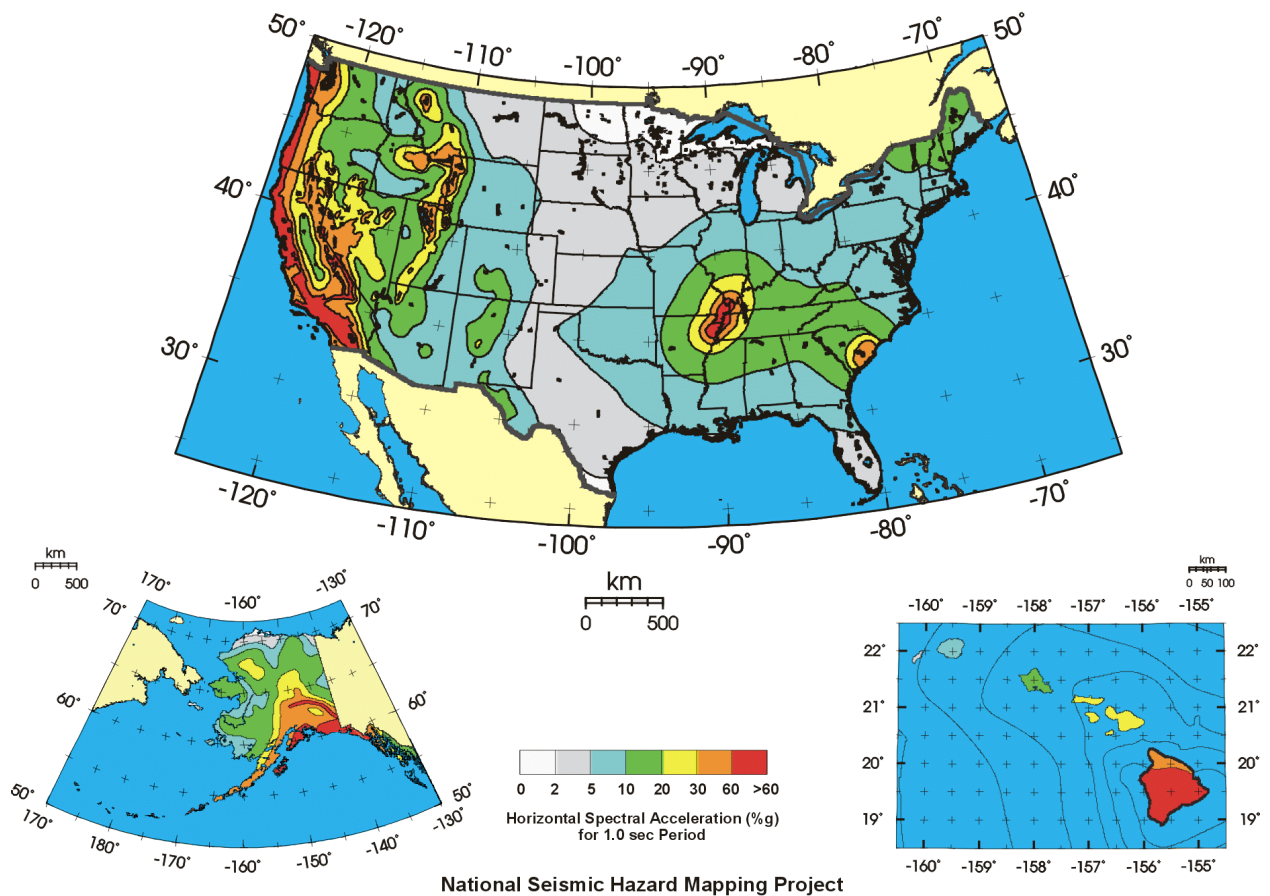


Seismic Design Parameters for use with the 2000 International Building Code, 2000 International Residential Code, 1997 NEHRP Seismic Design Provisions, and 1997 NEHRP Rehabilitation Guidelines



**Seismic Design Parameters
for use with the
2000 International Building Code,
2000 International Residential Code,
1997 NEHRP Seismic Design Provisions,
and
1997 NEHRP Rehabilitation Guidelines**

by

E. V. Leyendecker, A. D. Frankel, and K. S. Rukstales

February, 2000

Prepared by the U. S. Geological Survey
in Cooperation with
the Federal Emergency Management Agency
and
the Building Seismic Safety Council



**Seismic Design Parameters
for use with the
2000 International Building Code,
2000 International Residential Code,
1997 NEHRP Seismic Design Provisions,
and
1997 NEHRP Rehabilitation Guidelines**

by

E. V. Leyendecker¹, A. D. Frankel², and K. S. Rukstales³

The 2000 *International Building Code (International Code Council, ICC)*, 2000 *International Residential Code (ICC)*, 1997 *NEHRP Recommended Provisions for Seismic Regulations for New Buildings (Building Seismic Safety Council, BSSC)*, and 1997 *NEHRP Guidelines for the Seismic Rehabilitation of Buildings (NEHRP Guidelines for the Seismic Rehabilitation of Buildings)* use a design procedure that is based on the use of spectral response acceleration rather than the traditional peak ground acceleration and/or peak ground velocity or zone factors. The spectral response accelerations used in the design documents are obtained from maps accompanying each document.

This report describes a CD-ROM that has been prepared for use with the *IBC*, *IRC*, *NEHRP Provisions*, and the *NEHRP Guidelines*. The CD allows the determination of map values by entering latitude-longitude or zip code. This will greatly simplify obtaining values of spectral response accelerations for use with the new design procedure.

¹ Research Civil Engineer, U. S. Geological Survey, MS 966, Box 25046, DFC, Denver, CO, 80225

² Geophysicist, U. S. Geological Survey, MS 966, Box 25046, DFC, Denver, CO, 80225

³ Physical Science Technician, U. S. Geological Survey, MS 966, Box 25046, DFC, Denver, CO, 80225

INTRODUCTION

The 1997 *NEHRP Recommended Provisions for Seismic Regulations for New Buildings* (*NEHRP Recommended Provisions for Seismic Regulations for New Buildings*, hereafter referred to as *NEHRP Provisions*) uses a design procedure that based on the use of spectral response acceleration rather than the traditional peak ground acceleration and/or peak ground velocity or zone factors. The spectral response procedure requires a minimum of two spectral response accelerations to obtain design values. A series of maps were prepared for use with the procedure. The 1997 *NEHRP Guidelines for the Seismic Rehabilitation of Buildings* (*NEHRP Guidelines for the Seismic Rehabilitation of Buildings*, hereafter referred to as *NEHRP Guidelines*) has also adopted the spectral approach. A single map package accompanies the two NEHRP reports. The package includes a set of Maximum Considered Earthquake ground Motion Maps (MCE maps) and a set ground motion maps based on a 10% probability of exceedance in 50 years (10% maps). The *NEHRP Povisions* use only the MCE maps while the *NEHRP Guidelines* use both sets of maps.

The spectral response approach was adopted for use in the 2000 *International Building Code* (*International Building Code*, hereafter referred to as *IBC*) along with the MCE maps used in the *NEHRP Provisions*. The *IBC* maps differ only in size and number from the MCE maps used in the *NEHRP Provisions*. Other than this difference, the MCE maps are the same in the two documents. The *IRC* uses a single map that was derived from the MCE maps used in the *NEHRP Provisions*. Neither the *IBC* or *IRC* use the 10% maps. The *NEHRP Guidelines* use the set of maps accompany the *NEHRP Provisions*. The spectral response accelerations used in the design documents may be obtained from the maps accompanying each document.

Although simple in approach, it can be cumbersome to work with multiple maps. In order to simplify use of the maps and the new design procedure, a CD-ROM has been prepared that allows obtaining spectral response accelerations by latitude-longitude or zip code. This report describes use of the CD-ROM and how the values obtained from it may be used with the three procedures. It should be noted that the values obtained from the CD are the same for the *NEHRP Provisions* and the *IBC* so there are three instead of four procedures. This report does not provide background to the development of the maps. The reader is referred to Appendices A and B of FEMA 303 (BSSC) and Leyendecker, et al (2000) are for the rationale and details of the map development. Note that both FEMA 302 and 302 are included in the Documentation portion of the CDROM in PDF format.

MAPS

The maps used in the design documents are included on the CDROM in PDF format. The maps include the map package used with the NEHRP documents and the maps used in the *IBC* and *IRC*. The maps cover all fifty states of the United States as well as Puerto Rico, Culebra, Vieques, St. Thomas, St. John, St. Croix, Guam, and Tutuila.

SOFTWARE AND USER GUIDE

Software on the CDROM is written in Visual Basic to operate on a PC with a Windows 95 or later operating system. It self installs and uses the usual mouse and point and click approach. The data are interpolated for a specific latitude-longitude or zip code which the user enters. Output for an entry uses the included data base to interpolate for the specific site. Tabulated data, which are viewed on screen, includes the spectral ordinate data the site. These data may be printed in hard copy or saved in an ASCII comma-delimited file. This type of file can be brought into a lot of software, such a spreadsheet program, for additional processing. Additionally the user can request a plot of the spectrum for on-screen viewing. These plots can also be printed. The software can also be used to view the various maps by selecting from a list of the maps. Once brought up the maps can be zoomed (using Acrobat Reader which the program accesses for the user) and printed.

The maps were prepared from gridded data sets. All these data are included on the CDROM. The software use these data to obtain values by latitude-longitude and zip code. Comparison of the map values against the values obtained from the software provides a good sanity check against input errors such as the wrong latitude-longitude. Data include the MCE ground motion data and the 10% in 50 year probabilistic ground motion data. The MCE data are used all the design documents. However, the *NEHRP Guidelines* require both data sets. There are three types of output corresponding to three different design documents - *IBC/NEHRP Provisions* design parameters, *NEHRP GUIDELINES* design parameters, and *IRC* design parameter. The same information could be obtained from the maps included on the CD but it would much more laborious.

IBC/NEHRP Provisions - The MCE spectral accelerations output for a site are two spectral values required for design. The user can request that site factors be included in the two spectral values. The user can also use the program to calculate an MCE response spectrum, including site factors. This response spectrum can also be viewed on screen and printed. Soil factors can be calculated and included in calculations by simply selecting the site class, the program then calculates the soil factor based of the MCE parameters. Note that the *IBC/NEHRP Provisions* multiply the MCE values by 2/3 to obtain so-called design values.

