4 USER'S MANUAL DESCRIPTION

This section describes in detail the various functions of the P-CARES system and their usages. P-CARES is an integrated system for quickly assess of the response of soil and structural systems under seismic motions, by means of either deterministic or probabilistic analysis. It includes a site response analysis module, a soil-structure interaction (SSI) and structural analysis modules, and a number of relevant pre/post processing tools. P-CARES system provides a convenient graphical user interface (GUI) to accept user input, to perform and manage a variety of analyses, and to produce analytical results which an analyst use to quickly develop insights. It is an event driven system that involves mouse clicks and keyboard entries, and allows the input data be prepared on-screen, entered in any order, and edited later. To enhance the usability, the GUI also provides context sensitive mechanisms in that inter-dependent items are updated dynamically when the controlling information is changed. For example, if the number of soil layers is changed, the available options for input motion locations are updated automatically.

The user is encouraged to refer to the short tutorial for a quick overview of the program execution. To minimize development cost and ensure product quality, P-CARES has been developed based on a variety of open source software packages which will be described in the subsection of system requirements. The major components of P-CARES will be discussed in Subsection 4.3 to provide an outline of the various types of analyses (usages). Tasks that are common to other functions are introduced in Subsection 4.4. These common tasks are simple and the user should get familiar with them before any real application of P-CARES. The seismic motion analysis module, site response analysis module, and the SSI and structural analysis module, and the post processing module are described separately in their own subsections. These four major components are described in the same order as appeared in the command tree of the main GUI, although they can be combined in various ways to accomplish different types of analysis.

4.1 Short Tutorial

The P-CARES program can be installed using the installer "Setup.exe." In addition to creating a pcares2 folder in Start/All Programs, the installer also has options for creating desktop and quicklaunch icons.

To start the P-CARES program, do one of the following:

- Click the pcares2 program at Start/All Programs/pcares2/.
- Click the pcares2 icon on the desktop.
- Click the pcares2 icon in the quicklaunch toolbar.

To Close the P-CARES program, do one of the following:

- Click ☒ at the upper right corner of the P-CARES main window.
- Click Menu File->Quit.

Any unsaved data will be prompted to save before closing.

There is a command tree on the left part of main GUI including most of the functions of P-CARES (see Figure 4-1). Clicking an analysis module will display in the main display panel a brief description of the functions that the module can provide; clicking a command brings its interface to the main display panel. The GUI controls behave in the same way as they do in other applications on the Windows platform.

When conducting a soil profile modeling or a structural modeling, the user should save the project frequently by clicking [save icon] on the toolbar or by selecting "save" in the File menu, to prevent any possible lose of data.

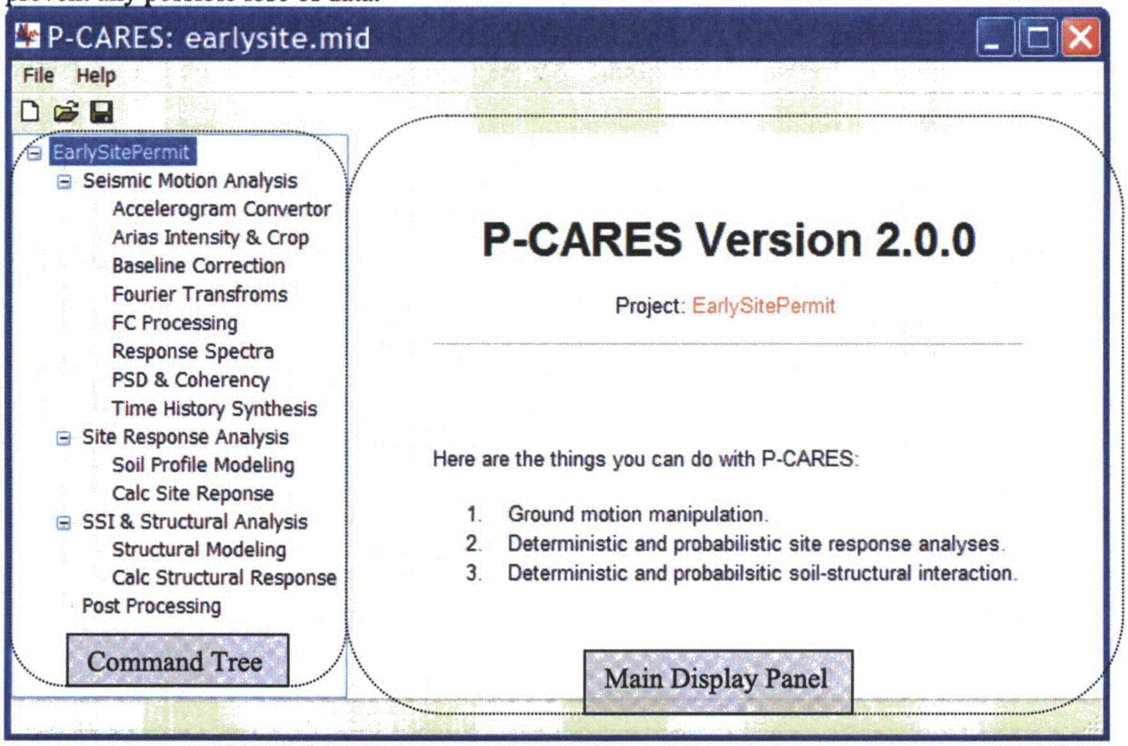


Figure 4-1 P-CARES Main GUI

4.2 System Requirements

Although P-CARES has been developed and tested on the Windows XP, SP2 platform, consideration has been given for potential deployment on multiple platforms. The computing core, which includes the free field convolution analysis, kinematic interaction, structural analysis, and some other frequently used utilities, is written in standard FORTRAN 90/95 and is portable to other platforms. The rest of the modules, including the probabilistic simulation, execution management, and the GUI, are written in the Python programming language that is open source and freely available to all popular platforms. The GUI is developed in wxPython, a Python binding to the C++ wxWidgets GUI library that is available to multiple platforms. These programming tactics in P-CARES development ensure its portability over multiple platforms.

Five software packages required to run P-CARES are open source packages and are freely available. These required packages are described in the following.

Python: it is an object-oriented, interpreted, open source, and free-of-charge programming language that is widely used for rapid application development (RAD) in many industries. It has been practically endorsed with its successful stories by the renowned organizations such as NASA and GOOGLE. It has a very clear syntax, highly optimized and versatile data structures, and many robust and efficient packages that can be used to minimize the developers' effort. It can be easily extended with C, C++, and FORTRAN to meet the speed requirement when heavy number crunching is involved. The development of P-CARES takes advantage of Python's extensibility by compiling upgraded existing CARES codes in FORTRAN into Python extension modules. Python can be downloaded from http://www.python.org. The current stable version 2.4.3 is used in P-CARES development.

Numarray: it is a Python module for fast array processing. It can be downloaded and installed from http://www.stsci.edu/resources/software_hardware/numarray. The current version 1.5.1 is used in P-CARES development.

Numeric: it is a package similar to Numarray and is developed before Numarray. It is not used directly by P-CARES, but is used by other packages that P-CARES relies on. Please note that the development of this package has stopped. The numeric Python community is currently working on a new package named NumPy to replace both Numarray and Numeric. However, Numpy was not used in the development of P-CARES for concerns of stability, which is typical for any new packages. Numeric can be downloaded from http://numeric.scipy.org/. The version 23.8 is used during P-CARES development.

wxPython: it is a package for the GUI development of P-CARES. It can be downloaded from http://www.wxpython.org/. The current version 2.6.3.3 is used in P-CARES development.

Matplotlib: it is the plotting module used to develop the on-screen plot generation capability in P-CARES. It can be downloaded from http://matplotlib.sourceforge.net/. The version 0.87 is used to develop P-CARES.

vtk: it is a 3D visualization toolkit for viewing the structural model in P-CARES. The vtk source code can be downloaded from http://public.kitware.com/VTK/get-software.php. The version 5.0 is used to develop P-CARES.

These required packages to execute P-CARES are invisible to the user, because the P-CARES program has been converted to a standard Windows program using another open source tool py2exe, which compressed all python source codes into one file and collects all necessary binary Python modules and their dependent DLLs (dynamic link library) to the program folder. The installer Setup.exe is made using "Inno Setup", a free installer maker for Windows operation systems. Some other packages are used in the development but are not required in the execution of P-CARES. These software packages include: Compaq Visual FORTRAN 6.6c, MS Visual C++ .NET 2003, f2py, and wxDesigner. The license files for all free software packages used in development of P-CARES are shipped with the program.

Memory and disk space of modern computers are mostly abundant for P-CARES. P-CARES should be able to run smoothly on any recent computers; it has been tested on a laptop with a 1.4 GHz CPU.

4.3 Components of P-CARES

There are two aspects of P-CARES: (1) the physical layout in the GUI with which the user sees and interacts on-screen, and (2) the logical combinations of various components on-screen to perform various analyses. These two aspects coincide in some cases, such as the utilities for seismic motion analysis, but are different in some other cases. For example, the site response analysis and the SSI & Structural analysis are organized into two distinct groups in the GUI, which, however, can also be regrouped functionally as either deterministic or probabilistic site and structural analysis. This subsection first describes the module organization of P-CARES in terms of the GUI, and then describes various types of analysis that can be performed in P-CARES.

