Pezeshk (2005) – ENA. Reference: Tavakoli & Pezeshk (2003).
24. Toro et al. (1997) - Gulf Region of NA. References: Toro, G.R., Abrahamson, N.A. and Schneider, J.F (1997); Silva, W., Pyke, R., Youngs, R., and Idriss, I.M. (1996); Electric Power Research Institute (EPRI) (1993); and, Toro, Gabriel R. (2002).
25. Toro et al. (1997) - Mid-Continent of NA. References: Toro, G.R., Abrahamson, N.A. and Schneider, J.F (1997); Silva, W., Pyke, R., Youngs, R., and Idriss, I.M. (1996); Electric Power Research Institute (EPRI) (1993); and, Toro, Gabriel R. (2002).
26. Youngs, Chiou, Silva & Humphrey (1997). Reference: Youngs, R.R., Chiou, S.J., Silva, W.J. and Humphrey, J.R. (1997).
27. Zhao et al. (2006) – Japan. Reference: John X. Zhao et al. (2006).

Three equations for prediction of significant-duration are also provided:

28. Abrahamson & Silva (1996). Reference: Abrahamson and Silva (1996).
29. Bommer, Stafford & Alarcon (2009). Reference: Bommer et al. (2009).
30. Kempton & Stewart (2006). Reference: Kempton and Stewart (2006).

Please refer to the above references for detailed information on the use and application of these attenuation relations.

To plot an attenuation relation, first select what type of plot you would like to use by choosing one of the four options on the top right section of the form. There are four options: **Peak Ground Acceleration**, **Peak Ground Velocity**, **Acceleration Spectrum**, and **Velocity Spectrum**. Depending on what type of ground motion parameter you choose, different relations will be available. For example, by default, when the **Peak Ground Acceleration** option is chosen, most of the equations are enabled (i.e., they are not grayed out). If you choose the **Peak Ground Velocity** option, then only the Atkinson & Boore (1997) - Cascadia; Atkinson & Boore (2006) ENA; Atkinson & Silva (2000) – California; Campbell, K.W. (1997);

Sabetta & Pugliese (1996); and, SEA99, Spudich et al. relations will be enabled and the others will be disabled (i.e. shown as grayed out options).

Next, select which attenuation relations you want to use by clicking on the check box next to each. An **x** appears in the box when an attenuation relation is selected. Use the *Tab* key or the mouse to place the cursor on the **Magnitude** text box, and enter the earthquake magnitude. Enter the distance and depth in the **Distance** and **Depth** text boxes, respectively. Select other options as explained below, depending on the relations chosen. The **Plot** command button is enabled when at least one attenuation relation is selected. Click on the **Plot** button to display the curve. Please note that the depth value used in the Campbell (1997) equation is the depth to basement rock. Thus, if you are using several relations at the same time, use the **Ground Motion Attenuation Relations - Parameters** form to enter depth values for each attenuation relation.

The **Curve for specific period** option allows you to plot the spectral acceleration or velocity attenuation curve (i.e., acceleration or velocity vs. Distance) for specific periods. When selecting more than one attenuation relation, the attenuation curve will be displayed only for those equations that have coefficients for that specific period. Check the **Period** column for each attenuation relation's coefficients to determine if a period value is acceptable. Enter the value for the period in the text box next to the label.

Depending on the attenuation relation selected, there are other options that can be used. Some relations classify the faulting mechanism of an earthquake into one of a number of categories. The different categories are shown in the **Style of Faulting** section of the form. By default, the **Strike Slip** type is chosen. You can select other types by clicking on any of the options shown. The type selected will be used for all of the relations that it applies to when those relations are selected. Note that an attenuation relation will not be selected (i.e. an **x** is shown on the check box) if the **Style of Faulting** option selected does not apply to this relation. The **Subduction** option in the **Style of Faulting** list only applies to the Zhao et al. (2006) relation.

The **Intraslab** and **Interface** options apply to the Youngs, Chiou, Silva & Humphrey (1997); Atkinson & Boore (2003); and Zhao et al. (2006) relations. By default, the **Intraslab** option is selected, thus the attenuation relation for intraslab events will be used. To use the attenuation relation for interface events, click on the **Interface** option.

The **M \pm Sigma** option is used to plot the median attenuation curve, and the curves that represent the median plus and the median minus sigma. When this option is selected, only one of the attenuation relations will be used, i.e. the top attenuation relation selected will be the one used.

The **Plot Spectra vs. Frequency (Hz)** option is used to change the X-axis to the frequency scale. When this option is selected, an **x** appears in the check box. To deselect this option, click on the check box, this will switch to the period scale in the X-axis.

A value for the shear wave velocity (V_s) to a depth of 30 meters can be entered in the **Shear Wave Velocity to 30 m** label, in m/sec.

When using the **Vertical** component option, the attenuation relations and/or coefficients for the vertical component of PGA, PGV and PSA will be used.

The **Site Class** options are used with the Atkinson & Boore (2003) and Zhao et al. (2006) attenuation relations. By default, the attenuation relation for **Site Class A** is selected. A different site class can be chosen by clicking on the respective option. The site classes represent the NEHRP classes (see Table 2 of Zhao et al. (2006) for equivalent site class definitions). Further, for the Atkinson & Boore (2003)

relation, classes A and B represent rock. In addition, the user can select a region for the Atkinson & Boore relation by selecting the **Cascade**, **Japan**, or **Other** option; and, the **Regional SD** option for region specific error terms.

For the Toro et al. (1997) attenuation relations, the equations used are those for **Moment Magnitude**.

For Bozorgnia & Campbell (2003), when considering the effect of the hanging wall, it is necessary to enter r_{jb} , or the closest distance to the surface projection of fault rupture (Campbell, K.W. and Bozorgnia, Y., 2003a; Boore et al., 1997). Alternatively, the fault dip angle, δ , can be used instead. To enter r_{jb} , click on the **Rjb** command button to display the **R_{jb} and R_x Distance** form. On this form, enter the r_{jb} distance for each value of r_{seis} . If you need more information about this distance, please refer to Campbell, K.W. and Bozorgnia, Y. (2003a) and Abrahamson, N.A. and Shedlock, K.M. (1997). The dip angle value can be entered in the **dip (deg)** text box. By default, the peak ground acceleration is estimated using the attenuation relation for uncorrected PGA. To use the corrected PGA attenuation relation, click on the **Corrected** option of the **Bozorgnia (PGA)** options. Please note that the value of PGA used in the computation of the standard deviation, σ_{lnY} , is determined based on the choice of the **Bozorgnia (PGA)** options.

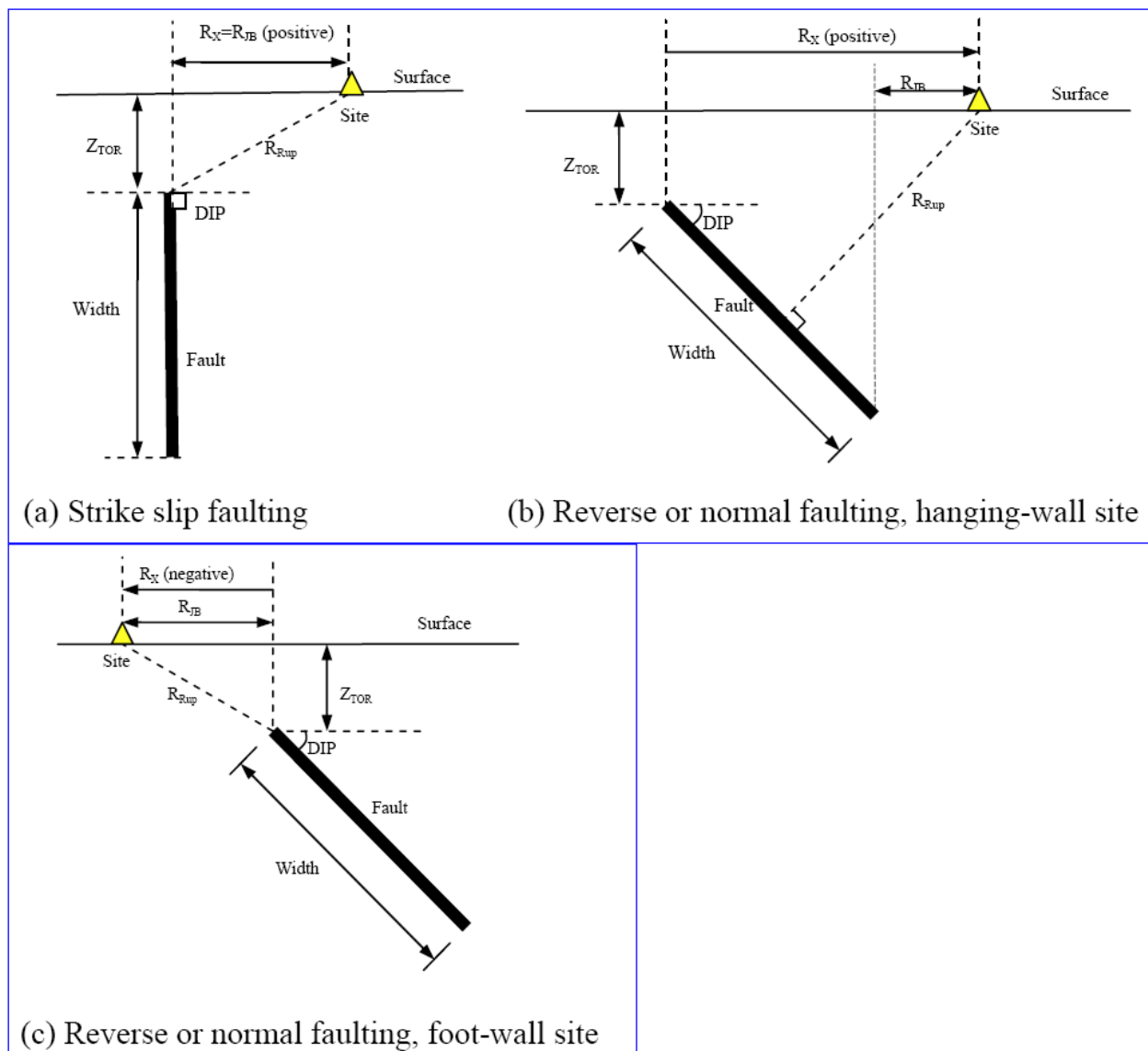
The R_{jb} and R_x distances are also required when using the Campbell & Bozorgnia (2003); Abrahamson & Silva (2008) – NGA; Akkar & Bommer (2008); Boore, D. & Atkinson, G. (2008) – NGA; Campbell & Bozorgnia (2008) – NGA; Chiou, B. & Youngs, R. (2008) – NGA; and, Campbell, Bozorgnia & Hachem (2010) relations. To enter R_{jb} and R_x , click on the **Rjb** command button to display the **R_{jb} and R_x Distance** form. Note that the program will plot the PHA vs. Distance, where for the NGA equations the distance is R_{rup} and for the Campbell & Bozorgnia (2003) it is R_{seis} . Accordingly, when R_{jb} and/or R_x are needed, these should be computed and entered in the respective columns of the **R_{jb} and R_x Distance** form. Similarly, for the Boore & Atkinson NGA and the Akkar & Bommer relations, the program will also plot the PHA vs. Distance wherein distance is assumed to be R_{rup} , but the program will use R_{jb} entered in the respective column of the **R_{jb} and R_x Distance** form for the computations.

The single value of R_{jb} or R_x distance used for computation of response spectra can be entered in the **r_{jb} (km)** or **R_x** text box, respectively. For the Boore & Atkinson NGA, the value of distance entered in the **r_{jb} (km)** text box is used instead of the value entered in the **Distance** text box. The figure shown in the next page, and included in the PEER NGA Excel spreadsheet, will help you understand the distance definition in a more clear way.

For a definition of the parameters in the **NGA Parameters** section of the form, please refer to references for the NGA attenuation relations. The user can manually enter a value for each parameter, or enter the “DEF” string to use the default values. For the Z_1 and $Z_{2.5}$ parameters, the default values are based on relationships provided in Abrahamson & Silva (2008), Campbell & Bozorgnia (2008) and Chiou & Youngs (2008), based on the $V_{S,30}$. For the Z_{tor} and Width values, the program will use the relations presented in Kakkamos et al. (2010).

In the Sabetta & Pugliese (2009) relation, the data for the Joyner-Boore distance are used. Further, when computing response spectra, the program will use the distance entered in the **r_{jb}** text box.

The ground motion parameters recommended by Stewart, Liu & Choi (2003) are taken as the product of their amplification factors and the median attenuation values for rock obtained from the Abrahamson & Silva (1997) relation. For this relation, a classification category can be selected from the **Stewart** combo list in the **Other Site Conditions & Options** section of the form. In addition, the effect of the hanging wall can be accounted for by selecting the **Stewart** option of the **Hanging Wall** options.



When an attenuation relation can be applied to more than one site condition (e.g. rock and deep soil), D-MOD2000 will by default use the attenuation relation for rock when plotting the ground motion parameters. To plot these parameters for other site conditions, select the appropriate option for each attenuation relation from the **Other Site Conditions & Options**. Some specific information about these options is:

- In the Campbell (1997) attenuation relation, the coefficients for local site conditions are defined by selecting one of five options: Alluvium/firm soil, soft rock, hard rock, generic soil, or generic rock. By default, the option for hard rock is selected. For the generic options, default values of depth to basement rock of 1 and 5 km for rock and soil respectively, are used in the attenuation relation.
- For the Abrahamson & Silva (1997, 2008 NGA), Bozorgnia & Campbell (2003), Chiou & Youngs (2008 NGA) or Stewart et al. (2003) attenuation relations, select the corresponding

option of the **Hanging Wall** options to use the factor to distinguish between ground motions on the hanging wall and footwall of dipping faults.

When using the ground-motion prediction equations for significant-duration by Abrahamson & Silva (i.e. **A&S 1996**), Bommer, Stafford & Alarcon (**BSA 2009**) or Kempton & Stewart (i.e. **K&S 2006**), the magnitude value is entered in the **Magnitude** text box. For Kempton & Stewart and Bommer, Stafford & Alarcon, the value for V_{s-30} is entered in the **Shear Wave Velocity to 30 m** text box; and, the value of Z_{tor} entered in the **Ztor** text box for the BSA. The Mediand±Sigma options also apply to these equations. By default, for Abrahamson and Silva, the equation for rock is used. If you wish to use the equation for soil, click on the **Abrahamson & Silva (1996) – Duration Soil** option to select it. The base model by Kempton and Stewart can be corrected for near-fault conditions by selecting the **Kempton & Stewart (2006) – Near-Fault** option. The result plotted will be the D_{a5-95} value, i.e. the time interval between 5-95% of the Arias Intensity as a function of the acceleration record.

For those attenuation relations that yield pseudo velocity (PRV), the Pseudo Absolute Acceleration (PAA) is obtained using the following equation:

$$PAA = \frac{2\pi(PRV)}{(981)T}$$

In addition, for those attenuation relations that yield pseudo absolute acceleration, the Pseudo Relative Velocity is obtained using the following equation:

$$PRV = \frac{(981)T(PAA)}{2\pi}$$

In which T is period in seconds.

The attenuation data can be saved to a text file by selecting the **Save Attenuation Data** option. This text file can then be open with other applications, e.g. Excel, for further use. The path and name of the text file can be changed by clicking on the command button with the folder icon next to the text box. When plotting acceleration response spectra, a CSV (comma separated values) file will also be created in the same path using the same name but with the extension “.csv”. This file can be opened with Excel for further processing. The CSV file will only save the data for one response spectrum.

When obtaining response spectra, the **GM** option will compute the geometric mean spectrum for the set of relations selected for the common range of periods.

The **WA** option is used to obtain a “weighted” spectrum, i.e., different weights summing up to 1.0 can be assigned to the relations selected to compute a weighted spectrum. To enter the weights, first select between 2 and 10 relations and then click on the **Weight** command button to display the **Model Weight** form.

Ground Motion Attenuation Relation:	Weight
Youngs, Chiou, Silva & Humphrey (1997):	0.25
Atkinson & Boore (2003) - Subduction:	0.25
Zhao et al. (2006) - Japan:	0.50

In this form, enter the weights for each relation in their respective text boxes. The weights should add up to 1.0 and each weight should be greater than 0.0. Also, when obtaining target response spectrum, the geometric mean or the weighted spectrum will be used as the target.

To enter the data for a target response spectrum that can be plotted with the other spectra, click on the **Target** button to display the **Target Response Spectrum** form. In this form, you can enter values of period and spectra for a target response spectrum. To plot the target spectrum, also select the **Plot Target SPC** option.

Conditional Mean Spectrum: This option is provided to compute the conditional mean spectrum as defined by Baker (2009) and further explained in Baker & Cornell (2005a, 2005b, 2006a, 2006b, 2008) and Baker & Jayaram (2008). An example of the applicability of this spectrum in the selection of ground motions for analysis is provided by PEER Ground Motion Selection and Modification Working Group (2009). This option only works with a few selected ground motion relations. To select this option, click on the **Epsilon** check box, then enter a value for epsilon in the text box. Based on the ground motion relation selected, a list of periods will be displayed when clicking on the down-arrow for the **Period** list. Click on the down-arrow to display the list and then click on the period that you would like to use for computation of the conditional mean spectrum. To plot the results, click on the **Plot** command button. Both the ground motion spectrum and the conditional mean spectrum will be displayed. When obtaining target response spectrum, only the conditional mean spectrum will be plotted.

Ground Motion Parameters

D-MOD2000 - Ground Motion Parameters

Plot Print Help Close

Peak Acceleration Value: 0.09 g

RMS of the Acceleration Time History: 0.0165 g

Arias Intensity: 0.4217 ft/sec

Bracketed Duration: 13.6 sec

Trifunac & Brady Duration: 27.3 sec

Smoothed Spectral Predominant Period, T₀: 0.184 sec

Predominant Spectral Period, T_p: 0.125 sec

Average Spectral Period, T_{avg}: 0.501 sec

Mean Period, T_m: 0.332 sec

☒ Husid Plot ☐ Fourier Spectrum

☐ Plot Ground Motion ☐ Amplitude vs. Period

☐ Response Spectrum Smooth Points: 0

☐ Power Spectrum

This form presents various parameters used to characterize a ground motion, which can then be used to select a representative time history for site specific response analyses. These parameters include peak ground acceleration, Arias Intensity, Root-Mean-Square of the acceleration time history (RMSA), bracketed duration, Trifunac & Brady duration, and predominant period (Hu et al., 1996; Kavazanjian et al., 1997; Kramer, 1996). In addition, you can plot a graph of the Normalized Arias Intensity, or Husid Plot, together with the ground motion; and the computed and smoothed Fourier Amplitude Spectra.

The Peak Acceleration Value is the maximum, absolute acceleration value of the time history.

The energy content of the acceleration time history provides another means of characterizing strong ground motions. A measure of the total energy content of a ground motion is given by the Arias Intensity, which is defined by the following relation:

$$I_A = \frac{\pi}{2g} \int_0^{t_f} [a(t)]^2 dt$$

Where t_f is the duration of ground shaking, $a(t)$ the ground acceleration, and g is the acceleration of gravity. A plot of the increase of the energy content as a ratio of the total energy versus time is known as a Normalized Husid Plot. The root-mean-square of the acceleration time history, or RMSA, is also used as a measure of the energy content. The RMSA is defined by the following relation:

$$RMSA = \sqrt{\frac{1}{t_f} \int_0^{t_f} [a(t)]^2 dt}$$

In D-MOD2000, the time interval between 5 and 95 percent of the total Arias Intensity is used to compute the RMSA.

The *Bracketed Duration* of strong motion is the time interval between the first and last acceleration peaks greater than a specified acceleration value, or threshold acceleration. The value shown in the above form

is for a threshold acceleration of ± 0.05 g. Based on the Normalized Husid Plot, the *Trifunac & Brady Duration* is the time interval between 5 and 95 percent of the total Arias Intensity.

Other parameters commonly used to evaluate the frequency content of a ground motion are the predominant spectral period, T_p , or commonly defined as the “... *period of the maximum spectral acceleration.*” (Rathje et al., 2004); the smoothed spectral predominant period, T_o , which “....*attempts to define the peak in the response spectrum by smoothing the spectral accelerations over the range where S_a is greater than $1.2 * PGA$* ” (Rathje et al., 2004); and, the average spectral period, T_{avg} , defined as an average period (over a specified frequency range) weighted by the spectral accelerations (Rathje et al., 2004). To compute these periods, the response spectrum for 5% damping is first computed using equally spaced periods on a log axis to obtain T_o , and then the spectrum is computed a second time using equally spaced periods on an arithmetic axis to obtain T_{avg} .

Another indicator of frequency content of accelerograms is the Mean Period, T_m , defined as (Rathje et al., 1998; Stewart et al., 2001):

$$T_m = \frac{\sum_i C_i^2 \left(\frac{1}{f_i} \right)}{\sum_i C_i^2}$$

Where: C_i = Fourier amplitudes of the entire accelerogram
 f_i = Discrete Fourier transform frequencies between 0.25 and 20 Hz.

The value for T_m is shown on the text box next to the **Mean Period, T_m** label.

On the bottom section of the form there are two plotting options. The **Husid Plot** option will display a graph of the Normalized Husid Plot. If you select the **Plot Ground Motion** option, then the acceleration time history will be plotted on the same graph with the Husid Plot. In the plot, the section of the Husid Plot for the Trifunac & Brady duration is shown as a red curve.

The **Fourier Spectrum** option will plot the Fourier amplitude spectrum. By default, the Fourier response spectrum is plotted using frequency values in the X-axis. Alternatively, to plot the Fourier amplitudes vs. period click on the **Amplitude vs. Period** check box to select it.

After selecting one of the plotting options, click on the **Plot** command button to display the graphs. When plotting the response and the Fourier spectra, T_p , T_o , T_{avg} and T_m will be shown on the graphs.

You can print the results by using the **Print** command button.

IBC Response Spectra

The screenshot shows the 'D-MOD2000 - IBC Response Spectra' dialog box. It includes the following fields and options:

- Location Input:** Longitude (123 degrees, 12 minutes, 0 seconds) and Latitude (47 degrees, 6 minutes, 0 seconds).
- Manual Entry Option:** A checkbox labeled 'Enter spectral acceleration values manually' and a checkbox for 'MCE Spectrum'.
- Spectral Accelerations:** Fields for 'S_s for Short period, S_s:' (1.3347 g's) and 'S_a for 1-second period, S₁:' (0.5073 g's).
- Long-Period Transition:** A field for 'T_L:' (4 sec).
- Region:** Radio buttons for 'Conterminous United States', 'Central/Eastern US - Vs: 2000 m/s', 'Alaska', 'Hawaii', and 'Puerto Rico'.
- Probability:** Radio buttons for '2% in 50 yrs', '5% in 50 yrs', and '10% in 50 yrs'.
- Year of Data:** Radio buttons for '1999', '2003', '2008', and '2010'.
- Soil Profile Type:** Radio buttons for 'A: Hard Rock', 'B: Rock', 'C: Very Dense Soil and Soft Rock', 'D: Stiff Soil Profile', 'E: Soft Soil Profile', and 'F: Soil requiring site-specific evaluation'.

This form is used to select the options and/or enter the data necessary to plot a MCE or a design response spectrum in accordance with the IBC (International Code Council, 2003; ASCE, 2006).

The procedure followed to obtain the spectrum starts by first selecting spectral accelerations at short period, S_s , and at 1-second period, S_1 , from the Maximum Considered Earthquake (MCE) Ground Motion Maps provided in the IBC code. The MCE maps were based on the U.S. Geological Survey (USGS) probabilistic hazard maps (Leyendecker et al., 2000; Frankel et al., 1996; Frankel et al., 2002; USGS, 2008, 2010); however, for some selected areas, the USGS maps were modified to incorporate deterministic ground motions and to apply engineering judgment. In D-MOD2000, either the S_s or S_1 values can be entered manually or they can be automatically obtained from the files of gridded points used to create the USGS hazard maps. However, as previously noted, the maps included in the IBC are not “exactly the same” as the USGS maps for selected areas. Accordingly, the second option in D-MOD2000 should only be used for those regions for which the USGS maps were not modified. Leyendecker et al. (2000) briefly explain where the probabilistic USGS maps are and/or are not applicable.

We recommend that you review the article by Leyendecker et al. (2000) for more information about the creation of the Maximum Considered Earthquake Ground Motion Maps. Also, before using the automatic option, check that your site is located in a region where the USGS maps are applicable; or, use this option to obtain “approximate” values of S_s and S_1 that are to be compared to the values on the IBC maps.

In accordance with the IBC, the maps used in D-MOD2000 are for 0.2 and 1.0 second spectral response acceleration with 2% probability of exceedance in 50 years for the Conterminous United States, Alaska, Hawaii and Puerto Rico. For the other maps included in the IBC (i.e. Culebra, Vieques, St. Thomas, St. John, St. Croix, Guam and Tutuilla), the user needs to enter the values for S_s and S_1 manually. Please note that the program uses two sets of maps for the **Conterminous United States** region, i.e. the data maps generated in 2003 and 2008 updates of the National Seismic Hazard Maps (Frankel et al., 2002; U.S. Geological Survey, 2003a, 2003b, 2008, 2010). For Alaska, the program uses the maps developed in either 1999 or 2007; for Hawaii the maps developed in 1999; and, for Puerto Rico the 2003 maps. The 2008 and 2010 updates of the maps were recently released by the USGS (2008, 2010). Although these latest updates have not been adopted for use in the IBC code, these maps are included with the program for comparison purposes only; i.e., at this moment they should not be used for any other purpose other

than to compare the values. To use a specific year, click on the year's option to select it. The issue year for the maps used is shown on the **Spectral acceleration in g's** label.

For the 2010 and WUS options, a $V_{S,30}$ value can be selected from the down-list. However, it is recommended to visit the USGS web site for the most recent information and values regarding the hazard maps.

If you want to use the maps to obtain the spectral accelerations S_s and S_1 , first click on the **Enter the site's location to obtain spectral accelerations from USGS maps** option to select it, and then enter the latitude and longitude of your site in degrees, minutes and seconds. There is no need to enter a negative sign for the longitude value as required by the online NEHRP website. Next, select one of the **Region** options and the site class by selecting one of the **Soil Profile Type** options. The spectral values for the four grid points that surround your site are retrieved from the files, and if necessary, the values interpolated between the four grid points. The S_s and S_1 values are displayed in their corresponding text boxes on the upper right corner of the form.

To enter the values of S_s and S_1 manually, first click on the **Enter values of spectral acceleration manually** option to select it. Then, enter the value for S_s on the text box next to the **S_a for Short period, S_s** label; and, the value for S_1 on the text box next to the **S_a for 1-second period, S_1** label. In this option, you also need to select one of the **Soil Profile Type** options. The long-period transition period, T_L , needs to be entered in the **Long-Period Transition, T_L** text box.

By default the program will compute the design spectrum. If you need to use the MCE spectrum, click on the **MCE Spectrum** option to select it. When the spectrum is plotted, either the **Design** or **MCE** word will be shown on the plot label to indicate which spectrum is being used. When this form is called from the RRS form, the default spectrum will be the MCE.

If you would like to manually enter the values for period and spectral acceleration, select the **User** option. The **User** command button will be enabled when this option is selected. This option will display the **User Defined Response Spectrum** form. In this form, you can enter values of period and spectra for a user defined response spectrum that will be used to compute the modified spectrum using the results of the RRS analysis. In this way, you can enter a user-defined spectrum and select the IBC 80%-design spectrum to be plotted on the same graph with the modified spectrum.

After you have entered the above input information, click on the **Ok** button to compute the spectrum and to return to the previous form. If you click on the **Cancel** button, you will return to the previous form without modifying the input information if any had been selected previously.

If any of the options is disabled or results for any of the parameters are not shown on the respective text box, this is due to the maps for this option or for these parameters not being available from the USGS.

Import Acceleration Data

History No.	Layer No.	Column Weight	No. Values	Time Step	History Information

This form is used to import acceleration files for use in the Newmark Method for displacement analysis included with D-MOD2000. The applications supported by D-MOD2000 are ProShake and Quake/W.

In short, first, you will select an output file created by another application, e.g. ProShake; then, read that output file to determine if there are any acceleration time histories and how many there are (D-MOD2000 will only read the first 6 acceleration time histories found in the file); and finally, create a series of output files, i.e. one per acceleration time history, in the format used by D-MOD2000 to perform the displacement analysis with the Newmark Method.

Before using any of the files created with this form, we highly recommend that you compare the contents of each file with the data in the original output file to determine if the data were read correctly. You can use a text processor to open the files.