Using the notation in these two design documents, the design ground motions are defined as a function of the MCE ground motions S_S and S_I where S_S = MCE spectral acceleration in the short-period range for Site Class B; S_I = MCE spectral acceleration at the 1.0 second period for Site Class B (*NEHRP Provisions*, Sec. 4.1.2.4). Other Site Classes are accounted for by applying soil factors to the MCE values. Site Class effects are accounted for by using $S_{MS} = F_a S_S$ for the short period, where F_a is the site coefficient, and $S_{MI} = F_v S_I$ for the long period, where F_v is the site coefficient. Site coefficients are discussed in *NEHRP Provisions*, Sec. 4.1.2.4. A table of these coefficients is included in the software.

Design spectral accelerations (S_{DS} and S_{DI}) are obtained by multiplying S_{MS} and S_{MI} by 2/3 - that is $S_{DS} = (2/3) S_{MS}$ and $S_{DI} = (2/3) S_{MI}$. The user should review the *NEHRP Provisions* and *IRC* documents thoroughly to understand proper application of the values obtained from the CDROM

Figure A below show both the MCE spectrum and the design spectrum and how they are calculated using the two spectral values. Other key values used in calculating the spectra are defined in the figure.

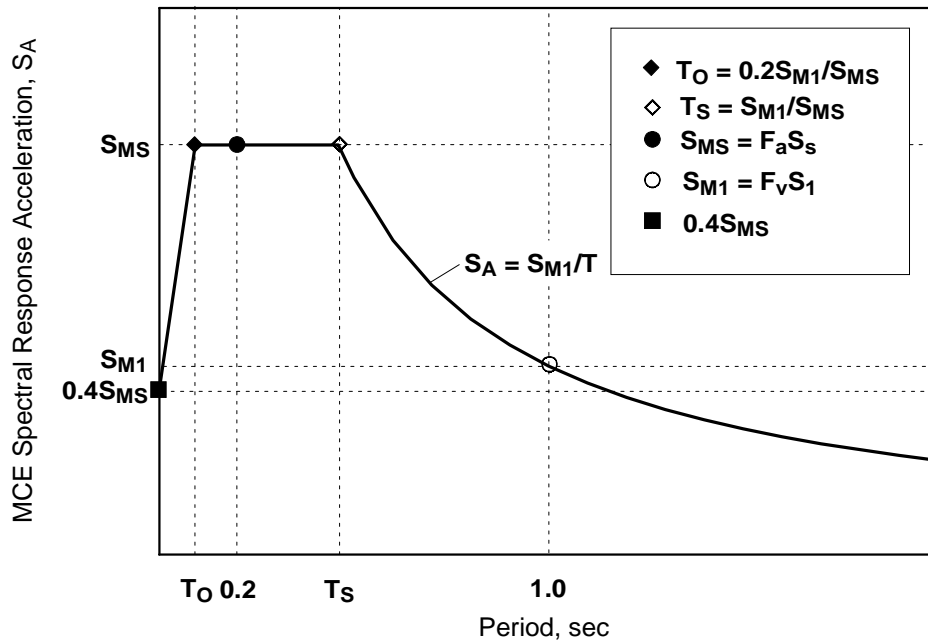


Figure A. Definition of MCE Response Spectrum

NEHRP GUIDELINES - Both the MCE map data and 10% in 50 year map data are available on the CD. The MCE output is as described for *IBC/NEHRP* case above. The type of output for the 10% in 50 year parameters is the same as the type of output for the MCE parameters. A 10% in 50 year spectrum is calculated by substituting the 10% values for the MCE values in Figure A. Soil factors can be calculated and included in calculations by simply selecting the site class. These two cases provide the user with the data required for the so-called Basic Safety Earthquake 1 (BSE-1) and Basic Safety Earthquake 2 (BSE-2) ground motion hazard as described in FEMA 273. The Basic Safety Earthquake 2 (BSE-2) parameters are the same as the MCE parameters. The Basic Safety Earthquake 1 (BSE-1) parameters are the smaller of either: (1) 2/3 times the MCE parameters or (2) the 10% in 50 year parameters. Refer to FEMA 273, p 2-19 for more precise wording.

IRC - The CD allows entry of the latitude-longitude (or zip code) with the result being the *IRC* category - A, B, C, D1, D2, and E. The output also provides all of the numbers used to obtain the *IRC* category so the designer can decide if a more rigorous design might be warranted. The design category is calculated using the MCE data.

Table 1 shows the general information for installing and operating the software. A CDROM user guide is developed as a series of figures numbered Figure 1 through 17 following this text. Each figure is a screen copy obtained while running the program on the CD. The caption for each figure contains extensive text so the user does not have to go back and forth between text and figure. The figures go through an example using the above *IBC/NEHRP Provisions* in some detail and then give a sample for the other two approaches. It is suggested the user run the software with the information in the figures as a tutorial to gain experience in using the software. Additional information is available in readme.txt files on the CDROM.

CONCLUDING REMARKS

The CD-ROM has been developed to simplify obtaining design ground motions for use in the *IBC, IRC, NEHRP Provisions*, and *NEHRP Guidelines*. The CDs are intended to be as user friendly as possible and to quickly give the designer the data needed for design so more time can be spent on actual design and not looking up the "load" data. The intent of USGS, BSSC, and FEMA is to simplify and reduce the time required for at least part of an already complex process.

Comments and suggestions are welcome and may be sent to the individuals named below:

E. V. Leyendecker
email - leyendecker@usgs.gov
Phone 303-273-8565
FAX 303-273-8600
U. S. Geological Survey
P. O. Box 25046, MS 966
Denver, CO 80225

T. R. Hollenbach
email - thollenbach@nibs.org
Phone 202-289-7800
FAX 202-289-1092
Building Seismic Safety Council
1090 Vermont NW, Suite 700
Washington, DC 20005-4905

REFERENCES

- Building Seismic Safety Council. 1998. *NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures*, Part 1- Provisions. 1998. Building Seismic Safety Council. Federal Emergency Management Agency, FEMA 302.
- Building Seismic Safety Council. 1998. *NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures*, Part 2 - Commentary. Federal Emergency Management Agency, FEMA 303.
- Frankel, A., C. Mueller, T. Barnhard, D. Perkins, E. Leyendecker, N. Dickman, S. Hanson, and M. Hopper. 1996. *National Seismic Hazard Maps, June 1996: Documentation*, U.S. Geological Survey, Open-file Report 96-532.

International Code Council, Inc. 2000. *International Building Code*. 2000. Building Officials and Code Administrators International, Inc., International Conference of Building Officials, and Southern Building Code Congress International, Inc.

International Code Council, Inc. 2000. *International Residential Code*. 2000. Building Officials and Code Administrators International, Inc., International Conference of Building Officials, and Southern Building Code Congress International, Inc.

Leyendecker, E. V., Hunt, R. J. , Frankel, A. D., and Rukstales, K. S. 2000. *Development of Maximum Considered Earthquake Ground Motion Maps*, Earthquake Engineering Research Institute, *Spectra* , in press.

Table 1. General Instructions for the Program

Installation

Click on Start.

Run Setup.exe on the CDROM and follow the instructions.

You may be requested to update selected files. This is required.

The program will be installed in Seismic Design with an executable file named Seismic Design.exe.

System Requirements

A PC (or compatible) with Windows 95, Windows 98, or Windows NT.

Pentium Processor with 32 MB of RAM, 200 MHZ recommended.

A minimum screen resolution of at least 800 x 600.

A hard drive with 30 MB of available for installing the software.

Operation

Click on Start. Click on Programs. Select Seismic Design from the Programs list or place an icon on the Desktop.

Files

Random Access Data files are in the directory MCE97Data on the CD.

PDF Map files are in the directory MCE97Maps on the CD. Adobe Acrobat is required to view the maps. Acrobat Reader version 4 is included on the CD. This version is recommended for maximum benefit in viewing and printing of the PDF map files.