4.3.1 Organization of Modules

Various components in P-CARES, including the computing core written in FORTRAN 90/95 and the probabilistic simulation codes, are organized and controlled through the main GUI as shown in Figure 4-1. The P-CARES GUI is a standard window that encapsulates the typical frame controls (e.g. the icon, minimizing, maximizing, and closing buttons on the title bar), and the functional components pertaining to various P-CARES's functions. These functional components consists of a menu bar, a toolbar, a tree structured panel for commands, and a main display panel.

Figure 4-2 shows the organization of the components of P-CARES in terms of the GUI layout, similar to the items in the command tree in Figure 4-1. The top four components are the major functional categories implemented in P-CARES, each of which consists of a number of either independent or interconnected components. The utility tools under seismic motion analysis module are independent of each other, and have their own console style interfaces displayed in the main display panel. The purpose of these utilities is to provide a centralized location to facilitate the accelerogram processing that spans the pre/post processing, examination, and synthesis. The site response analysis module provides several forms for data entry and edit for the soil column model, random variable and correlation definitions, various analysis options, and the optional kinematic SSI analysis to generate SSI input motion for the structural analysis module. This module consists of a few pages of interfaces to organize the input data. Both deterministic and probabilistic analyses can be opted for site response analysis module. The structural analysis module is similar to the site response analysis module in that it provides several forms to take user input and create the structural model, and presents analysis options for standalone deterministic SSI analysis, frequency domain shaker analysis, and joint SSI analysis that can be deterministic or probabilistic analysis depending on the analysis choice in the site response analysis. The post processing module stands out purely to process the simulation results for the site responses and the structural responses. It can produce various statistical plots for soil layer properties and generate response spectra for free field responses and the structural response. The statistics for the soil layer properties include the mean, minimum, maximum, median, and an arbitrary number of percentiles; while those for the soil and structural responses include the mean, median, various percentiles, and the input motion.

The menu and toolbar in Figure 4-1, not shown in the organization chart, serves to create, open, or save a project, which corresponds to a directory that holds all files related to the project. The name of the project, stored in the master input data file, appears as the root of the command tree. A new project that is not saved has a default name "Unnamed". The file name of an opened master input data file is shown on the title bar of the main GUI. The naming convention of the files is described in subsection 4.4.1.

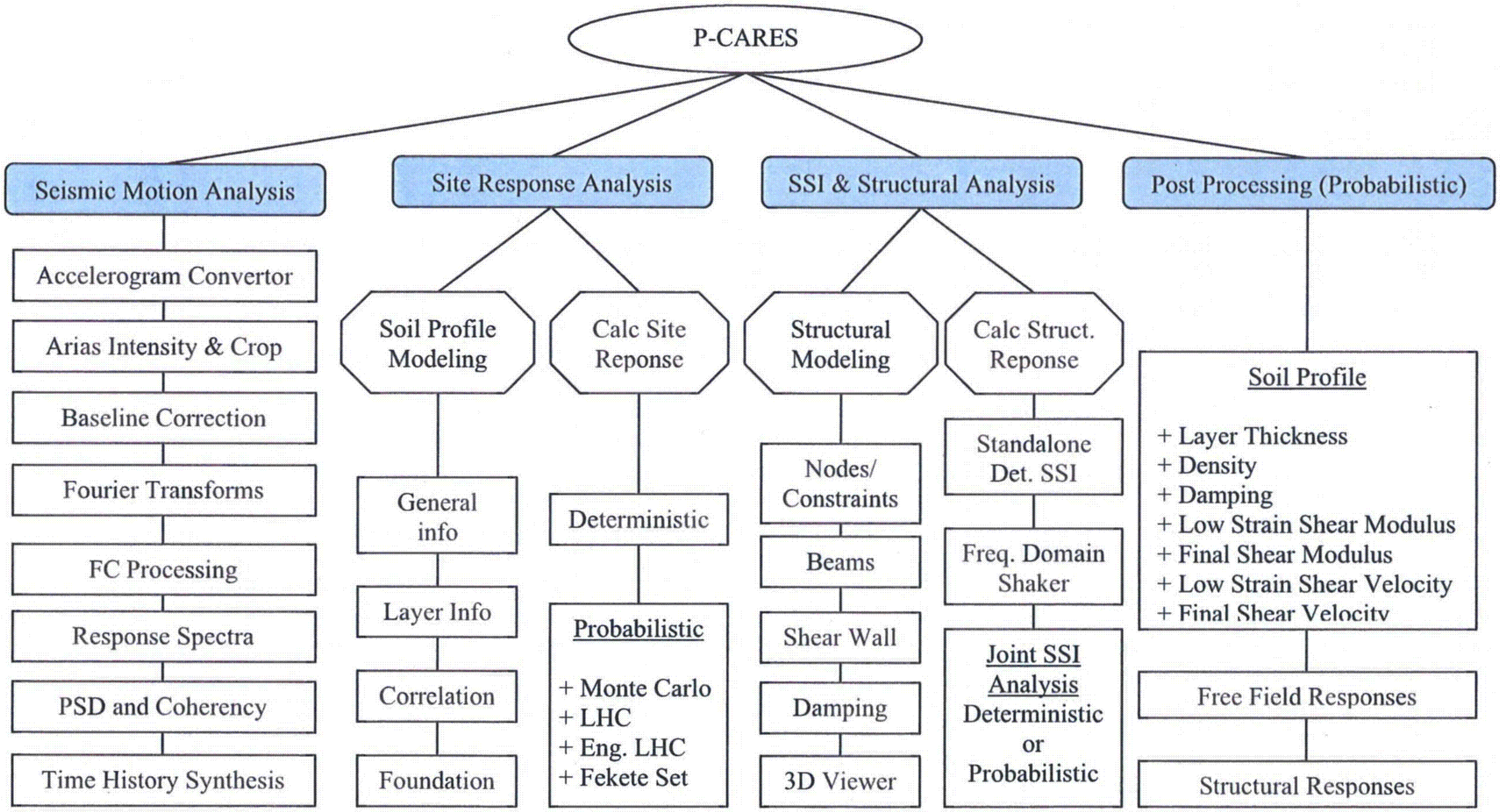


Figure 4-2 P-CARES Component Layout

4.3.2 Analysis Options

This section outlines the typical usages of P-CARES for various analysis scenarios. The GUI layout is designed for the user's greatest convenience in conducting common analyses, such as site response analysis or structural analysis separately. However, various components can be combined to achieve analyses that involve free-field convolution, kinematic soil-structure interaction, and the structural analysis. Therefore, the capacities of P-CARES and the pertinent procedures are summarized in the following for the user's choices.

Accelerogram Manipulations

Given an accelerogram, in a format of time history or Fourier components, the user can manipulate it in seismic motion analysis module. The accelerogram can be either an earthquake record or a response record in the soil or the structure, and can be converted from other format to P-CARES format. The implemented manipulations include Arias intensity calculation, record cropping and zero padding, baseline correction, FFT and invert FFT, Fourier spectra filtering and smoothing, response spectra, power spectra density and coherency, and time history synthesis. All plots can be saved in a few popular image formats ready for insertion into a report, or can also be saved in plain data format that can be imported by other software for further exploration.

Deterministic Site Response Analysis

The soil column model can be built using the soil profile modeling command in the site response analysis module. For a Deterministic analysis, the user does not need to provide the probabilistic distribution parameters for the soil layer properties, and the correlation table. If a joint SSI and structural analysis is not to be performed, the foundation data is not needed. The final soil profile and the output motions are saved to individual files for post processing. In particular, the output motion files are in the format of Fourier component, and can be processed using seismic motion analysis tools. The user must choose the "Deterministic" analysis option to activate this analysis.

Probabilistic Site Response Analysis

In addition to the data prepared for the deterministic site response analysis, the user must enter the probabilistic distribution for the soil layer properties, and fill in the correlation table if the correlations between soil layers are required. The user must choose the "Probabilistic" analysis type, select a simulation scheme among the Monte Carlo simulation, Latin Hypercube sampling (LHC), engineering LHC, and Fekete point set methods, and provide the number of samples to be used for this analysis type. The output motions and final soil profiles can be processed in the post processing module.

Standalone Deterministic SSI Analysis

The structural analysis module can be used as a standalone package. The structural model, including the SSI node and the output nodes, can be constructed using the structural modeling command of the SSI and structural analysis module. The SSI model, the base and side soil properties, and foundation types and dimensions are required to calculate the SSI coefficient. Each degree of freedom of the SSI node can be assigned an input motion in the format of Fourier components. The output motions are saved in individual files to be processed using seismic motion analysis utilities. The output files are under names as "ST*n*-*d*.fc", where *n* stands for the node id and *d* stands for the directions, i.e. one of the X, Y, Z, RX, RY, and RZ.