For ProShake, D-MOD2000 supports two types of output files: 1) files with the extension *.RAW; and, 2) files with the extension *.LYR. For Quake/W, D-MOD2000 uses the History Node file, i.e. files whose extension starts with the letter "O".

To select an output file, first select one of the software applications, and then click on the **File** command button to display the **Open Output File** dialog form. By default, for ProShake a listing of the files with the extension *.LYR will be automatically displayed. To select files with the extension *.RAW, click on the down-arrow for the list box next to the **Files of type** label and then select the ProShake *.RAW option. For Quake/W, a listing of files whose extension starts with the letter "O" will be displayed. Double-click on the file to select it and return to D-MOD2000. The file name and its path will be shown on the text box next to the **ProShake** or **Quake/W File** label. The next step is to read the contents of the output file to extract the information necessary to create the acceleration time history file. In ProShake, D-MOD2000 will only read the first 6 acceleration time histories in the file.

Click on the **Read** command button to start reading the output file. After a few seconds, some information for the acceleration time histories will be displayed in the text boxes on the form. The number shown on the **History No.** column indicates the position of this time history in the output file. In ProShake, the number of the soil layer for which the acceleration time history was computed is shown on the **Layer No.** column. For Quake/W, the number of the node will be shown in the **Node No.** column. As noted in the **Newmark Method - Accelerogram File** section of this document, a weighted-average file created from a series of files can be used in the Newmark Method included with D-MOD2000. To

create this average file, you need to know the weight of the soil column above the layer. However, this value is not read from the ProShake or Quake/W output file, thus, a number is not shown on the **Column Weight** column for the time history. If you know this value, you can enter it in the specific text box for each time history, otherwise, a value of 0.00 (zero) will be saved in the new time history file. The number of values for each time history is shown in the **No. Values** column, and the time step for the acceleration time history in the **Time Step** column. A description for each history found in the output file is shown on the **History Information** column. For ProShake, if a file of type *.RAW is read, this description is usually a number that identifies the ground motion used (e.g. 1, 2, etc.). For files of type *.LYR, this description will be the path to the ground motion file used in the analysis (e.g. C:\PROSHAKE\YERBA.EQ), and other information such as number of values, period, etc.. For Quake/W, the information on this text box will be the information shown in the second line of the history node file. You can modify the description for the history by entering up to 128 characters in this text box.

To create the acceleration time history files compatible with D-MOD2000, click on the **Export** command button. An individual file will be created for each time history displayed in this form. For ProShake, each file will have a name such as **PrSk#L##.AHL**, wherein the number before the **L** is the number on the **History No.** column, and the number after the **L** is the number shown on the **Layer No.** column. For example, for the time history shown on the fifth row in the form above, the file name will be **PrSk5L17.AHL**, i.e. this is the file for the fifth time history in the file, and it is for layer 17. The files will be written to the directory shown on the **Export Directory** box. For Quake/W, each acceleration file will have a name that starts with the string **QkeW** followed by the number in the **Node No.** column, and will have an extension of **AHL**. For example, **QkeW79.AHL** is the acceleration time history for node 79, extracted from a Quake/W history node file.

The output files created have the following format:

```

0      2048      0.0200      3      8      9
ProShake Output File: C:\ProShake\Output\Shake.lyr
Acceleration Time History],17, 0, 1,C:\Download\EduShake\TREAS.EQ, 2048, .0200
-.000408 -.002954 -.002443 -.000820 -.000282 .000451 .000215 -.000442

```

The values shown on the first line are: the weight of the soil column above the layer (e.g. 0); the number of values in the acceleration time history (e.g. 2048); the time step for the acceleration time history (e.g. 0.02 seconds); the number of header lines in this file (e.g. 3 header lines); the number of data columns used to write the acceleration values (e.g. 8 columns are used, see line four); and, the number of digits that form each data column (e.g. 9 digits per column, see line four).

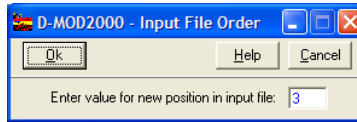
The second line describes the type of output file used to create this file and its path (e.g. a ProShake output file named Shake.lyr located in the C:\ProShake\Output directory). The third line shows the header line found in the original ProShake output file for this specific acceleration time history. The fourth and subsequent lines are the values of acceleration for the time history saved in the file. This file can now be used in D-MOD2000 to perform the Newmark Displacement Analysis as explained in the **Newmark Displacement Analysis** section of this document.

If the acceleration values in the source file are in units other than g's then you need to select a factor to convert the values to units compatible with D-MOD2000, i.e. fractions of acceleration of gravity (g's), if necessary. Some files provide motion data in different units, for example cm/sec², ft/sec², etc.. To convert the units, select a factor that represents the units of the acceleration data in the source file from the list of options shown on the **Acceleration Units** list box. Remember that these are the units of the source or original data. Click on the down arrow of the list and select an option. After selecting a unit, a multiplication factor value will be displayed on the **Multiplier** box. This is the multiplication factor that

will be used to convert the values. For example, to convert values of acceleration from cm/sec^2 to g's, you need to divide each value by 980.665 cm/sec^2 ; which is equivalent to multiply each value by $1/980.665 = 1.0191716\text{E-}03$. If the accelerations in the source file are in units that are not shown in the list, select the **Other** option, and then enter the correct multiplication factor in the **Multiplier** text box.

The **Directory** command button can be used to select the directory where the acceleration files generated will be stored. This button will display the **Choose Output Directory** form.

Input File Order



Enter value for new position in input file: Enter the value for the new position of an option in the input file. For example, if you set **Option 4 - Material Properties** in position 4 and **Option 7 – Input Motion** in position 3, you will need to reorganize your input file so that D-MOD_2 executes Option 4 before Option 7. To do this, click on Option 4 on input file option's list of the **Non-Linear Earthquake Response Analysis** form, and then click the **Order** button. Then, enter 3 on the data cell and click on the **Ok** button. Control will be returned to the **Non-Linear Earthquake Response Analysis** form, and the options will be reorganized automatically. To cancel this action without modifying the order, click on the **Cancel** button.

Legend Text



The screenshot shows a software dialog box titled "D-MOD2000 - Legend Text". It features a standard Windows-style title bar with a small icon on the left and minimize, maximize, and close buttons on the right. Below the title bar is a row of five buttons: "Ok", "Next", "Reset", "Help", and "Cancel". The main area of the dialog contains five text input fields, each preceded by a label: "Curve 1:", "Curve 2:", "Curve 3:", "Curve 4:", and "Curve 5:". The "Curve 1" field is populated with the text "Abrahamson & Silva (1997) - Rock/shallow soil - Strike Slip - M: 7.5". The other four fields are empty.

This form is displayed by clicking on the **Legends** command button on the graphics window. When the form is displayed, the legends for the first five curves are shown in the text boxes. To edit the legend, place the cursor on the text box and enter the new legend. Each legend has a maximum length of 80 characters.

To display the legends for the following set of five curves, click on the **Next** button. Click on the **Ok** button to return to the graphics window. If you don't want to modify the legends, click on the **Cancel** button.

The **Reset** command button is used to restore the original legends for the curves.

Material Parameters and Curve Fitting Constants

D-MOD2000 - Material Parameters and Curve Fitting Constants

Choose Help Cancel

Material Parameters and Curve Fitting Constants of the Pore Water Pressure and Degradation Models for Sand

Material: **Banding Sand (BS)**

Material Description: Banding Sand (BS): poorly-graded commercially available sand; D_r approximately 40%; D₅₀ = 0.19; C_c = 0.9; C_u = 1.4; minimum dry unit weight of 90 pcf; maximum dry unit weight of 106 pcf - Reference: Dobry et al. (1985)

k (ft/sec)	ν	f	P	F	s	γ_{tv} (%)
.00055	1	1	1	10.9	1	.017

This form is used to display the material parameters and curve fitting constants for the different models used in D-MOD. The data included in this form are the same as those shown in Appendices A and B.

To select the parameters and/or constants for use in one of the materials of Option 4, first click on the down arrow of the **Material** list and then select a material by clicking on it. The material and/or parameters will be updated on the respective text boxes. To use these values for the material in Option 4, click on the **Choose** command button. Click on **Cancel** if you don't want to select any material and return to Option 4 without importing any values.

Mean/Scaling Response Spectrum

File No.	No. Values	Time Step	Scaling Factor	No. Header	Values per Line	No. Digits	Motion Identification	Pair
1	9387	.005	1	4	5	15	0141-270	2
2	9387	.005	1	4	5	15	0141-360	1
3	11031	.005	1	4	5	15	5080-270	4
4	11031	.005	1	4	5	15	5080-360	3
5	4150	.01	1	4	5	15	531-E	6

This form can be used to obtain the mean spectral acceleration response spectrum for a series of ground motion records. The mean value can then be compared to a target spectrum in order to visually evaluate how well the shape of the average spectrum compares to the shape of the target spectrum. A more detailed explanation about selecting ground motion records for analysis based on how well they match a target spectrum is given by Bommer and Acevedo (2004), Hancock et al. (2005), Kottke and Rathje (2007), and PEER Ground Motion Selection and Modification Working Group (2009). To use the form, the user needs to select a number of ground motion files, a target spectrum; and, optionally, enter a range of periods of interest.

There are three different command buttons that can be used to select ground motion files. First, you can select an object motion listed in the earthquake records database by clicking on the **Quakes** button to display the **Earthquake Records Database** form. This form shows a listing of the records saved in the **D-MOD2000.EQ** file. Once the list is displayed, you can choose a record by highlighting it and clicking on the **Ok** button, or by double clicking on it. The data for the record will be shown on their respective fields upon returning to this form.

To select files that are not included in the database of earthquake records, click on the **Other** command button to display the **Acceleration Time History File** dialog form. Switch to the appropriate folder, select the ground motion file and click on the **Open** command button. The file name and path will be displayed on the list shown below the **File of Acceleration Time History** label. In order to read and use the data saved in the file you need to enter:

1. The total number of acceleration values that form the object motion file in the **No. Values** text box;
2. The time interval between each acceleration value in the **Time Step** text box;
3. If the motion will be scaled to a different peak acceleration value, then enter the scaling value used to modify the acceleration in the **Scaling Factor** text box;
4. The number of lines at the beginning of the file that are used to describe the object motion in the **No. Header** text box; and,
5. The number of acceleration values on each line in the **Values per Line** text box; and, the number of digits that form an acceleration value in the **No. Digits** text box.

The **Other** command button can also be used to select multiple files at a time. Also, use the **Other** command button to select files downloaded from the PEER NGA Ground Motion Database, i.e. *.AT2 files. Please note that these files are not in a format compatible with SHAKE, but can still be used with this feature of the program. If you want to convert some of these files to a format compatible with SHAKE after the scaling procedure, use the **Export** command button.

More detailed information about these values is provided in the **Plot Object Motion** or **Response Spectra for Ground Motion** sections of this manual.

The third option used to select ground motion files is with the **Convert** command button. This button is used to display the **Conversion of Ground Motion File** form that can be used to convert ground motion files from different units and/or formatting to a file that can be used with D-MOD2000. Further information on this feature is provided in the **Conversion of Ground Motion File** section of this manual. Upon returning to this form, the information used to read the file is displayed in their respective columns.

The **View** command button can be used to view the contents of a ground motion file. This will help you to collect the information needed to define the formatting of the file if necessary. To do this, first select a file by clicking on its name/path, then click on **View**. When you click on the file's name/path the check box will be selected or de-selected. Note that when the check box is not selected, the file will not be used for computation of the average spectrum. The first 60 lines of the file will be displayed on a form, with the first characters displayed in red representing the numbers of each row of data in the file followed by a "|". These characters are not part of the source file and are only shown to number the rows. After the row numbers, the alphanumeric characters that constitute the information saved in the file for each row are shown. Note that the characters are displayed as blue on a white background, and that every tenth character is displayed in red. However, if the tenth character is a "blank space" then the character is not shown. This is done to guide the user when defining the order of the data in the file.

As noted before, the average spectrum will be compared to a target spectrum. There are six options used to select the target spectrum: **Attenuate**, **EuroCode**, **IBC**, **NEHRP**, and **User's**. Select one of these options and then click the **Target** command button to display the respective form. Further information for the first four options is provided in the respective sections of this manual. The **Other** option will display the **Response Spectra for Ground Motion** form. This form can be used to compute the response spectrum using the data saved in a ground motion file. If you would like to manually enter the values for period and spectral acceleration, select the **User's** option. This option will display the **User Defined Response Spectrum** form. In this form, you can enter values of period and spectra for a user defined response spectrum.

A period range of interest can be shown on the graph of results. Enter a lower and upper value in the **T_{min}** and **T_{max}** text boxes, respectively. A dashed line will be shown across the graph at each period value.

If you want to scale the spectra to a specific spectral value at a target period, enter the period in the **T_{match}** text box and click on the check box to select this option. The program will compute the scaling factor necessary to scale each spectrum to that spectral value and display it in the **Scaling Factor** column.

If you want to use both horizontal components, select the Geometric Mean option. The program will compute the geometric mean spectrum and use this spectrum in the selection process. Before using this option, you need to define the corresponding pair for each motion. Enter the number of the file that is the pair for each file in the Pair column. For *.AT2 file, the program will automatically try to identify each corresponding pair. For example, in the screen shot in the previous page, the first file is file number one. For this file the corresponding pair is file number two. In the **Pair** text box for the first file a 2 is shown indicating that file number 2 is the corresponding pair.

Once you have selected a suite of ground motion files and a target spectrum, click on the **Scale** command button to compute the average response spectrum. In D-MOD2000, the analysis consists of obtaining the 5% damping pseudo-acceleration response spectrum for each ground motions selected and then obtaining an average value of spectral acceleration for each period.

To aid in comparing the spectra, the fit is evaluated through the root-mean-square-error (RMSE) as recommended by Kottke and Rathje (2007):

$$RMSE = \sqrt{\frac{1}{n_p} \sum_{i=1}^{n_p} (\ln Sa_{scaled,avg,i} - \ln Sa_{target,i})^2}$$

Where,

- RMSE = root-mean-square-error.
- n_p = number of periods in range of interest.
- $Sa_{scaled,avg,i}$ = average scaled pseudo-spectral acceleration for records considered at period T_i , for periods within the period range of interest.
- $Sa_{target,i}$ = target pseudo-spectral acceleration at the same period T_i for periods within the period range of interest.

The RMSE for the computed average spectrum is shown next to the RMSE label. Further, the fit is computed only for the range of periods of interest. For calculation of the response spectrum, 300 periods equally spaced in a log space, between 0.01 seconds and 10 seconds are used.

To plot the results click on the **Plot** command button.

To delete a ground motion file from the list of motions, click on the name/path for the file to highlight it and then on the **Remove** command button.

The input and output data can be saved to a text file using the **Save** command button. The data can be retrieved from the file using the **Open** command button. This file is an ASCII text file, thus, it can be open with other software applications for other purposes by the user.

An alternative way of finding the scaling coefficients is by using a computer program developed by Kottke and Rathje (Kottke and Rathje, 2007). This program, **sigmaSpectra**, selects and scales motions from a suite of a user provided library of motions so that their average fits a target response spectrum. After the user has executed sigmaSpectra, the results can be imported into D-MOD2000 and used to compute the mean and median spectra as explained previously. The installation file for sigmaSpectra is saved in the sigmaSpectra folder when D-MOD2000 is installed. Please run this installation file to install sigmaSpectra.

The following is a quick tutorial on how to use sigmaSpectra and how to use the results with D-MOD2000.

First, you need to create a library of ground motion files that will be used by sigmaSpectra to create different suites of ground motion files whose average closely match a target spectrum. This library is formed by ground motion records downloaded from the PEER web site at:

<http://peer.berkeley.edu/nga/>

These files should have the extension *.AT2, which is typically the extension automatically given to the files downloaded from the PEER website. Further, these files should have the same names as those entered in the **Motion Identification** column of the **Mean Response Spectrum** form. For example, in the form below, the library of ground motion files is saved in:

c:\Program Files\SHAKE2000\SigmaSpectra\Example

Within this folder, there may be other folders where files for specific seismic events are stored; e.g., the files for ground motion histories recorded for the 11/24/87 Superstition Hills event, B-SUP045.AT2 and B-SUP135.AT2, are located in the *Superstition Hills* subfolder.

	Period (s)	Spec. Accel. (g)	Ln Stdev.
1	0.01	0.338501	0
2	0.02	0.345571	0
3	0.03	0.373274	0
4	0.05	0.457061	0
5	0.075	0.573421	0
6	0.1	0.667904	0
7	0.15	0.766799	0
8	0.2	0.810631	0
9	0.25	0.763515	0
10	0.3	0.69956	0

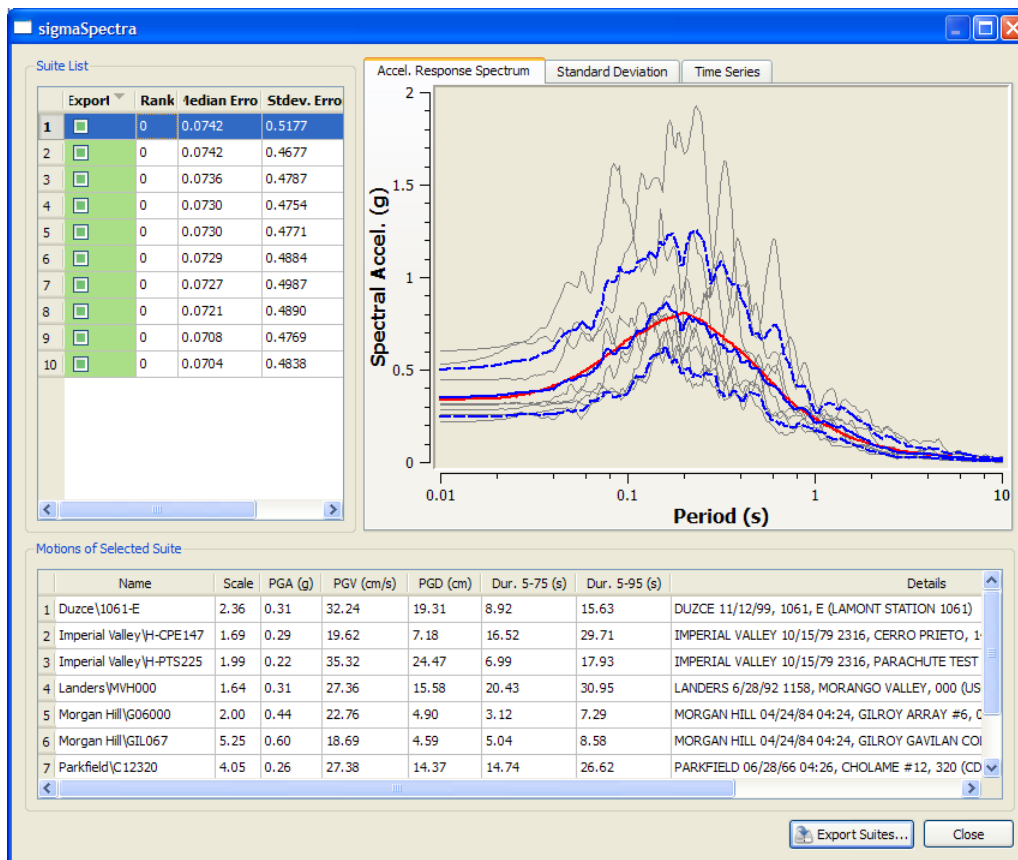
Suite	Median RMSE	Max Error	Std RMSE	Sigma Inf
[1/10]	0.0704	24.0343%	0.4838	1.00
[2/10]	0.0708	18.1245%	0.4769	1.00
[3/10]	0.0721	21.8924%	0.4890	1.00
[4/10]	0.0727	26.8634%	0.4987	1.00

After the library is created, use the **Select Path** command button to select the path where the library of ground motion files is stored. As shown on the previous form, for this example the path selected would be *c:\Program Files\SHAKE2000\SigmaSpectra\Example*. Then use the **Number of motions in suite** and **Seed combination size** options to select the number of motions per suite and the size of the seed combination for the analysis, respectively. Refer to Kottke and Rathje (2007) for more detailed information on these options.

Data for the target response spectrum; i.e. period, spectral acceleration and standard deviation, are entered in their respective columns located on the **Target Response Spectrum** section of the previous form. The data can be entered manually, i.e. place the cursor on the text box and type in the numbers, or you can copy the data from another application, e.g. Excel, and paste them in the respective data column using the **Paste** command of the **Edit** menu item.

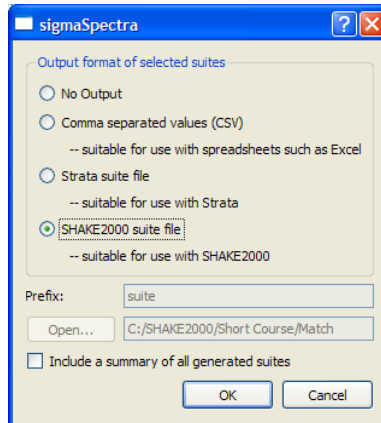
sigmaSpectra uses the periods entered for the target spectrum to compute the response spectrum for the ground motions used in the matching process. If you would like to increase the number of periods, you can use the **Interpolate period** option. Click on the check box for this option to select it, and then use the options in the **Period Interpolation** section of the form to define the settings and values for the interpolation.

After you have selected the ground motion library and set other options and values, click on the **Compute** command button to do the matching. Once the program has completed the calculations, the results for the first suite of ground motions will be automatically displayed as shown below.



This form shows the response spectra for each ground motion on the suite; the target, median and median \pm standard deviation response spectra; and the ground motion files that form the suite. It also lists the different suites created on the upper left corner of the form. To view the results for other suite, click on the row for that suite to select.

To use these results with D-MOD2000, you need to export the data using the **Export Suites** command button. First, select the suites that you want to export by clicking on the check box for each suite on the **Export** column. Then click on the **Export Suites** command button to display the following file dialog form.

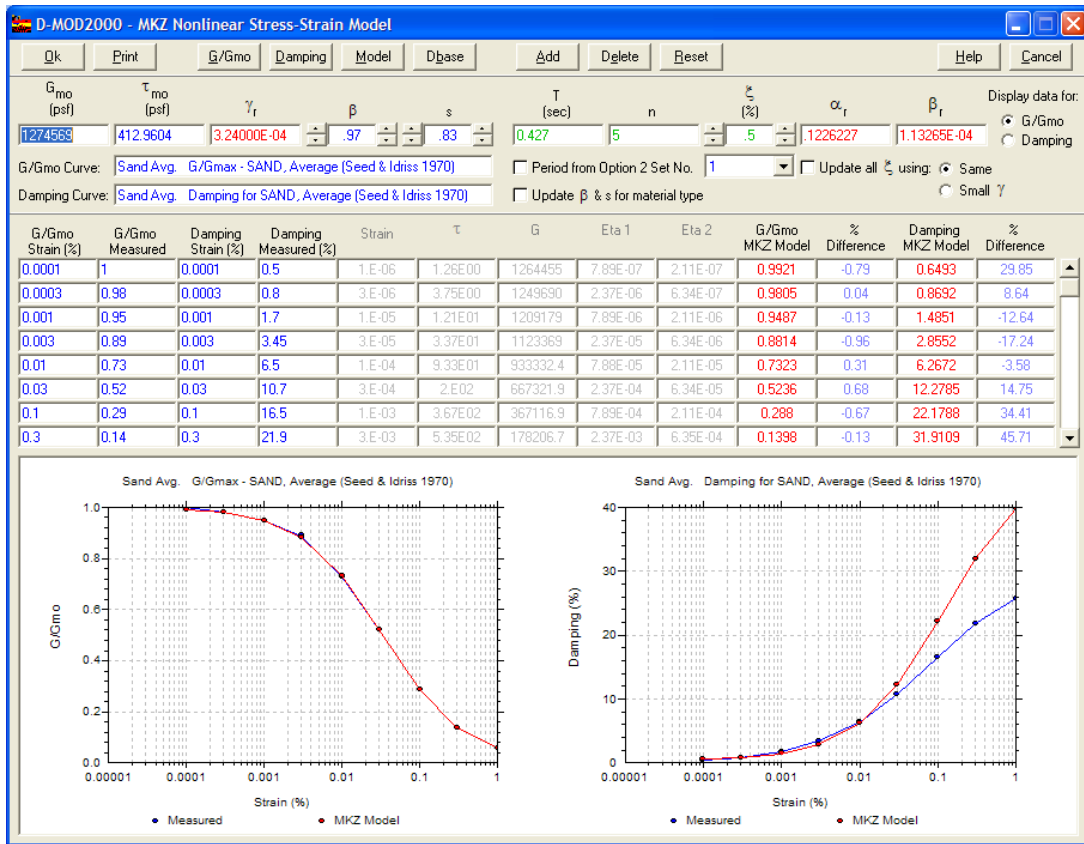


On this form, click on the **Open** command button to select the folder where the results file will be saved; then, click on the **SHAKE2000 suite file** option to select it. To create the results file, click on **Ok**. This file will be automatically given the *SuiteLog.txt* file name and extension.

In the **Mean Response Spectrum** form of D-MOD2000, click on the open folder icon next to the text box for **Motion Selector Suite** and use the file dialog form to select the *SuiteLog.txt* file created with **sigmaSpectra**, and then click on **Open**. The results for the first suite will be shown on the text box. To select a different suite, open the list by clicking on the down arrow, and then select the suite. The scaling coefficients for each motion in the suite will be updated and those for the motions not included in the suite will be changed to 1.0. Then, click on the **Scale** command button to conduct the matching analysis; and, use the **Plot** command button to display the results as explained before.

After you have obtained a suite of motions that fit the target spectrum, the information about the ground motions can be exported to an EDT file in the form of Options 6 & 7 used by D-MOD. To do this, first click on the **Export** command button to display the **Export to EDT File** dialog form. Select the EDT file you would like to add the information to, and then click on **Save**. If you wish to add this information for use with the random creation of data feature, first create the random EDT file before exporting the data.

MKZ Nonlinear Stress-Strain Model



This form is used to calculate the modulus reduction and damping curves using the MKZ non-linear stress-strain model (Matasovic and Vucetic, 1993). It is also used to find the MKZ model parameters β and s (by trial and error), and to calculate stiffness-proportional Rayleigh coefficients α_R and β_R . More detailed information about the Rayleigh coefficients is provided in Appendix C.

The required input is in blue (for the MKZ model fit), and in green (to evaluate Rayleigh damping coefficients α_R and β_R); although the viscous damping term ξ is shown in green, it is also used in the MKZ model fit. For D-MOD_2 analysis, use $0.1\% \leq \xi \leq 5.0\%$ for most practical applications; and, $n = 0$ for simplified Rayleigh damping; or, $n = 1, 3, 5$ or 7 for full Rayleigh damping. More detailed information on the computation of the Rayleigh damping coefficients is presented in Appendix C.

To find the MKZ model parameters β and s (by trial and error), you can either enter the values for strain, G/G_{mo} and damping ratio manually, or you can import/model a curve. G/G_{mo} curves can be imported by clicking on the **G/Gmo** command button to display the **G/Gmax Curves Database** form. After selecting a material, the data for the curve will be shown in the respective text boxes. Similarly, a damping ratio curve for a material can be imported by clicking on the **Damping** command button to display the **Damping Ratio Curves Database** form.

The G/G_{mo} and damping ratio curves can also be estimated using any of the theoretical models included with the program. Click on the **Model** command button to display the **Dynamic Material Properties**

Model form. This form is used to enter the input data for the different relationships for estimating normalized shear modulus and material damping ratio of soils. The relationships included with D-MOD2000 are those developed by Darendeli, M.B. (2001); Ishibashi and Zhang (1993); and, Zhang, Andrus and Juang (2005).

If you enter your own data for the G/G_{mo} and Damping ratio curves, these can be added to the database of material properties using the **Dbase** command button.

To change a value of β , s and ξ enter the value manually in the respective text box; or, use the up/down arrows to increase/reduce the values by 0.05 units (right side) or 0.01 units (left side). The curves will be automatically updated to show the effects of changing the values.

After you have entered the values for strain, G/G_{mo} and damping, you can “fit” a curve by varying the values of initial ($t = 0$), tangent shear modulus, G_{mo} ; shear stress at reference strain, τ_{mo} ; reference shear strain, γ_r ; and, the curve-fitting parameters β and s .

Different materials of Option 4 may use the same G/G_{mo} and Damping Ratio vs. strain curves as the one shown on the form. If that is the case, you can then update the values of β and s for each material by selecting the **Update β & s for material type** option. However, you may still need to check the other materials to determine if the new values of β and s are appropriate as how well the model fits the curves also depends on the values of G_{mo} and τ_{mo} for each material. The way the program determines which materials are the same is based on comparing the description of both the G/G_{mo} and damping ratio curves; i.e., the program will compare the description shown on the **G/G_{mo} Curve** and **Damping Curve** text boxes on this form with every other material and for those materials for which the descriptions are identical, the program will set the same values of β and s .