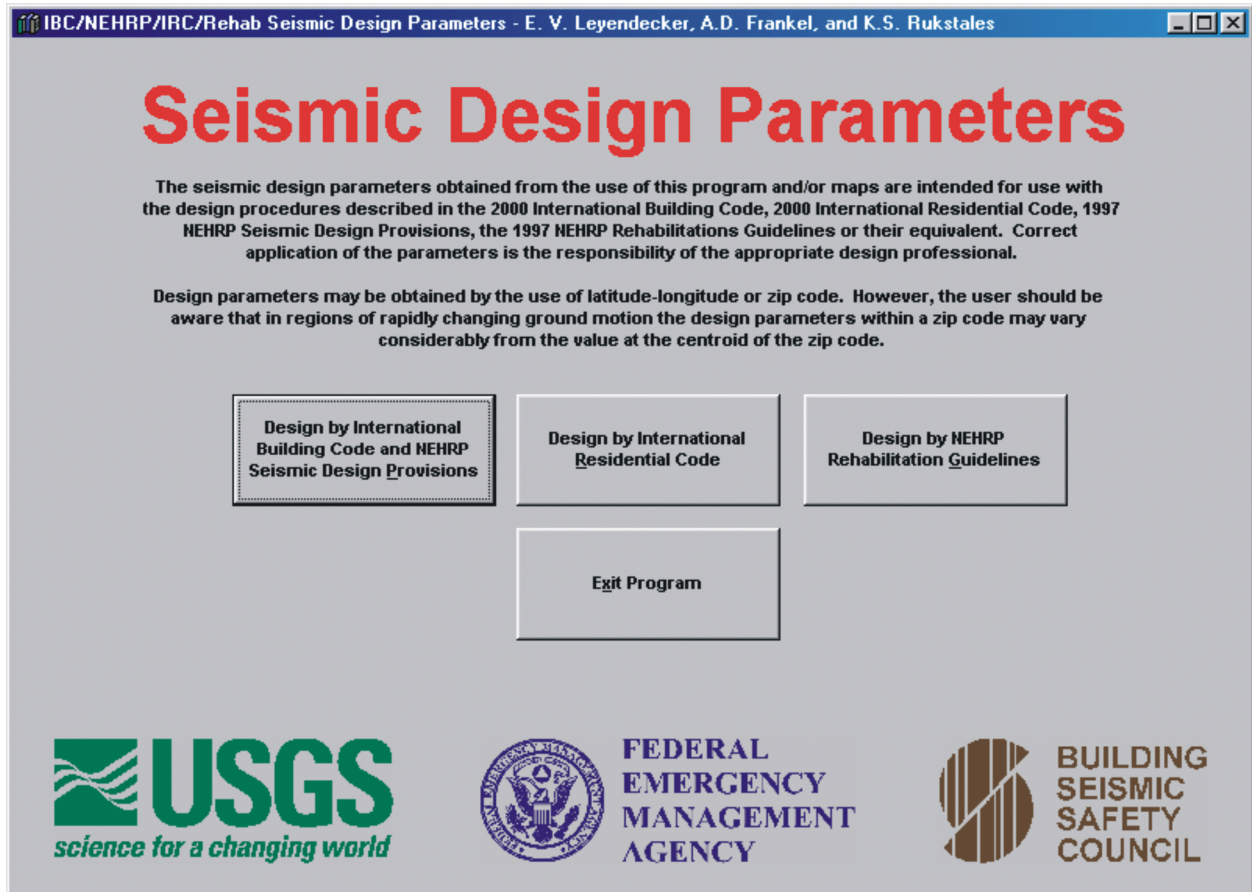


Figure 1. **IBC/IRC/NEHRP/Rehab Design Parameters.** The opening screen contains controls for obtaining design parameters for the International Building Code, International Residential Code, NEHRP Recommendations for Seismic Design of New Buildings, and the NEHRP Guidelines for the Seismic Rehabilitation of Buildings. Typically a control may be accessed in three ways - (1) using the Mouse to place the cursor over the control and pressing the left mouse button, (2) using the Tab key to cycle through the controls and pressing the Enter key, or (3) holding down the Alt key and pressing the underlined character on the key. Many users will find methods (1) and (3) a convenient way to move rapidly between controls and screens. Use whatever method or combination of methods is most convenient. Selecting the control labeled “Design by International Building Code and NEHRP Seismic Design Provisions” will open the screen shown in Figure 2. This control and the screen in shown in Figure 2 will be used to illustrate most of the controls and screens. The other two controls will only be briefly described.

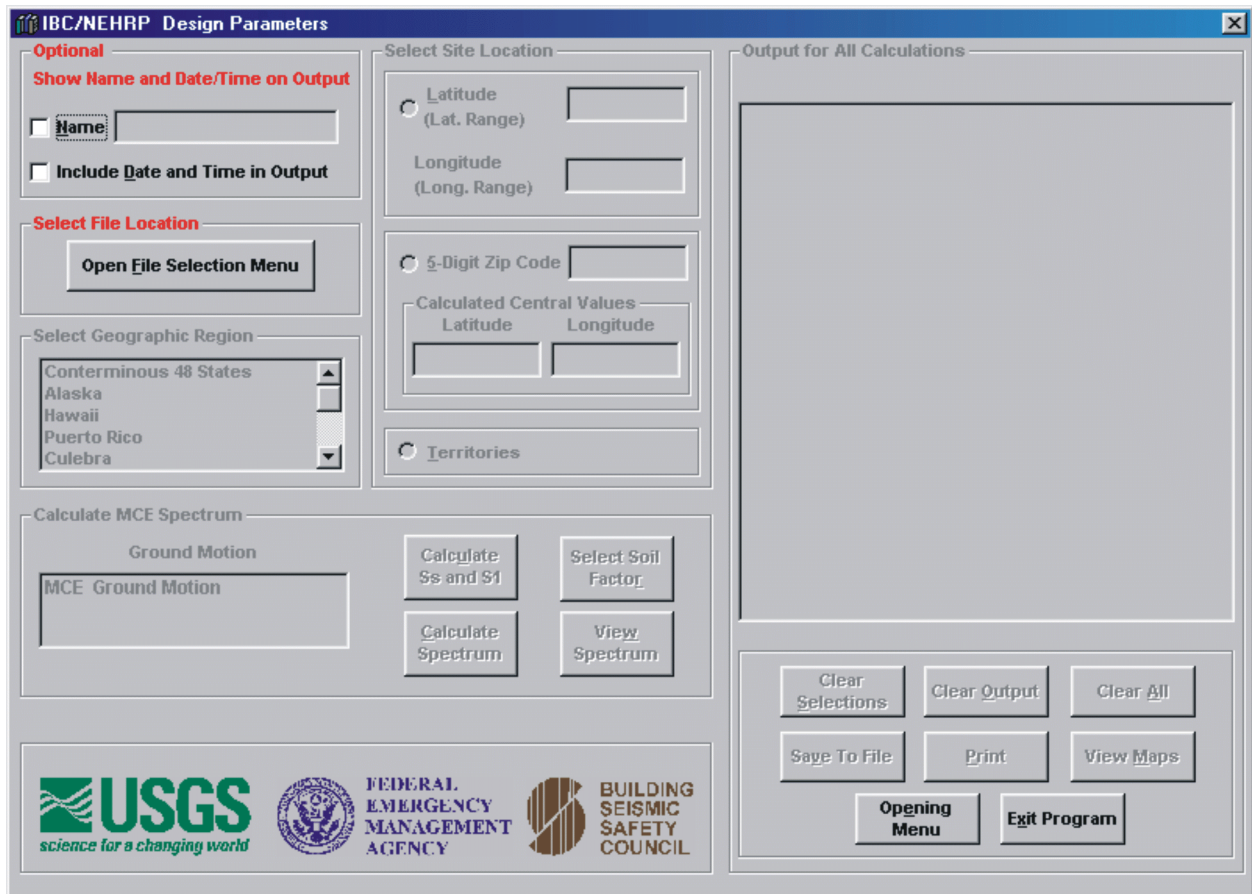


Figure 2. **IBC/NEHRP Design Parameters.** Selecting the control discussed in Figure 1 opened the screen shown in this figure. The contents of the screen are accessed sequentially. Portions that can not be accessed are grayed out. In general, the user is guided through the program by the use of titles in red and controls with titles in black. This is a clue as to what control or option should be used next. At the point shown in the figure, the user may use the option for entering a name and date or proceed directly to the **Open File Selection Menu** control. Although not required, this option is a convenient way to include a name or project description in the output. The option is followed by selecting the **Open File Selection Menu** control. Throughout the program, “tool tips” (notes with a yellow background that explain the meaning or use of a control) will appear if the cursor is held over a control or option. Selecting Opening Menu control takes the user to the screen in Figure 3. Note that in this screen the user may return to the screen in Figure 1 by selecting the **Opening Menu** control. The **Exit Program** control closes the program.

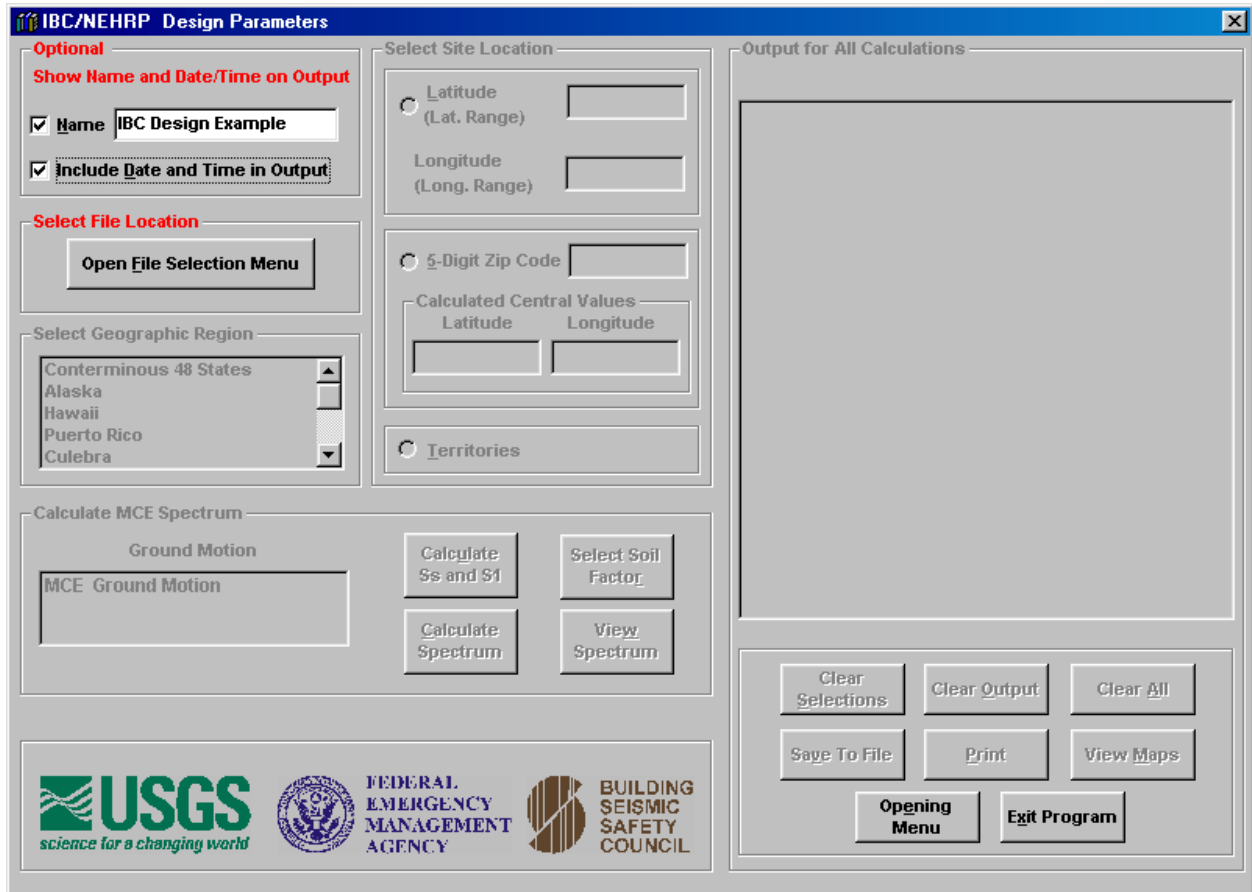


Figure 3. **Optional Name and Date Entry.** The name and date option have been selected. Both will be included with the output calculations. If only one is selected, then only the one will be included. The date and time are the computer time. In order to proceed, the user must select the **Open File Selection Menu** control.