Frequency Domain Shaker Analysis

This analysis is similar to the standalone deterministic SSI analysis except that it does not require the input motions at the SSI node. Rather, it requires a forcing function defined at a certain direction of a given node. The forcing function is defined for a list of user-specified frequencies, which can be quickly generated in P-CARES if a regular frequency increment is used. The output files are under names as "SH*n*-*d*.fc", where *n* stands for the node id and *d* stands for the directions, i.e. one of the X, Y, Z, RX, RY, and RZ. Please note that even if the output files are named with extension ".fc", the user should not try to use them in situations that FFT is involved, because the user specified frequency list extremely unlikely fulfills the FFT requirement.

Joint Deterministic SSI Analysis

The site response analysis and the structural analysis can be chained together to perform the full scale soil structure interaction analysis. In addition to the soil and structural models built in the deterministic site and structural analyses as previously discussed, the user must select the "Deterministic" analysis type in the soil calculation and the "Joint SSI" analysis type in the structural analysis. The user need to provide the foundation information during the soil modeling and the kinematic soil-structure interaction should be included in the site response analysis. Since P-CARES automatically sets the SSI model, calculates the base and side soil properties from the soil column model, and retrieves the SSI motions generated in the site response analysis, the user need not provide the SSI model, foundation information, soil properties, and SSI input motion in the structural model, in contrast to the requirement in the standalone deterministic SSI analysis and the frequency domain shaker analysis. The output motions are stored in individual files, under names as "JD*n*-*d*.fc", where *n* stands for the node id and *d* stands for the directions, i.e. one of the X, Y, Z, RX, RY, and RZ.

Joint Probabilistic SSI Analysis

The user can also perform a probabilistic simulation that embraces the site response analysis, the kinematic soil structural interaction, and the structural analysis. It is achieved by a probabilistic site response analysis followed by a structural analysis with the "Joint SSI" analysis option. As in the joint deterministic SSI analysis, the kinematic soil-structure interaction should be enabled and the pertinent information should be provided in the site response analysis. The user also need not provide the SSI model, foundation information, soil properties, and SSI input motion in the structural model. The SSI motions, generated in the site response analysis and used as input in the structural analysis, include a translational component and a rotational component and are stored in a database file. The output motions at the user specified nodes are stored in a database file that can be processed in the post process module.

Post Processing of Database Files

Three database files accepted in the post processing are for final soil profiles, soil responses at various user specified depths, and structural responses at the user specified nodes. The final soil profile database includes the soil layer thickness, soil damping, soil density, low strain shear wave velocity, final shear wave velocity, low strain shear modulus, and final shear modulus. The soil and structural response database include the input motion and responses, all in Fourier component format. Because the calculation of response spectra for every sample is a time consuming task, the generated response spectra are stored in a file and are opted for direct use without regeneration if the analysis has not been re-executed. The statistics used in the post processing for simulation include mean, minimum, maximum, median, and an arbitrary number of percentiles that the user can specify. All plots can be saved in a few popular image formats ready for insertion into a report, or can also be saved in plain data format that can be imported by other software for further exploration.

4.4 General Remarks on P-CARES Usage

To avoid repetitive narrations, this section describes some procedures or conventions that are common to or frequently used in most of the P-CARES interfaces.

4.4.1 File Name Conventions

As introduced before, a project is a collection of related files contained in a directory. These files follow certain naming conventions that are either restrictively required or recommended. The user is strongly encouraged to follow these rules in naming files. A file name in all capital characters usually means an intermediate file dumped out by P-CARES, which may or may not be in the text format. If a file is not included in the follow table, it is still used or generated by P-CARES but may not be useful for the user.

File Extensions

.mid	The extension for the master input file, which hold all data regarding the soil and structural properties. Only one master input file is needed in any of the project directory. The input motion and the output motions are not included in this file but in their own individual files. The master input data file name will be displayed on the title bar to indicate the current project.
.acc	The P-CARES accelerogram file is a slightly revised CARES format. The base name of this file may be the file name of a Fourier component file indicating it is transformed from that Fourier component file.
.fc	The Fourier component file of an accelerogram. The P-CARES format is revised slightly from the CARES format. The base name of this file is the file name of the accelerogram.
.rs#	The file holds a response spectrum. The symbol # indicates the damping used in generating this response spectrum curve. For example, if 5% damping is used, the response spectrum is saved in a file named ".rs5". The base name of this file is the file name of the accelerogram.
.DB	Binary database file for the simulation results, i.e., for the simulated soil profiles and output motions in the soil and structural analysis.
.HDB	Similar to **.DB** but it is invisible to the post processing module.
.psd	The power spectra density file.
.fps	A file holds a Fekete Point set. The base name is in a format of "FeketeCube[nDim]-[nSim]" , where "FeketeCube" means that the Fekete point set is in the hypercube, [nDim] is the dimension of the random space, and [nSim] is the number of points (samples) in this file. The number of points of a Fekete Point set is required to be greater than the dimension of the random space.
.POST	A file is generated in the post processing module, and is used to save the lengthy calculation of the response spectra during post processing.
.plt	A file contains the figure data, which is saved from the plotting toolbar and can be imported into Excel using the tab-delimited format.

An accelerogram file or a Fourier component file may have a name chained as ".acc.fc.acc...", as a result from multiple applications of the FFT and inverse FFT. This arrangement in P-CARES is purposed to be a safe measure that prevents the possibility to overwrite a file accidentally. The user can easily delete any of these files using Windows Explorer, if they are believed to be no longer useful.

File Prefixes

File prefixes are used to signify the operations have been made on the original file. The prefixes may be chained in a file name if the accelerogram was modified with more than one operation. Using prefixes is an additional safety measure, besides the use of chained file extensions as described above.

bl_	The accelerogram is baseline corrected. It may appear in an accelerogram or a Fourier component file name.
cropped_	The accelerogram is cropped from the original one.
sm_	This Fourier component file is processed by window smoothing. It may appear in an accelerogram file that is transformed from a smoothed Fourier component file using FFT.
bw_	This Fourier component file is filtered by the Butterworth filter. It may appear in an accelerogram file that is transformed from a filtered Fourier component file using FFT.

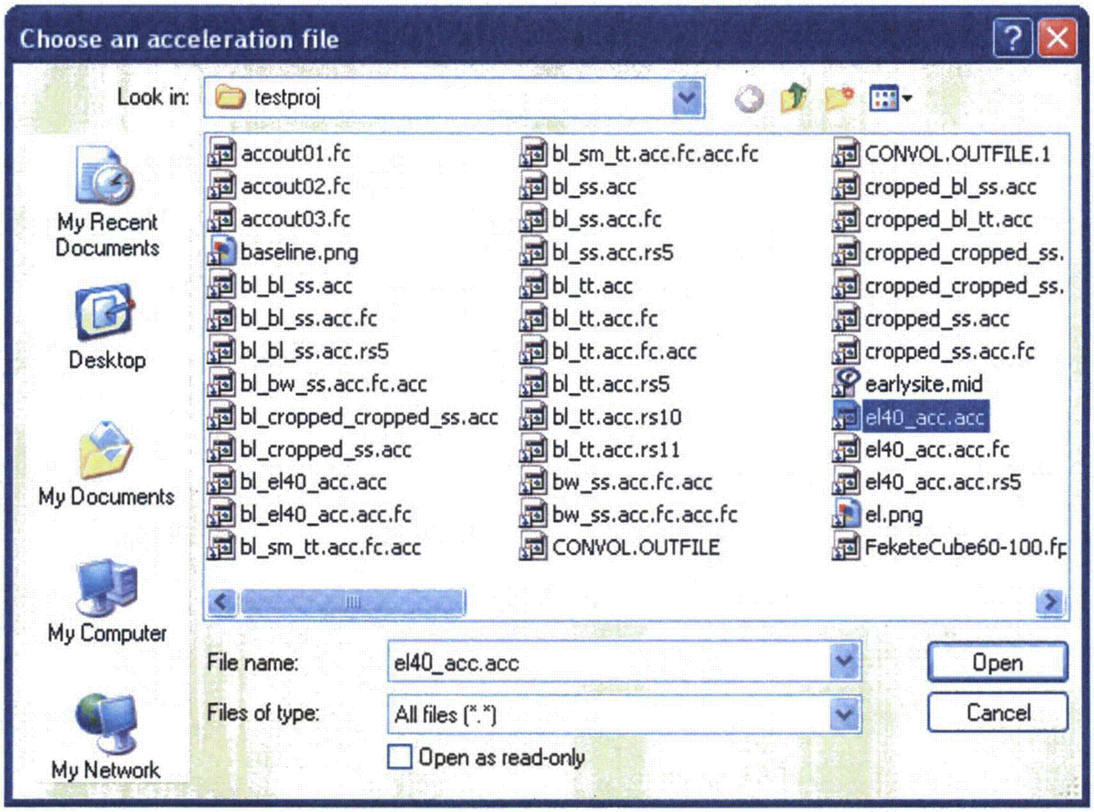
4.4.2 File Name Input and File Browser

There are many occasions where a file name is requested by P-CARES. The common approach in P-CARES is to type in a file name or browse the file system for a file name. The following picture shows this typical combination.