A description of the G/G_{mo} or damping ratio curve can be entered in the text box next to the **Shear Modulus Curve** or **Damping Ratio Curve** label, respectively. If the curves are imported or modeled, the description will be entered automatically upon returning to this form. This label will be displayed as a graph title.

When entering data for either curve, a new data-row can be inserted at the cursor's location by clicking on the **Add** command button. Similarly, a data-row can be removed by clicking on the **Delete** command button. The **Reset** command button is used to delete the data for both curves.

The **Display data for** options are used to switch between calculated values of γ (or “Strain” in the above form), τ , G , Eta 1, and Eta 2 for G/G_{mo} or damping. These data would be different if the values for strain used to define the G/G_{mo} curve are different from the values of strain used to define the damping ratio curve.

The stiffness-proportional Rayleigh coefficient β_R is calculated by entering values for viscous damping coefficient, ξ ; an odd integer, n ; and, predominant period of the soil deposit, T . A “dry run” of D-MOD_2 can be used to calculate the predominant period of the soil deposit; or, it can be computed by selecting the **Period from Option 2 Set No.** option. With this option, the thickness and material type for each layer will be obtained from the Option 2 set chosen. Knowing the material type for each layer, the value of V_s is obtained from Option 4 for each material. The period is then calculated as $4H/V_{s,avg}$ (where H is the height of the soil profile and $V_{s,avg}$ is the weighted-averaged shear wave velocity of the soil profile).

The viscous damping coefficient value is typically in the 0.1% to 5% range. More rigorous procedures to establish α_R and β_R can be found in Hudson et al. (1994).

When entering values of viscous damping, ξ , there are a number of options that can be used to use the same value for all of the other materials. To use this value of ξ for all of the other materials, first click on the **Update all ξ using** option to select it. After this, one of two options can be used. The first, **Same**, is used when the same value of ξ will be used. For example, on the form on the previous page a value of 3 would be assigned to each material of Option 4.

If instead you prefer to use the small strain damping ratio from the curve, select then the **Small γ** option. With this option, the program will assign the damping ratio for the smallest strain from the curve as the value for ξ for each material. Please note that ξ will depend on the damping ratio curve used for each material, it may or may not be the same for every material. For example, on the form on the previous page, if the **Small γ** option is selected, then the program will use $\xi = 0.36$ for the current material.

To evaluate the goodness of fit, the **% Difference** column shows the difference between the measured value and the value obtained from the MKZ model. For example, for the modulus reduction value this is calculated as:

$$\% \text{ Difference} = \left[\frac{\left(\frac{G}{G_{mo}} \right)_{MKZ \text{ model}} - \left(\frac{G}{G_{mo}} \right)_{measured}}{\left(\frac{G}{G_{mo}} \right)_{measured}} \right] * 100$$

When returning to the Option 4 form, the program will update all of the other materials to change the ξ value based on the option selected, and recalculate the values of α_r and β_r . If you change the value of ξ on the form, but do not select the **Update all ξ using** option, then ξ will only change for this material. The program will also compute new values for other materials if the value of **T** or **n** changes.

When using the **Small γ** option, the program will set minimum and maximum default values of 0.5 and 5 if the values from the damping ratio curve are less or greater than, respectively. If you still would like to use different values, you can manually change them.

NEHRP Response Spectra

D-MOD2000 - NEHRP Response Spectra

Ok Reset Help Cancel

Spectral Response		Site Coefficients		Site Class
S_s :	1.20 g's	F_a :	1	<input type="radio"/> A: Hard Rock
S_1 :	0.419 g's	F_v :	1	<input checked="" type="radio"/> B: Rock
Long-period				<input type="radio"/> C: Very Dense Soil and Soft Rock
T_L :				<input type="radio"/> D: Stiff Soil
4 sec				<input type="radio"/> E: Soil with $V_s < 600$ ft/s (180 m/s)
<input checked="" type="checkbox"/> MCE Spectrum				<input type="radio"/> F: Soil requiring site-specific evaluation

This form is used to select the options and/or enter the data necessary to plot a response spectrum in accordance with Section 3.3 of NEHRP (Building Seismic Safety Council, 2004a & 2004b).

The procedure followed to obtain the spectrum starts by first entering spectral accelerations at short period, S_s , and at 1-second period, S_1 , from the Maximum Considered Earthquake (MCE) Ground Motion Maps provided as Figures 3.3-1 through 3.3-14 on the NEHRP Provisions. These values are entered in the S_s and S_1 text boxes respectively. By default, a Long-period transition period, T_L , of 4 seconds is shown on the T_L text box. If you would like to use a different value, enter the appropriate value in this text box. The program will only accept values of 4, 6, 8, 12 or 16 seconds for T_L as these are the only values used in the maps on Figures 3.3-16 through 3.3-21 of NEHRP.

Next, select the site class by choosing one of the **Site Class** options. The F_a and F_v values will be computed and displayed in their corresponding text boxes on the upper right corner of the form.

By default, the program will compute the design spectrum. If you need to use the MCE spectrum, click on the **MCE Spectrum** option to select it. When the spectrum is plotted, either **Design** or **MCE** will be shown on the plot label to indicate which spectrum is being used. When this form is called from the RRS form, the default spectrum will be MCE.

If you would like to manually enter the values for period and spectral acceleration, select the **User** option. The **User** command button will be enabled when this option is selected. This option will display the **User Defined Response Spectrum** form. In this form, you can enter values of period and spectra for a user defined response spectrum that will be used to compute the modified spectrum using the results of the RRS analysis.

After you have entered the above input information, click on the **Ok** button to compute the spectrum and to return to the **Response Spectrum Plot Menu** form. If you click on the **Cancel** button, you will return to the plot menu form without modifying the input information if any had been selected previously.

The **Reset** button is used to set the values of the form to their default values.

Newmark Displacement Analysis

This feature of D-MOD2000 allows you to determine permanent slope displacements due to earthquake shaking, using the Newmark Method. For more complete information on the methodology and data used in this feature, please refer to the papers by Houston et al. (1987), Matasovic et al. (1998) and Newmark (1965).

In D-MOD2000 two different approaches are used to create an algorithm for the Newmark Method as recommended by Houston et al. (1987) and by Franklin and Chang (1977). The approach by Houston et al. allows the use of the upslope component of the yield acceleration in order to account for upslope movement. However, when only the downslope component of the yield acceleration is used, both approaches yield similar results. To select a method, click on the radio button for the method's option.

When this form is first displayed, the cursor is on the **Project** text box. Enter the description (up to 80 characters) for the analysis you will be doing. Press the *Tab* key, or use the mouse pointer to move the cursor to one of the **Yield Acceleration** options. The first option, **Constant Acceleration**, allows you to use a constant value for the yield acceleration. When this option is selected, the text box next to the label is enabled, and the cursor is placed on it. Enter the value for the yield acceleration.

The second option, **Changes with time**, allows you to enter values of yield acceleration that vary as a function of time. After you select this option, the **Edit** command button next to the text box will be enabled. Click this button to display the **Yield Acceleration Function** form. Enter the data for time, yield acceleration and a brief description for the function in the **Description** text box. Then click on the **Ok** command button. Upon returning to the displacement screen, the description will be displayed on the text box.

The next option, **Changes with displacement**, allows you to enter values of yield acceleration that vary as a function of displacement. Matasovic et al. (1998) provide an example of this application. These data are entered as described previously for the **Changes with time** option.

To select an acceleration time history to use in the displacement analysis, click on the **File** command

button on the **Acceleration Time History** line to display the **Newmark Displacement Ground Motion File** form. Use this form to select a time history file; or, to create a weighted-file from a series of files that may represent different columns on the soil profile. If you would like to scale this acceleration time history to a different value of maximum peak acceleration, place the cursor on the **Maximum Acceleration Value** text box and enter the value for the new peak acceleration in g's. If you enter 0 (zero), a scaling factor of 1 (one) will be used and the record will not be changed.

An option to account for the upslope movement is included in D-MOD2000. Normally, the error in not including the upslope movements is not significant (Jibson, 1993; Newmark, 1965). To include the upslope movement, click on the check box for the **Include upslope movement** option. If you select this option, you need to enter a value for the static factor of safety. Based on the method proposed by Houston et al. (1987), the static factor of safety is used to compute the upslope component of the yield acceleration based on the following equation:

$$a_{y,upslope} = a_{y,downslope} \left[\frac{FS_{static} + 1}{FS_{static} - 1} \right]$$

Where $a_{y,downslope}$ is the downslope value of yield acceleration. To enter the static factor of safety, place the cursor on the text box next to the **Static Factor of Safety** label and enter the value.

When working with English units, a default value of 386.4 in/sec² is used for the acceleration due to gravity. A value of 981 cm/sec² is used when working with SI units. However, you can change this value to obtain the results using a different system of units. Select a different acceleration value by clicking on the down arrow key of the list box next to the **Acceleration due to Gravity** label and choose a new value.

After you have entered all the information, the displacements are computed automatically. The results will be displayed in the **Maximum**, **Minimum** and **Average** displacement text boxes. A value of displacement is computed by using the acceleration data as they are saved in the input file. If the acceleration time history is significantly unsymmetrical, then Houston et al. (1987) recommend that the history be reversed. A second value of displacement is calculated by first reversing the acceleration time history, i.e. the sign of each value is changed, and then by conducting the analysis a second time. The displacement values are compared to determine the maximum and minimum, and an average value is computed.

The data can be saved to a text file by clicking on the **Save** command button. This will display the save file dialog box. Enter a name for the text file where all this information will be saved for future retrieval using the **Open** command button. The acceleration, velocity and displacement time histories are also saved in this data file. The **Append** command button can be used to add the current results at the end of the output file.

You can print the results by using the **Print** command button. This button will display the **Print Displacement Results** form.

To plot the results, click on the **Plot** command button. You can select to plot the three graphs at the same time or each graph separately. When using the **Franklin & Chang** option, plots of the relative values for acceleration, velocity and displacement are also available. The **Reversal** option allows you to plot the results obtained using the reversed acceleration time history.

Newmark Displacement Ground Motion File

File No.	Column Weight	No. Values	Time Step	No. Header	Values per Line	No. Digits
1	934.72	19392	.005	3	8	15
2	1347.68	19392	.005	3	8	15

There are four options for selecting an accelerogram for the Newmark's method:

- The first one is to use a file that was obtained from processing of the output files from D-MOD_2. The file is given a name such as **xxxxxA#L###.AHL** or **xxxxxA#L###.HEA**, where **xxxxx** is the label used to name the output files; **A** stands for analysis, and the number following it is the analysis number; and, **L** means layer and is followed by three numbers which are the layer number. Files identified with the extension *.AHL (or acceleration history at layer) are those created from the acceleration time histories; and, those with the extension *.HEA (or horizontal equivalent acceleration) are those created from the shear stress time histories. As explained in Bray et al. (1995) for the seismic analysis of landfills, the HEA, or horizontal equivalent acceleration, at a specific depth and time can be obtained as the ratio of the shear stress to the total vertical overburden stress. Accordingly, these files are created using the shear stress histories computed and the overburden stress computed using the thicknesses and unit weights for the soil layers.

To select a file, click on the check box next to the first **(Click Choose to select a file)** label. Then on the **Choose** command button to open the **Open Acceleration Time History** dialog box. Select a file and then click on **Ok** to return to the form. Some information will be displayed on the boxes next to the file name. Click on **Ok** to return to the **Newmark Displacement Analysis** form.

- The second option is to create an average file from a series of files. The method used to compute an average accelerogram in D-MOD2000 is as recommended by Abramson et al. (1996). In this method, a weighted average approach is used to compute an average file from a series of **n** files based on the equation:

$$Acc_{avg} = \frac{\sum_{i=1}^{i=n} m_i a_i(t)}{\sum_{i=1}^{i=n} m_i}$$

Where,

- m_i = mass of unit column directly above point **i** (when using *.HEA files, this value will be 1.0)
- $a_i(t)$ = acceleration response at point **i**

To create the average accelerogram, first select up to fifty motion files. To do this, click on the check box next to the first (**click Choose to select a file**) label (an **x** is shown on the box when a file is selected), then on the **Choose** command button to display the **Open Acceleration Time History** dialog box. Select a file then click on **Ok** to return to the form. Some information will be displayed on the boxes next to the file name. Use the scroll bar to display check boxes for additional files. After selecting the files, you need to choose a name for the average file. By default D-MOD2000 will give this file the name **output.nmk**, and will save it in the directory selected for the output files in the main menu form. The name and path will be shown on the text box next to the **Weighted average accelerogram file** label. If you would like to use a different name and/or path, click on the **Save** command button to display the **Save Accelerogram File** form. Then, select a file or enter a new name in the **File name:** text box. This file is given the extension *.NMK by default. Click on **Ok** to return to the file selection form.

After you have selected the files and have chosen a name, click on the **Motion** command button to create the file. Only the files for which an **x** is shown on the check box will be used in the calculation of the average file. Finally, click on the **Ok** command button to return to the **Newmark Displacement Analysis** form.

- Import an acceleration file created by another application (e.g. ProShake, Quake/W). In short, first, you will select an output file created by another application, e.g. ProShake; then, read that output file to determine if there are any acceleration time histories and how many there are (D-MOD2000 will only read the first 6 acceleration time histories found in the file); and finally, create a series of output files, i.e. one per acceleration time history, in the format used by D-MOD2000 to perform the displacement analysis with the Newmark Method. To access this feature, click on the **Import** command button to display the **Import Acceleration Data** form.
- **Using other acceleration history file:** If you want to use the data saved in a file different from the ones described above, use the **Other** command button to display the **Acceleration Time History** dialog box to select the file that you want to use. The name of the file will be displayed next to the option button on the bottom section of the form. Now you need to enter the following information on the data cells below the file name. First, you need to select the file by clicking on the button next to the **Other Acceleration Time History** label. This will enable (i.e. the mouse cursor changes to the *I-beam* appearance when placed on the cells) the data cells to enter the data. We'll use the following example to explain the information necessary to plot the object motion.

Example:

```
D-MOD2000 Sample Object Motion
Time Period = 0.01      Number of Points = 2048
 0.024455  0.000868  -0.019352  -0.012488   0.003331   0.030202   0.021586  -0.022183   1
-0.050340 -0.025930   0.000123   0.020366  -0.000176  -0.008401  -0.013457  -0.014927   2
```

No. Values: This is the total number of acceleration values that form the object motion file. For the above example, there are 2048 points in the file, thus, you will enter 2048 in this cell.

Time step: Enter the time interval between each acceleration value. For this example, it is 0.01 seconds.

No. Header (or Number of header lines): Enter the number of lines at the beginning of the file that are used to describe the object motion. In the above example, the first two lines are the header lines. Thus, you will enter a 2 in this data cell.

Values/Line (or Number of values per line): Enter the number of acceleration values on each line. For the above example, there are 8 values on each line. The last number (e.g. 1) only identifies the row number. Thus, you would enter an 8 in this cell for this specific example.

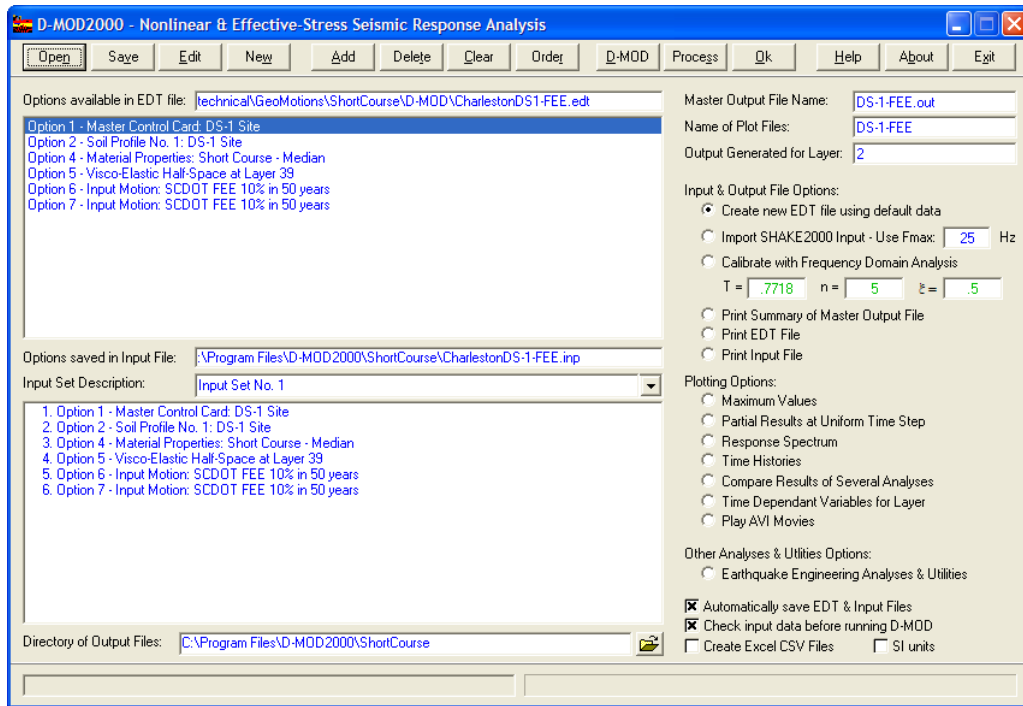
No. Digits (or Number of digits per value): Enter the number of digits that form an acceleration value. In the above example, each value is defined by 9 digits, including the spaces. Therefore, you would enter a 9 for this specific example.

Units: For the Newmark Displacement Analysis the values of acceleration are in g's. If the values saved in the file are in other units (e.g. ft/sec², cm/sec², or mm/sec²), then select the appropriate units by clicking on the up or down arrows to scroll through the different options. This way, the data will be converted from these units to g's. For example, if the data in the file were in ft/sec², then you scroll down until **ft/sec/sec** is shown on the **Units** box. The values will be divided by 32.2 to transform them to g's.

Free format: With this option the data from the file are read "free format", i.e. no consideration is given to the number of digits in each column, or to the number of columns in a row. When you select this option (an **x** is shown on the check box), you only need to provide the **No. Values**, **Time Step** and **No. Header** values, and then select the dimensions for the Y axis by clicking on the up or down arrow keys next to the **Units** text box. To be "free format" the data in the file have to be separated by at least one blank space or be in different lines.

The **View** command button can be used to view the contents of a ground motion file. This will help you to collect the information needed to define the formatting of the file if necessary. To do this, first select a file using the **Other** button to select other files. The first 60 lines of the file will be displayed on a form, with the first three characters displayed in red representing the numbers of each row of data in the file followed by a "|". These characters are not part of the source file and are only shown to number the rows. After the row numbers, the alphanumeric characters that constitute the information saved in the file for each row are shown. Note that the characters are displayed as blue on a white background, and that every tenth character is displayed in red. However, if the tenth character is a "blank space" then the character is not shown. This is done to guide the user when defining the order of the data in the file.

Nonlinear Earthquake Response Analysis



This is the Main Menu form for D-MOD2000. It has three main uses: 1) to create the input file for D-MOD_2; 2) to process the master and auxiliary output files created by D-MOD_2; and, 3) to allow the user access to plotting and other engineering analyses features of the program.

In this section, we will first explain the main working file in D-MOD2000. This file is identified by the extension *.EDT. This file is a database file that stores the data for the different options for D-MOD_2. You can have any number of sets of data for each option, i.e., 8 sets of option 1 data, 6 sets of option 2, etc. The total maximum number of all sets for all of the options combined is 32,000. You can then select from this database those options that you want to use in the analysis and save them in an input file for D-MOD_2.

The difference between an *.EDT file and other files is that the options are saved sequentially, beginning with option 1, and so on. For example, an EDT file for D-MOD2000 could be composed by the following options.

```
Option 1 - Master Control Card: Single Sand Layer within Clay Deposit
Option 1 - Master Control Card: Clay Deposit
Option 2 - Soil Profile: Single Sand Layer within Clay Deposit
Option 2 - Soil Profile: Clay Deposit
Option 4 - Material Description
Option 5 - Properties of Visco-Elastic Half-Space
Option 6 - Dynamic Analysis Solution Control Card
Option 7 - Input Motion: CHI-CHI 09/20/99, ALS, E (CWB)
Option 7 - Input Motion: Nisqually, WA, Earthquake - 2/2001 - Olympia; DNR Building
```

By selecting specific options from this database, you could create different input files for D-MOD_2. For example, you could create an input file, as shown in the following:

Option 1 - Master Control Card: Single Sand Layer within Clay Deposit
 Option 2 - Soil Profile: Single Sand Layer within Clay Deposit
 Option 4 - Material Description
 Option 6 - Dynamic Analysis Solution Control Card
 Option 7 - Input Motion: Nisqually, WA, Earthquake - 2/2001 - Olympia; DNR Building

To create an *.EDT file, you have four options. First, you may select the **Create new EDT file using default data** option.

Second, you may start from scratch by creating sets for each option using the **New** command button to display the **Option List** form. Each new option will use default values. You will have to enter your project's specific data for each option using the editing forms provided with D-MOD2000.

Third, you can edit an existing file by using the **Open** command button to display the **Open Existing EDT File** dialog form. This allows you to simply modify existing data without the need to retype data that is similar to each project, e.g. material properties. A backup copy of the EDT file will be automatically created in the Backup\D-MOD folder. This backup copy can be used to restore your original file, and it can also be used to restore some of the other working files as explained in the following sections.

Or fourth, you could import the data from an input file for SHAKE2000. To do this, select the **Import Data from SHAKE2000 Input File** option then click on **Ok**. Using the file dialog window, select the SHAKE2000 input file and click on **Open**. The program will read the input file and create the different options for D-MOD2000. A few comments about this procedure are recommended here;

- The program will use the value of maximum frequency, i.e. f_{\max} , entered in the text box next to the **Import SHAKE2000 Input – Use Fmax** option. The default value of 25 Hz is recommended for most analysis.
- Using f_{\max} the program will determine the maximum thickness for each layer of the D-MOD soil column based on $h_{\max} < V_s / (4 * f_{\max})$. The V_s value is obtained from SHAKE's Option 2 for each soil layer. If the thickness for each layer in SHAKE's Option 2 is greater than its respective h_{\max} , then the layer will be subdivided in layers until the thickness of each layer is less than or equal to h_{\max} . It is likely then that the D-MOD column may have more layers than the SHAKE column.
- A layer for the half-space in SHAKE's Option 2 will not be created in D-MOD's Option 2.
- For D-MOD's Option 4, the program will create one "material" for each layer of the SHAKE column, i.e., if the SHAKE column as defined by Option 2 has 16 layers, then the program will create 16 different materials for D-MOD's Option 4. For each material, the G_{m0} will be assigned to be equal to G_{\max} or calculated based on the total unit weight and V_s from SHAKE's Option 2. Each material in D-MOD's Option 4 will also be assigned the G/G_{\max} vs. strain and Damping Ratio vs. strain curves based on the soil type code in SHAKE's Option 2. Further, the program will assign default values for some of D-MOD's Option 4 values based on the description of these curves. For example, if the description for the G/G_{\max} curve includes the word "sand", the program will assign default values for a sand material. Other words that will be used to define default values are "clay", "silt", "rock", "cohesionless", "waste", "peat", and "gravel". For clay soils, the program uses the default values for plasticity index of 15; however, it will also accept "PI-30" or "PI 30", "PI-50" or "PI 50", and "PI-100" or "PI 100". Other values for material properties are provided in Appendices A and B.
- D-MOD's Options 6 & 7 will be created based on the data in SHAKE's Option 3. For D-MOD's Option 7, the program will use the multiplication factor from SHAKE's Option 3 as the acceleration scaling constant in D-MOD's Option 7 if available. Alternatively, the program will

use the maximum acceleration value in SHAKE's Option 3 to calculate an acceleration scaling constant after reading the acceleration data from the ground motion file.

- D-MOD requires the ground motion file to be in the FORTRAN "F" format, e.g. 8F9.6, etc. The program will display a warning message if any of the ground motion files in SHAKE's Option 3 is not in the "F" format, but will not change the formatting of the file. You will need to manually change the format of the file before using this ground motion file in the D-MOD analysis.
- Based on the values in SHAKE's Option 4, the program will create a D-MOD's Option 5 if the ground motion is assigned as an outcrop motion. The program will also set the half-space control number in D-MOD's Option 1 to "1" to reflect this.
- For D-MOD's Option 1, the program will by default assign layer number 2 as the top saturated layer and the last layer as the bottom saturated layer.
- In D-MOD's Option 1, the analysis type control number will be set by default to "1", i.e. total stress analysis.
- If there are more than one set of a SHAKE option in the input file, the program will create a D-MOD option for each.

After importing the SHAKE information, you need to review and modify the different D-MOD options created to ensure the default data are appropriate for your D-MOD analysis.

To differentiate the input file from the EDT database file, you should give it a different name and extension when saving them. The main database file does not need to have the EDT extension; however, by default, when using the **Open** command button, D-MOD2000 will present you with a list of files that end with this extension. When the database file is saved, the options will be saved in numeric order, and all the sets for each option will be grouped together.

The options available in the EDT file are shown on the top list box, i.e. the **EDT File's Option List**. This list is used to select the options that the user can edit and options to be included in the input file. The vertical scroll bars on the right side of the list box can be used to scroll between the options. To edit an option, click on it to highlight it and then click on the **Edit** button. You can also double click on the option to edit it. If you want to remove an option from the *.EDT file, highlight it and then click on the **Delete** button. The option cannot be un-erased. To create a specific option that is not included in the *.EDT file, or to create a new set of an existent option, click on the **New** button. This button will display the **Option List** form used to select new options.

To save the *.EDT and Input files, click on the **Save** button. The files can be saved automatically after you edit an option, or before you execute D-MOD_2, by selecting the **Automatically save EDT & Input Files** check box.

The **Check input data before running D-MOD** option is selected by default. When this option is selected, the data in the different options that form the input data will be checked to determine if there are any errors that may cause problems during the execution of D-MOD_2. For example, a different number of soil layers in Options 1 and 2 will cause D-MOD_2 to crash. The program attempts to detect this and other errors before execution of D-MOD_2 is started. The user will be provided with detailed information on the error. If you are sure that your data are correct and do not wish to check the data before execution of D-MOD_2 starts, click on the check box to de-select this option.

When the **Automatically save EDT & Input Files** option is selected (an **x** is shown on the check box) the EDT and Input files will be automatically saved every time you return from editing an option (using the **Edit** command button), or previously to execute D-MOD_2 (with the **D-MOD** command button).

By default, D-MOD2000 will use English units for most of the data used in the program. If you wish to use SI units, select the **SI units** option by clicking on the check box. Please note that the original source code for D-MOD_2 was written to work in Imperial units. Accordingly, when working with SI units, the input data for D-MOD_2 are transformed to English units before executing D-MOD_2. This transformation only takes place for the data saved in the input file, and does not affect the data shown on the different D-MOD2000 forms. Similarly, the output data provided by D-MOD_2 are in English units. When working with SI units, these data are converted to SI units during processing of the data.

The **Create Excel CSV Files** option can be used to save the output data from D-MOD as comma separated values (CSV) files that can be opened with Excel. The program will use the name shown in the **Name of Plot Files** text box and add three letters to identify the data in the file. For example, D-MODout-ACC.csv will save the acceleration time histories. The files will be created in the folder shown on the **Directory of Output Files** text box.

A few of the features included in D-MOD2000 are available only on SI units, e.g., the attenuation relations. This is the case when the feature has been originally developed using the SI units, and to support the worldwide move towards a common system based on the SI units. For most data used in D-MOD2000, the units for each value are shown on each form.

To create an input file for D-MOD2000, select the options you want to include from the top list (i.e. **EDT File's Option List**) in the order they will be executed by D-MOD_2. The options selected will be shown on the bottom list box (**Input File's Option List**) with the order number next to them. To include an option in the input file, first select the option by clicking on it to highlight it, and then click on the **Add** button. More than one set of input options can be created in order to create different input files. The information about each set will be saved in the EDT file. To switch between sets, click on the down arrow next to the description text box and select a different set.

A description for this set of input options is entered in the text box next to the **Input Set Description** label. To create and/or delete a set, click on any of the options on the input list window and then click on the **Clear** command button. On the message box, if you click on **Yes**, the current set will be deleted and a new set created. If you click on **No**, the current set will be kept and a new set created. When a new set is created, a default description string is entered in the description text box; and, the input list window is cleared. With each set of input options, the name and path to the input file, the output directory, the name of the two output files and the name of the plot files are also saved in the EDT file.