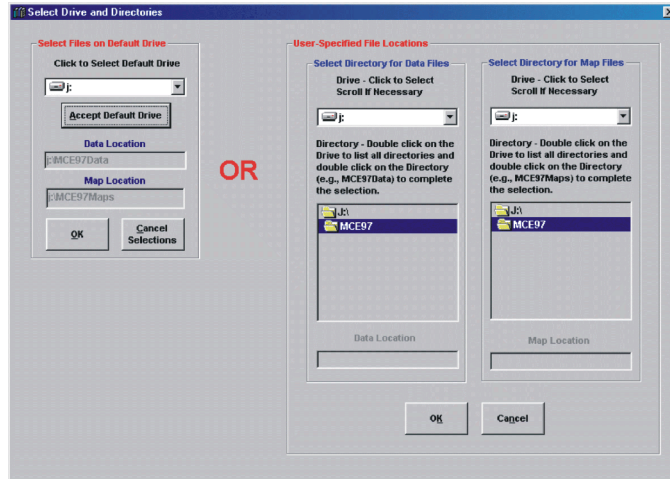


Figure 4. **Select Files on Default Drive.** This is the menu for selecting drives for data and map files. If data and map files are left on the CD or put on a single hard drive, the menu on the left is the simplest to use. Any drive may be selected as long as it has both the data and map files. An error message will appear if an incorrect drive is selected. If files are left on the CD-ROM, specify the CD-ROM drive letter as shown and press **Accept Default Drive**. Press **OK** to return to the main menu.

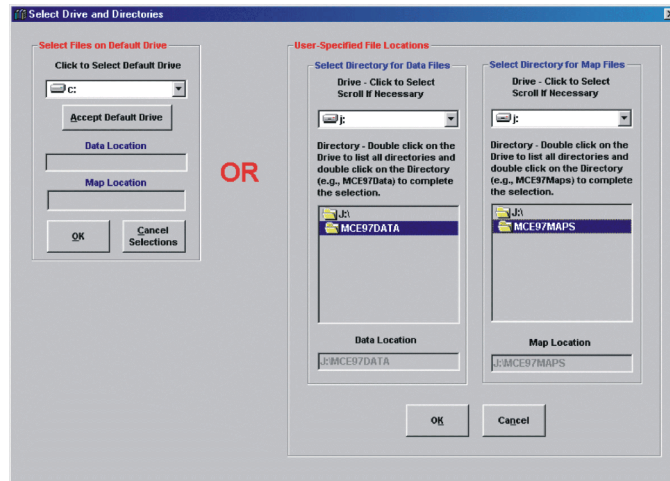


Figure 5. **User Specified File Locations.** This menu only needs to be used if files are moved from the CDROM. In the case shown the user has specified the file locations. The drive is still j: for both data and map files. The files could be on different hard drives, other removable storage media, etc. However, the names of the directories on a drive must be the same as those shown. That is MCE97Data for the data files and MCE97Maps for the map files. These directories are selected automatically when using the menu in Figure 4. This menu does not need to be used if the files are left on the CDROM or they are on the same hard drive.

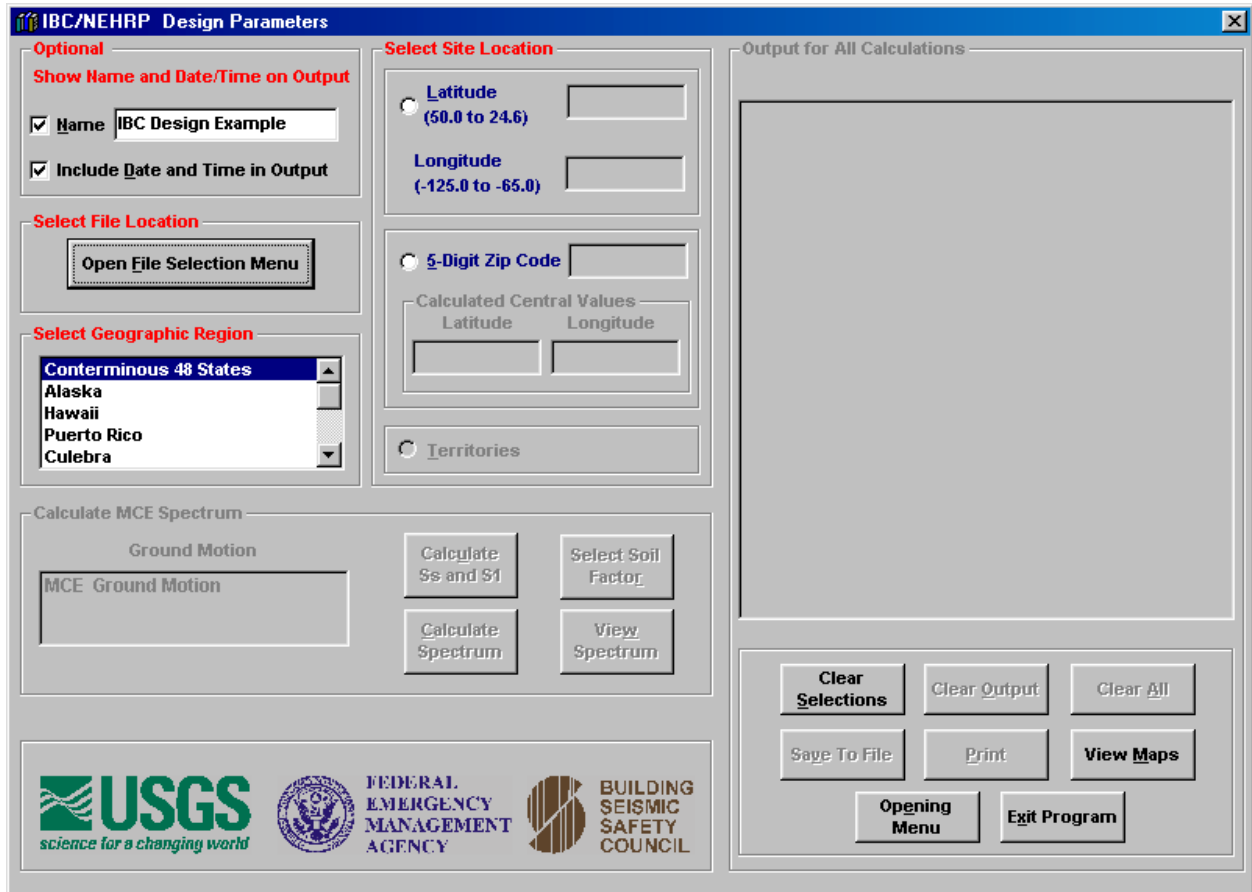


Figure 6. **Select Geographic Region.** Geographic Regions may be selected by clicking on the text. The selected region is highlighted in blue. Additional regions are visible by using the scroll bar. Site locations for the conterminous 48 states, Alaska, and Hawaii may be specified by latitude-longitude or zip code as shown in the **Select Site Location** frame. The so-called “radio buttons” may be used to select either method of locating a site. The buttons are shown in white and their descriptions are shown in blue. The control **View Maps** allows the user to access the maps used in the various design procedures.

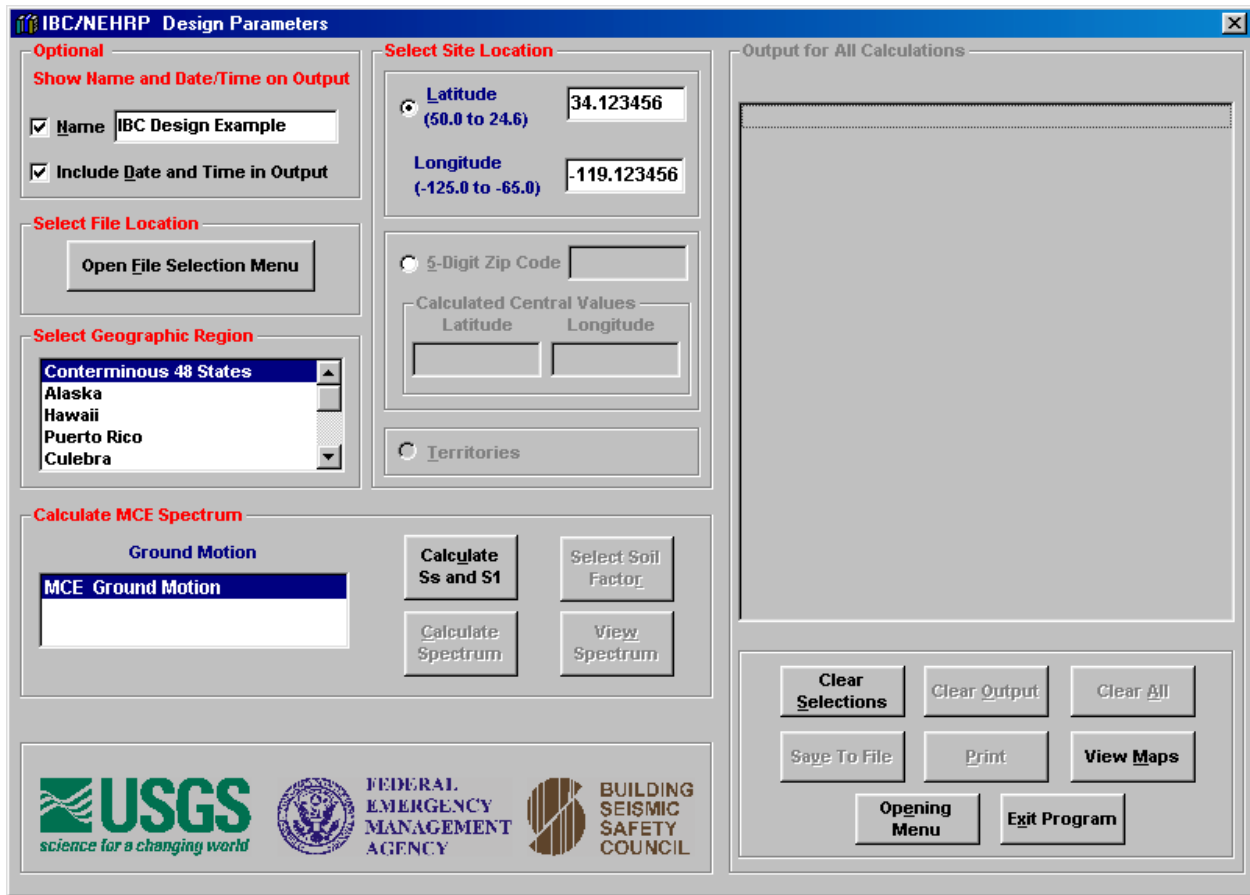


Figure 7. **Select Site Location.** Site locations may be specified by either latitude-longitude or zip code (except for the territories). The latitude-longitude option has been selected in this screen. Notice that the lat-long range is shown adjacent to text box for entering values. The range changes according to the geographic region selected. If the site is specified by zip code, the central values of the zip code are computed and shown in the text boxes. It is important to be aware that when the zip code option is selected, the value is determined at the central values shown. They are not maximum or minimum values for the zip code. In some areas, such as coastal California, there may be significant variation within a zip code. The user may get an idea of the variation by entering different lat-long pairs near the central values or looking at contours on the design maps. The design maps, included on the CDROM, will be discussed later.