Name	File Name Box and Browse

Description	This is a combination of file name input box and a Browse button. The user can either type in the file name if he knows the file, or can browse the file system for the desired file name.
Browse	When clicked, P-CARES will show the following file browser dialog. Browsing through the directories and select the desired file.

Name	File Brower



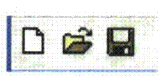
Description | This is a standard file browser used by most applications on Windows XP. This browser has two variations: one for opening and the other one for saving. A saving browser in P-CARES asks the user's permission to overwrite a file if it has already existed in the project directory. Selecting a file will put its name to the File name text box.

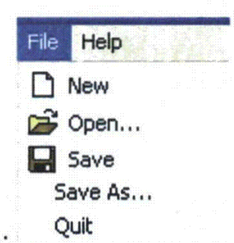
Open | When clicked, the file name will be returned to the program that called the browser, and will usually put in the file name input box if there is one. Actions taken on this file depend on the particular application situation.

Cancel | When clicked, no file name will be returned to the program.

4.4.3 Toolbar and Menus

Name | Toolbar and Menu

Tool bar: 

Menu: 

Description | Tool bar and Menu share most of their functions. These buttons and menu items are for project-wise operations.

New When clicked, the buffer holding the master input data will be cleared. If unsaved data available, the user will be prompted for saving before clearing the buffer.

Open Fires up a file browser to select a master input data file. The File extension is set to "*.mid"

Save Save the master input data buffer to the file opened previously. If this is a new project and has not been saved before, a file browser will be displayed for a directory and file name; after saving, the file name will be on the title bar.

Save as Save the current buffer to a file name that is return from a file browser. The current project is closed and the new project using the new mid file becomes the current project.

Quit Exit P-CARES. If the project is not saved, an alert dialog will be displayed requesting the user's confirmation for saving before exiting.

4.4.4 Plotting Toolbar

For all plot panels that produce and manipulate figures, there is a toolbar attached at its bottom side to manipulate the figures on the plot panel.

Name Plotting Toolbar

Description This toolbar in P-CARES is an extended version from the original Toolbar2 of matplotlib, which is the plotting package used in P-CARES for plot generation. The buttons are for plot navigation, plot properties settings, annotation, and figure and data saving. The first seven buttons are the standard buttons from matplotlib.

Home  Clicking this button resets the plot to its original configuration.

Backward  Go one step back in the navigation history, which may consist of the panning and zooming actions. If there are no steps left in the history for backing, this button is disabled.

Forward  Similar to the Backward button. These forward and backward buttons work in a way similar to the navigation buttons in a web browser.

Pan/Zoom  *Pan mode*: press and hold the left mouse button and drag the plot. If key "x" or "y" is pressed while panning, the motion will be restricted to the x or y direction.
Zoom mode: press and hold the right mouse button and drag the pointer to a new position. The x dimension of the plot will be zoomed in proportionally to

the rightward movement or zoomed out proportionally to the leftward motion; similar zooming for y direction if upward or downward movement involved. If “x”, “y”, or CONTROL key is pressed while zooming, the zoom will occur only in x direction, y direction, or preserving the aspect ratio.

Window Zoom

Zoom in mode: Press and hold the left mouse button, and drag to draw a rectangle that covers the region to be zoomed. Releasing the left mouse button zooms into the rectangular region.
Zoom out mode: using the right mouse button to draw the rectangle will make the whole plot be plotted within the rectangle.

Fig. Margin

Adjust the marginal spaces and the spaces in between the subplots. It will display a dialog as in Figure 4-3.

Save Fig.

Clicking this button displays a file save dialog to save the current plot in one of these formats: PNG, BMP, PS, EPS, and SVG.

Save Data

Clicking this button displays a file save dialog to save all the curves into a data file, which has special line range indicators to facilitate post process using Excel. The data file can be directly imported into Excel.

Annotation

Clicking this button to activate the annotation capability of P-CARES. The mouse location will be traced as a dynamically updated blue text at the lower right corner of the plot panel. Clicking left mouse button will add the (x; y) coordinates on the plot; if the clicked point is sufficiently close to a point on any curve, a red dot will be placed at that point on that curve (see Figure 4-4). If both axes are in log scale, annotation on curves does not work for a reason unknown to the authors. Annotations cannot be saved into a data file.

Delete Annotation

Clicking this button removes all the annotations on the plot.

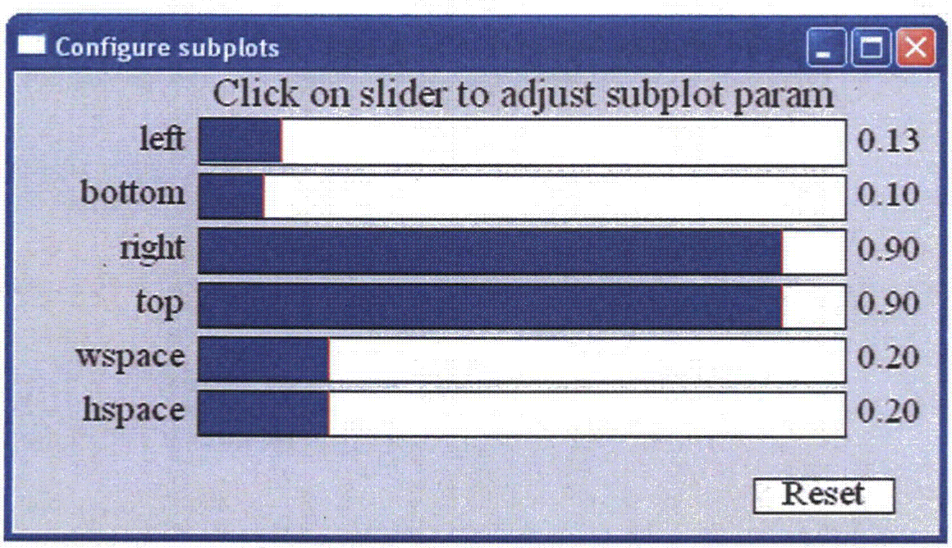


Figure 4-3 Subplot Configuration Dialog

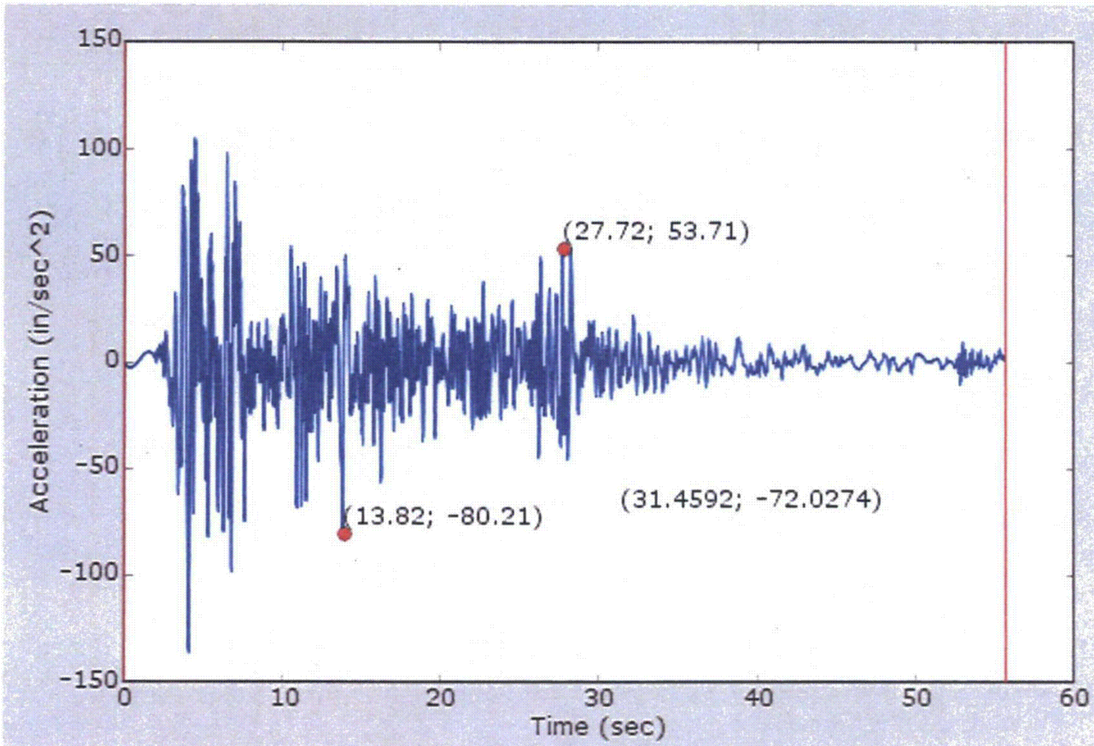


Figure 4-4 An Annotated Accelerogram

4.4.5 Progress Dialog

For some lengthy calculations, such as the probabilistic simulation and the Fekete point set generation, P-CARES displays a progress dialog to instruct the user the state of the calculation and to prevent the user's confusion with a non-responsive program. The progress dialog shows the current iteration number, the total number of iterations for the whole calculation, a progressive bar, the elapsed time, estimated time, and the remaining time for the purpose of reference. The user can cancel the calculation in the middle of the process, but should be aware of the result files are invalid. Alternatively, when the calculation is expected to be completed in a short period of time, a busy mouse pointer will be shown instead of the progress dialog.