The **Order**, **Remove** and **Clear** buttons are not enabled, i.e. they are grayed out. These buttons are enabled when an option from the input file's option list is selected. Once you have selected the options, you can reorganize them with the **Order** button, remove any with the **Remove** button, and delete all the options from this list box with the **Clear** button. Then, use the **Save** command button to store these options in the input file. A file dialog form will be displayed requesting you to enter the name for the file. Alternatively, you can select to overwrite an existing file by selecting it.

Before you execute D-MOD_2, you need to enter the name of the master output file and select a directory path where the files created by processing of the master output file will be saved. Place the cursor on the text box next to the **Master Output File Name** label and type in the name for the file, followed by a period and the extension (e.g. *Example.out*). D-MOD2000 will not add an extension to the end of the file if it is not entered. You can enter up to 32 characters. Blank spaces are not allowed.

Next, place the cursor on the text box next to the **Name of Plot Files** label and type in a name that will be used to identify the files created during processing of the master output file. A maximum of 8 characters is allowed as input for this text box. This name will be “added” to a default name and extension

depending on the type of data saved in the file. These files will be saved to the folder shown on the text box next to the **Directory of Output Files** label. To change the location of the output directory, there is a command button located next to the text box (i.e. the button with the open folder icon). Click on this button to display the **Choose Output Directory** form, select a different folder by double clicking on it, and then click on the **Ok** button to return to this form. In the text box next to the **Output Generated for Layer** label, enter the number of the layer for which time-dependent variables will be generated and stored.

To execute D-MOD_2, click on the **D-MOD** command button. You will be prompted to save the input file. When the D-MOD DOS window opens, you will be prompted to enter the name of the input file; the name of master output file; and, depending on the value of the NPLD variable in Option 6, the number of the layer for which time-dependent variables will be generated and saved. Please note that for both the input and master output files, you need to provide the path to the file, if these files are not saved in the same path as the D-MOD executable file. The D-MOD executable file is saved in the folder where D-MOD2000 was installed.

After you have executed D-MOD_2, you need to process the master output file created. D-MOD2000 will read the output file and extract the information that is most useful to the user, and store it in a series of ASCII files that are used by the **Plot Data** options described below. To process the output file, click on the **Process** command button. A message window will be displayed after processing is completed.

The time for processing depends on the amount of data stored in the master output file. It could take from a few seconds to a few minutes. For example, for the extreme case when using a soil column with 200 layers, a ground motion record with 32,000 points, with data being saved for every time step, and running the program on a Pentium Celeron 2.2 laptop, processing of the output file took approximately 35 minutes. At the end of processing, a message window is displayed that shows a list of the layers that liquefied, and the “D-MOD terminated normally” message if execution of D-MOD_2 terminated normally, i.e. there were no errors during execution of the program. If there are any errors, then it is recommended to use a text processor (e.g. WordPad) to open the master output file and browse through the input data and results to obtain more information.

Processing of the master output file will create files that have the name entered in **Name of Plot Files** text box, with the “aux” label added, and an extension depending on the data saved in the file. For example, if we used the “Example” label for the name of the plot files and requested results for layer 3, the following files would be created:

Exampleaux.acc	Acceleration
Exampleaux.vel	Velocity
Exampleaux.dpl	Displacement
Exampleaux.max	Maximum values
Exampleaux.nst	Normalized shear stress
Exampleaux.pwp	Pore Water Pressure ratio
Exampleaux.stn	Shear Strain
Exampleaux.sts	Shear Stress
ExampleA1L3.var	Time dependant variables for layer 3
ExampleA1L3.ahl	Acceleration Time History at layer 3
ExampleA1L3.heh	Equivalent Acceleration Time History at layer 3

Each of the “aux” files above, except the *.MAX file, will save the time history for the respective variable. It should be noted that the number of values and the time step for the time history will be

determined based on the values entered in variables NC and NCPR of Option 6. The total number of points is partially determined by the NC variable, i.e. the total number of numerical integrations to be performed.

If NC is set equal to the number of values in the ground motion input file, then the entire accelerogram will be used to calculate the dynamic response of the soil column. However, the number of results in the output file is also determined by the values of the NCPR variable, i.e. the partial number of numerical integrations to be performed prior to printing of time-history values in the master output file. For example, if NC is set equal to the total number of values in the input ground motion, and NCPR is set equal to “1”, then results will be saved in the master output file at every time step. Hence, the time step for the results will be the same as the time step for the input ground motion. The time histories are saved for each layer of the soil column.

If auxiliary output files were created for a specific layer, then an additional file will be created that can be used for example in a Newmark Displacement analysis. This file will have the extension of *.AHL and will save the acceleration time history data. The file will have the same name as the output files, plus the letter “A” followed by a number representing the number of the analysis conducted; and, the letter “L” followed by a number that corresponds to the layer number entered in the **Output Generated for Layer** text box.

Display/Print Input & Output Options:

To print the EDT or Input file, first click on the **Print EDT File** or the **Print Input File** option, respectively, and then click on the **Print** command button. This will display the **Print *.EDT and Input Files** form.

The **Print Summary of Master Output File** option will display the first section of the master output file, i.e. the input data; and, the bottom section of the master output file, i.e. the table of maximum values. After you have selected this option, click on the **Print** button to display the form.

Plotting Options:

To execute a plot option click on the option to select it, and then click on the **Plot** button to plot the data saved in the file. The file for each option is formed by using the path shown in the text box next to the **Directory of Output Files** label, the file name shown in the **Name of Plot Files** text box, and the file extension for each option. For example, the *c:\D-MOD2000\output\exampleaux.acc* file would store the acceleration values for each soil layer, for every numerical integration step used. The data in this file would be read when using any of the options in this group.

Maximum Values: This option will plot a graph of the maximum values for acceleration, shear strain, normalized shear stress and PWP Ratio versus depth along the soil column. After selecting this option, click on the **Plot** command button to display the **Plot Results** form.

Partial Results at Uniform Time Step: This option will plot a graph of the dependent variable versus depth and time along the soil column. After selecting this option, click on the **Plot** command button to display the **Plot Results** form. The graph in this form can also be “animated”, i.e. the change of the variable with time and depth will be displayed.

Response Spectrum: Select this option to display plots of response spectrum for different damping ratios for any layer. The different response spectra plotted are: Relative Displacement (S_d), Relative Velocity (S_v), Pseudo-Relative Velocity (PSV), Absolute Acceleration (S_a), and Pseudo-Absolute Acceleration (PSA) versus Period. After selecting this option, click on the **Plot** command button to display the **Plot of Response Spectrum** form. By default, the absolute acceleration spectrum for 5% damping for layer number 1 will be displayed upon loading of the form. You can select other layers, or other damping ratios in the form.

Time Histories: This option is used to plot the dependent variable time history for a layer of the soil column. After selecting this option, click on the **Plot** command button to display the **Plot Results** form. By default, the acceleration time history for layer 1 will be displayed upon first loading of the form.

Compare Results of Several Analyses: This option is used to plot simultaneously results from up to 6 different analyses. The results that can be compared include maximum values, response spectra and partial results at uniform time step.

Time Dependant Variables for a Layer: When executing D-MOD, results for a specific layer can be saved in auxiliary output files. This option will plot the results for this layer only. When processing the output file created by D-MOD_2, the auxiliary output files will be read and the data saved to a file with an extension of *.VAR. The name of this file will be formed by the label entered in the **Name of Plot Files**; followed by the letter “A” and a number representing the number of the analysis; and, the letter “L” followed by a number which is the number of the layer entered in the **Output Generated for Layer** text box. For example “WildSHCA1L3.VAR” would be the name for a file created using the “WildSHC” for the name of the output files; for analysis number one, i.e. “A1”; and, for layer number 3, i.e. “L3”. After choosing this option, click on the **Plot** command button to open the file dialog box and select a *.VAR file.

Calibrate with Frequency Domain Analysis: This option is used when plotting the response spectrum obtained for a specific layer (as explained in the **Time Dependant Variables for a Layer** option above) and comparing the spectrum to that obtained from a SHAKE analysis. When this option is selected, you will be asked for a *.VAR file the first time the option is used. For subsequent uses of this option, the same VAR file will be used.

This option is used to facilitate the calibration of the nonlinear analysis against an equivalent-linear analysis when estimating the viscous damping. When using this option, you can change the values of T , n and ξ . After changing these values, click on the **D-MOD** command button to conduct a new analysis. After the D-MOD DOS window closes, click on **Process** to process the output file and then click on **Plot** to compare the spectra. To change the VAR file, click on the **Time Dependant Variables for a Layer** option and then on **Plot**. The next time you use the calibration option, you will be asked for a new VAR file.

The best way to estimate viscous damping is by calibrating the D-MOD analysis against an equivalent-linear, i.e. SHAKE, analysis that has a constant value of viscous damping at all frequencies. To this end, n and ξ can be evaluated in an iterative procedure as follows:

1. Develop a SHAKE column and perform the SHAKE analysis to obtain the response spectrum at the surface level. Limit the input ground motion to ≤ 0.4 g's and shear strains to $\leq 0.5\%$.
2. Develop the D-MOD column to match the SHAKE column as close as possible and use $n=5$ and $\xi = 0.5$.
3. Perform the nonlinear analysis using the D-MOD command button.

4. Compare the response spectrum from SHAKE to the response spectrum from D-MOD (use the **Process** command button to process the output file, load the VAR file and then plot the results. Use the **Graph** button to display the response spectrum menu and then the **Other** command button to obtain the response spectrum using the acceleration time history file obtained from the SHAKE analysis). The value shown as MSE is the mean square root difference between the spectra and it is only intended to provide the user a guidance to help determine how close the spectra are; e.g., the closer the number to zero the closer the match is.
5. Adjust n and ξ and repeat from step 3 until a “satisfactory” match between the SHAKE and D-MOD spectra and shear strain vs. depth is obtained.

After running D-MOD, use the **Process** command button to process the output data. You will be asked to open the VAR file to compute the response spectrum for the layer and also to open the calibration file created by SHAKE2000. If there is no calibration file, click on **Cancel**. You can open the calibration file later by using the **Open** command button when the **Calibrate with Frequency Domain Analysis** option is selected. An step-by-step example of how to perform the calibration procedure is provided in the Quick Tutorial document saved in the *Manual* folder.

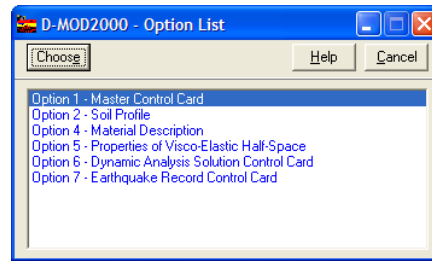
Section 5 of Stewart et al. (2008) provides more information on the calibration procedure between the equivalent-linear and nonlinear analyses.

Play AVI Movie: This option is used to play up to 2 movies created with D-MOD2000. Select this option and then click on the **Play** command button to display the **Video Player** form.

Other Analyses & Utilities Options:

Earthquake Engineering Analyses & Utilities: This option will display a form that includes a number of other analyses and utilities useful in geotechnical earthquake engineering. These include Ground Motion Attenuation Relations; Ground Motion Parameters; Ground Motion File Utilities – Conversion & Database; Newmark Method – Displacement Analysis; Response Spectra for Ground Motion; and, U.S. Geological Survey Seismic Hazard. After selecting this option, click on the **Ok** command button to display the form.

Option List



This form is used to select D-MOD_2 options that are not already included in the *.EDT file, or to create new sets of an option. Default values will be given to the option. To select an option, click on the option to highlight it and then click on the **Choose** button to return to the **Earthquake Response Analysis** form. The new option will be shown on the option list. You can also double click on the option to select it.

Options for Table of Results

D-MOD2000 - Options for Table of Results

Ok Help Cancel

Title: Wild Life Site

Subtitle 1: Site Response

Subtitle 2: D-MOD2000

Page Header: Master Output File: C:\D-MOD2000\SAMPLE\wildSHB.out - Page No.

Page Footer: Page No.

Column Title: Column Heading

Cell Numbers: Column Data

Font:

☒ Bold

☐ Italic

☐ Underline

Alignment:

☒ Left

☐ Center

☐ Right

Show on Page:

☐ Page Number

☐ Page Border

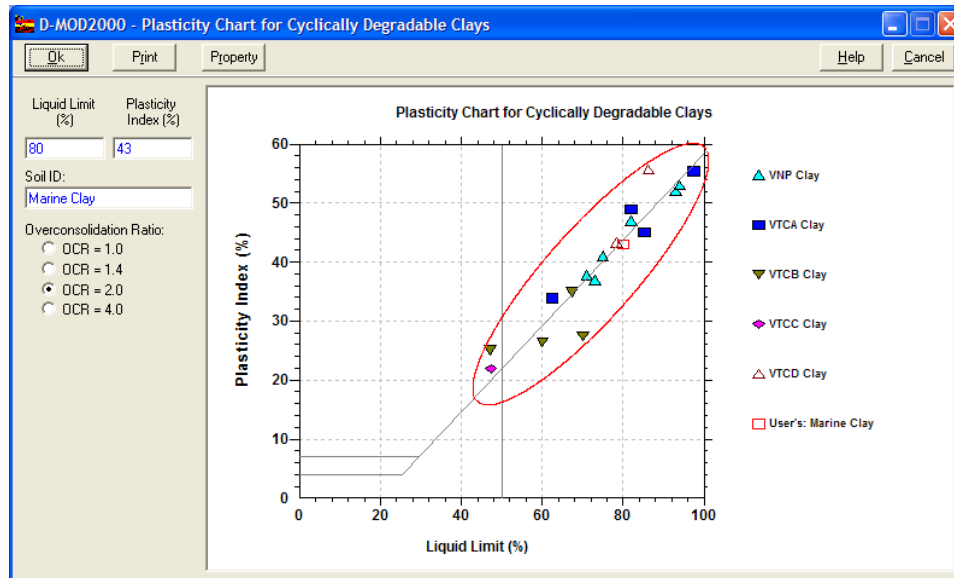
This form is used to change the title and subtitles of the analysis, and their font attributes. You can also add a footer and a header to the printout. By default, when the form is displayed, the cursor is set to the **Title** cell. You can use the *Tab* key or the mouse to place the cursor on the other cells.

To change the properties of a cell, place the cursor on the cell, and then click on the different options on the bottom section of the form. For example, to display the title in bold face, and aligned with the left margin, place the cursor on the **Title** cell and click on the **Bold** check box, then on the **Left** option button. The text on the cell will be displayed in bold face.

When the cursor is moved between cells, the current options for each cell are shown with an **x** on the check box for the font attributes, and by a **dot** on the option button for the alignment options.

The **Page Header** and **Page Footer** options use the same font attributes, and will display the last options set. However, they do not use the same alignment option.

Plasticity Chart of Cyclically Degradable Clays

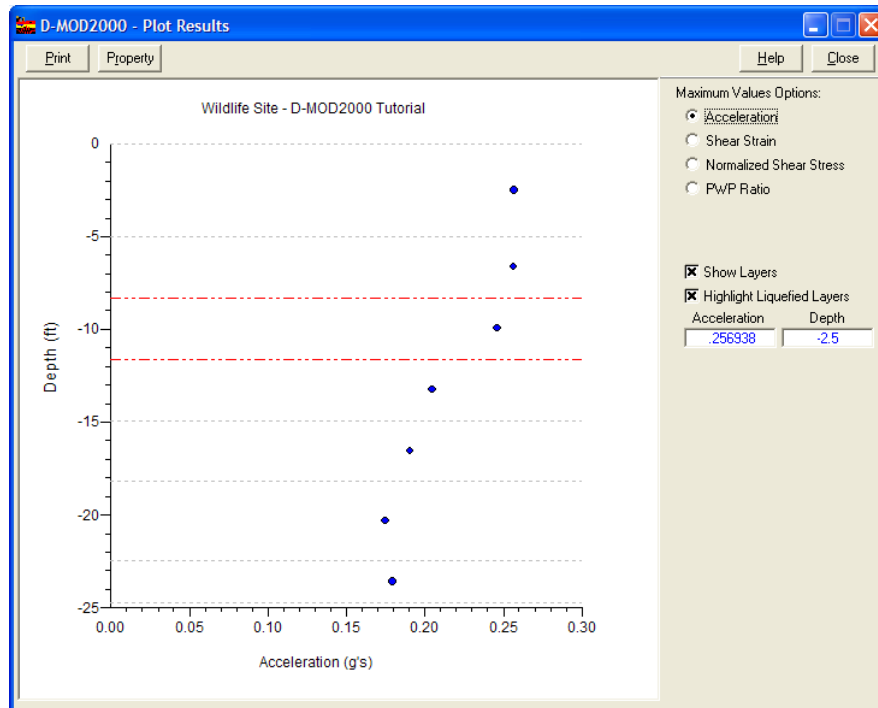


The user can use this form to see if his/her soil falls within the range of soils for which parameters of the Matasovic and Vucetic (1995) model have been developed. In general, if subject soil falls within the limits shown on the plot, generic model parameters may be used.

The liquid limit and plasticity index values should be entered in the appropriate text boxes. The label for your soil can be entered in the text box below the **Soil ID** label. This label will be shown as the last legend on the legend section of the graph. Also, select a value of OCR if applicable. After entering the information for your soil, click on the **Ok** command button to return to the materials form.

Note that the PWP generation / cyclic degradation model for clay was developed for cyclic analysis of offshore foundations, not for geotechnical earthquake engineering applications. However, the model can be used for the earthquake engineering applications within the shear strain range for which it has been developed (i.e., $0 < \gamma < 0.15\%$). The red ellipse delineates the zone of generic model parameters applicability. We recommend reading the Matasovic and Vucetic (1995) paper before using this model.

Plot Maximum Values



This form is used to display the maximum values of the dependent variables vs. depth. To change the variable displayed (i.e. acceleration, shear strain, normalized shear stress, or PWP ratio), click on one of the **Maximum Values Options** options. The graph will be updated automatically.

The layers that form the soil column can be displayed by selecting the **Show Layers** option. Further, the layers that liquefied can be highlighted as red lines when selecting the **Highlight Liquefied Layers** option.

To display the X and Y coordinates of a specific point on the graph, click on any point along the graph to display its coordinates in the text cells shown on the right side of the form.

The graphics routine includes a number of property pages that can be used for customization of the graph. For example, you could add a 3-D look to the graph, or change the colors. The property pages are accessed through the **Property** command button. More help on the graph control property pages can be obtained by clicking on the **Help** command button of these pages.

To print a copy of the graph, or to copy the graph to the Windows Clipboard for use by other applications, click on the **Print** command button to display the **Graphics Print Menu** form.

Plot Object Motion

Using object motion files included as Option 7 sets in an *.EDT file: You can plot the object motions included as Option 7 in an *.EDT file. To do this, click on the **EDT** command button to open the **Open EDT File with Object Motion Files** dialog box to select the file. The file name and path are displayed on the text box next to the **EDT File** label, and the name of the object motion files (from the Option 7 sets) displayed next to the option buttons on the upper part of the form. In the Format text box, you will define how the data in the ground motion file will be read. This is done by defining the format, i.e. the way the data are written on the file, of the acceleration values. This is based on the syntax used in the Format statement of the FORTRAN computer language (e.g., 8F9.6, 4E15.6E2). Additional information on the object motion is shown next to each file. To plot a file, click on the option button for the file, and then click on the **Plot** command button. After a few seconds, the object motion will be plotted on the screen.

Using an object motion file not included in an *.EDT file: If you want to use the data saved in a file that is not included as an Option 7 in an *.EDT file, use the **Other** command button to display the **Open Object Motion File** dialog box to select the file that you want to plot. The name of the file will be displayed next to the **Earthquake File** option button on the bottom section of the form. Now you need to enter the following information on the data cells below the file name. First, you need to select the file by clicking on the option button. This will enable the data cells to enter the data. We'll use the following example to explain the information necessary to plot the object motion.

Example:

```
STATION: 2702 AMU ANCHORAGE, GOULE HALL .
61.189N 149.801W SL GLACIAL TILL GRND LEV 2 STORY BLDG .
AR-240 CHANNEL 1 N315E SCALE=1.925(*) PER=.0520 DAMP=.59 .
EVENT: 1975 JAN 01 03:55 61.920N 149.720W 58KM M=6.0 V .
EPIC DIST = 81KM AZIMUTH AT STN = 183
FILTERS: HI-PASS 0.15HZ ORD 3 LO 50-100HZ TAPER BASELINE.
YEAR= 0 JULIAN DAY= 0 HOUR= 0 MINUTE= 0 SECOND= 0 COMPONENT=
SAMPLES/SEC=200 FILTER TYPE=BUTTERWORTH CORNER= 0.15 ORDER=3 DATA TYPE=AC
NO OF POINTS= 3720, UNITS=CM/SEC**2, CM/SEC, AND CM
```

```

0.049344 -0.011564 0.044214 0.036526 0.027073 0.039972 0.039483 0.030785
0.035475 0.026584 0.014714 0.013246 0.000550 0.000876 -0.007465 -0.015113
-0.009943 -0.012849 -0.011799 -0.012492 -0.013971 -0.011197 -0.011350 -0.016224
.....
.....
-0.002152 -0.000184 -0.001245 -0.003100 -0.001377 -0.001204 -0.003773 -0.003376
-0.002223 -0.002468 -0.002356 -0.001785 -0.000602 -0.000215 -0.000439 -0.000572

```

This example shows the top 12 and bottom 2 lines of an acceleration time history file. Using this information, you will need to enter the following data to describe the time history:

No. Values: This is the total number of acceleration values that form the object motion file. For the above example, there are 3720 points in the file, thus, you will enter 3720 in this cell.

Time step: Enter the time interval between each acceleration value. For this example, it is SAMPLES/SEC or $1/200 = 0.005$ seconds.

No. Header (or Number of header lines): Enter the number of lines at the beginning of the file that are used to describe the object motion. In the above example, the first nine lines are the header lines. Thus, you will enter a 9 in this data cell.

Values/Line (or Number of acceleration values per line): Enter the number of acceleration values on each line. For the above example, there are 8 values on each line. Thus, you would enter an 8 in this cell for this specific example.

No. Digits (or Number of digits per acceleration value): Enter the number of digits that form an acceleration value. In the above example, each value is defined by 10 digits, including the spaces. Therefore, you would enter a 10 for this specific example.

Units: This list provides you with a series of units that are used to plot the correct units on the graph, or to select the acceleration units of your file when computing the ground motion parameters using the **GMP** command button. This list is only enabled when a file is selected using the **Other** button. For ground motion files selected with either the **EDT** or **Quakes** command buttons, the program assumes that the acceleration values in the file are in units of g's. In the above example the original units of the file were in cm/sec^2 , however the values shown are in g's, the original header lines were kept to maintain consistency with the source file.

Free Format: Select this option if the values in the file are separated by at least one blank space, and if each row of acceleration values is formed only by acceleration data (i.e. some old ground motion files used to have an integer number either at the beginning or at the end of the row that identified the row number, this number is not an acceleration value and thus should not be read. If you select the free format option, then this value will be read.). If this check box is selected (an **x** is shown), then you don't need to enter values for **Values/Line** and **No. Digits**. If the values in the file are not separated by blank spaces, i.e. they appear as a continuous row of numbers, then the numbers entered in the **Values/Line** and **No. Digits** columns are used as a means of separating the numbers in columns.

After you have entered the information above, or selected a file with either the **EDT** or **Quakes** command button, click on the **Plot** button to display the time history.

The **All three** option of the **Plot Time History for** options allows you to plot the acceleration, velocity and displacement time histories in one graph.

The **View** command button can be used to view the contents of a ground motion file. This will help you to collect the information needed to define the formatting of the file if necessary. To do this, first select a file from the list of ground motions in the EDT file, use the **Quakes** command button to select a file from the database of ground motion files, or use the **Other** button to select other files. The first 60 lines of the file will be displayed on a form, with the first three characters displayed in red representing the numbers of each row of data in the file followed by a “|”. These characters are not part of the source file and are only shown to number the rows. After the row numbers, the alphanumeric characters that constitute the information saved in the file for each row are shown. Note that the characters are displayed as blue on a white background, and that every tenth character is displayed in red. However, if the tenth character is a “blank space” then the character is not shown. This is done to guide the user when defining the order of the data in the file.

Earthquake Records: You can plot the object motions listed in the ground motion files database by clicking on the **Quakes** button to display a listing of the files saved in the **D-MOD2000.EQ** file. Once the list is displayed, you can choose a record by highlighting it and clicking on the **Ok** button, or by double clicking on it. The data for the ground motion will be shown on the **Other** section of the form. To plot the object motion click on the **Plot** button.

Analysis of Ground Motions: A series of options are included that may help the user with the visual analysis of the ground motions. This is helpful to evaluate the reliability of the ground motion record for use in geotechnical analyses. For example, for some ground motion files the displacement time history obtained from double integration of the acceleration time history may be unreasonable (e.g. it may increase or decrease without bounds). One possible explanation for this incompatibility is that in practice, when a ground motion history is processed, the velocity and displacement time histories are obtained by applying additional corrections (Trifunac and Lee, 1973). However, the acceleration time history may not reflect these corrections. Accordingly, the three histories are not fully compatible with one another, although each may represent the best estimate of the quantity at the site. A similar problem has been evaluated by Crespellani et al. (2003) who studied the effect of the techniques used for processing strong ground motion records on the results obtained from Newmark displacement analyses.

A simplified baseline correction of the acceleration time history is done by applying a parabolic baseline correction to the acceleration time history with minimization of the mean square of the resulting velocity (Brady, A.G., 1966, as referenced in Nigam & Jennings, 1968). The “corrected” time histories for acceleration, velocity or displacement will be displayed when the respective time history and the **Baseline corrected** options are selected.

For integration of the acceleration time history, D-MOD2000 will use a default value of 0.0 for both the initial velocity and displacement. If the user wishes to use a different value, the initial value for velocity should be entered in the text box next to the **V** label; and, the initial value for displacement entered in the text box next to the **D** label. The units for these initial values should be as shown by the respective unit labels.

When the acceleration time history values are given as ratios of gravity (i.e. g’s), the user has the option to plot and/or save the input acceleration, derived velocity and displacement, and corrected time histories in a different set of units, e.g. cm/sec², gals, etc.. To do this, select a set of units from the **Units for Time Histories** list of options. Some options show two sets of units, e.g. **g’s & ft** or **gals & cm**; and, a few others only the units for acceleration, e.g. **ft/sec²**. For options that show two sets of units, the acceleration values will be provided based on the first set and the velocity and displacement values will be based on the second set (e.g. acceleration in g’s and velocity and displacement in ft/sec and ft, respectively). Please note that these options will not be used when the input acceleration values are in units other than g’s.

Today, the user can obtain ground motion records from a variety of sources. Many of these sources provide the acceleration, velocity and displacement time histories in the same file. Usually these are the “processed” histories. Accordingly, if the user wishes to obtain the best estimate of either the velocity or the displacement time history, he/she should use that provided with the original source file for the ground motion. For the ground motions provided with D-MOD2000, the web addresses of the sources from which most of the files were obtained are included in the **Database of Earthquake Records** section of this manual. The processed velocity and displacement time histories may also be obtained from these same sources. As a simplifying alternative, an option is included in D-MOD2000 that saves the computed velocity and displacement time histories from the original ground motion record, and the baseline corrected acceleration, velocity and displacement time histories for further use. To create the file, first select the **All three** and **Baseline corrected** options. Next, click on the **Save to file** check box. A default file name and path are shown on the text box at the bottom of the form next to the **AVD File** label. To select a different file, click on the open-folder icon. Then, click on the **Plot** command button to display the graph of the time histories. Please note that it is up to the user to decide on the suitability of these computed time histories for further use in other analyses.