The control **Clear Selections** clears the data related to specifying a site.

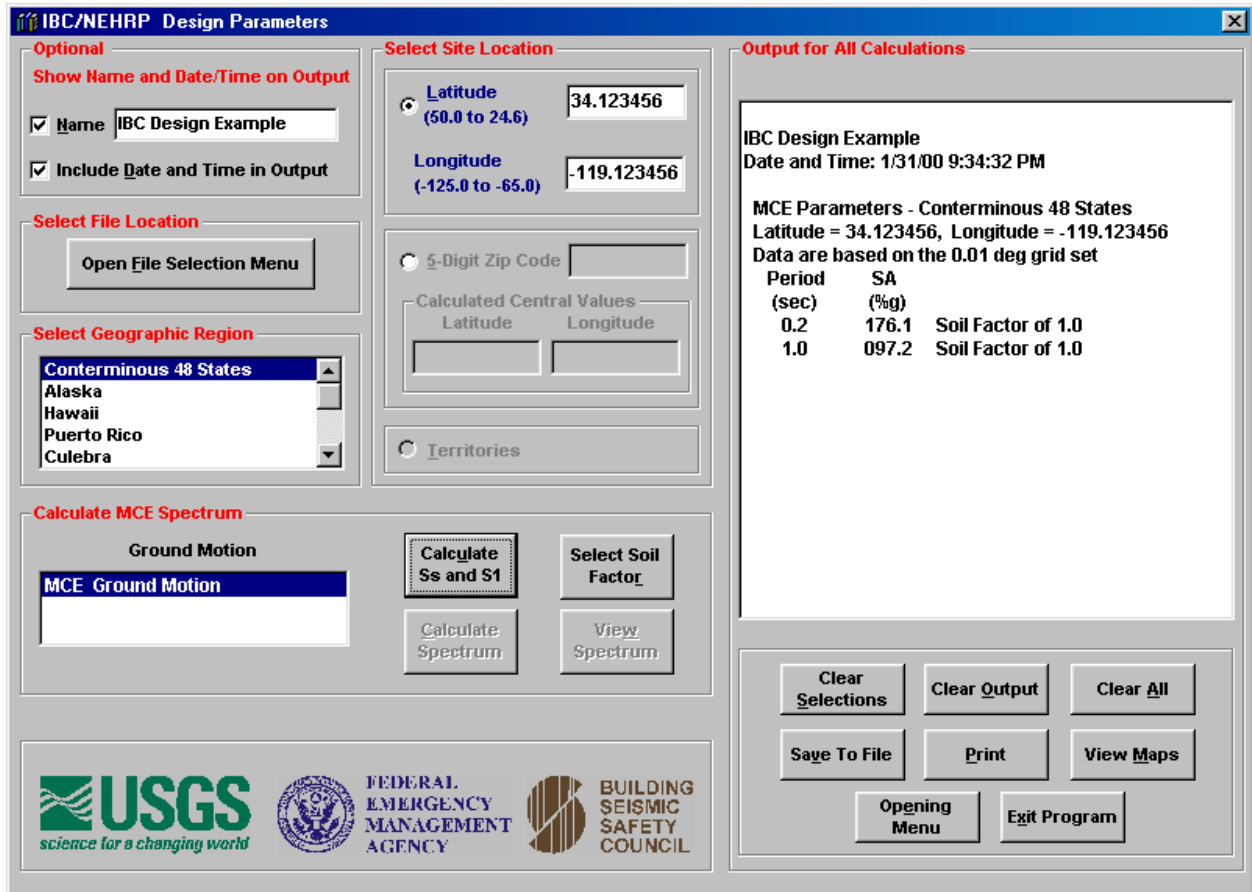


Figure 8. **Calculate S_s and S_1 .** The short and long period MCE parameters were calculated by pressing the **Calculate S_s and S_1** control. Notice the optional name and date are shown with the output. The latitude and longitude used to calculate the values are also shown so there is a record of the input with the output. The values are calculated by interpolation using four surrounding grid points. These grid points are in the data files in the directory MCE97Data. Data are gridded at different spacing for different regions. In the case shown the grid spacing is 0.01 deg. In the central and eastern United States the spacing is 0.1 deg. This latter spacing would not be adequate for a region such as the southwest where there are many faults.

There are four additional controls shown below the output box that are now active. These are explained below:

Clear Output clears the contents the contents of the output box.

Clear All combines Clear Selections and Clear Output.

Save To File saves the contents of the output box to an ASCII comma-delimited file.

Print sends the contents of the output box to a printer.

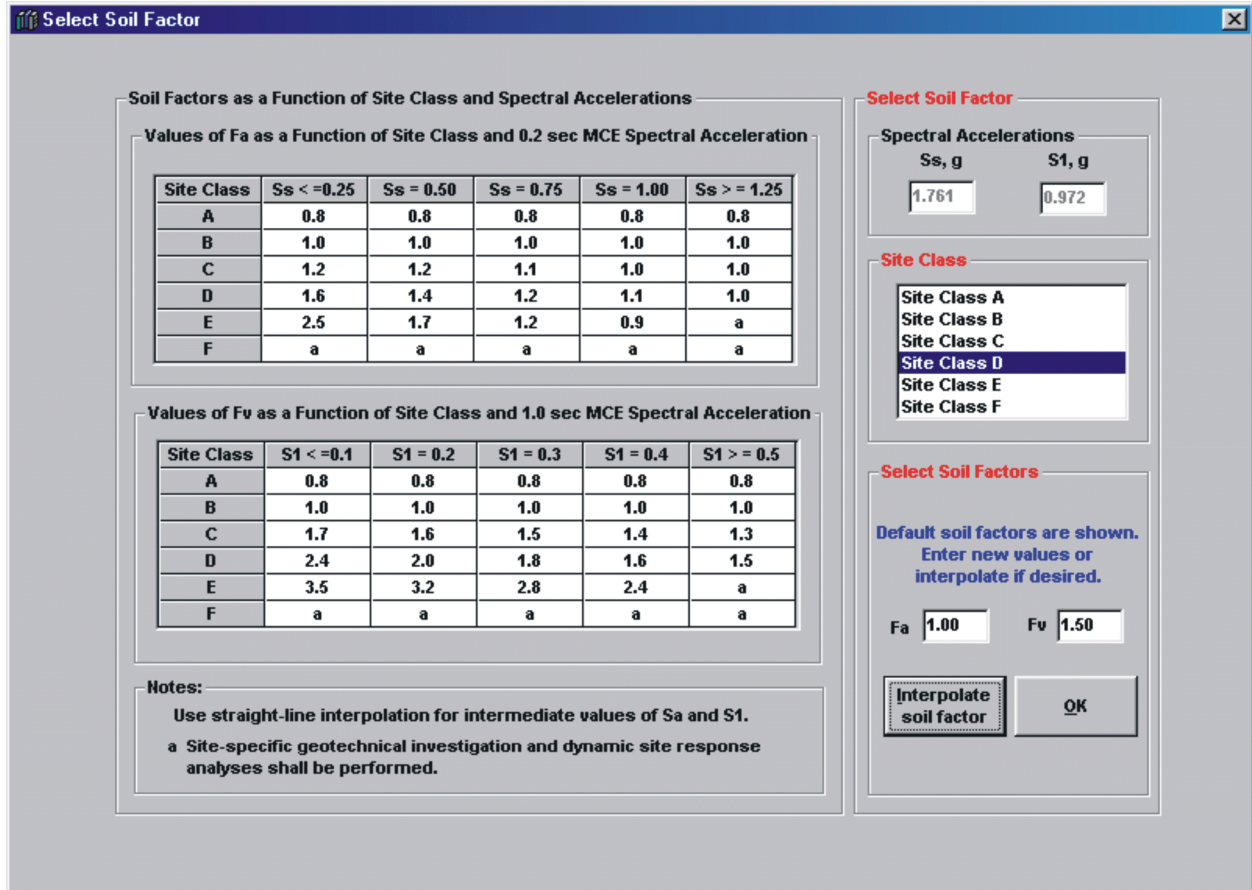


Figure 9. **Select Soil Factor.** The select soil factor menu opens after clicking the **Select Soil Factor** control shown in Figure 8. The default site class is Site Class B. If the site is a different class, select the new one by clicking on the appropriate text. Site factors for the new Site Class are computed by pressing the **Interpolate Soil Factor** control. Other site factors such as those based on a site-specific study may be used by entering them in the site factor text boxes. Selecting **OK** saves the soil factors and returns to the screen shown in Figure 8.