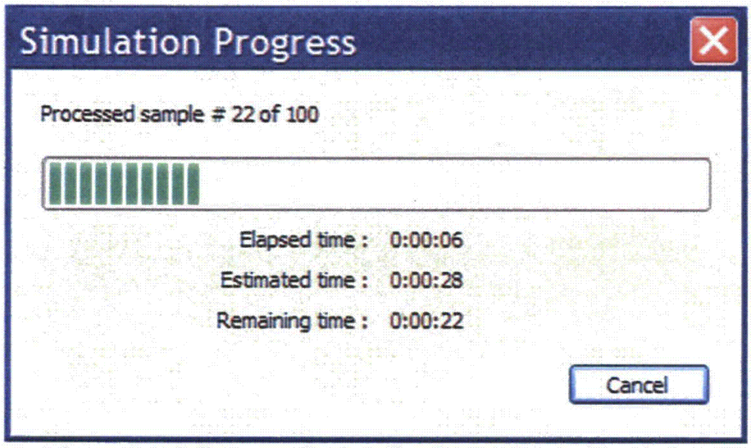


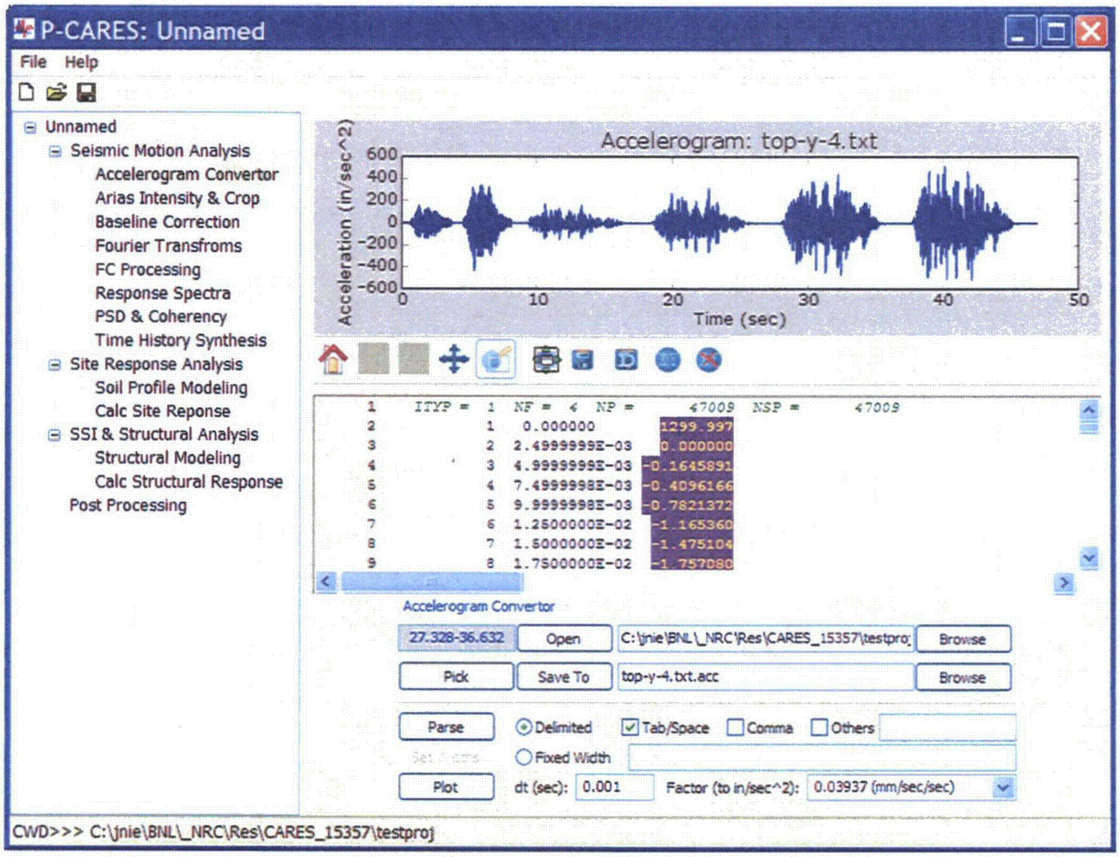
Figure 4-5 A Progress Dialog For Probabilistic Simulation

4.5 Seismic Motion Analysis

This section presents a detailed description of all the utility tools for the seismic motion analysis. The user should refer to Subsection 4.4 for commands not described explicitly in this section.

4.5.1 Accelerogram Convertor

This tool converts a raw accelerogram, either recorded or generated, from a column-oriented text format to the P-CARES format.



Description This utility reads in a raw accelerogram in text format and converts it into the P-CARES format. The control showing the colorized text is the read-only styled text editor, in which texts are not allowed to enter and change. The raw accelerogram file can either be delimited by chars such as Tab and comma, or can define its data fields by fixed widths such as those outputs from a FORTRAN program. The basic procedure is (1) to parse the file to get the colorized fields, (2) to click the acceleration fields in one line, (3) to parse again to select accelerogram data, (4) to set dt and factor and to plot, (5) to pick the desired range for saving, (6) to save to a file. Any line that cannot be parsed into number fields is considered as a comment line. The user can click the gray space after the line number to comment/uncomment a line.

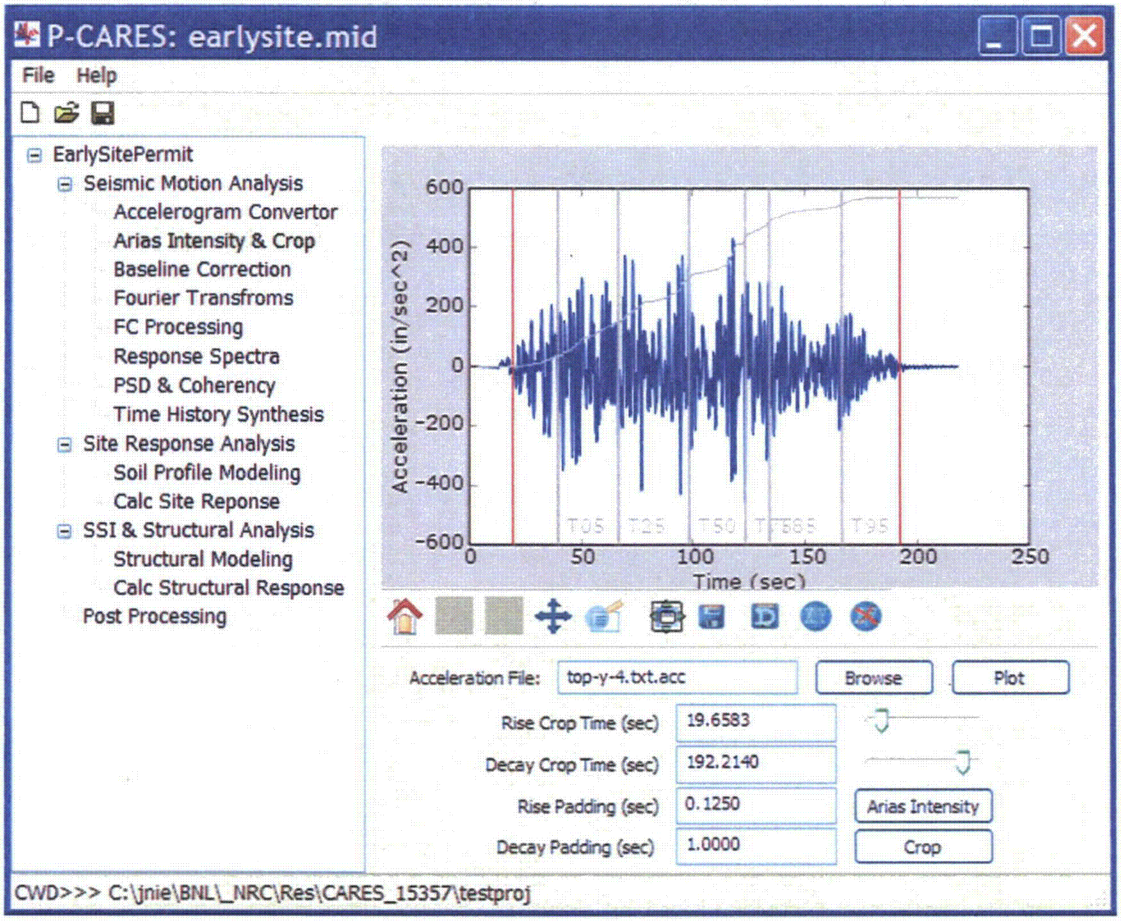
Open Open the file in the read-only styled text editor, provided that a file name has been typed in or browsed in.