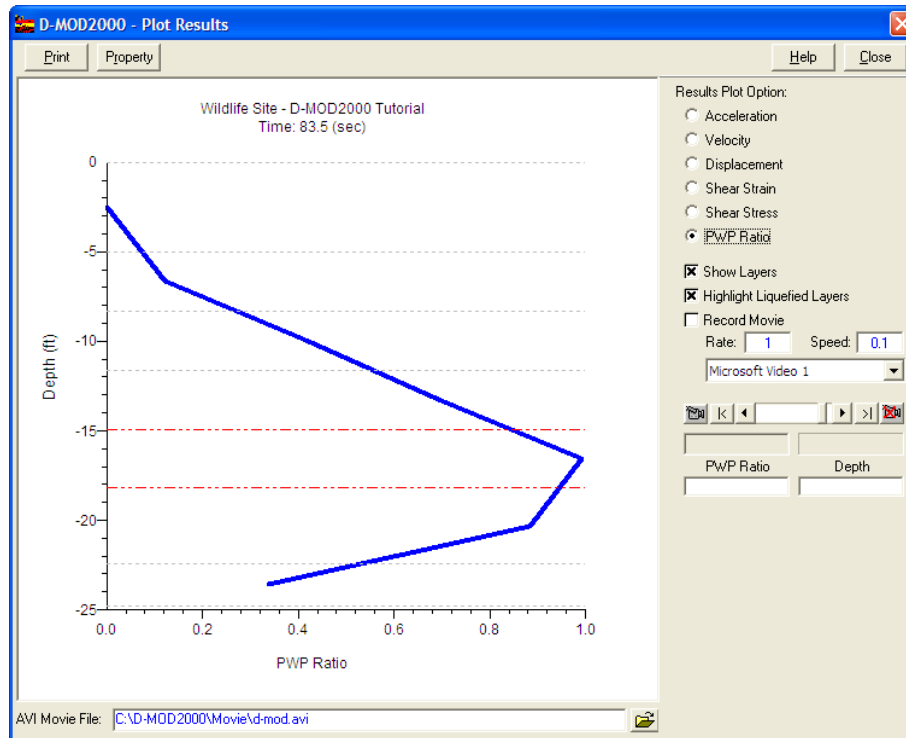
The **Scale** command button is used to display the **Mean Response Spectrum** form. This form can be used to obtain the mean/median spectral acceleration response spectrum for a series of ground motion records. The mean/median value can then be compared to a target spectrum in order to visually evaluate how well the suite of ground motions selected match the target spectrum.

Ground Motion Parameters: Various parameters used to characterize a ground motion can be obtained by using the **GMP** command button. These parameters include peak ground acceleration, Arias Intensity, Root-Mean-Square of the acceleration time history (RMSA), bracketed duration, Trifunac & Brady duration, predominant period, average period and mean period. More information on these parameters is provided in the **Ground Motion Parameters** section of this manual.

The mean period is commonly obtained using the Fourier amplitude spectrum. The method used in D-MOD2000 to compute the FFT is that summarized in Press et al. (1986). The FFT option only works for acceleration time histories, i.e. if necessary the data will be converted to g's before obtaining the FFT.

To obtain the parameters, first select one of the motions in the EDT file, use the **Quakes** command button to select a file from the database of ground motion files, or use the **Other** button to select other files and then click on the **GMP** button. After a few seconds the **Ground Motion Parameters** form is displayed to show the parameters. If the units for the motion file selected with the **Other** command button are either cm/sec², ft/sec² or m/sec² then the acceleration values will be converted to g's using the appropriate conversion factor before computing the Fourier spectrum. The Fourier spectrum can also be computed for velocity or displacement time histories, however, when the **Ground Motion Parameters** form is displayed, only the Fourier Spectrum options will be enabled. Other parameters will only be calculated and displayed for acceleration time histories.

Plot Partial Results at Uniform Time Step



This form is used to display the dependent variables vs. depth and time graph; i.e., the change on the variable with depth and time can be displayed as an “animated” graph.

To change the variable displayed (i.e. acceleration, velocity, displacement, shear strain, shear stress, or PWP ratio), click on one of the **Results Plot Option** options. The graph will be updated automatically. Depending on the amount of data, this may take a few seconds.

The layers that form the soil column can be displayed by selecting the **Show Layers** option. Further, the layers that liquefied can be highlighted as red lines when selecting the **Highlight Liquefied Layers** option.

By default, the variable at the first time step; i.e., first numerical integration step for which data were saved in the master output file, will be displayed when loading this form or when changing the variable. If you would like to display the results for other time steps, click on the **left** or **right arrow** buttons to move through the results one time-step at a time, backwards or forwards respectively. Also, click and hold the mouse down on the sliding bar, and slide the bar to move faster through the time history of results.

The button with a camcorder icon is used to “animate” the graph; i.e., a “movie-like” presentation of the results starting at the first time-step and automatically continuing until the last time step will be presented. To stop the animation, click on the icon with the red cross on the camcorder. The < and > buttons will draw the first time step or the entire graph, respectively.

You can create a movie file (AVI) that can be played with the Windows Media Player or other players, by first selecting the **Record Movie** option. The movie will be saved to the path and file shown on the text box at the bottom of the form. If you want to save the movie to a different file, click on the open folder icon to change it. The number in the **Rate** text box controls how often a frame is added to the movie. For example, a value of 5 will indicate that every fifth frame will be added to the movie file. In other words, when the animation starts, the graph is updated every time step; however, with a value of 5 for frame rate, every fifth time step a frame will be added to the movie file.

The value in the **Speed** text box can be interpreted as the time between frames. The greater this number, the slower the movie will play, i.e. the longer the time a frame will be shown on the screen before a new frame is displayed. It should be noted, that movie files can be very large, hundreds of megabytes, or a few gigabytes. So, before creating a movie file, check that there is enough space on the hard drive or drive where the movie file is to be stored. Also, the creation of the movie can take a considerable amount of time, e.g. a couple of hours for a movie with a couple of thousand frames. To determine the best settings for the movie, i.e. how often a frame is created from the graph and the time between frames, you will need to try different combinations.

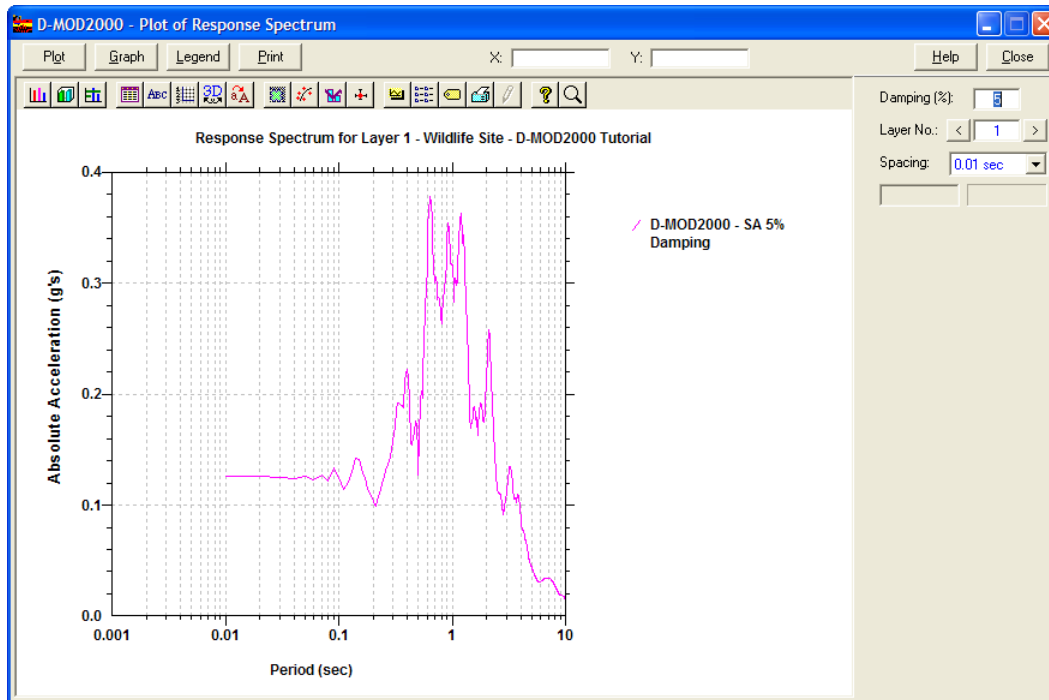
The list of options below the **Rate** and **Speed** text boxes is a list of video compressor options available in your computer. The selection of the option that works best for you is a trial and error approach. We recommend the use of the **Microsoft Video 1** option if available. If the “Fail to save AVI file” error message is displayed when creating a movie, try a different compressor option.

To display the X and Y coordinates of a specific point on the graph, click on any point along the graph to display its coordinates in the text cells shown on the right side of the form.

The graphics routine includes a number of property pages that can be used for customization of the graph. For example, you could add a 3-D look to the graph, or change the colors. The property pages are accessed through the **Property** command button. More help on the graph control property pages can be obtained by clicking on the **Help** command button of these pages.

To print a copy of the graph, or to copy the graph to the Windows Clipboard for use by other applications, click on the **Print** command button to display the **Graphics Print Menu** form.

Plot Response Spectrum



This form is used to plot the response spectrum calculated using the acceleration time history computed for a layer. By default, the 5% damping Absolute Acceleration spectrum for layer number 1, i.e. the surface layer, is plotted when loading this form.

To plot the response spectrum for a different layer, click on the < or > command buttons to scroll through the different layers, or type in the layer number in the text box. Then, click on the **Plot** command button to display the spectrum.

A new value of damping can be entered in the text box next to the **Damping (%)** label. This value should be entered as a percentage, i.e. **5** instead of **0.05**. To plot the new spectrum, click on the **Plot** command button.

The **Spacing** list is used to select the spacing between the period values used to compute the response spectrum. Click on the down arrow list to select a different value. A spacing of 0.01 seconds creates a spectrum with 1000 points starting with 0.01 seconds, while a spacing of 0.001 seconds will create a spectrum with 10,000 points starting at 0.001 seconds. Please note that using a smaller value for spacing will lengthen the time needed for computation and for plotting of the spectrum.

To display a menu of available spectra, click on the **Graph** command button. The **Response Spectrum Plot Menu** form showing the different spectra options (e.g. pseudo-absolute acceleration, relative displacement, etc.) will be displayed. This form can also be used to select other spectra to plot, e.g. attenuation, NEHRP, IBC, Eurocode or the user's own spectrum.

The graphics routine includes a number of property pages that can be used for customization of the graph. For example, you could add a 3-D look to the graph, or change the colors. The property pages are

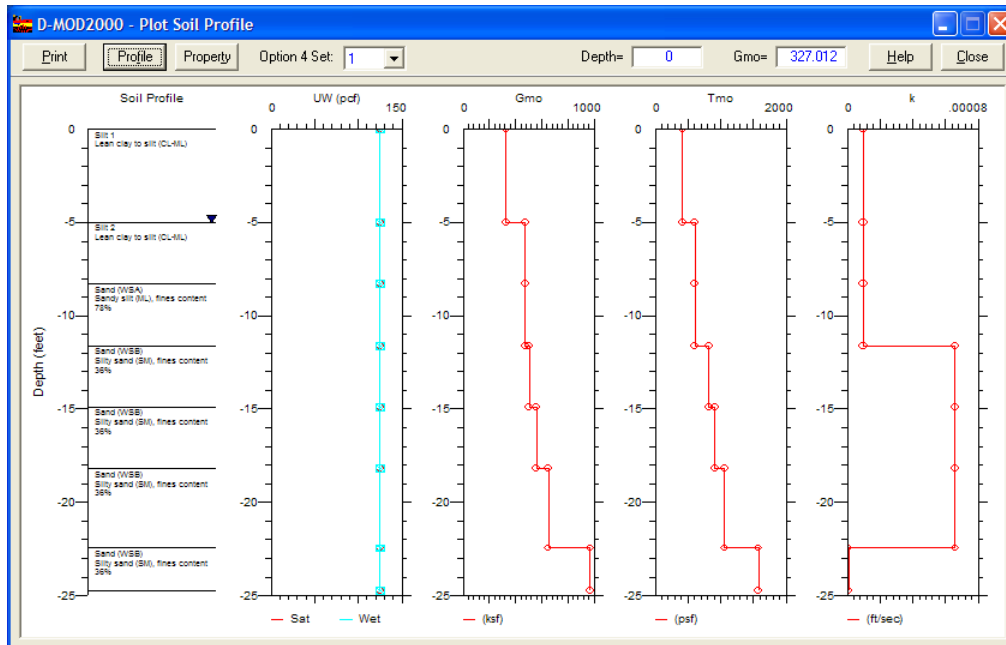
accessed through the icons shown on the upper part of the graph. More help on the graph control property pages can be obtained by clicking on the **Help** command button of these pages.

To display the X and Y coordinates of a specific point on the graph, click on any point along the graph to display its coordinates in the text cells shown on the right side of the form.

A copy of the graph can be printed, or copied to the Windows Clipboard for use by other applications, by clicking on the **Print** command button. This will display the **Graphics Print Menu** form that can be used for printing.

To change the legends of the curves, click on the **Legend** command button. This will display the **Legend Text** form.

Plot Soil Profile



This form will display a series of graphs that summarize the Options 2 and 4 input data. You can also display a graph of the soil column with soil type information. By default, when the graphs are first displayed the left most graph will show the soil layers as they were entered in Option 2. When you click on the **Profile** command button, the **Soil Profile Information** form is displayed. On this form you can enter data for the bottom elevation of the soil layer, and a description of the soil type.

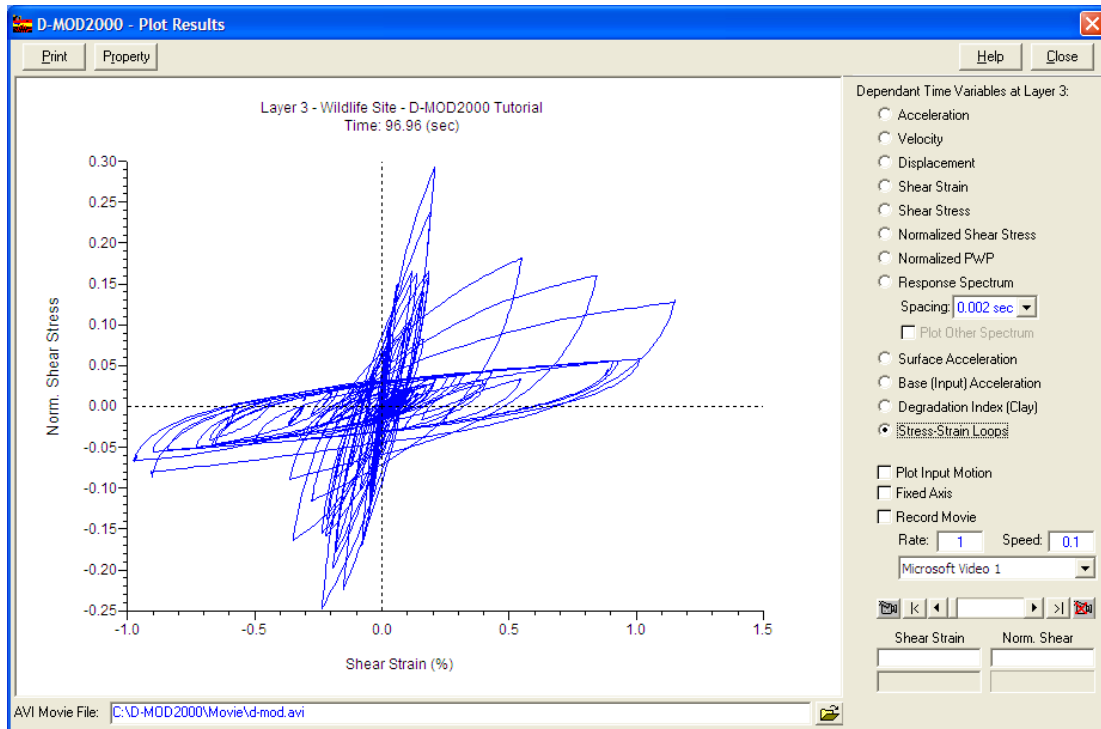
X Y coordinates: When you left-click on a symbol on any of the graphs, except the soil layers graph, the **X** and **Y** coordinates for that point will be displayed on the text boxes above the graphics window. Also, note that when you click on a graph, that graph will become the default graph when using the **Property** command button.

Graph Properties: The properties of a graph (e.g. symbol color, axis values, etc.) can be modified using the property pages of the graphics server. To display the property pages for a graph, first left-click on any symbol of the graph to display its coordinates, and then click on the **Property** command button. To obtain more information about the different properties of the graph, click on the **Help** command button of the property pages.

Option 4 Set: If there is more than one set of Option 4 in the EDT file, you can select a different set of material properties to display with the soil column. To select a different set, click on the down arrow to display the list of Option 4 sets available and click on the one you would like to display.

Printing: To print the graphs, click on the **Print** command button to display the **Graphics Print**

Plot Time Histories



This form is used to display the time history for acceleration, velocity, displacement, shear strain, shear stress, PWP ratio, normalized shear stress and the time dependant variables for a layer of the soil profile.

When plotting time histories for each layer, a different variable can be plotted by selecting one of the **Time History Options**. If a different option is selected for the same layer, then the graph will be refreshed automatically. However, if a different layer is selected by clicking on either the < or > command buttons or by typing in the layer number in the text box, then you may need to click on the **Plot** command button to refresh the graph.

When plotting the stress-strain loops, the **Plot Input Motion** and **Fixed Axis** options will be enabled. The **Time Step** option is used to plot the stress-strain loops as a time-series plot, i.e. the graph will be draw one point at a time. The base (input) acceleration time history can also be plotted by selecting the **Plot Input Motion** option. When using these options with large amounts of data, drawing of the graph will take several minutes. By default, the axis of the stress-strain loops graph are scaled according the range of values being plotted, i.e. the scale shown on the axis will change every time the graph is drawn.

If you want to plot the graph with axes that are not redrawn every time a point is plotted, select the **Fixed Axis** option. If you would like to display the results for other time steps, click on the **left** or **right arrow** buttons to move through the results one time-step at a time, backwards or forwards respectively. Also, click and hold the mouse down on the sliding bar, and slide the bar to move faster through the time history of results.

The button with a camcorder icon is used to “animate” the graph; i.e., a “movie-like” presentation of the results starting at the first time-step and automatically continuing until the last time step will be presented. To stop the presentation, click on the button with the red cross icon.

You can create a movie file (AVI) that can be played with the Windows Media Player or other players, by first selecting the **Record Movie** option. The movie will be saved to the path and file shown on the text box at the bottom of the form. If you want to save the movie to a different file, click on the open folder icon to change it. The number in the **Rate** text box controls how often a frame is added to the movie. For example, a value of 5 will indicate that every fifth frame will be added to the movie file. In other words, when the animation starts, the graph is updated every time step; however, with a value of 5 for frame rate, every fifth time step a frame will be added to the movie file.

The value in the **Speed** text box can be interpreted as the time between frames. The greater this number, the slower the movie will play, i.e. the longer the time a frame will be shown on the screen before a new frame is displayed. It should be noted, that movie files can be very large, hundreds of megabytes, or a few gigabytes. So, before creating a movie file, check that there is enough space on the hard drive or drive where the movie file is to be stored. Also, the creation of the movie can take a considerable amount of time, e.g. a couple of hours for a movie with a couple of thousand frames. To determine the best settings for the movie, i.e. how often a frame is created from the graph and the time between frames, you will need to try different combinations.

The list of options below the **Rate** and **Speed** text boxes is a list of video compressor options available in your computer. The selection of the option that works best for you is a trial and error approach. We recommend the use of the **Microsoft Video 1** option if available. If the “Fail to save AVI file” error message is displayed when creating a movie, try a different compressor option.

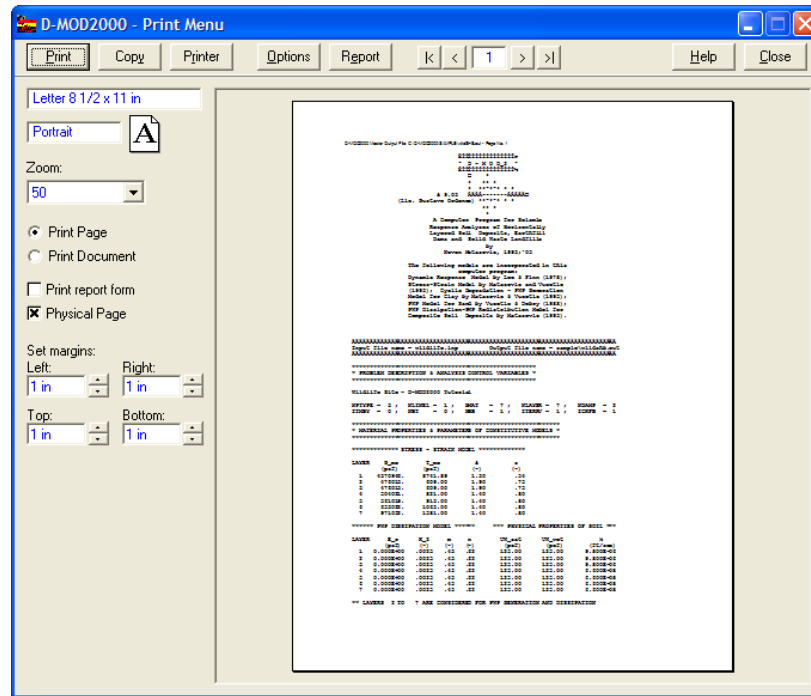
The |< button will draw the results for the very first time step, i.e. the graph will be deleted and only a point will be shown, you can then draw the graph one time step at a time by using the **right arrow** button. The |> button will draw the graph up to the last time step, i.e. the time history of the stress-strain loop will be shown in its entirety. Stepping through time also applies to the base (input) motion graph when this graph is selected.

The graphics routine includes a number of property pages that can be used for customization of the graph. For example, you could add a 3-D look to the graph, or change the colors. The property pages are accessed through the **Property** command button. More help on the graph control property pages can be obtained by clicking on the **Help** command button of these pages.

The **Spacing** list is used to select the spacing between the period values used to compute the response spectrum. Click on the down arrow list to select a different value. A spacing of 0.01 seconds creates a spectrum with 1000 points starting with 0.01 seconds, while a spacing of 0.001 seconds will create a spectrum with 10,000 points starting at 0.001 seconds. Please note that using a smaller value for spacing will lengthen the time needed for computation and for plotting of the spectrum. The **Plot Other Spectrum** option is used to simultaneously plot a spectrum computed using the **Other** option of the Response Spectrum Plot Menu form. With this option, you don’t need to recalculate the other spectrum when conducting different D-MOD analysis.

To print a copy of the graph, or to copy the graph to the Windows Clipboard for use by other applications, click on the **Print** command button to display the **Graphics Print Menu** form.

Print Menu



This form is used to print tabular results or input data. An explanation of the different options in this form is given in the following.

The **Zoom** list can be used to select a magnification factor for the print viewing window. To open the zoom selection list, click on the arrow, and then click on one of the magnification factors.

D-MOD2000 uses the standard printer dialog form from Windows to select a printer and/or to change the properties of the printer and paper used to print the graph (e.g. paper size, orientation, etc.). This form can be displayed by clicking on the **Printer** command button.

The **Options** button will display a form that can be used to change the title and subtitle for the analysis, and the font attributes such as bold face, italic, etc.; and to optionally add a header and/or footer to the page.

To print the table, click on the **Print** button. A message window is displayed indicating the default printer, and a **Cancel** button that can be used to stop printing.

When printing either the *.EDT or input file, the **Print Page** option is selected by default. When this option is selected, only the displayed page will be printed. If you would like to print the entire document, select the **Print Document** option. By default, the file will be printed using tables and descriptions for the different data. Use the <, <<, > or >> buttons to display other pages of data.

Print report form: Select this option to print a form on the same sheet of paper as the table of results. To create the form, click on the **Report** command button to display the **Company & Project Information** form, and then on the **Form** command button to display the **Report Form Development** form.

Physical page: This option determines whether the logical page used by the printer control should correspond to the entire physical page or only to its printable area. Most printers have a “logical” paper size that corresponds to the printer's printable area, and a “physical” paper size that corresponds to the actual page size. The physical paper size is always a little larger than the logical paper size. If this option is selected (an **x** is shown on the check box), the program will print to the physical page. This option only works when the **Print report form** option is selected.

New margins for the paper sheet can be entered in the **Set margins** text boxes, or by clicking on the respective arrow buttons. Please note that the table of results has a specific size and changing the default margin settings may prevent the table from being printed in its entirety.

To return to the previous form, click on the **Close** button.

Report Form Development

No.	X left (in)	Y left (in)	X right (in)	Y right (in)	Box	Thickness
1	.5	.5	8	.5	<input type="checkbox"/>	25
2	.5	.5	.5	10.5	<input type="checkbox"/>	25
3	.5	10.5	8	10.5	<input type="checkbox"/>	25
4	8	.5	8	10.5	<input type="checkbox"/>	25
5	.5	9.5	8	9.5	<input type="checkbox"/>	25
6	5	9.5	5	10.5	<input type="checkbox"/>	25
7	5	9.7	8	9.7	<input type="checkbox"/>	15
8	5	9.9	8	9.9	<input type="checkbox"/>	15
9	5	10.1	8	10.1	<input type="checkbox"/>	15
10	5	10.3	8	10.3	<input type="checkbox"/>	15

This screen is used to create a form that can be printed together with your graphs. The process of creating a form consists of entering the coordinates of the end points and the thickness for each line on the form. You can then use the **Company & Project Information** form to enter textual information that is printed as part of the form.

The origin of coordinates (i.e. $x = 0$ & $y = 0$) is the top left corner of the paper sheet; and, the dimensions are those set for the paper (e.g. for the standard letter size of 8.5" by 11", the dimensions are in inches). Also, remember that the **Physical page** option of the **Graphics Print Menu** form may affect the way your form fits on the paper. This option determines whether the logical page used by the printer control should correspond to the entire physical page or only to its printable area. Most printers have a "logical" paper size that corresponds to the printer's printable area, and a "physical" paper size that corresponds to the actual page size. The physical paper size is always a little larger than the logical paper size. If this option is selected (an **x** is shown on the check box), the program will print to the physical page.

To better understand how to create a form, open the standard form included with D-MOD2000 and then modify it as explained in the following. The example described in the following paragraph is for a letter size paper (8.5" x 11") and portrait orientation. To change paper type or orientation, click on the **Printer** command button to display the printer dialog window.

For this example, first, click on the **Open** command button to display the file dialog form. If necessary, change to the directory where D-MOD2000 is installed, and select the **shakey2k.frm** file. Now, click on **Open**. You will return to this screen, and the form will be displayed on the graphics window, and the information about each line shown on the text boxes. For each line, the coordinates of its end points and thickness are shown on the text boxes.

To complete this form, enter the following lines: First, place the cursor on the **X left** text box for line No. 4 and type in **6**. Press the *Tab* key to move the cursor to the text box on the **Y left** column. Enter **9.7**. These are the coordinates for the left end point of the line. Now, press the *Tab* key to move the cursor to the text box on the **X right** column and enter **8**. Place the cursor on the text box for the **Y right** column, and enter **9.7**. By default, a line thickness of **25** pixels is shown when entering data for a new line. We will reduce the thickness to 15 by clicking on the down arrow key next to the text box on the **Thickness** column until 15 is shown in it. A new line has been added to the form on the bottom right corner. To

magnify the form, double-click on the graphics window with the left-button of the mouse. Double clicking with the right button reduces the size of the drawing.

Repeat the above procedure for the following lines:

X left	Y left	X right	Y right	Thickness
6	9.9	8	9.9	15
6	10.1	8	10.1	15
6	10.3	8	10.3	15

If you select the **Box** option (an **x** is shown on the check box) then the coordinates entered will be taken as the upper-left and bottom-right corners, respectively, of a rectangle.

To save the information for the form, click on the **Save** command button to display the file dialog form, and then click on **Save** to save the data. You can enter a different file name to save each form you create to a new file.

When you create your own forms, you can enter a description for the form on the text box next to the **Description** label. This description can be up to 80 characters long, and will not be shown on the form.

Each time you place the cursor on either the **X left**, **Y left**, **X right**, or **Y right** columns the **Add** and **Delete** command buttons are enabled. If you want to add data for a new line, place the cursor on the line where the new line will be located, and click on the **Add** button. A new line will be created, and the coordinates and thickness for the new line will be the same as those for the line immediately below. Now, you need to modify the information for the coordinates and thickness for the new line. The **Delete** button is used to delete a line from the form. Place the cursor on either the **X left**, **Y left**, **X right** or **Y right** columns and then click on the **Delete** button. The data for the line will be removed from the form, and the information for the other lines updated accordingly. The **Reset** command button will delete the information for all of the lines.

After you have created the form, click on the **Ok** command button to return to the **Company & Project Information** form.

Response Spectra for Ground Motion

D-MOD2000 - Response Spectra for Ground Motion

Ok Directory Other View Save Spectra Plot Motion Help Close

CHI-CHI 09/20/99, TCU070, W (CW8)
 CHI-CHI 09/20/99, TCU070, N (CW8)
 COALINGA 07/22/83 0239, SKUNK HOLLOW, 360 (USGS STATION 1605)
 COALINGA 07/22/83 0239, SKUNK HOLLOW, 270 (USGS STATION 1605)
 LOMA PRIETA 10/18/89 00:05, ANDERSON DAM DOWNSTREAM, 360 (USGS STATION 1652)
 LOMA PRIETA 10/18/89 00:05, ANDERSON DAM DOWNSTREAM, 270 (USGS STATION 1652)
 PALM SPRINGS 07/08/86 0930, N PALM SPR P.O., 300 (USGS STATION 5070)
 PALM SPRINGS 07/08/86 0930, N PALM SPR P.O., 210 (USGS STATION 5070)
 NAHANNI, CANADA 12/23/85, SITE 2, 330

Ground Motion File	No. Values	Time Step	Scale Acc.	No. Header	Values/Line	Format
Crusta\TCU070-W_AT2.eq	18000	0.005		8	8	(8F9.6)

Source File: Chi Chi\TCU070-W_AT2.txt
 D-MOD2000 Conversion: 18000 .005 8 8 9 (8F9.6)
 Acceleration Units: (g's) - No. Values: 18000 - Time Step: .005 (secs)
 Data Format: (8F9.6) - No. Header Lines: 8
 PEER STRONG MOTION DATABASE RECORD. PROCESSING BY PACIFIC ENGINEERING.