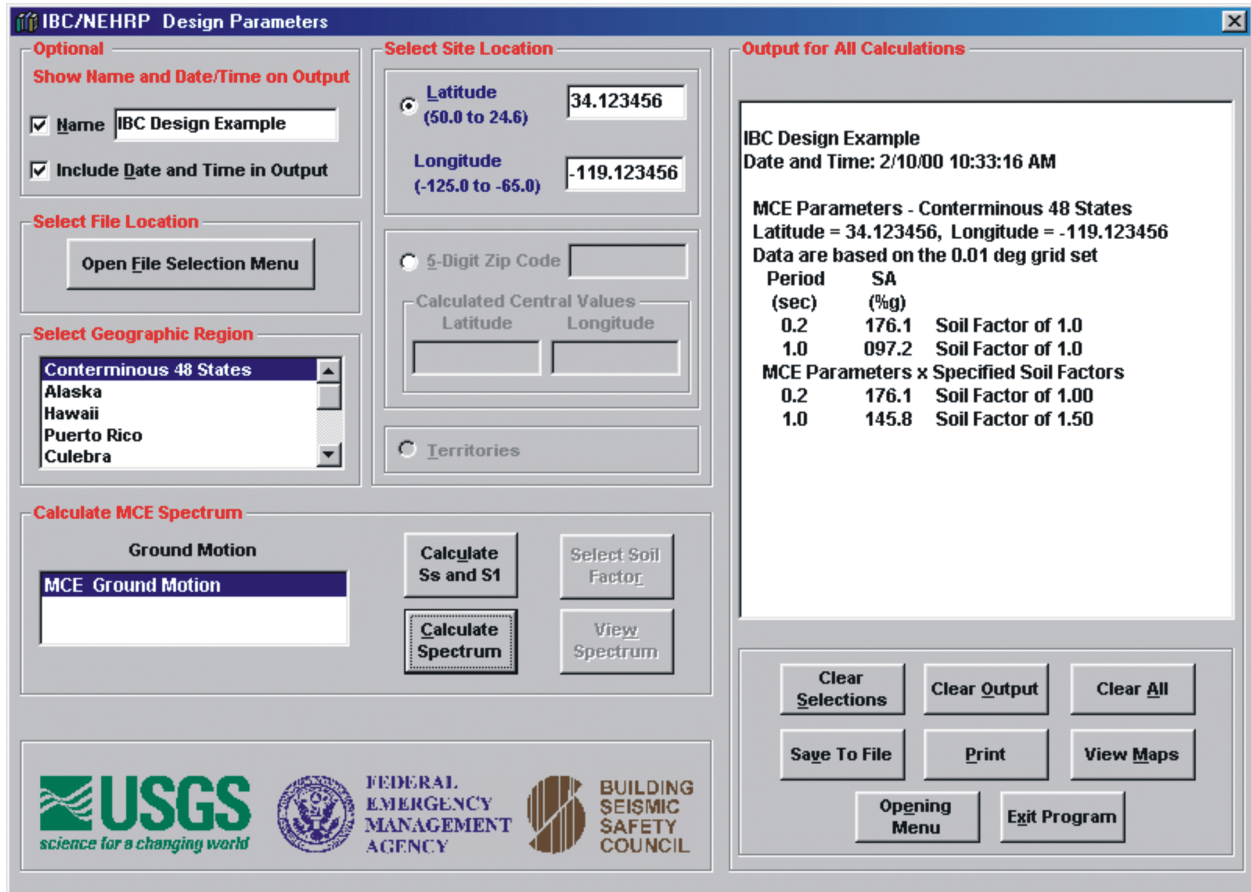


Figure 10. **Calculate Spectrum.** A design spectrum may be calculated selecting the **Calculate Spectrum** control. The calculated spectrum is based on the two MCE design parameters and the two soil factors. If a spectrum is not required, another site may be entered. Sites may be located by either latitude-longitude or zip code. Output will be accumulated unless the **Clear Output** is selected. This is discussed later.

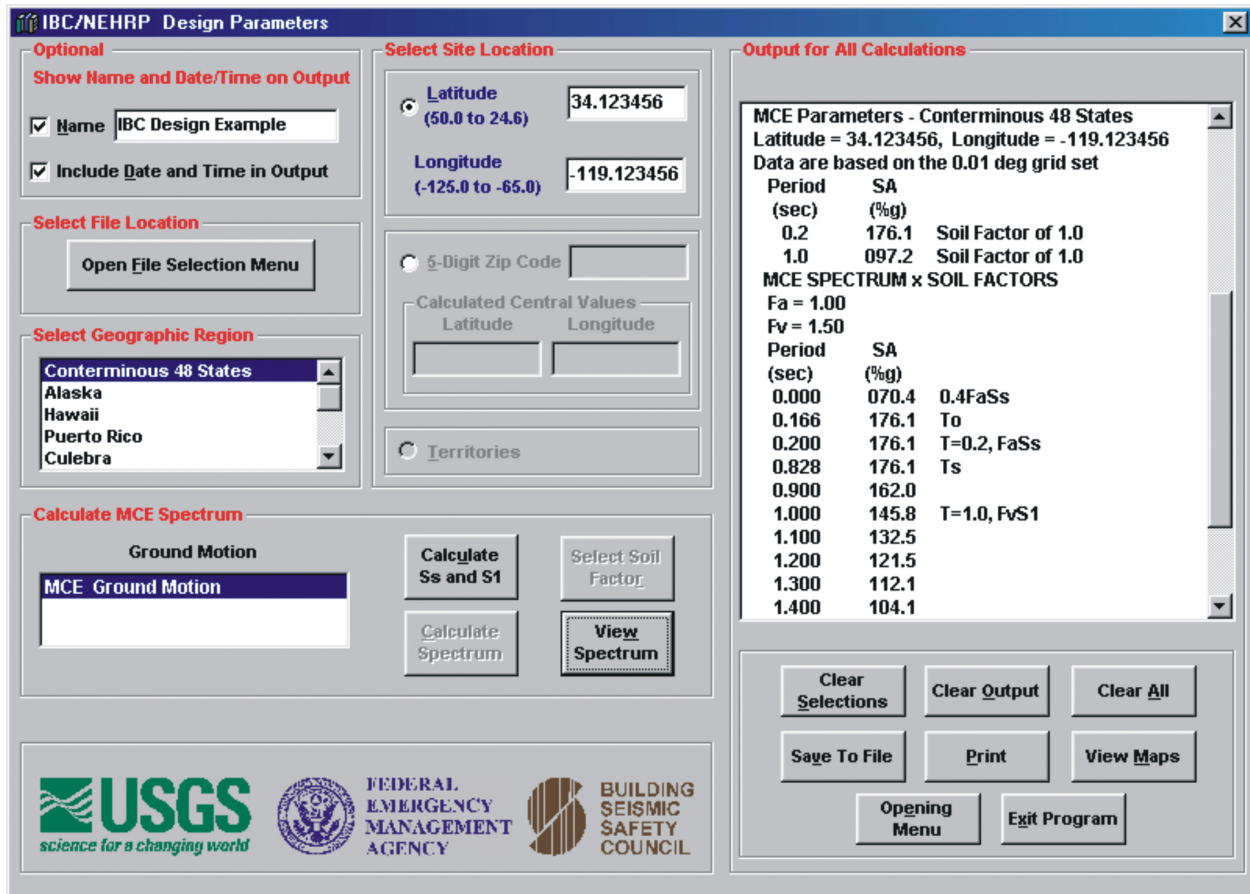


Figure 11. **Spectrum Calculations.** A response spectrum is calculated after selecting Calculate Spectrum in Figure 10. The spectrum is calculated at 0.1 sec intervals. The 0.0 sec period is a placeholder for peak ground acceleration which is approximated as $0.4FaSs$ using the equations in the design documents. Other key points on the spectrum are shown in Figure 11, along the procedure used to calculate the point. These values are used to plot a response spectrum which may be viewed by selecting **View Spectrum**.

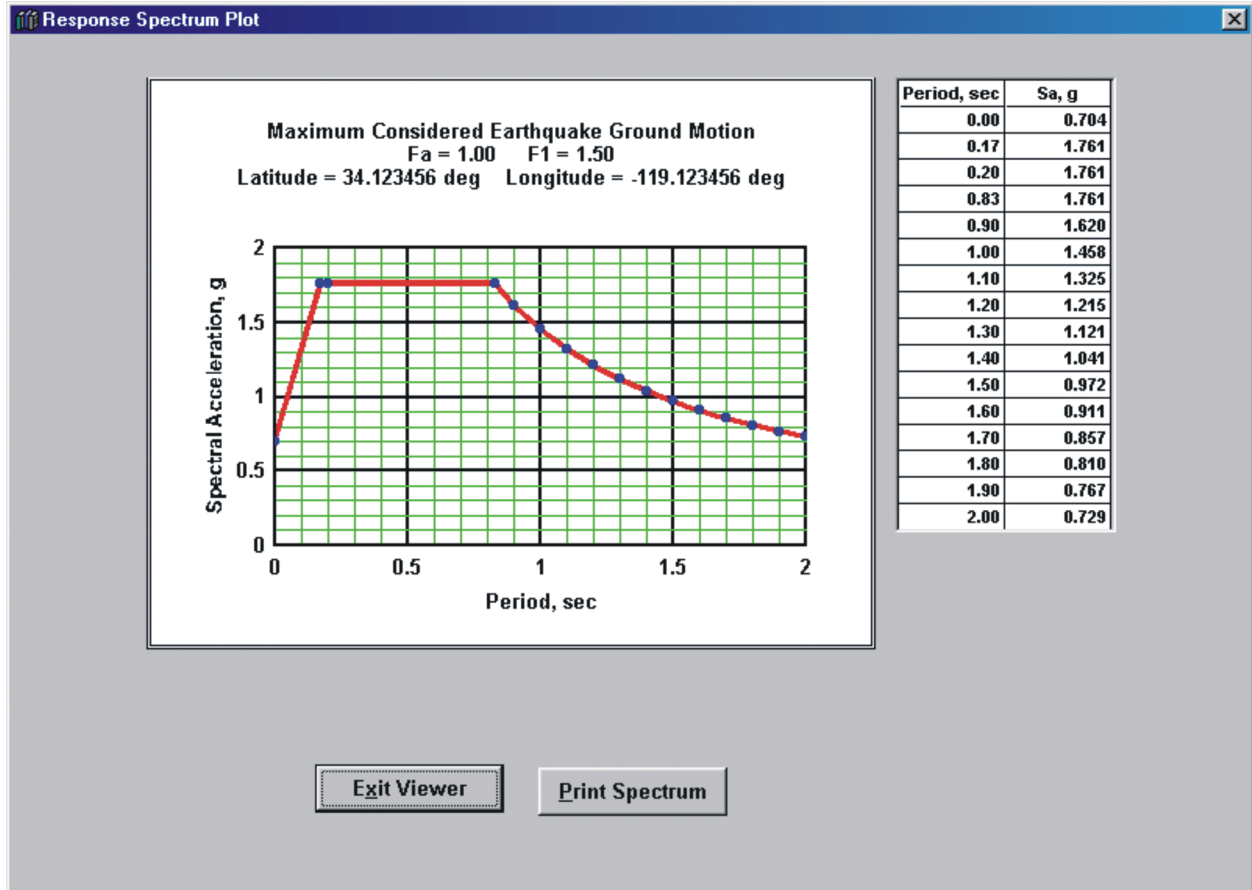


Figure 12. **Response Spectrum Plot.** A spectrum based on the calculations in Figure 11 is shown in the plot. The calculated points are shown as solid blue circles. The values used to prepare the plot are shown in the adjacent list box. These are the same as those in the output box shown in Figure 11. The plot includes data, site location, soil factors, and type of ground motion (MCE in this case). The plot and its data points are may be printed by selecting **Print Spectrum**. At this time the figure may not be saved as a file.