Parse When clicked for the first time after the raw accelerogram file is opened, P-CARES uses the current delimiting method and parameters to colorize the data fields and make them clickable. When clicked after the user selects the data fields (one per column is sufficient), P-CARES selects all accelerogram data along each column.

Delimited Select this option, if the raw file is delimited with chars such as Tab, space, comma, and other arbitrary chars.

Tab/Space	Select this delimiter if the raw file is delimited with Tab and/or space.
Comma	Select this delimiter if the raw file is delimited with commas.
Others	Select this if the delimiter in the raw file is none of the Tab, Space, and comma. The user needs to specify the char after this option.
Fixed Width	Select this option if the raw file defines its data field by fixed width, e.g., formatted outputs from a FORTRAN program. If this option is selected, the "Set Widths" button will be enabled. The user can then type a comma separated list of column ids in the text box after this option, and then click the "Set Widths" to update the columns within the styled text editor. The user then needs to parse the raw file to get the colorized and clickable data fields. As a more convenient alternative, the user can use CTRL+F after clicking the styled text editor to activate a column picker function. A yellow popup will show the current position, and clicking at the current position sets a column id and the style text editor dynamically colorizes the current line. Use CTRL+F again to disable this function.
Set Widths	Click this button to refresh the internal column ids in the styled text editor when the Fixed Width option is used.
dt (sec)	Type in the time increment of the raw accelerogram, which can often be found in the first few lines of the raw accelerogram.
Factor	A factor to convert the acceleration unit in the raw accelerogram into in/sec^2, which is used in P-CARES. A few common factors are provided in the drop down list.
Plot	After the acceleration fields are set by parsing twice and the time increment and the conversion factor are set, click this button to plot the time history in the plot panel.
Pick	Click this button to activate the range selection function. When enabled, the user can click and drag in the plot panel to select a range for saving. The selected range will be displayed in the shaded field above this button. Clicking the shaded field to reset the selected range to the whole record.
Save To	Save the selected segment of the raw accelerogram to the file supplied by the user. The output file name is automatically initialized to be the raw file + ".acc"; however the user can provide a different name.

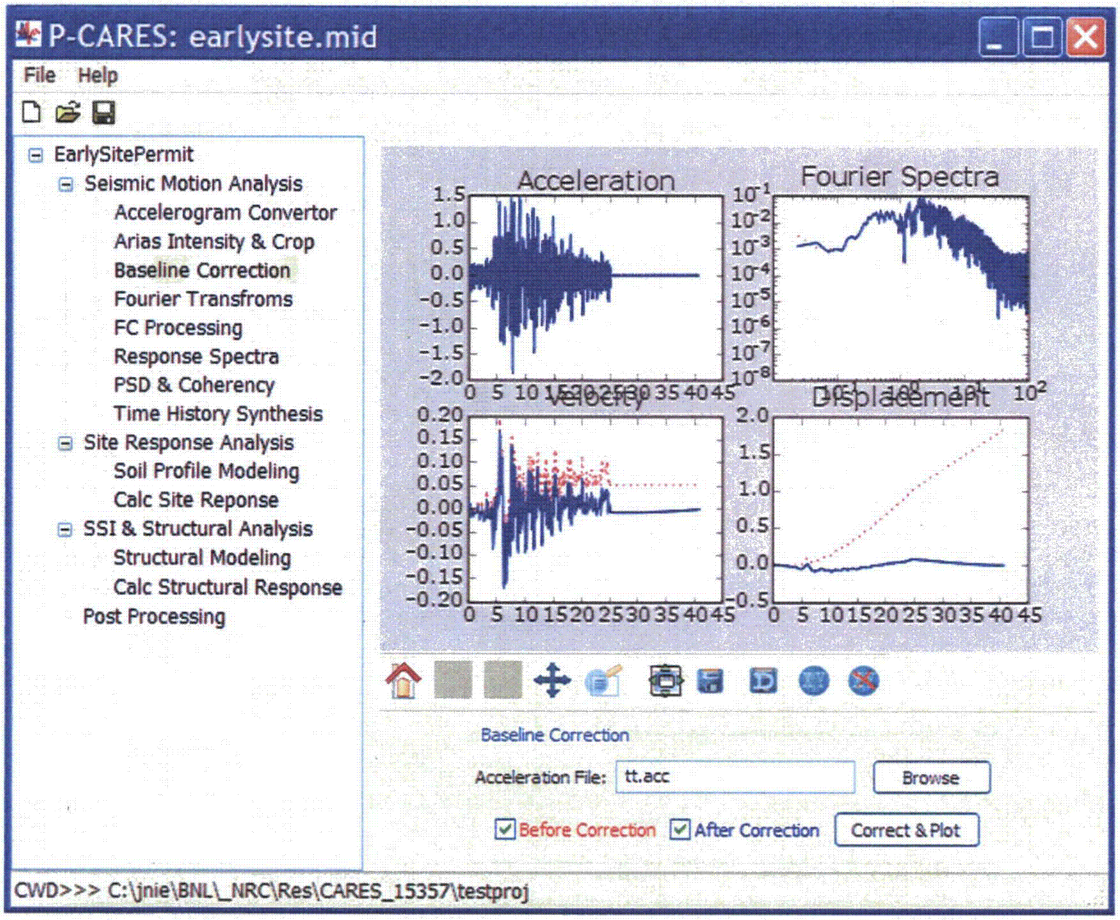
4.5.2 Arias Intensity and Cropping



Description	This utility reads in and plots an accelerogram for inspection. Cumulative Arias Intensity and a few percentile time stations can overlay on the top of the accelerogram. These overlaying curves can work as references in defining the strong ground motion and in cropping an excessively long record.
Plot	After a valid accelerogram file name is entered, clicking Plot button clears the plot panel and then displays the new accelerogram.
Arias Intensity	Clicking this button calculates and plots the cumulative Arias Intensity and some typical percentile locations for reference.
Rise Crop Time	Either the text box or the sliding handle can define the start time where the record would be cut. A vertical red line indicates the start time dynamically on the plot.
Decay Crop Time	Similar to above, but defines the end time.
Rise Padding	Defines the time for zero padding at the beginning of the cropped record.
Decay Padding	Defines the time for zero padding at the end of the cropped record.
Crop	Clicking this button applies the cropping operation using the rise crop time,

decay crop time, rise padding time, and decay padding time defined above. The cropped record is saved to a file under a name according to the general naming convention.

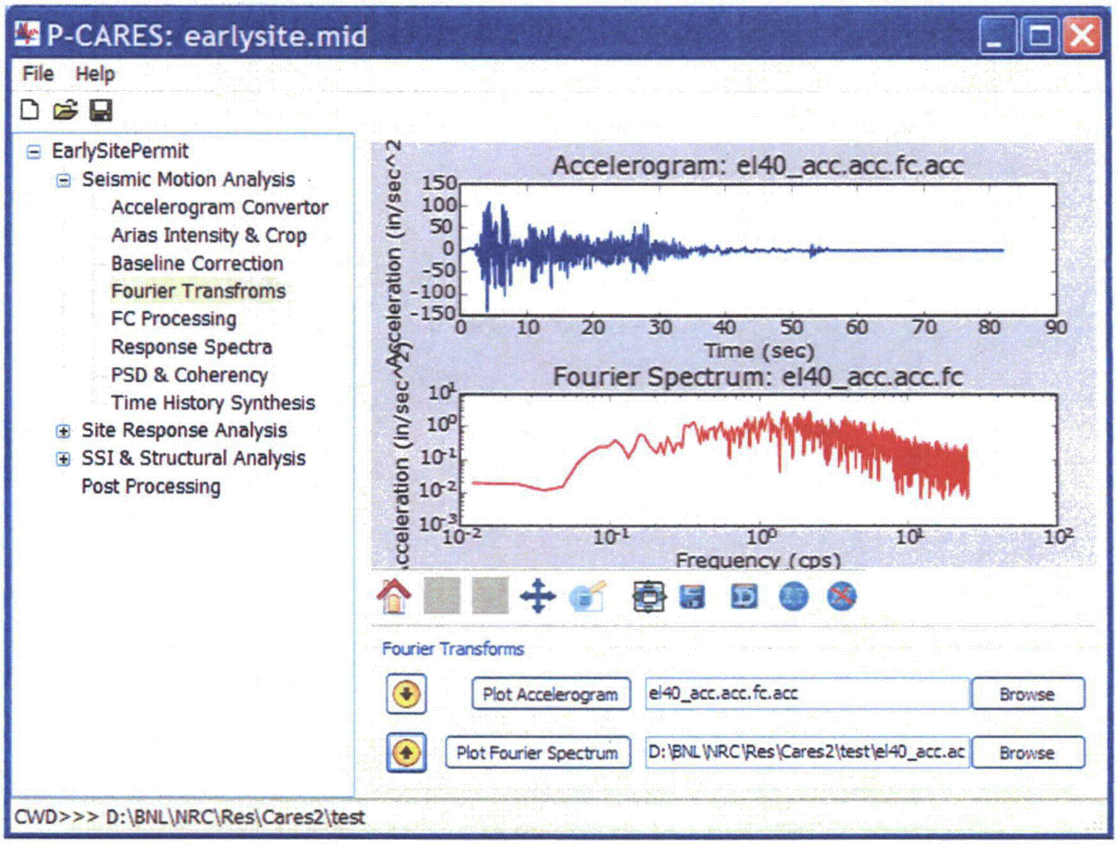
4.5.3 Baseline Correction

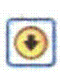


Description	This utility reads in an accelerogram and removes the residual velocity and displacements. It can also plot the accelerogram, Fourier spectrum, velocity, and displacement curves both before correction and after correction. The correction is based on a Lagrange multiplier method (Borsoi, L. and Ricard, A. 1985). The modifications to the accelerogram have been observed minimal, while the residual velocity and displacement can be effectively removed.
Before Correction	A check box opts for the set of curves (dotted red lines) corresponding to the original accelerogram.
After Correction	A check box opts for the set of curves (solid blue lines) corresponding to the corrected accelerogram