Damping Ratios (in decimal): .05 Period spacing: 0.01 sec

File for Response Spectra Data: C:\D-MOD2000\Quakes\Crusta\LOB090_AT2.spc

☒ Other Ground Motion File: C:\D-MOD2000\Quakes\Crusta\LOB090_AT2.eq

No. Values	Time Step	Scale Acc.	No. Header	Values/Line	No. Digits	Units
7984	.005		8	8	9	g's

☐ Free Format

☒ Path to Earthquake Files: C:\D-MOD2000\Quakes

This form is used to compute the response spectra for a ground motion. The routine used by D-MOD2000 is based on the SPECTR computer program (Donovan, 1972).

To compute the response spectra, first select a ground motion file. There are two ways you can select a ground motion file. First, you can use the information stored in the D-MOD2000.EQ file; or second, by using the **Other** command button to select a file and then entering the information necessary to read the data.

1. **Ground Motion Files defined in D-MOD2000.EQ:** Included with D-MOD2000 is a series of ground motion files that can be used for seismic analysis with D-MOD2000. Basic information for each record is saved in the **D-MOD2000.EQ** data base file located in the same directory where D-MOD2000 is installed. This file is an ASCII text file that can be modified to include new information about new records. However, the formatting in the file should not be modified. Use the **Directory** command button to choose the path to directory where the earthquake motion files are stored. After clicking on this button, the **Path to Earthquake Files** form will be displayed. Use the mouse to select the drive and directory, and then click on the **Ok** button. The directory will be displayed on the text box next to the **Path to Earthquake Files** check box. In the D-MOD2000.EQ data file, the name of the earthquake ground motion file is stored as shown on the data box next to the **Ground Motion File** label. Due to restrictions on D-MOD2000, it is difficult to include the entire path to the file in the D-MOD2000.EQ file. For example, if the path to the earthquake file is saved as **quakes\alaska.eq** in the D-MOD2000.EQ file, but the physical path to the file in the hard disk is **c:\D-MOD2000\quakes\alaska.eq**, and depending on the last directory path used, D-MOD2000 may not be able to find the file to plot it. This is because D-MOD2000 will look for it in the last directory path from which data was accessed, and if in this path the subdirectory **quakes** is not found, then the file **alaska.eq** will not be found either and an error will occur during plotting. To work around this, use the **Directory** command button to select the **C:\D-MOD2000** path. Then D-MOD2000 will look for the file **c:\D-MOD2000\quakes\alaska.eq** instead of only **quakes\alaska.eq**. To select an

earthquake record, click on it to highlight it. The information stored in d-mod2000.eq for this file will be displayed on the corresponding cells. If you wish to scale the ground motion to a different value of peak acceleration, enter the new peak value in the **Scale Acc.** text box. Each acceleration value will be scaled proportionally to the ratio of the specified scale acceleration to the maximum acceleration of the time history.

2. **Using an object motion file not included in the D-MOD2000.EQ file:** If you want to use the data saved in a file that is not included in D-MOD2000.EQ, use the **Other** command button to display the **Open Object Motion File** dialog box to select the file that you want to plot. The name of the file will be displayed next to the option button on the bottom section of the form. Now you need to enter the following information on the data cells below the file name. First, you need to select the file by clicking on the check box next to the **Other Ground Motion File** cell (an **x** is shown on the check box). This will enable (i.e. the mouse cursor changes to the I-beam appearance when placed on the cells) the data cells to enter the data. We'll use the following example to explain the information necessary to plot the object motion.

Example:

```
D-MOD2000 Sample Object Motion
Time Period = 0.01   Number of Points = 2000
.024455 .000868-.019352-.012488 .003331 .030202 .021586-.022183  1
-.050340-.025930 .000123 .020366-.000176-.008401-.013457-.014927  2
```

No. Values: This is the total number of acceleration values that form the object motion file. For the above example, there are 2000 points in the file, thus, you will enter 2000 in this cell.

Time step: Enter the time interval between each acceleration value. For this example, it is 0.01 seconds.

Scale Acc.: Maximum acceleration to be used, in g's; each acceleration value will be scaled proportionally to the ratio of the specified scale acceleration to the maximum acceleration of the time history.

No. Header (or Number of header lines): Enter the number of lines at the beginning of the file that are used to describe the object motion. In the above example, the first two lines are the header lines. Thus, you will enter a 2 in this data cell.

Values/Line (or Number of values per line): Enter the number of acceleration values on each line. For the above example, there are 8 values on each line. The last number (e.g. 1) only identifies the row number. Thus, you would enter an 8 in this cell for this specific example.

No. Digits (or Number of digits per value): Enter the number of digits that form an acceleration value. In the above example, each value is defined by 8 digits, including the spaces. Therefore, you would enter an 8 for this specific example.

Units: For the computation of response spectra, the values of acceleration are in **g's**. If the values saved in the file are in other units (e.g. ft/sec², cm/sec², or mm/sec²), then select the appropriate units by clicking on the up or down arrows to scroll through the different options. This way, the data will be converted from these units to **g's**. For example, if the data in the file are in ft/sec², then you scroll down until **ft/sec/sec** is shown on the **Units** box. Then, the values will be divided by 32.2 to transform them to **g's**.

Free format: The data from the file are read “free format”, i.e. no consideration is given to the number of digits in each column, or to the number of columns in a row. When you select this option (an **x** is shown on the check box), you only need to provide the **No. Values, Scale Acc., Time Step** and **No. Header** values, and then select the dimensions for the Y axis by clicking on the up or down arrow keys next to the **Units** text box. To be “free format” the data in the file have to be separated by at least one blank space, a comma, a tab, or be in different lines.

Period spacing: This list is used to select the spacing between the periods used to compute the response spectrum. Click on the down arrow list to select a different value. A spacing of 0.01 seconds creates a spectrum with 1000 points starting with 0.01 seconds, while a spacing of 0.001 seconds will create a spectrum with 10,000 points starting at 0.001 seconds. Please note that using a smaller value for spacing will lengthen the time needed for computation and for plotting of the spectrum.

Once you have selected a ground motion file, you need to enter the values of damping ratio used for the computation of the response spectra. To add a new ratio, place the cursor on the first blank cell next to the **Damping Ratios (in decimal)** label and enter the value in decimal (e.g., 5% damping is entered as 0.05). The number of damping ratios will be increased automatically every time you enter a new damping value. To delete a ratio, place the cursor on the corresponding cell, and use the *Delete* key. Then press the *Tab* key to move the cursor to a different cell. The number of damping ratios will be decreased, and the ratios will move to occupy the empty cells.

After you have entered at least one value of damping ratio, the **Spectra** command button will be enabled. Click on this button to compute the response spectra for the ground motion. The results will be automatically saved in the file shown on the text box next to the **File for Response Spectra Data** label. To select a different file to save the data in, click on the **Save** command button and select, or enter the name for, a new file.

The results can be plotted by clicking on the **Plot** command button. By default, the Relative Displacement spectrum is plotted. If you want to plot other spectra (e.g. relative velocity, absolute acceleration, etc.), click on the **Graph** command button to display the **Response Spectrum Plot Menu**. In this form, you will be able to select other computed spectra, and other spectra from codes and attenuation relations.

The **View** command button can be used to view the contents of a ground motion file. This will help you to collect the information needed to define the formatting of the file if necessary. To do this, first select a file using the **Other** button to select other files. The first 60 lines of the file will be displayed on a form, with the first three characters displayed in red representing the numbers of each row of data in the file followed by a “[”. These characters are not part of the source file and are only shown to number the rows. After the row numbers, the alphanumeric characters that constitute the information saved in the file for each row are shown. Note that the characters are displayed as blue on a white background, and that every tenth character is displayed in red. However, if the tenth character is a “blank space” then the character is not shown. This is done to guide the user when defining the order of the data in the file.

The ground motion can be plotted by clicking on the **Motion** command button.

When this form is called from the **Ratio of Response Spectra** form, the damping ratio text boxes and the list of period values will be disabled, i.e. the user will not be able to modify these values.

The **Ok** command button will be enabled after the spectrum has been computed for the respective motion using the **Spectra** command button.

Response Spectrum Plot Menu

The screenshot shows the 'D-MOD2000 - Response Spectrum Plot Menu' dialog box. It contains the following fields and options:

- ACC File:** C:\D-MOD2000\TurkeyFlat\Turkey152aux.acc
- Project:** Turkey Flat Valley Center - Within / full damping (n = 5; c = 0.5%)
- Profile:** Turkey Flat Valley Center - Within / full damping (n = 5; c = 0.5%)
- Layer No.:** 1
- Earthquake:** C:\D-MOD200
- Damping Values:** ☒ Response spectrum for 5% damping
- Type of Response Spectrum:**
 - ☐ Relative Displacement
 - ☐ Relative Velocity
 - ☐ Pseudo-Relative Velocity
 - ☒ Absolute Acceleration
 - ☐ Pseudo-Absolute Acceleration
- X Axis:** ☒ Period ☐ Frequency
- Response Spectrum Type:**
 - ☐ AASHTO ☐ NEHRP
 - ☐ Attenuate ☐ Other
 - ☐ EuroCode ☐ Target
 - ☐ IBC ☐ UBC
- Buttons:** Ok, Help, Return
- Save Spectrum Data:** ☐ C:\D-MOD2000\dmodspc.txt

This form is used to select different response spectra and damping ratio options for plotting.

To display the spectrum for a damping value, place the cursor on the damping check box and then click the left button on the mouse. An **x** will appear in the check box to indicate your selection. To choose a **Type of Response Spectrum**, click on the appropriate check box, then, click on the **Ok** button to display the graph. To cancel a selection, click on the box again to remove the **x**.

There are three possible combinations for displaying the response spectrum:

- Select one damping value and one type of response spectrum.
- Select one damping value and two types of response. The two types of response spectrum are either Relative Velocity & Pseudo-Relative Velocity, or Absolute Acceleration & Pseudo-Absolute Acceleration.
- Select as many damping values as desired, up to the total shown, and only one type of spectrum.

Other options and/or features available are:

- **Period:** Select this option to use the period (sec) scale in the **X**-axis.
- **Frequency:** Select this option to use the frequency (Hz) scale in the **X**-axis.
- **Normalized:** Use this option to plot the normalized response spectrum. This option only works when plotting S_a or PSA spectra.
- **Relative Displacement (S_d):** Plot the Relative Displacement versus period.
- **Relative Velocity (S_v):** Plot the Relative Velocity versus period.
- **Pseudo-Relative Velocity (PSV):** Plot the Pseudo-Relative Velocity versus period.
- **Absolute Acceleration (S_a):** Plot the Absolute Acceleration versus period.
- **Pseudo-Absolute Acceleration (PSA):** Plot the Pseudo-Absolute Acceleration versus period.

AASHTO: This option allows you to plot the AASHTO response spectra. This option can only be used with the **Acceleration** response spectra and **5% damping**. You can use this option together with the

Mean, Site, Attenuate or NEHRP options. After clicking on the **AASHTO** button, the **AASHTO's Seismic Response Coefficients** form will be displayed.

Attenuate: This option allows you to plot pseudo absolute acceleration or pseudo relative velocity spectra, predicted using published attenuation relations. This option can only be used with either the **Acceleration** or **Velocity** response spectra, and **5% damping**. After clicking on the **Attenuate** button, the **Ground Motion Attenuation Relations** form will be displayed.

EuroCode: This button is used to select the options and/or enter the data necessary to plot a design response spectrum in accordance with Part 1 of the Eurocode 8 (European Committee for Standardization, 2000).

IBC: Use this command button to plot a design response spectrum using the procedure set forth in the International Building Code. This button will display the **IBC Design Response Spectrum** form that can be used to select the appropriate spectrum.

NEHRP: This option allows you to plot up to two site-specific response spectra in accordance with Section 3.3 of NEHRP (Building Seismic Safety Council, 2004a & 2004b). This option can only be used with either the **Absolute Acceleration** or **Pseudo-Absolute Acceleration** response spectra, and **5% damping**.

Other: This command button is used to open the **Response Spectra for Ground Motion** form. In this form, the response spectra for a recorded ground motion can be computed.

Target: Click on this button to display the **Target Response Spectrum** form. In this form, you can enter values of period and spectra for a target response spectrum that will be plotted together with the other spectra.

UBC: Design spectra using the 1997 Uniform Building Code (UBC) method, can be determined by clicking on the **UBC** button. This button will display the **UBC Design Spectra** form.

Check to plot: Once you have selected a response spectra option (Attenuate, NEHRP, IBC, Target, UBC, or AASHTO), the corresponding option will be enabled (i.e., will not be grayed out). The purpose of this option is to allow the user to switch on and off the plotting of the response spectra. For example, if you have selected the NEHRP spectra and entered the coefficients, an **x** will appear in the check box next to the NEHRP label. This means that every time that you click on the **Plot** command button, these spectra will be plotted together with any other spectra selected. If you click on the check box, the **x** will be removed, and when you click on the **Plot** button, the NEHRP spectra will not be plotted. To plot them again, just click on the check box again. You don't need to re-enter the coefficients.

The response spectra data can be saved to a text file by selecting the **Save Spectrum Data** option. This text file can then be open with other applications, e.g. Excel, for further use. The path and name of the text file can be changed by clicking on the command button with the folder icon next to the text box.

R_{jb} & R_x Distance

No.	Distance (km)	R_{jb} (km)	R_x (km)
1	7.0597	0	
2	7.1191	.918	-.5
3	7.2945	1.836	-1
4	7.5779	2.7541	-1.5
5	7.9576	3.6721	-2
6	8.4207	4.5901	-2.5
7	8.9543	5.5082	-3
8	9.5465	6.4262	-3.5
9	10.1871	7.3443	-4
10	10.8676	8.2623	-4.5
11	11.5809	9.1803	-5
12	12.3214	10.0984	-5.5
13	13.0844	11.0164	-6
14	13.8662	11.9345	-6.5
15	14.6638	12.8525	-7

Rjb & Rx Distance Description:
D-MOD2000 Short Course Rrup, Rjb & Rx distances

Rjb & Rx Distance File:
C:\Geotechnical\GeoMotions\ShortCourse\D-MOD\RrupDistance.RjX

This form is used to enter R_{jb} , or the closest distance to the surface projection of fault rupture used by the Akkar & Bommer (2007) – Europe/Middle East; Campbell & Bozorgnia (2003); Campbell & Bozorgnia (2008) – NGA; Boore, D. & Atkinson, G. (2008) – NGA; Chiou, B. & Youngs, R. (2008) – NGA; and, the R_x distance used by the NGA attenuation relations. Note that the program will plot the PHA vs. Distance, where for the NGA equations the distance is R_{rup} and for Campbell & Bozorgnia (2003) it is R_{seis} . Accordingly, for the NGA relations R_{jb} and R_x should be computed and entered in the R_{jb} and R_x columns of the **R_{jb} and R_x Distance** form. Similarly, for the Boore & Atkinson NGA relation, the program will also plot the PHA vs. Distance wherein distance is assumed to be R_{rup} , but the program will use R_{jb} entered in the respective column of the **R_{jb} and R_x Distance** form for the computations. For further information on these distances, please refer to the respective reference for each relation.

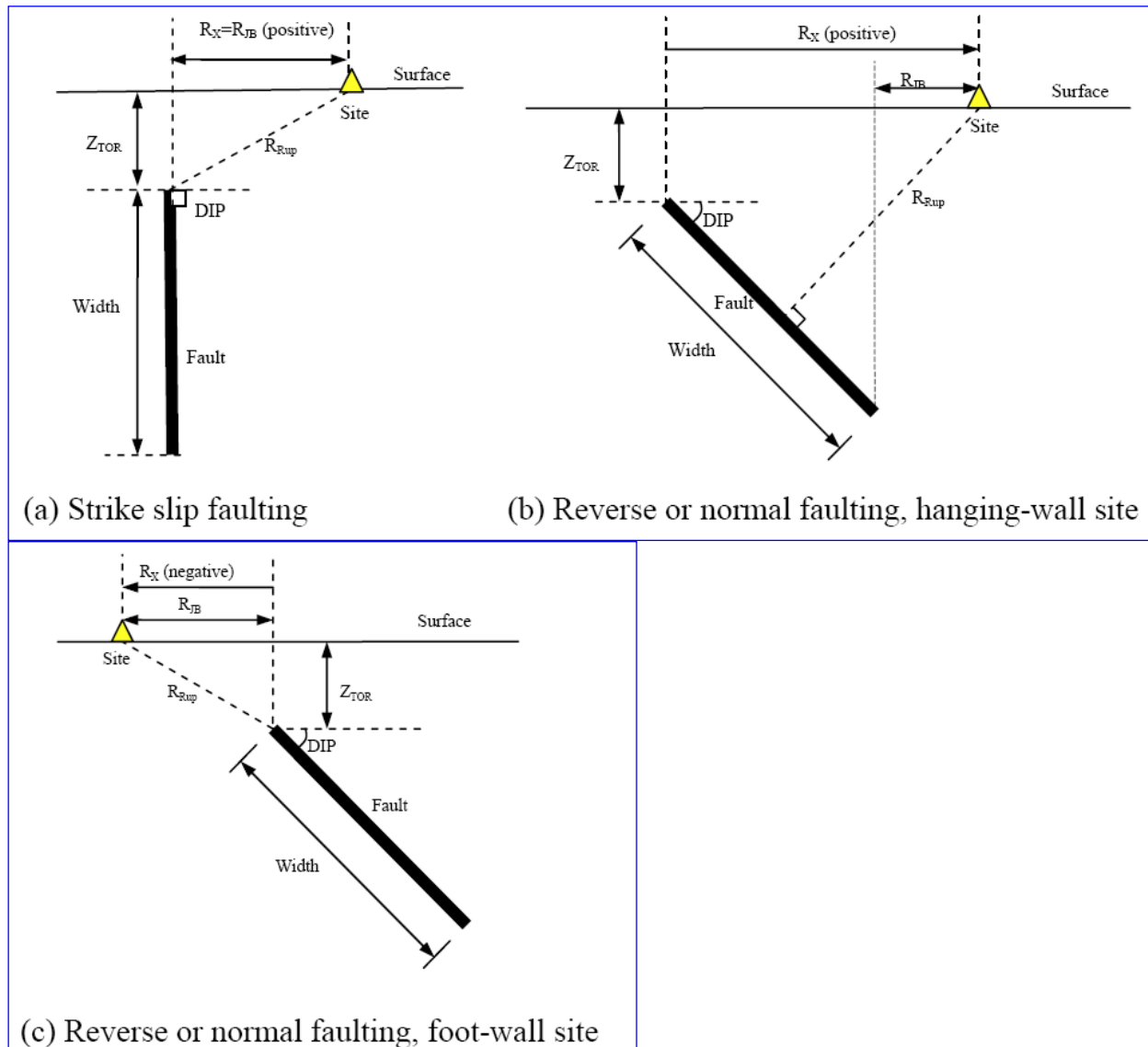
To enter the data, place the cursor on the text box for R_{jb} column and type in the values in kilometers. Please note that the default values shown on the R_{jb} and R_x columns are not representative of any particular field situation. Also enter values for Distance based on the attenuation relation being used. For example, for the Campbell & Bozorgnia NGA the values on the Distance column will correspond to the values for R_{rup} . When computing the attenuation values, the program will linearly interpolate between the values entered to obtain the corresponding R_{jb} and R_x when specific values for a distance are not entered. The program will only accept values greater than 1 for distance.

After you have entered the information for each R_{jb} and R_x , click on the **Ok** command button to return to the **Ground Motion Attenuation Relations** form.

Each time you place the cursor on the Distance, R_{jb} or R_x columns the **Add** and **Delete** command buttons are enabled. If you want to add data for a new Distance, place the cursor on the distance where the new values will be located, and click on the **Add** button. New values will be created, and the values will be the same as those for the Distance immediately below. The **Delete** button is used to delete the data for a

Distance from the table. Place the cursor on the Distance, R_{jb} or R_x value column and then click on the **Delete** button. The data for the Distance will be removed from the table, and the information for the other Distances updated accordingly. The **Reset** command button will delete all the information on the table and display the default values. The **Save** command button is used to save the data in a text file for future use. These data can be retrieved using the **Open** command button.

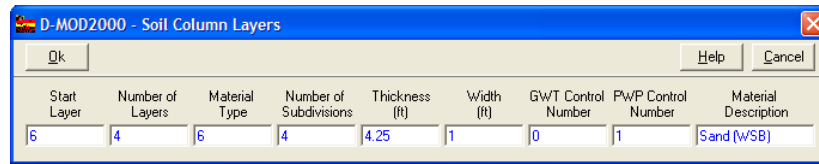
The **Rjb – Rx** command button can be used to compute values of R_{jb} and R_x for the distances shown on the **Distance** column (or R_{rup} on the figure). The computation of the distance is based on the geometries shown on the following figures (a), (b) and (c) included in the PEER NGA Excel spreadsheet.



For the computation of the R_{jb} and R_{rup} distances, the program will first assume default values of either R_{jb} or R_x and then use the equations presented by Kaklamanos et al. (2010) to compute R_{rup} . For these equations, the value of the *source-to-site azimuth* can be entered in the **Azimuth** (°) text box.

The information and data used for the computation, i.e. dip, style of faulting, Z_{TOR} , and width; are entered in the **Ground Motion Attenuation Relations** form.

Soil Column Layers



Start Layer	Number of Layers	Material Type	Number of Subdivisions	Thickness (ft)	Width (ft)	GWT Control Number	PWP Control Number	Material Description
6	4	6	4	4.25	1	0	1	Sand (WSB)

This form is used to create more than one layer for a soil column. The number of layers shown in the **Number of Layers** text box will be added beginning one layer after the number of the layer shown in the **Start Layer** text box. For example, in the above form 4 layers will be created after layer 6, i.e. new layers 7, 8, 9 and 10 and the values shown for material type, number of subdivisions, thickness, width, GWT control number, PWP control number and material descriptions will be used for each layer. If there are any existing layers 7 through 10, the information on those layers will be scrolled up and will form layers 11 through 14. After entering the information for the new layers, click on the **Ok** command button to return to the Option 2 form and create the new layers. Click on **Cancel** to return to the Option 2 form without creating the new layers.

Soil Profile Information

Layer No.	Depth to Layer Bottom (feet)	Soil Type	Soil Description
1	5	Silt 1	Lean clay to silt (CL-ML)
2	8.3	Silt 2	Lean clay to silt (CL-ML)
3	11.6	Sand (w/SA)	Sandy silt (ML), fines content 78%
4	14.9	Sand (w/SB)	Silty sand (SM), fines content 36%
5	18.2	Sand (w/SB)	Silty sand (SM), fines content 36%
6	22.45	Sand (w/SB)	Silty sand (SM), fines content 36%
7	24.75	Sand (w/SB)	Silty sand (SM), fines content 36%
8			
9			
10			

This form is used to enter information to create a soil column that will be displayed with the data input from Options 2 and 4. The soil column is made up of layers, and for each layer, you need to enter the depth to the bottom of the layer and a description for the soil type on the layer.

To enter the data, first place the cursor on the text box for the **Depth to Layer Bottom** column and type in the depth to the bottom of the layer (e.g. 10.5). Next, press the *Tab* key once to move the cursor to the text box for the **Soil Type** column and type in a short (up to 24 characters) description of the soil that forms the layer (e.g. Silty Sand with Gravel). Move the cursor to the text box for the **Soil Description** column and enter a longer description for the soil in the layer (e.g. Brown, loose to medium dense, wet, some organics, etc.). Depending on the space allowed for printing on each layer, D-MOD2000 will display first the information entered in the **Soil Type** column, and then display the information entered in the **Soil Description** column. If there is not enough space to display the information (i.e. the space is even smaller than the font size used for the text), then no information will be shown.

After you have entered the information for each layer, click on the **Save** command button to save the information on an ASCII text file. You can retrieve the information for future use with the **Open** command button. To return to the previous form, click on the **Ok** command button.

Each time you place the cursor on the **Depth**, **Soil Type** or **Soil Description** column the **Add** and **Delete** command buttons are enabled. If you want to add data for a layer, place the cursor on the layer where the new layer will be located, and click on the **Add** button. A new layer will be created, and the depth, type and description for the new layer will be the same as those for the layer immediately below. Now, you need to modify the information for the depth, type and description for the new layer. The **Delete** button is used to delete a layer from the soil column. Place the cursor on the **Depth**, **Soil Type** or **Soil Description** column and then click on the **Delete** button. The data for the layer will be removed from the soil column, and the information for the other layers updated accordingly. The **Reset** command button will delete the information for all of the soil layers.

Target/User Defined Response Spectrum

No.	Period (sec)	Sa (g)
1	.01	.205103
2	.02	.204986
3	.03	.251402
4	.04	.277798
5	.05	.332531
6	.06	.403763
7	.07	.369617
8	.08	.353096
9	.09	.398489
10	.1	.412686
11	.11	.510092
12	.12	.466243
13	.13	.461648
14	.14	.599316
15	.15	.603417

Target Response Spectrum:
Wildlife Site - Superstition Hills - 360 Degrees - Surface

Target Response Spectrum File:
C:\D-MOD2000\Sample\WildSurface360deg.tgt

This form is used to enter values for a user-defined spectrum that can be plotted together with other spectra or spectra values used with the Ratio of Response Spectrum analysis. You need to enter a value for the period in seconds, and a value for the spectra values in the appropriate dimensions.

To enter the data, first place the cursor on the text box for the **Period** column and type in the value. Next, press the *Tab* key once to move the cursor to the text box for the **PSV**, **Sa** or **Spectral Value** column and type in the value for the spectra.

An alternative way of entering the data is to use one of the standard spectra available in D-MOD2000. The form used to define one of the standard spectra can be displayed by clicking on the **Attenuate**, **EuroCode**, **IBC**, or **NEHRP** command button. For example, clicking on the **Attenuate** command button will display the **Ground Motion Attenuation Relations** form. In this form, select one attenuation relation, enter the parameters or select the options used by the attenuation relation, and then click on the **Plot** command button. You need to plot the spectra to calculate the values. This also helps you determine if the spectrum is the one you want to use. After plotting the spectra, click on the **Ok** command button to return to this form. The periods and spectra values will be shown on the data cells of the form. A description of the spectrum will be shown on the text box below the **Target Response Spectrum** label. This description can be modified and/or entered manually by placing the cursor in the text box and typing in the desired information.

After you have entered the information for each period-spectra pair, click on the **Ok** command button to return to the previous form.

Each time you place the cursor on the Period, PSV, Sa or Spectra Value columns the **Add** and **Delete** command buttons are enabled. If you want to add data for a new period-spectra pair, place the cursor on the period where the new values will be located, and click on the **Add** button. A new period-spectra pair will be created, and the values for the new pair will be the same as those for the pair immediately below.

Now, you need to modify the information for the period and spectral value. The **Delete** button is used to delete a pair from the table. Place the cursor on the **Period**, **Spectra Value**, **Sa** or **PSV** column and then click on the **Delete** button. The data for the pair will be removed from the table, and the information for the other pairs updated accordingly. The **Reset** command button will delete all the information on the table. The **Save** command button is used to save the data in a text file for future use. These data can be retrieved using the **Open** command button.