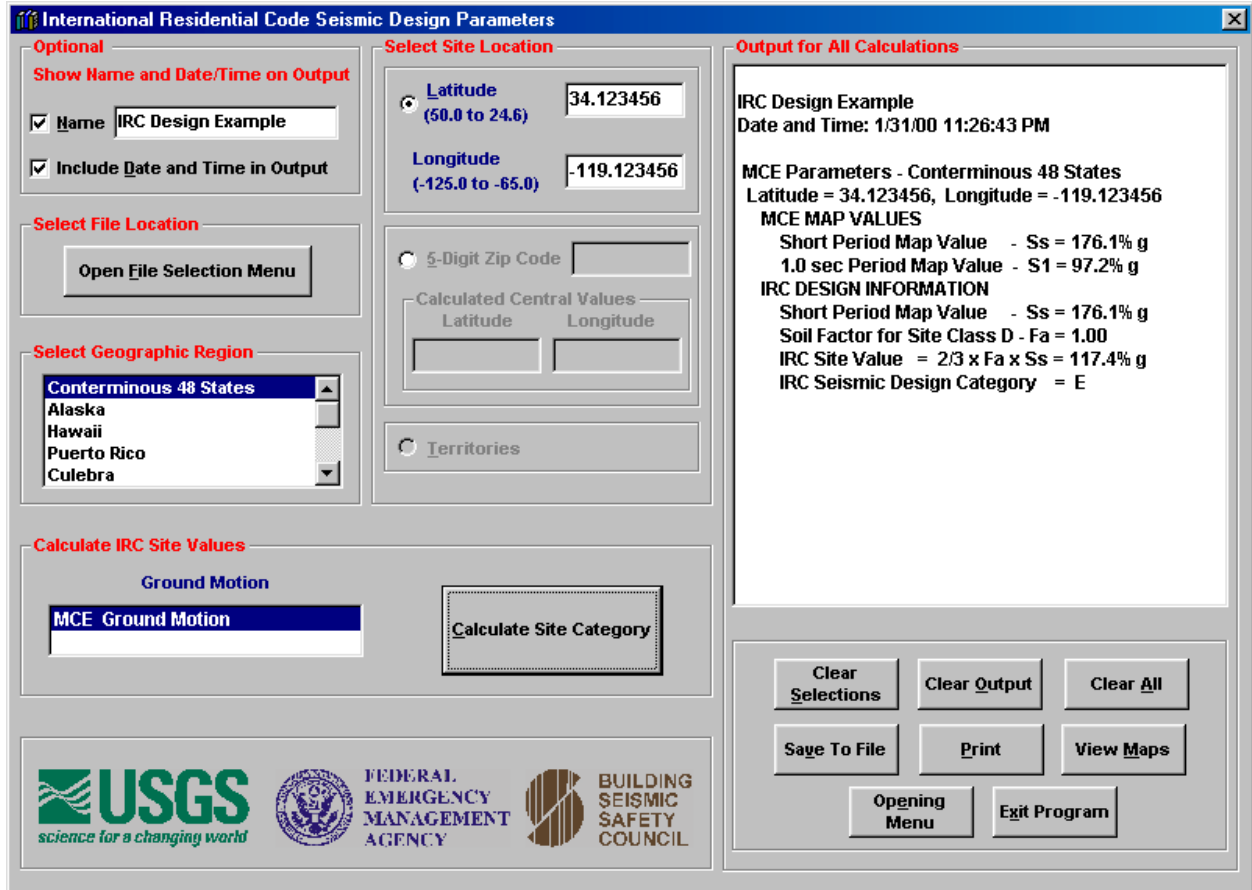


Figure 13. **International Residential Code.** The IRC portion of the program operates the same as the IBC/NEHRP portion of the program. However, there is no design spectrum or selection of soil factor. These do not apply to the IRC. Instead the program computes the IRC Seismic Design Category, in this case it is Category E. All factors used to determine the category are also shown for the information of the designer.

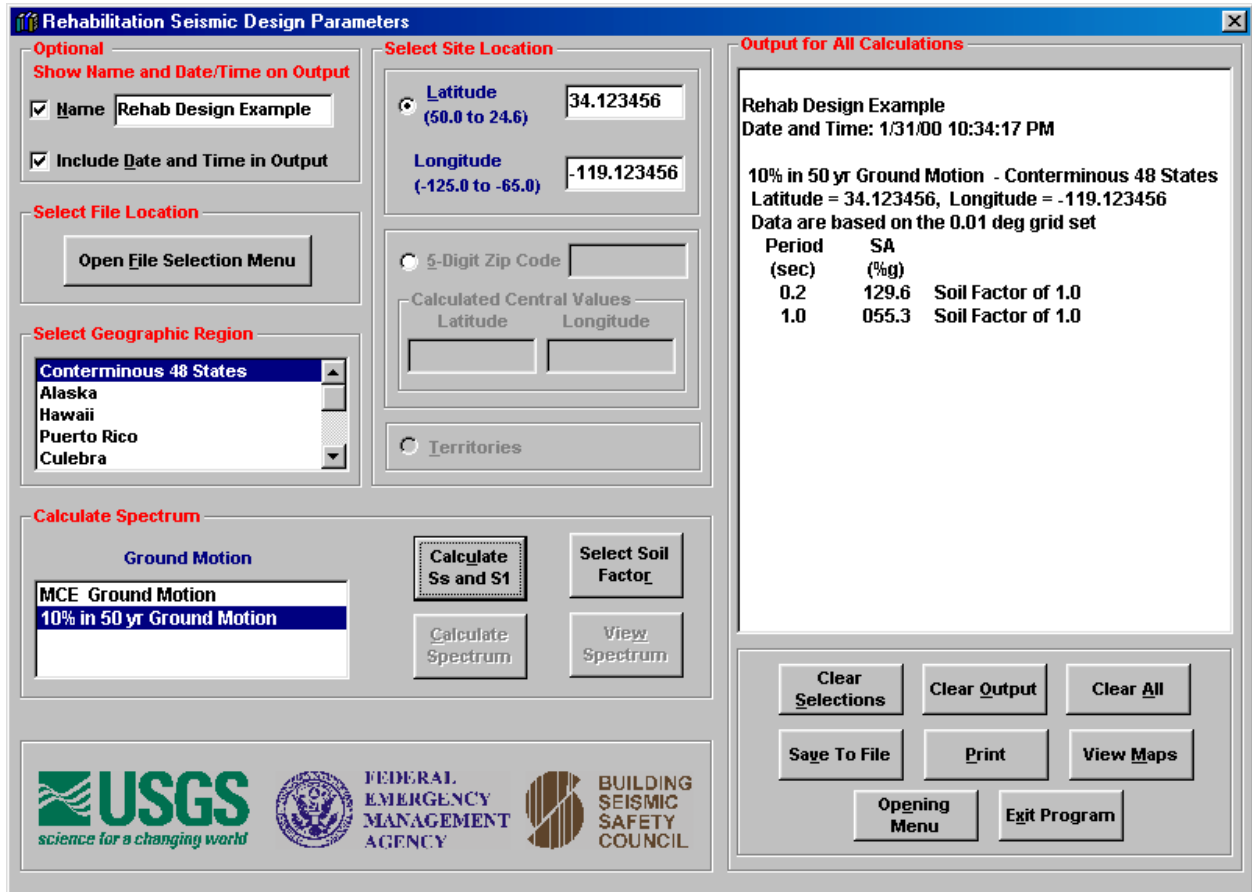


Figure 14. **Rehabilitation Design Parameters.** The Rehabilitation portion of the program operates almost exactly as the IBC/NEHRP portion of the program. In this procedure, the user can select either the MCE or 10% in 50 yr ground motion. Both are used in Rehabilitation Design.