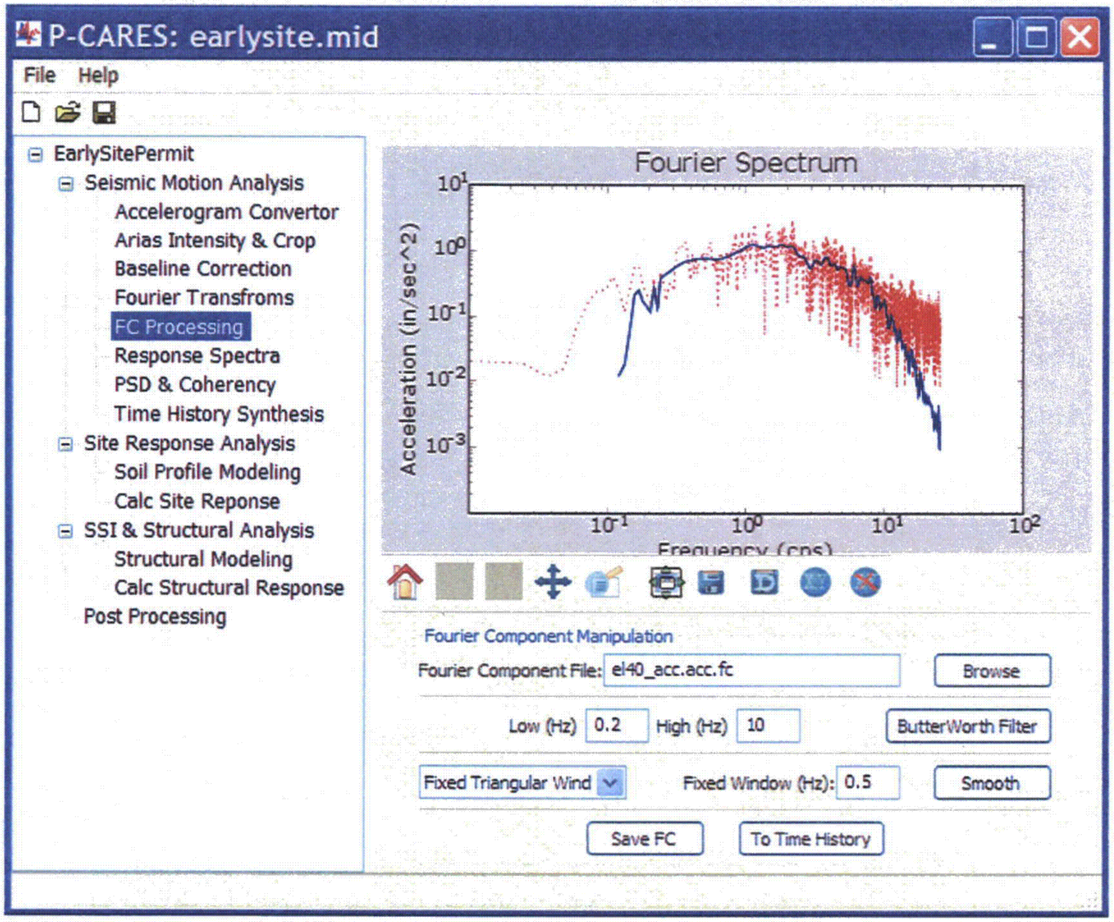
Correct & Plot	Performs the correction calculation and plots the various figures. Please note that although one can plot with different options for any number of times, the correction calculation is only carried out once for each new accelerogram. The corrected accelerogram and the Fourier spectra for both before correction and after correction are saved to files according the general naming convention.

4.5.4 Fourier Transforms



Description	This tool can reads in an accelerogram file or a Fourier component file and displays the pertinent figures. More importantly, it can transform between the time history and the Fourier spectra using FFT, and shows both figures.
Plot Accelerogram	Plot the time history if an accelerogram file is supplied.
Plot Fourier Spectrum	Plot the Fourier spectra in log-log scale if a Fourier component file is supplied.
	Perform the forward FFT and plot both the time history and the Fourier spectra.
	Perform the inverse FFT and plot both the time history and the Fourier spectra.

4.5.5 FC Processing



Description This utility reads in a Fourier component file and plots the Fourier spectrum in dotted red line. The Fourier components can be filtered with the Butterworth filter, and/or be smoothed with a fixed width or varying width triangular smoothing window. The original Fourier spectrum is not affected during both operations. The processed Fourier component curve (solid blue line) can be saved. Both original and processed Fourier component files can be transformed back in to time history using the inverse FFT.

Browse This button differs from the one in the general description by adding actions after the file name is returned. The added actions include clearing the plot buffer and plotting the Fourier spectrum that is just read in.

Low (Hz) A text box defines the low cutoff frequency for the Butterworth filter. Setting it equal to 0 turns off the high pass filter.

High (Hz) A text box defines the high cutoff frequency for the Butterworth filter. Setting it equal to 0 turns off the low pass filter.

Butterworth Filter Applies the Butterworth filter to the current Fourier components, while keeping the original Fourier spectrum intact. If both low and

	high cutoff frequencies are nonzero, this is effectively a band pass filter.
Triangular Window	Either a fixed width window or a varying width window can be specified. If a fixed width window is selected, the user needs to provide the window width in terms of frequency (Hz). If a varying width window is selected, the user needs to provide a percentage p of the center frequency f_0 that will be used to define the window width as pf_0.
Frequency Window (Hz)	Enter the frequency window width in this text box. The shown frequency 0.5 Hz has been used a number of applications and found works fine.
Varying Window (%)	(Not shown) Enter a percentage of the center frequency to define the dynamic frequency window width.
Smooth	Apply the triangular window smoothing.
Save FC	Save the processed Fourier spectra (in solid blue line) to a file under a name determined by the general naming conventions.
To Time History	Using the inverse FFT to transform both the original and the processed Fourier components to individual files. The names of the files follow the general naming convention.

A few examples are presented below to demonstrate the effects of the various operations. The operations taken are explained in the captions of these figures.

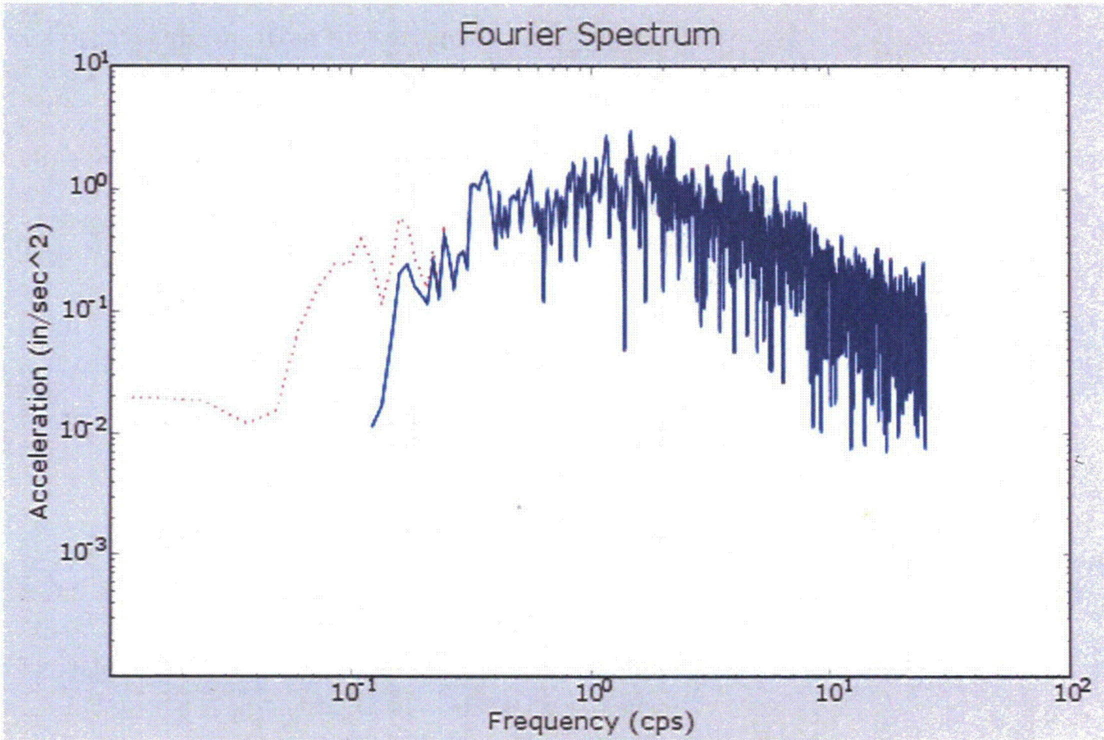


Figure 4-6 After a High Pass Butterworth Filtering (low=0.2 Hz)