UBC 1997 Response Spectra

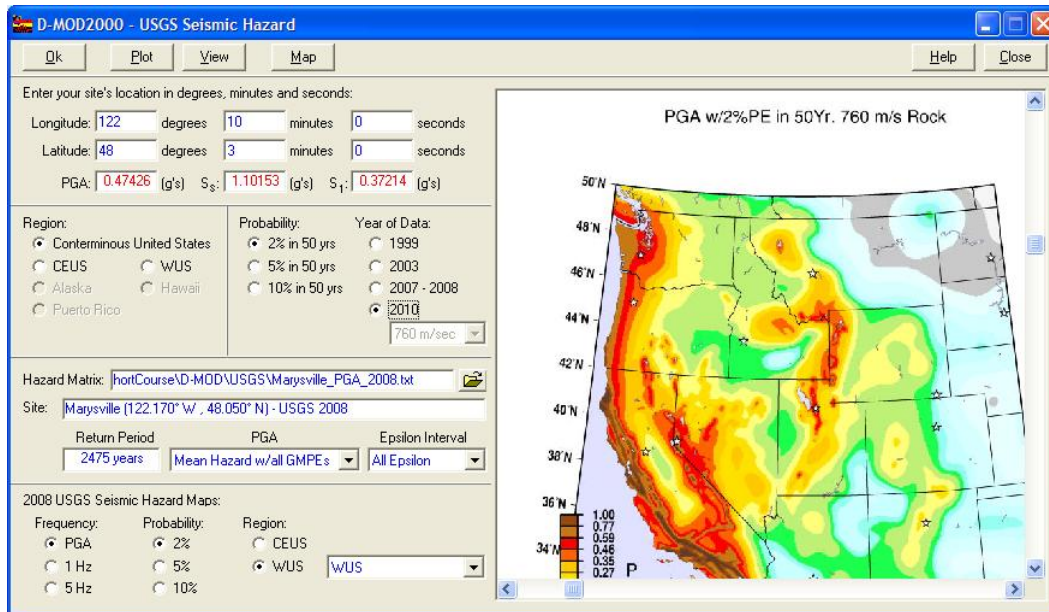
UBC Zone:	Soil Profile Type:	Seismic Source:
<input type="radio"/> Zone 1	<input type="checkbox"/> Sa: Hard Rock	<input checked="" type="radio"/> Type A
<input checked="" type="radio"/> Zone 2A	<input type="checkbox"/> Sb: Rock	<input type="radio"/> Type B
<input type="radio"/> Zone 2B	<input checked="" type="checkbox"/> Sc: Very Dense Soil and Soft Rock	<input type="radio"/> Type C
<input type="radio"/> Zone 3	<input type="checkbox"/> Sd: Stiff Soil Profile	Distance (km):
<input type="radio"/> Zone 4	<input type="checkbox"/> Se: Soft Soil Profile	<input type="text" value="0"/>
	<input type="checkbox"/> Sf: Soil Requiring Site-Specific Evaluation	

This form is used to select design spectra using the 1997 Uniform Building Code (UBC) method (ICBO, 1997).

To select a spectrum, first, select a zone from the **UBC Zone** options to determine the zone factor (Z). Next, select the spectra you would like to plot by clicking on the check boxes next to the different **Soil Profile Type** options. Note that the **Ok** button is enabled when at least one site type is checked. Then, click on the **Ok** button to return to the **Response Spectrum Plot Menu** form.

When you select the **UBC Zone 4** option, the spectra will be computed using the seismic source selected in the **Seismic Source** options, and the distance entered in the **Distance (km)** text box.

U.S. Geological Survey Seismic Hazard



This form is used to retrieve the Peak Ground Acceleration from the files of gridded points used to make the 1996/1999 USGS National Seismic Hazard Maps (Frankel et al., 1996), the updates of some of these maps (Frankel et al., 2002; U.S. Geological Survey, 2003a and 2003b; 2008, 2010); and also, to plot the results of the seismic hazard deaggregation for a site in the Conterminous United States.

For more information, to view or to download these maps, visit the USGS web site at:

<http://earthquake.usgs.gov/research/hazmaps/>

The files used in D-MOD2000 are for PGA with 2%, 5%, or 10% probability of exceedance in 50 years for the Conterminous United States, Alaska, Hawaii and Puerto Rico. The original files are approximately 80 Mb in size. For D-MOD2000, the files have been reprocessed and reduced to a more manageable size, and are installed in the **USGSmaps** subdirectory. Please note that the program uses two sets of maps. The 2008 and 2010 maps are included with the program for comparison purposes only; i.e., at this moment they should not be used for any other purpose other than to compare the 2003 maps to the most recent maps. The issue year for the map used is shown next to the (g's) unit's label. For the 2010 and WUS options, a $V_{s,30}$ value can be selected from the down-list. However, it is recommended to visit the USGS web site for the most recent information and values regarding the hazard maps.

To obtain the PGA, enter the latitude and longitude of your site in degrees, minutes and seconds, and then select one of the **Region** options, and any of the **Probability of Exceedance** options. There is no need to enter a negative sign for the longitude. The values of PGA, S_s and S_1 for each of the four points that surround your site are retrieved from the files, and if necessary, the values interpolated between the four grid points. The values are displayed in the corresponding text boxes.

The USGS interactive deaggregation website is located at:

<http://earthquake.usgs.gov/research/hazmaps/interactive/>

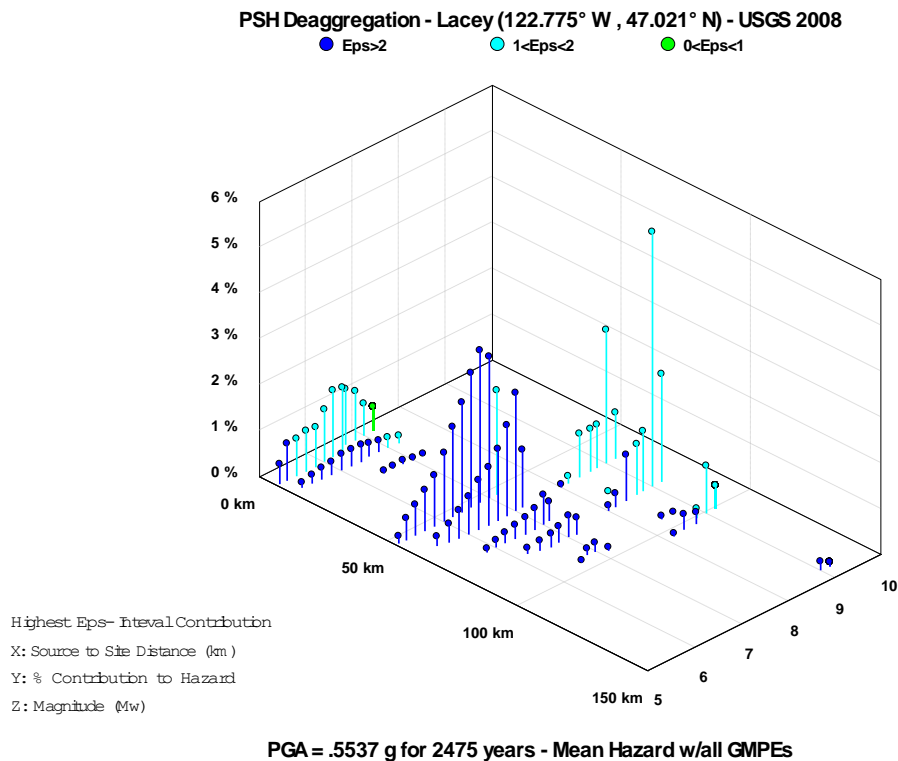
On this web site the seismic hazard deaggregation for a site in the Conterminous United States can be conducted. The results of this analysis are provided graphically, and also as an ASCII file. The data on this text file are used by D-MOD2000 to obtain a plot of the deaggregated distance, magnitude and ground-motion uncertainty for the specified parameters.

Once the file is displayed, use the **Save As** command of the **File** menu option in your browser to save the file to your hard drive. The file should be saved as a text file, thus, the **Text File (*.txt)** option should be shown on the **Save as type** box of the file dialog form.

On the **USGS Seismic Hazard** form of D-MOD2000, click on the command button next to the **Hazard Matrix** text box to display the **USGS Hazard Matrix** file dialog form. Switch to the folder where the file is saved, click on the file to select it, and then click on the **Open** command button to retrieve the data.

After opening the file, some information about the site and the return period is shown on the respective text boxes. Data for several SA frequencies are included in this file. A list of the available SA frequencies in the file is shown by clicking on the down-arrow of the **SA Frequency** combo list; or, **PGA** list when using the 2008 deaggregation results. When using the 2008 deaggregation results, the list will show the list of ground motion prediction equations listed in the hazard matrix file. The options on the **Epsilon Interval** list are used to create plots for the different hazard columns at each distance-magnitude (R, M) bin location. Once you have selected a frequency and epsilon interval, click on the **Plot** command button to display the seismic hazard deaggregation graph.

For example, when using the **Highest Eps** option, the plot of the results from the 2008 deaggregation of PGA for all of the ground motion prediction equations is shown below.



Please note that different colors are used for the graph bars. These colors represent the interval of epsilon (from the hazard matrix file) that contributes the most to that pair. For example, a section of the results from the hazard matrix file for the above graph are shown below.

```

*** Deaggregation of Seismic Hazard at One Period of Spectral Accel. ***
*** Data from U.S.G.S. National Seismic Hazards Mapping Project, 2008 version ***
PSHA Deaggregation. %contributions. site: Lacey long: 122.775 W., lat: 47.021 N.
Vs30(m/s)= 760.0 (some WUS atten. models use Site Class not Vs30).
NSHMP 2007-08 See USGS OFR 2008-1128. dM=0.2 below
Return period: 2475 yrs. Exceedance PGA =0.5537 g. Weight * Computed_Rate_Ex 0.403E-03
#Pr[at least one eq with median motion>=PGA in 50 yrs]=0.00011
#This deaggregation corresponds to Mean Hazard w/all GMPEs
DIST(KM) MAG(MW) ALL_EPS EPSILON>2 1<EPS<2 0<EPS<1 -1<EPS<0 -2<EPS<-1 EPS<-2
7.3 5.05 0.631 0.437 0.194 0.000 0.000 0.000 0.000
53.2 5.05 0.162 0.162 0.000 0.000 0.000 0.000 0.000
.....
.....
....
....
101.0 8.80 0.397 0.194 0.203 0.000 0.000 0.000 0.000
62.4 9.00 4.569 0.733 2.918 0.918 0.000 0.000 0.000
80.2 9.00 7.338 1.788 5.550 0.000 0.000 0.000 0.000
101.0 9.00 1.663 0.628 1.036 0.000 0.000 0.000 0.000
145.1 9.00 0.200 0.200 0.000 0.000 0.000 0.000 0.000
62.4 9.20 1.791 0.245 1.003 0.543 0.000 0.000 0.000
80.2 9.20 3.040 0.597 2.354 0.089 0.000 0.000 0.000
101.0 9.20 0.738 0.228 0.510 0.000 0.000 0.000 0.000
145.1 9.20 0.106 0.086 0.020 0.000 0.000 0.000 0.000

Summary statistics for above PSHA PGA deaggregation, R=distance, e=epsilon:
Contribution from this GMPE(%): 100.0
Mean src-site R= 52.4 km; M= 7.23; eps0= 1.52. Mean calculated for all sources.
Modal src-site R= 80.2 km; M= 9.00; eps0= 1.20 from peak (R,M) bin
MODE R*= 80.2km; M*= 9.00; EPS.INTERVAL: 1 to 2 sigma % CONTRIB.= 5.550
Modal-source dmetric: distance to rupture surface (Rrup or Rcd)

Principal sources (faults, subduction, random seismicity having > 3% contribution)
Source Category: % contr. R(km) M epsilon0 (mean values).
Cascadia M8.3-M8.7 Floating 7.44 77.8 8.53 1.54
Cascadia Megathrust 23.04 77.8 9.02 1.15
WUS Compr crustal gridded 10.87 8.3 6.12 1.11
50-km Deep Intraplate 43.46 59.5 6.61 1.99
Puget Lowlands gridded 14.13 7.8 6.31 0.94
Individual fault hazard details if its contribution to mean hazard > 2%:
Fault ID % contr. Rcd(km) M epsilon0 Site-to-src azimuth(d)
#*****End of deaggregation corresponding to Mean Hazard w/all GMPEs *****#

```

For this example, the pair with the highest epsilon-interval contribution corresponds to an M_w 9.0 event at a distance of 80.2 km (highlighted in yellow). For this particular pair, the maximum contribution of 5.55 is for the $1 < \text{Eps} < 2$ level (highlighted in light blue). Accordingly, for this pair a light blue color will be used when creating the graph.

The **View** command button can be used to view the contents of a hazard matrix file. The first lines of the file will be displayed on a form, with the first characters displayed in red representing the numbers of each row of data in the file followed by a “|”. These characters are not part of the file and are only shown to number the rows.

The **Ok** button will return you to the **Main Menu** form.

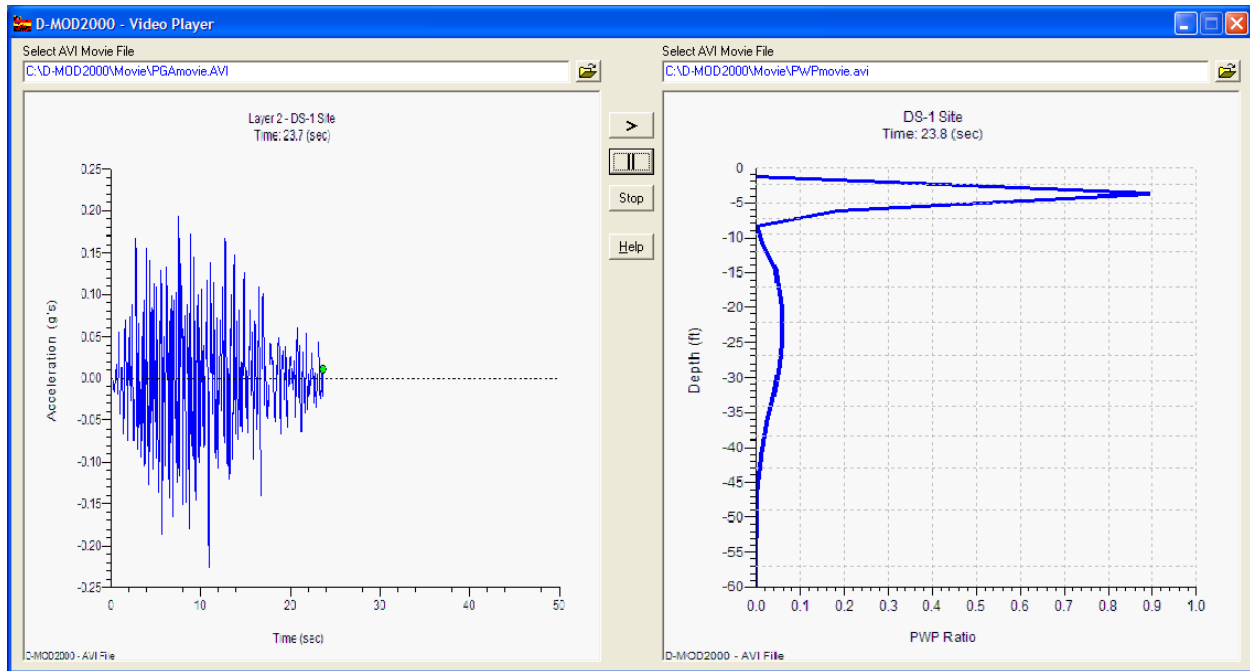
If any of the options is disabled or results for any of the parameters are not shown on the respective text box, this is due to the maps for this option or for these parameters not being available from the USGS.

To display a USGS Seismic Hazard map, click on the appropriate frequency, probability or region option and then click on the **Map** command button.

If any of the options is disabled or results for any of the parameters are not shown on the respective text box, this is due to the maps for this option or for these parameters not being available from the USGS.

To display a USGS Seismic Hazard map, click on the appropriate frequency, probability or region option and then click on the **Map** command button.

Video Player



This form is used to play up to 2 movies created with D-MOD2000.

To select a movie, click on the open folder icon, browse to the folder where the movie file (*.AVI) is located and click on **Open**. Then click on the **Play** (>) command button to start the videos. To pause the movie, click on || and then on > to start the movie again.

To return to the D-MOD2000 main menu form, click on the cross button on the upper right corner of the form to close this form.

Yield Acceleration Function

No.	Time (sec)	Yield Acc. (g's)
1	0	0.1
2	10	0.08
3	20	0.06
4	30	0.05
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		

Description:
Yield Acceleration Function

This form is used to enter data to define a yield acceleration (K_y) function, i.e. a description of a change in K_y with time or displacement (Houston et al., 1987; Matasovic et al., 1998). You need to enter a value for either time in seconds, or for displacement in the units selected for gravity in the **Newmark Displacement Analysis** form; and, a value for yield acceleration in g's.

To enter the data, first place the cursor on the text box for the **Time/Displacement** column and type in the value. Next, press the *Tab* key once to move the cursor to the text box for the **Yield Acc.** column and type in the value for K_y .

It is recommended that the first value entered should be that for a time/displacement of zero. Additionally, the last value for time should be greater than or equal to the length of the acceleration time history used; or, that the last value of displacement should be greater than the greatest value expected. The values of yield acceleration between two points of the function are obtained by linear interpolation. For a constant value of yield acceleration, the two values for the function between two time/displacement points should be equal.

A description of the function will be shown on the text box below the **Description** label. This description can be modified/entered manually by placing the cursor in the text box and typing in the desired information.

After you have entered the information for each time/displacement - K_y pair, click on the **Ok** command button to return to the **Newmark Displacement Analysis** form.

Each time you place the cursor on either the **Time/Displacement** or **Yield Acc.** columns the **Add** and **Remove** command buttons are enabled. If you want to add data for a new pair, place the cursor on the row where the new values will be located, and click on the **Add** button. A new pair will be created, and the values for the new pair will be the same as those for the pair immediately below. Now, you need to modify the information for the time/displacement and yield acceleration. The **Remove** button is used to

delete a pair from the table. Place the cursor on either the **Time/Displacement** or **Yield Acc.** column and then click on the **Remove** button. The data for the pair will be removed from the table, and the information for the other pairs updated accordingly. The **Reset** command button will delete all the information on the table.

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Appendix A - Generic Material Parameters and Curve Fitting Constants for Total-Stress Analysis

Table A-1
Curve Fitting Constants of the MKZ Stress-Strain Model
Part A – Liquefiable Sands and Silts

Material	Reference ⁽²⁾	$\gamma_r^{(3)}$	MKZ Model Parameters	
			β	s
Banding Sand (BS); poorly-graded commercially available sand; $D_r \approx 40\%$; $D_{50} = 0.19$; $C_c = 0.9$; $C_u = 1.4$; $\gamma_{d,max} = 106$ pcf.	Dobry et al. (1985), modified	(5)	(5)	(5)
Wildlife Site Sand A (WSA) (lose silty sand that liquefied in the past; void ratio 0.84 to 0.85; $D_r \approx 20\%$; 37 % fines; $N \approx 5$; $V_s \approx 350$ ft/s) ⁽¹⁾	Matasovic and Vucetic (1993)	0.00128 ($\gamma_{mo} = 1\%$)	1.7	0.67
Wildlife Site Sand B (WSB) (loose silty sand that liquefied in the past; void ratio 0.74 to 0.76; $D_r \approx 25\%$; 25% fines; $N \approx 6$ to 13; $V_s \approx 450$ to 500 ft/s) ⁽¹⁾	Matasovic and Vucetic (1993)	0.00163 ($\gamma_{mo} = 1\%$)	1.5	0.68
Heber Road Site Sand CF (lose sand; void ratio 0.70; $D_r \approx 40\%$; $V_s \approx 400$ to 466 ft/s) ⁽¹⁾	Matasovic and Vucetic (1993)	0.00046 ($\gamma_{mo} = 1\%$)	1.0	0.98
Heber Road Site Sand PB (medium dense clean sand that liquefied in the past; void ratio 0.70; $D_r \approx 45\%$; $V_s \approx 500$ to 600 ft/s) ⁽¹⁾	Matasovic and Vucetic (1993)	0.00088 ($\gamma_{mo} = 1\%$)	1.9	0.70
Santa Monica Beach Sand (SMB) (clean dense sand; similar to Monterey No. 0; void ratio = 0.56; $D_r \approx 75\%$; $V_s \approx 867$ ft/s) ⁽¹⁾	Matasovic and Vucetic (1993)	0.00049 ($\gamma_{mo} = 1\%$)	1.7	0.80
Silty Sand ($\sigma'_o = 25$ kPa or 552 psf) ⁽⁴⁾	Darendeli et al. (2001)	0.0002 ($\gamma_{mo} = 1\%$)	1.1	0.92
Silty Sand ($\sigma'_o = 100$ kPa or 2,089 psf) ⁽⁴⁾	Darendeli et al. (2001)	0.0004 ($\gamma_{mo} = 1\%$)	1.1	0.90
Silty Sand ($\sigma'_o = 400$ kPa or 8,354 psf) ⁽⁴⁾	Darendeli et al. (2001)	0.0008 ($\gamma_{mo} = 1\%$)	1.1	0.87
Silty Sand ($\sigma'_o = 1600$ kPa or 33,418 psf) ⁽⁴⁾	Darendeli et al. (2001)	0.0016 ($\gamma_{mo} = 1\%$)	1.1	0.85
Owi Island Sand; Placed as hydraulic fill at depths ranging from 6 to 14 m b.g.s.; 18 % < fines < 35 %	Darendeli et al. (2001)	0.001730 ($\gamma_{mo} = 1\%$)	6.0	1.10
Owi Island Silt; Placed as hydraulic fill at a depth of 6 m b.g.s.; 50 % < fines < 85 %	Darendeli et al. (2001)	0.003300 ($\gamma_{mo} = 1\%$)	0.9	0.95

Notes:

⁽¹⁾ See Figure A-1 for grain size distribution of the WSA, WSB, CF, PB, and SMB sands and OWI Island hydraulic fills; and Figure A-2 for stress-strain curve plot.

⁽²⁾ β and s were determined by curve-fitting of modulus reduction and damping curves published in references listed in this column. Use spreadsheet MKZ model form to develop new sets of the MKZ model constants.

⁽³⁾ $\gamma_r = \tau_{mo}/G_{mo}$, where G_{mo} is the initial (small strain) shear modulus, and τ_{mo} is the shear stress at shear strain equal γ_{mo} . For design based upon generic parameters, use γ_r and G_{mo} to calculate τ_{mo} .

⁽⁴⁾ σ'_o = (isotropic) effective confining stress.

⁽⁵⁾ Pick appropriate Darendeli et al. (2001) parameters based upon site-specific σ'_o .

Table A-2
Curve Fitting Constants of the MKZ Stress-Strain Model
Part B – Other Soils

Material	Reference ⁽¹⁾	γ_r ⁽²⁾	MKZ Model Parameters	
			β	s
Gravel (Similar to “weak rock” that comes with SHAKE91)	Shibuya et al. (1990)	0.000722 ($\gamma_{mo} = 0.1\%$)	0.36	0.40
Generic Sand (PI = 0)	Vucetic and Dobry (1991)	0.000324 ($\gamma_{mo} = 0.4\%$)	1.5	0.90
Generic Clay (PI = 15)	Vucetic and Dobry (1991)	0.000920 ($\gamma_{mo} = 1\%$)	1.3	0.85
Generic Clay (PI = 30)	Vucetic and Dobry (1991)	0.001600 ($\gamma_{mo} = 1\%$)	1.1	0.85
Generic Clay (PI = 50)	Vucetic and Dobry (1991)	0.002440 ($\gamma_{mo} = 1\%$)	1.0	0.85
Generic Clay (PI = 100)	Vucetic and Dobry (1991)	0.003610 ($\gamma_{mo} = 1\%$)	0.7	0.90
Generic Clay (PI = 200; Mexico City Clay)	Vucetic and Dobry (1991)	0.004610 ($\gamma_{mo} = 1\%$)	0.6	1.00
San Francisco Bay Mud (PI = 49)	Stokoe and Lodde (1978)	0.000990 ($\gamma_{mo} = 0.3\%$)	0.5	1.20
Sherman Island Peat	Boulanger et al. (1998)	0.01 ($\gamma_{mo} = 1\%$)	1.0	0.80
Generic Solid Waste (<i>Geoenvironment 2000</i>)	Kavazanjian and Matasovic (1995)	0.00160 ($\gamma_{mo} = 1\%$)	2.5	0.60
OII Landfill Solid Waste (“Recommended Curve”)	Matasovic and Kavazanjian (1998)	0.00316 ($\gamma_{mo} = 1\%$)	0.5	1.10

Notes:

⁽¹⁾ β and s were determined by curve-fitting of modulus reduction and damping curves published in references listed in this column. Use spreadsheet in MKZ form to develop new sets of MKZ model constants.

⁽²⁾ $\gamma_r = \tau_{mo}/G_{mo}$, where G_{mo} is the initial (small strain) shear modulus, and τ_{mo} is the shear stress at shear strain equal γ_{mo} . For design based upon generic parameters, use γ_r and G_{mo} to calculate τ_{mo} .

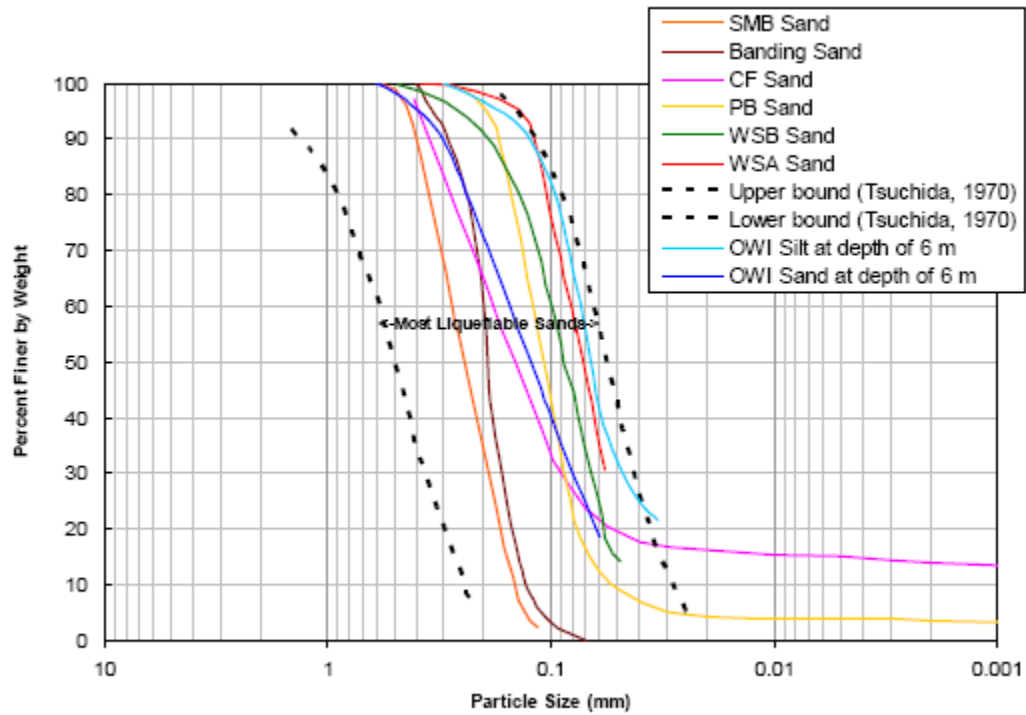


Figure A-1: Grain Size Distribution Curves for Liquefiable Sands and Silts Referred to in Table A-1.

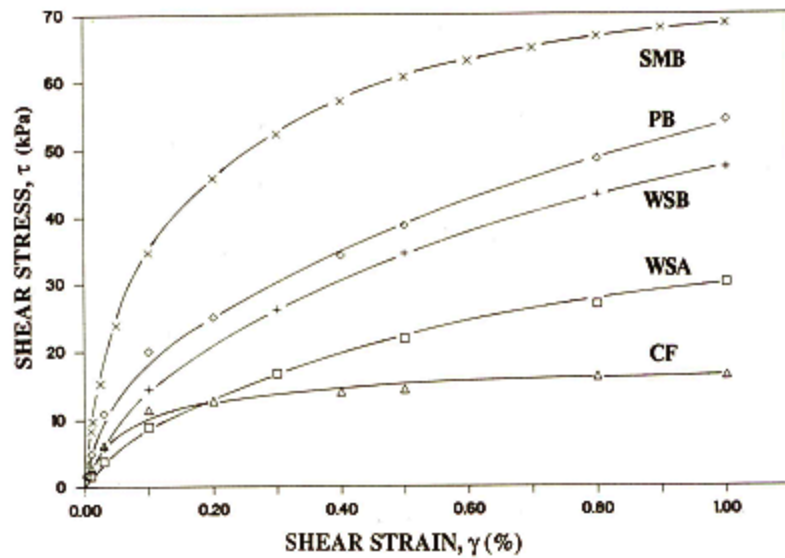


Figure A-2: Stress-Strain Curves of Liquefiable Sands Referred to in Table A-1.