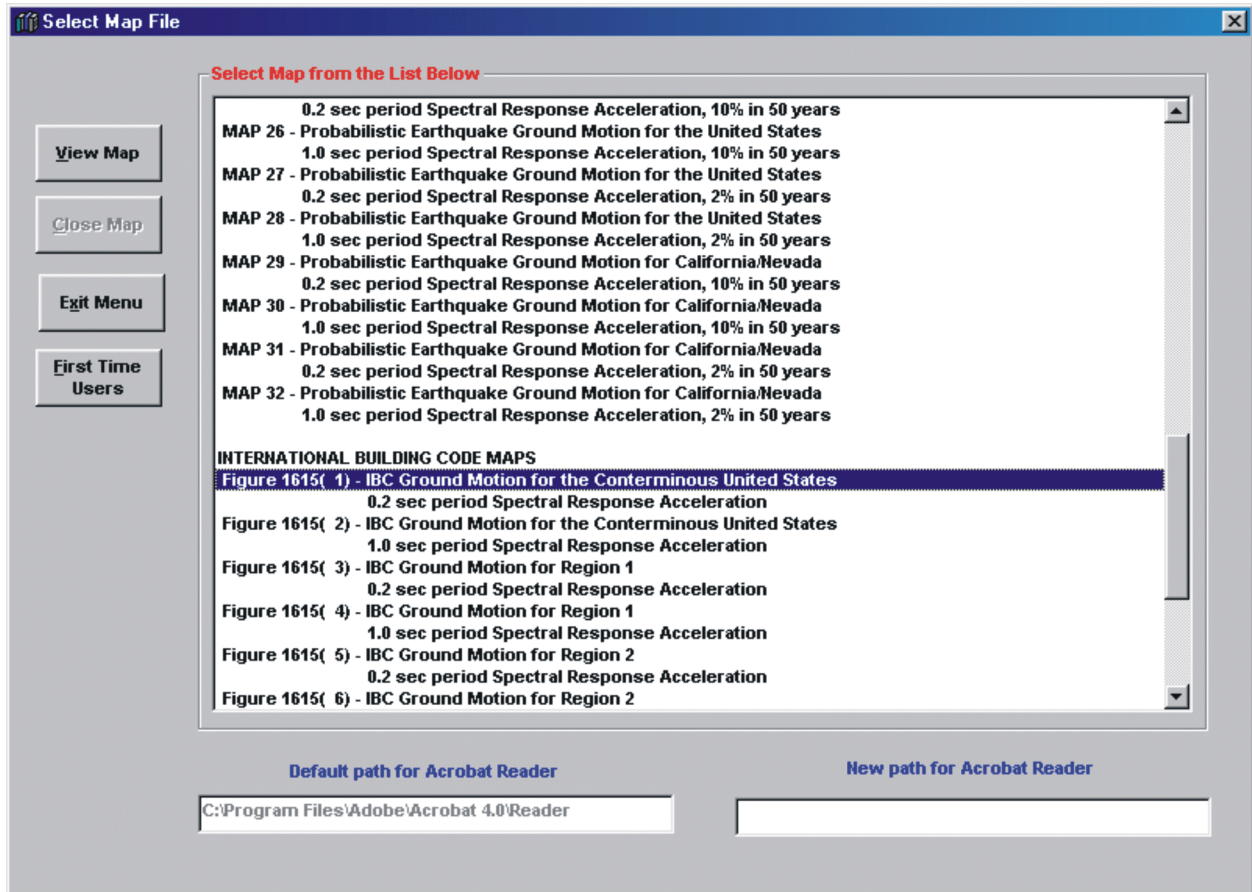


Figure 15. **Select MapFile.** The maps used in the design procedures may be viewed at anytime after the file locations have been specified. Clicking on the **View Maps** control shown in Figure 14 opens the menu shown in this figure. Click on a map to enable the View Map button. Click the View Map control to load the map. The map set include the entire set of maps included with the NEHRP Seismic Design procedure, the NEHRP Rehab design procedure, the IBC, and the IRC.

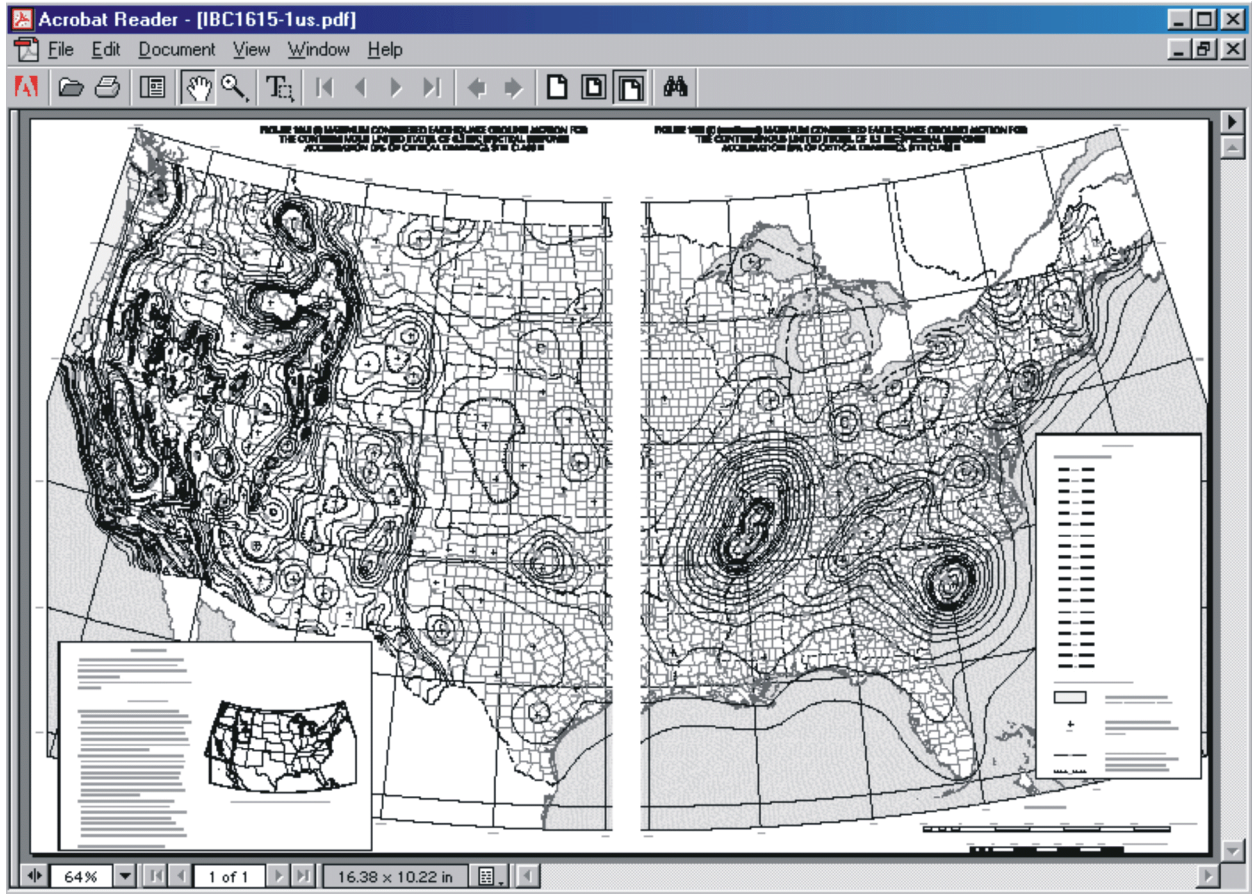


Figure 16. **Acrobat Reader.** The program automatically opens Acrobat Reader and loads the map file. The graphics select tool is used to select portions of the map for printing. Use the **Close Map** control to close the reader.

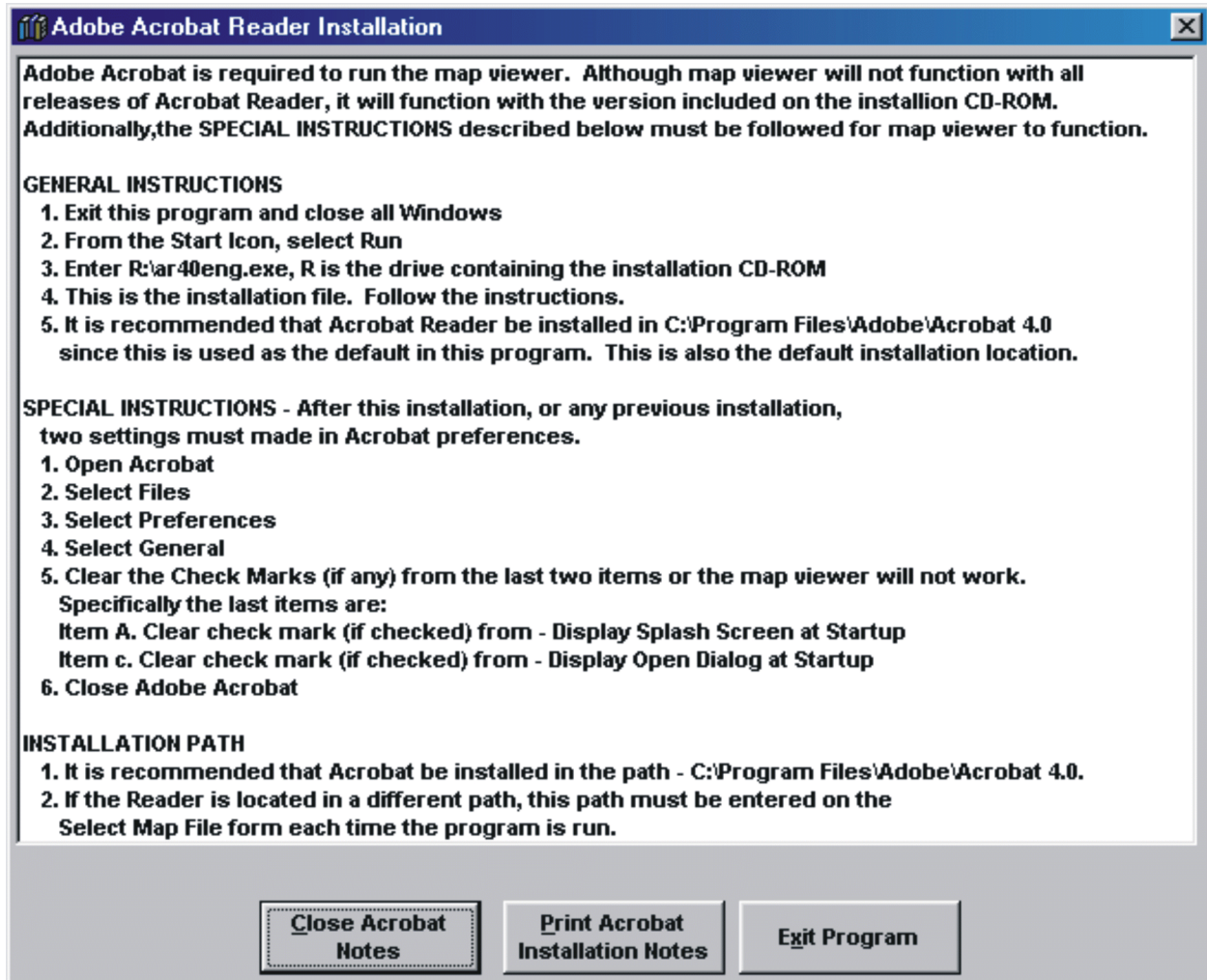


Figure 17. **Adobe Acrobat Reader Installation.** Acrobat Reader 4.0 is necessary to view and print the maps or portions of the maps. Earlier releases of the Reader give unpredictable results in line weights and do not allow printing selected portions of the maps. Special instructions must be followed to allow automatic loading of map files.