Appendix B - Generic Material Parameters and Curve Fitting Constants for Effective-Stress Analysis

Table B-1
Material Parameters and Curve Fitting Constants of the
Pore Water Pressure and Degradation Models (*Sand and Low-Plasticity Silt*)

Material ⁽¹⁾	Reference ⁽²⁾	k (ft/s)	Degradation Model v	Pore Water Pressure Model				$\gamma_{tv}^{(3)}$ (%)
				f	p	F	s	
Banding Sand (BS); poorly-graded commercially available sand; $D_1=40\%$; $D_{50}=0.19$; $C_c=0.9$; $C_u=1.4$; $\gamma_{d,min}=90$ pcf; $\gamma_{d,max}=106$ pcf	Dobry et al. (1985)	5.5×10^{-4}	1.0	1.0	1.00	10.9	1.00	0.017
Wildlife Site Sand A (WSA); void ratio 0.84 to 0.85; 37 % fines; $N \approx 5$; $V_s \approx 350$ ft/s	Vucetic and Dobry (1988)	9.8×10^{-4}	1.0	2.0	1.04	2.6	1.70	0.020
Wildlife Site Sand B (WSB); void ratio 0.74 to 0.76; 25 % fines; $N \approx 6$ to 13; $V_s \approx 450$ to 500 ft/s	Vucetic and Dobry (1988)	6.6×10^{-3}	1.0	2.0	1.04	2.6	1.70	0.020
Heber Road Site Sand PB; void ratio 0.70; 15 % fines; $V_s \approx 500$ to 600 ft/s	Vucetic and Dobry (1988)	1.4×10^{-4}	1.0	2.0	1.05	1.706	1.09	0.024
Heber Road Site Sand CF; void ratio 0.70; 22 % fines; $V_s \approx 400$ to 466 ft/s	Vucetic and Dobry (1988)	3.9×10^{-5}	1.0	1.0	1.071	1.333	1.08	0.022
Santa Monica Beach Sand (SMB); clean uniform beach sand similar to Monterey No. 0; void ratio = 0.56; zero fines; dense; $V_s \approx 867$ ft/s	Matasovic (1993)	3.3×10^{-1}	3.8	1.0	1.00	0.73	1.00	0.020
Owi Island <i>Sand</i> at depths from 6 to 14 m b.g.s.; silty fine sand placed as hydraulic fill; 18 % < fines < 35 %	Thilakaratne and Vucetic (1987)	6.6×10^{-3}	1.0	2.0	1.005	3.0	1.80	0.025
Owi Island <i>Silt</i> at depth of 6 m; placed as hydraulic fill; 50 % < fines < 85 %	Thilakaratne and Vucetic (1987)	9.8×10^{-4}	1.0	2.0	0.95	2.5	1.60	0.015

Notes:

⁽¹⁾ Grain size distribution curves for all of the sands and silts listed in this table are shown in Figure A-1. All model parameters were developed based upon cyclic DSS strain-controlled testing.

⁽²⁾ References listed in this column contain more detailed material characterization information as well as verification of curve fitting constants and material parameters on case histories. Full citations of these references are provided in the References section of this manual.

⁽³⁾ Volumetric threshold shear strain.

Table B-1 (continued)
Material Parameters and Curve Fitting Constants of the
Pore Water Pressure and Degradation Models (*Sand and Low-Plasticity Silt*)

Material ⁽¹⁾	Reference ⁽²⁾	k (ft/s)	Degradation Model v	Pore Water Pressure Model				$\gamma_{tv}^{(3)}$
				f	p	F	s	(%)
Warrenton, Oregon <i>Silt</i> recovered from 130 and 248 ft b.g.s.; 73% < fines < 99 %; 32.9 % < water content < 37.3 %; $86.3 < \gamma_{dry} < 88.9$ pcf; $822 < V_s < 1,086$ fps; OCR = 1.0;	Dickenson (2008)	not reported	1.0	1.0	1.0	0.493	1.761	0.06

Notes: (1) Plasticity chart for this silt is shown in Figure B-2.
(2) Full citation of this reference is provided in the References section of this manual.
(3) Volumetric threshold shear strain.

Table B-2
Material Parameters and Curve Fitting Constants of the
Pore Water Pressure and Degradation Model (*Clay*)

Material ⁽¹⁾	Reference ⁽²⁾	$\gamma_{tv}^{(3)}$ (%)	Pore Water Pressure and Degradation Model Parameters ⁽⁴⁾					
			s_t	r	A	B	C	D
Marine Clay (OCR = 1.0)	Matasovic and Vucetic (1995)	0.1	0.075	0.495	7.6451	-14.7174	6.3800	0.6922
Marine Clay (OCR = 1.4)	Matasovic and Vucetic (1995)	0.1	0.064	0.520	14.6202	-30.5124	18.4265	-2.5343
Marine Clay (OCR = 2.0)	Matasovic and Vucetic (1995)	0.1	0.054	0.480	12.9495	-26.3287	15.3736	-1.9944
Marine Clay (OCR = 4.0)	Matasovic and Vucetic (1995)	0.1	0.042	0.423	11.2634	-21.4595	11.2404	-1.0443

Notes:
⁽¹⁾ The PWP generation/cyclic degradation of clay model parameters have been developed based upon strain-controlled testing of five marine clays (VNP, VTCA, VTCB, VTCC and VTCD clays). These clays are characterized in Figure B-1. Note index properties of these clays ($50 \leq PI \leq 100$; $20 \leq LL \leq 60$).
⁽²⁾ Reference cited in this column contain more detailed material characterization information as well as verification of curve fitting constants and material parameters on case histories.
⁽³⁾ Volumetric threshold shear strain.
⁽⁴⁾ Valid for $0 < \gamma < 0.15\%$ (γ = shear strain).

Table B-3
Pore Water Pressure Dissipation Model (*Sand and Clay*)
Typical Values of k , E_r , and Martin's PWP Dissipation Model Curve Fitting Constants

Material	k (ft/sec)	Reference ⁽¹⁾	E_r (psf)	Martin's PWP Dissipation Model		
				K_2	m	n
Ottawa Sand ($D_r = 44\%$)	1×10^{-4} to 1×10^{-3}	Bhatia (1981)	N/A	0.0025	0.43	0.62
Crystal Silica Sand ($D_r = 45\%$; $\sigma_{vo}' = 1,000 - 4,000$ psf)	1×10^{-4} to 1×10^{-3}	Martin et al. (1975)	N/A	0.0025	0.43	0.62
Monterey No. 0 Sand (SP; $D_r = 60\%$; $D_{50} = 0.36$ mm; $C_c = 0.9$; $C_u = 1.5$)	1×10^{-4} to 1×10^{-3}	Bhatia (1981)	N/A	0.0025	0.43	0.62
Marine Clays ($50 \leq PI \leq 100$; $20 \leq LL \leq 60$; $1 \leq OCR \leq 4$)	1×10^{-8} to 1×10^{-7}	Matasovic (1993)	7.53×10^{-6}	N/A	N/A	N/A

Notes:

⁽¹⁾ Full references are provided in the References section of this manual.

N/A = Not Applicable; σ_{vo}' = vertical effective stress; PI = Plasticity Index; LL = Liquid Limit; OCR = Overconsolidation Ratio; k = saturated hydraulic conductivity;

E_r = unloading (rebound) modulus of soil.

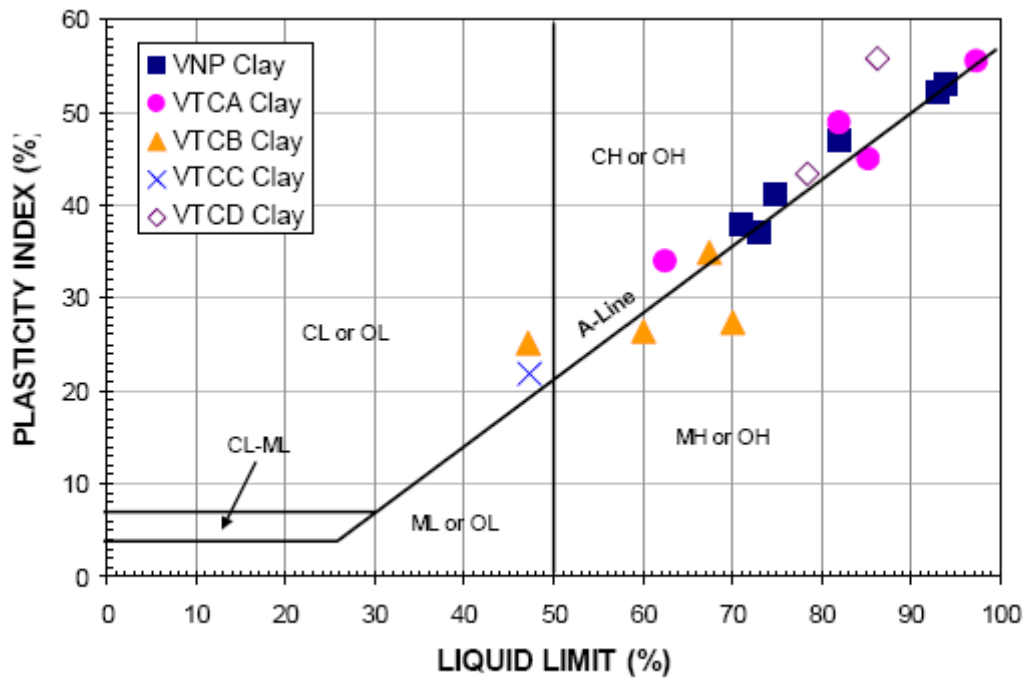


Figure B-1 Plasticity Chart for Cyclically Degradable Clays Referred to in Table B-2.

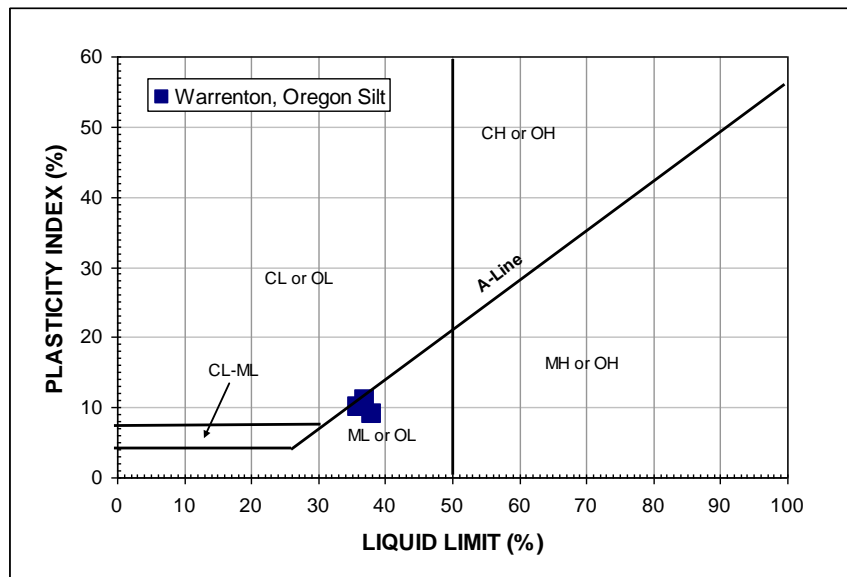


Figure B-2: Plasticity Chart for Cyclically Degradable Silt Referred to in Table B-1 (continued).

Appendix C - Evaluation of Rayleigh Damping Coefficients

Role of Viscous Damping in Non-Linear Analysis

D-MOD_2 solves the dynamic equation of motion in time domain using Newmark's β algorithm. The dynamic equation of motion is typically written as:

$$[M] \{\ddot{u}\} + [C] \{\dot{u}\} + [K] \{u\} = f(t) \quad (1)$$

where $[M]$, $[C]$ and $[K]$ are the diagonal mass matrix, viscous damping matrix, and non-linear stiffness matrix, respectively, $f(t)$ is excitation at the base of the layer, and $\{u\}$, $\{\dot{u}\}$ and $\{\ddot{u}\}$ are the displacements, velocities, and accelerations of the mass $[M]$ relative to the base. If $[C]$ is zero (or close to zero), acceleration response of a layer cannot be calculated, and the program crashes (ERROR MESSAGE "ACCELERATION RESPONSE TOO LARGE" appears in the printout).

Viscous damping is frequency dependent while the damping in soil is not frequency dependent. One may hypothesize that viscous damping may be used to provide for damping in the nonlinear site response analysis at very small strains where the hysteretic damping inherent to the non-linear soil models is nearly zero. To make this hypothesis valid, the viscous damping must be introduced into the non-linear site response analysis in a way that provides for hysteretic damping at very small strains with minimum variation of viscous damping over the range of frequencies of interest. In the non-linear analysis, viscous damping is expressed through viscous damping ratio, c which is commonly modeled as:

$$c = \alpha_R \mathbf{m} + \beta_R \mathbf{k} \quad (2)$$

where α_R and β_R are the Rayleigh damping coefficients and \mathbf{m} and \mathbf{k} are elements of the mass and stiffness matrices, respectively.

Figure D-1 illustrates how viscous damping, expressed through c , changes with frequency.

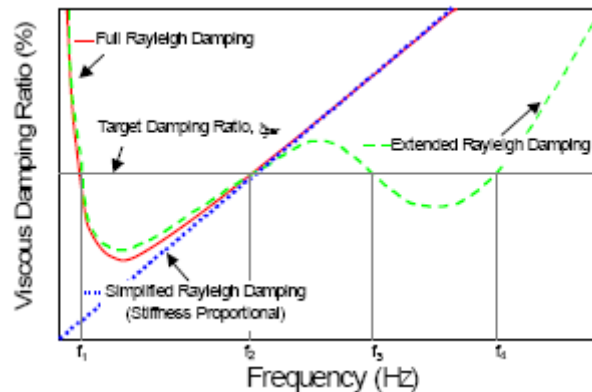


Figure D-1 Schematic Illustration of Viscous Damping Change with Frequency (after Park and Hashash, 2004).

The viscous damping ratio can be brought closer to a constant value of target damping ratio (ζ_{tar}) by specifying c at only one frequency (e.g., f_2 in Figure D-1) which is termed the *simplified* Rayleigh damping formulation; at two frequencies (f_1 and f_2) which is termed the *full* Rayleigh damping formulation (Hudson, 1994); and, at four frequencies (f_1 through f_4) which is termed the *extended*

Rayleigh damping formulation (Park and Hashash, 2004). D-MOD_2 accommodates all of these viscous damping formulations, and allows for different viscous damping to be specified for each layer in the profile.

Simplified Rayleigh Damping Formulation

The simplified Rayleigh damping formulation is the simplest and most commonly used formulation to introduce Rayleigh damping into the non-linear analysis (see, e.g., Lee and Finn, 1978; Matasovic, 1993). In this formulation, the first Rayleigh damping coefficient, α_R , is set to be zero while the second coefficient, β_R , is calculated as:

$$\beta_R = (\zeta_{tar} T) / \pi \quad (3)$$

where:

ζ_{tar}	Target damping ratio;
T	Fundamental period of (soil) deposit, calculated as $T = 4 H / V_{s,avg}$;
H	Thickness of the soil deposit; and,
$V_{s,avg}$	Average shear wave velocity of (soil) deposit (weighted average).

Review of Equation (2) shows that modeling of Rayleigh damping with the *simplified* formulation is equal to an assumption that viscous damping is solely stiffness proportional. The basis for this assumption is the fact that the mass matrix is always (numerically) much smaller than the stiffness matrix.

Full Rayleigh Damping Formulation

Calculate Rayleigh damping coefficients α_R and β_R as:

$$\alpha_R = \zeta_{tar} (4\pi/T) [n / (n+1)] \quad (4)$$

$$\beta_R = (\zeta_{tar} T) / [\pi (1 + n)] \quad (5)$$

where:

ζ_{tar}	Target damping ratio;
T	Fundamental period of (soil) deposit, calculated as $T = 1 / f_s = 4H / V_{s,avg}$;
f_s	Site frequency;
H	Thickness of the soil deposit;
$V_{s,avg}$	Average shear wave velocity of (soil) deposit (weighted average); and,
n	an <i>odd integer</i> (1, 3, 5 or 7); pick n by calibrating against the SHAKE analysis, or use n = 5 as the “best guess.”

Note that modeling Rayleigh damping using the *full* formulation corresponds to an assumption that viscous damping is both mass and stiffness proportional. Also note that, by setting $n = 0$, Equations (4) and (5) reduce to Equation (3).

Extended Rayleigh Damping Formulation

D-MOD_2 does not explicitly include a model for the extended Rayleigh damping formulation. However, the extended formulation can be simulated by direct input of viscous damping into the program. More details on how to apply the *extended* damping formulation can be found in Park and Hashash (2004).

Selection of Target Damping Ratio and Other Rayleigh Damping Model Parameters

The target damping ratio ζ_{tar} is, for most practical applications, in the 0.1 to 5% range. This is consistent with the hypothesis that viscous damping may be used to provide for damping at very small strains where hysteretic damping inherent to the non-linear soil models is nearly zero; hence, the fitted damping curve in the MKZ-model spreadsheet is adjusted for viscous damping. However, note that adding viscous damping may also contribute to over-damping at higher strains. The most accurate estimate of viscous damping can be obtained by calibrating the non-linear analysis against an equivalent-linear analysis that has a constant value of viscous damping at all frequencies. The calibration variables include the target damping ratio, ζ_{tar} , an *odd integer*, n , and target frequency, f .

Figure D-2 illustrates sample calibration of the non-linear analysis. Variables considered in the calibration include two target damping ratios (0.5% and 5%), three “odd integers” ($n = 0, 3$ and 5), and the following target frequencies: site frequency, f_s (defined as inverse of the predominant period of soil profile), mean frequency, f_m (defined as the weighted average site frequency with weights defined from the Fourier amplitudes spectrum; Rathje et al., 1998), and predominant frequency of the input motion, f_p (corresponds to the highest peak in the acceleration spectrum of the input motion). Acceleration response spectrum calculated using SHAKE91 is, for reference, also shown in Figure D-2.

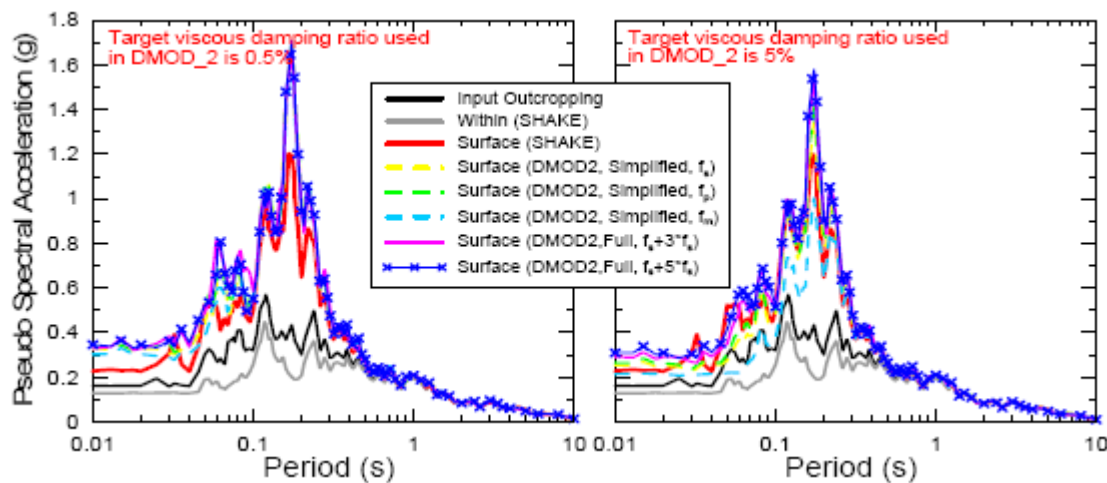


Figure D-2 Comparison of Response Spectra for Simi Valley Knolls School Site (Kwok et al., 2006).

Figure D-2 shows that ζ_{tar} is the dominant parameter in the Rayleigh damping model. Figure D-2 further shows that a relative close approximation of acceleration response spectra calculated by SHAKE91 can be obtained by careful selection of the damping model parameters.

Example Calculations

Given: fundamental period (frequency) of soil deposit, $T = 1/f_s = 0.153$ s, calculate Rayleigh damping coefficients using either Equations (1) through (3) or MKZ model form of the program.

Simplified Rayleigh damping formulation – use Equation (3):

Assume: $\zeta_{tar} = 0.5\%$.

$\alpha_R = 0$; and $\beta_R = 0.000244$

Full Rayleigh damping formulation – use Equations (4) and (5):

Assume: $n = 5$; and $\zeta_{tar} = 0.5\%$.

$\alpha_R = 0.342221$; and $\beta_R = 0.000041$

Figure D-3 below shows the surface acceleration response spectra calculated from surface acceleration response using SHAKE91 (Idriss and Sun, 1992) and D-MOD_2. These plots are based on total stress analysis and *within* motion with a stiff base. For reference, spectra of the *within* input motion are also shown in Figure D-3.

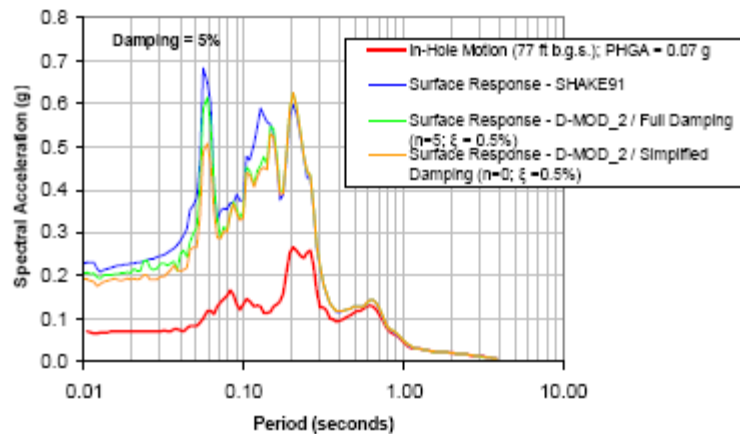


Figure D-3 Response Spectra of Input Motion and Surface Responses Calculated by SHAKE91 and D-MOD_2.

The D-MOD_2 results with both *full* Rayleigh damping ($n = 5$; and $\zeta_{tar} = 0.5\%$) and *simplified* Rayleigh damping ($n = 0$; and $\zeta_{tar} = 0.5\%$) show lower spectral ordinates than SHAKE91 at short periods (< 0.13 s) and the identical spectral ordinates at higher periods. The effect of *full* Rayleigh damping versus *simplified* Rayleigh damping is typically restrained to short periods and, in this example, relatively small. The simplified Rayleigh damping results are lower than the other solutions (SHAKE91 and/or D-MOD_2 with full Rayleigh damping) at short periods.

Concluding Remarks

In general, use of the *full* Rayleigh damping formulation, calibrated against SHAKE91 analysis, is recommended. However, for many practical situations (e.g., evaluation of soil liquefaction potential; Newmark-type seismic displacement analysis; site response of shallow soil profiles), simplified analysis with n set to 0 and ζ_{tar} to 0.5% should suffice.

Appendix D - Conversion Factors

Length		
To convert from	To	Multiply by
Inches (in)	Feet	0.083333
	Centimeters	2.54
	Meters	0.0254
Feet (ft)	Inches	12.0
	Centimeters	30.48
	Meters	0.3048
Meters (m)	inches	39.370079
	feet	3.2808399
	centimeters	100

Area		
To convert from	To	Multiply by
Square meters (m ²)	Square feet	10.76387
	Square centimeters	10000
	Square inches	1550.0031
Square feet (ft ²)	Square meters	0.09290304
	Square centimeters	929.0304
	Square inches	144
Square centimeters (cm ²)	Square meters	0.0001
	Square feet	0.001076387
	Square inches	0.1550031
Square inches (in ²)	Square meters	0.00064516
	Square feet	0.0069444
	Square centimeters	6.4516

Volume		
To convert from	To	Multiply by
Cubic centimeters (cm ³)	Cubic meters	1 x 10 ⁶
	Cubic feet	3.5314667 x 10 ⁻⁵
	Cubic inches	0.061023744
Cubic meters (m ³)	Cubic feet	35.314667
	Cubic centimeters	1000000
	Cubic inches	61023.74
Cubic inches (in ³)	Cubic meters	1.6387064 x 10 ⁻⁵
	Cubic feet	5.787037 x 10 ⁻⁴
	Cubic centimeters	16.387064
Cubic feet (ft ³)	Cubic meters	0.028316847
	Cubic centimeters	28316.847
	Cubic inches	1728

Force		
To convert from	To	Multiply by
Pounds (lb)	grams	453.59243
	kilograms	0.45359243
	Tons (short)	5 x 10 ⁻⁴
	kips	1 x 10 ⁻³
	Newtons	4.44822
Kips	Pounds	1000

Tons (short) (T)	Tons (short)	0.5
	kilograms	453.59243
	kilograms	907.18474
	pounds	2000
Kilograms (kg)	Kips	2
	grams	1000
	pounds	2.2046223
	Tons (short)	11.023113×10^{-4}
Kilonewtons (kN)	kips	2.2046223×10^{-3}
	newtons	9.80665
	pounds	224.81
	Tons (short)	0.1124
	kips	0.22481
	kilograms	101.97

Stress and Pressure

To convert from	To	Multiply by
Pounds/square foot (lb/ft ²)	Pounds/square inch	0.0069445
	Kips/square foot	1×10^{-3}
	Kilograms/square centimeter	0.000488243
	Tons/square meter	0.004882
	atmospheres	4.72541×10^{-4}
	Kilonewtons/square meter (kilopascals)	0.04788
Pounds/square inch (lb/in ²)	Pounds/square foot	144
	Kips/square foot	0.144
	Kilograms/square centimeter	0.070307
	Tons/square meter	0.70307
	atmospheres	0.068046
	Kilonewtons/square meter	95.76
Tons (short)/square foot (T/ft ²)	atmospheres	0.945082
	Kilograms/square meter	9764.86
	Pounds/square inch	13.8888
	Pounds/square foot	2000
	Kips/square foot	2.0
	Kilonewtons/square meter	95.76
Kips/square foot (ksf)	Pounds/square inch	6.94445
	Pounds/square foot	1000
	Tons (short)/square foot	0.5
	Kilograms/square centimeter	0.488244
	Kilonewtons/square meter	47.88
	Pounds/square inch	14.223
Kilograms/square centimeter (kg/cm ²)	Pounds square foot	2048.1614
	Feet of water (4°C)	32.8093
	Kips/square foot	2.0481614
	Tons/square meter	10
	atmospheres	0.96784
	Kilonewtons/square meter	98.067
Atmospheres	bars	1.0133
	Kilograms/square centimeter	1.03323

	Grams/square centimeter	1033.23
	Kilograms/square meter	10332.3
	Pounds/square foot	2116.22
	Pounds/square inch	14.696
	Tons (short)/square foot	1.0581
	Kilonewtons/square meter	101.325
Kilonewtons/square meter (kPa)	Pounds/square foot	20.886
	Pounds/square inch	0.145
	Tons (short)/square foot	0.01044
	Meters of water	0.1020
	Kips/square foot	0.02089
	Kilograms/square centimeter	0.01020
	Bars	0.01
	MegaPascals	0.001
	atmospheres	0.00987

To convert from	Unit Weight To	Multiply by
Grams/cubic centimeter (g/cm ³)	Kilograms/cubic meter	1000.0
	Pounds/cubic inch	0.036127292
	Pounds/cubic foot	62.427961
	Kilonewtons/cubic meter	9.8039
Kilograms/cubic meter (kg/m ³)	Grams/cubic centimeter	0.001
	Pounds/cubic inch	3.6127292 x 10 ⁻⁵
	Pounds/cubic foot	0.062427961
	Kilonewtons/cubic meter	9.80584 x 10 ⁻³
Pounds/cubic inch (lb/in ³)	Grams/cubic centimeter	27.679905
	Kilograms/cubic meter	27679.905
	Pounds/cubic foot	1728
	Kilonewtons/cubic meter	271.37
Pounds/cubic foot (lb/ft ³)	Grams/cubic centimeter	0.016018463
	Kilograms/cubic meter	16.018463
	Pounds/cubic inch	5.78703704 x 10 ⁻⁴
	Kilonewtons/cubic meter	0.157099
Kilonewtons/cubic meter (kN/m ³)	Grams/cubic centimeter	0.1020
	Kilograms/cubic meter	101.98
	Pounds/cubic inch	0.003685
	Pounds/cubic foot	6.3654

To convert from	Velocity To	Multiply by
Centimeter/second (cm/sec)	Meters/second	0.01
	Feet/second	0.032808399
	Feet/minute	1.9685039
Feet/second (fps)	Meters/second	0.30479999
	Feet/minute	60.0
	Centimeters/second	30.48
Meters/second (m/sec)	Feet/second	3.2808399
	Feet/minute	196.850394
	Centimeters/second	100.0
Feet/minute	Centimeters/second	0.508001

Meters/minute

0.3048