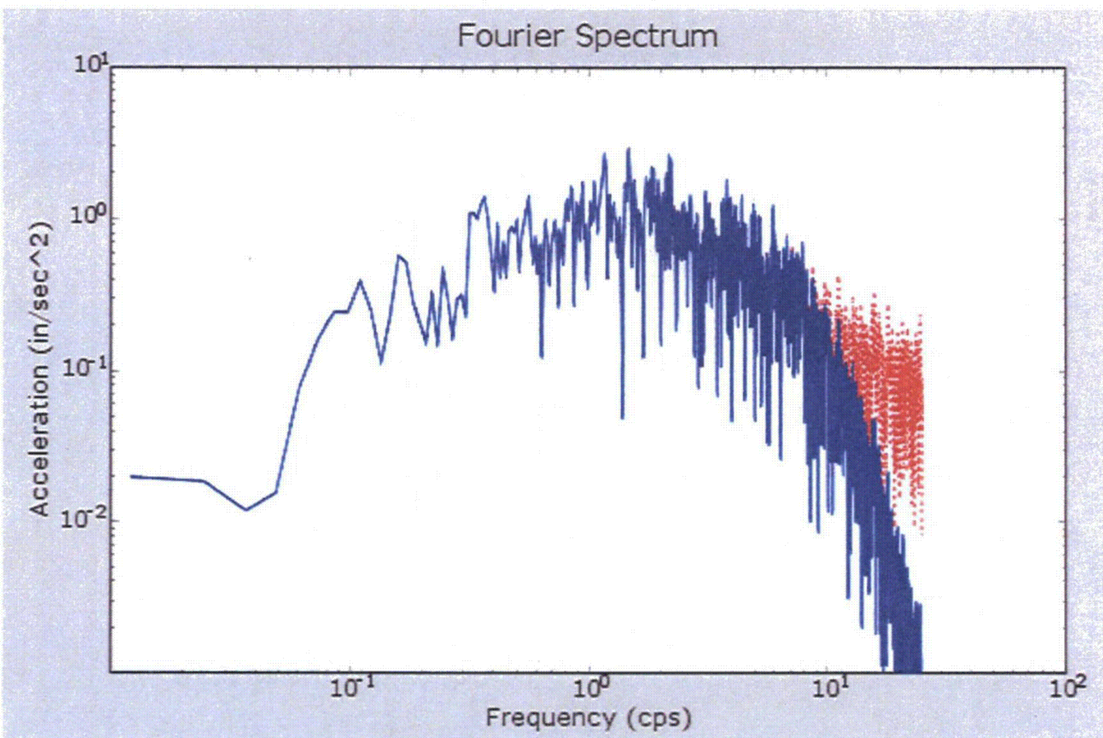


Figure 4-7 After a Low Pass Butterworth Filtering (High=10 Hz)

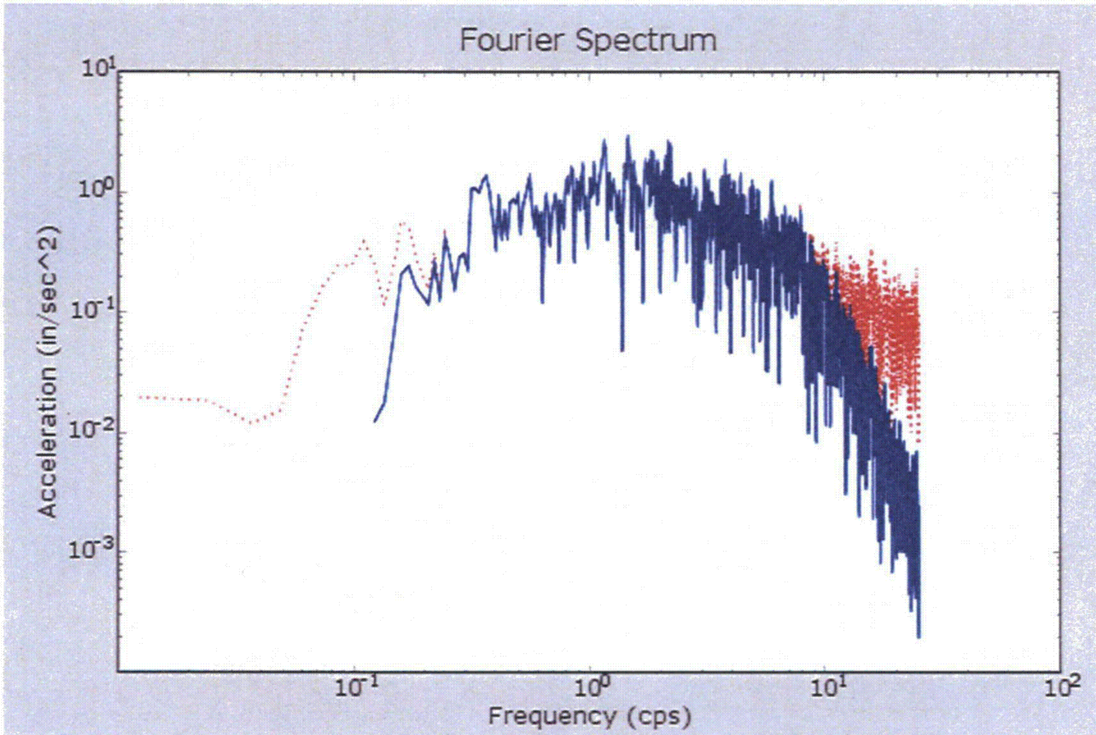


Figure 4-8 After a Band Pass Butterworth Filtering (Low=0.2 Hz, High=10 Hz)

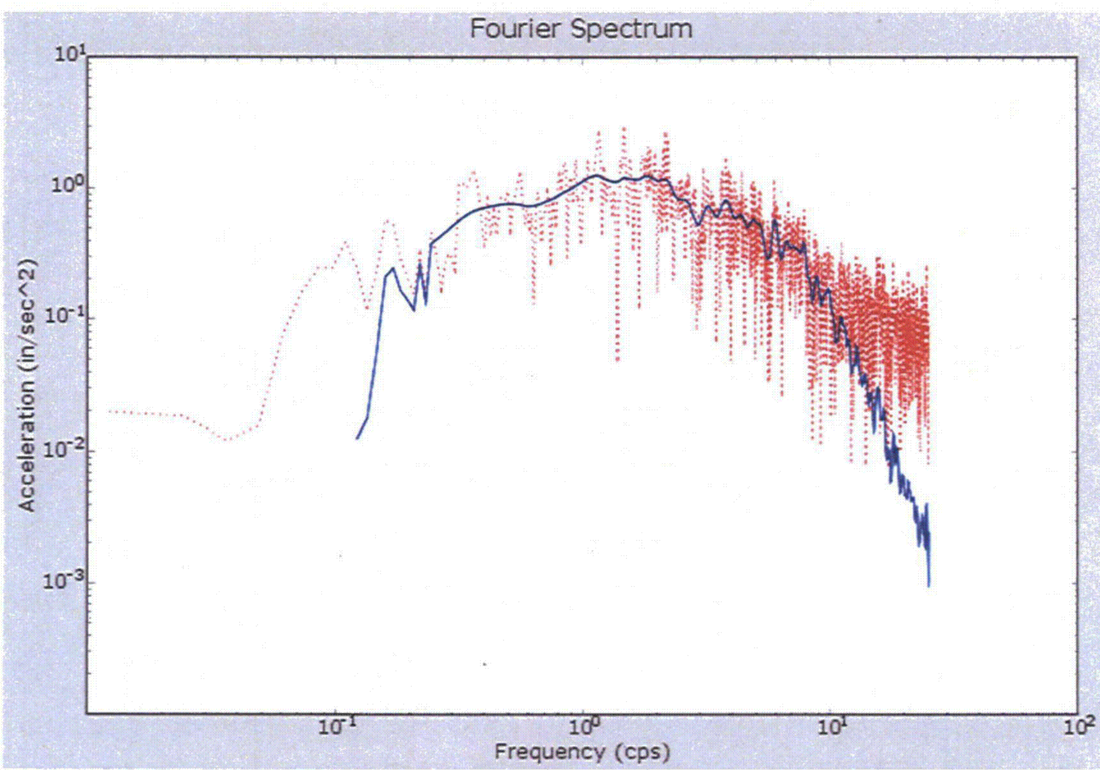


Figure 4-9 After Smoothing (fw=0.5 Hz) and Band Pass Filtering (Low = 0.2 Hz, High=10 Hz)

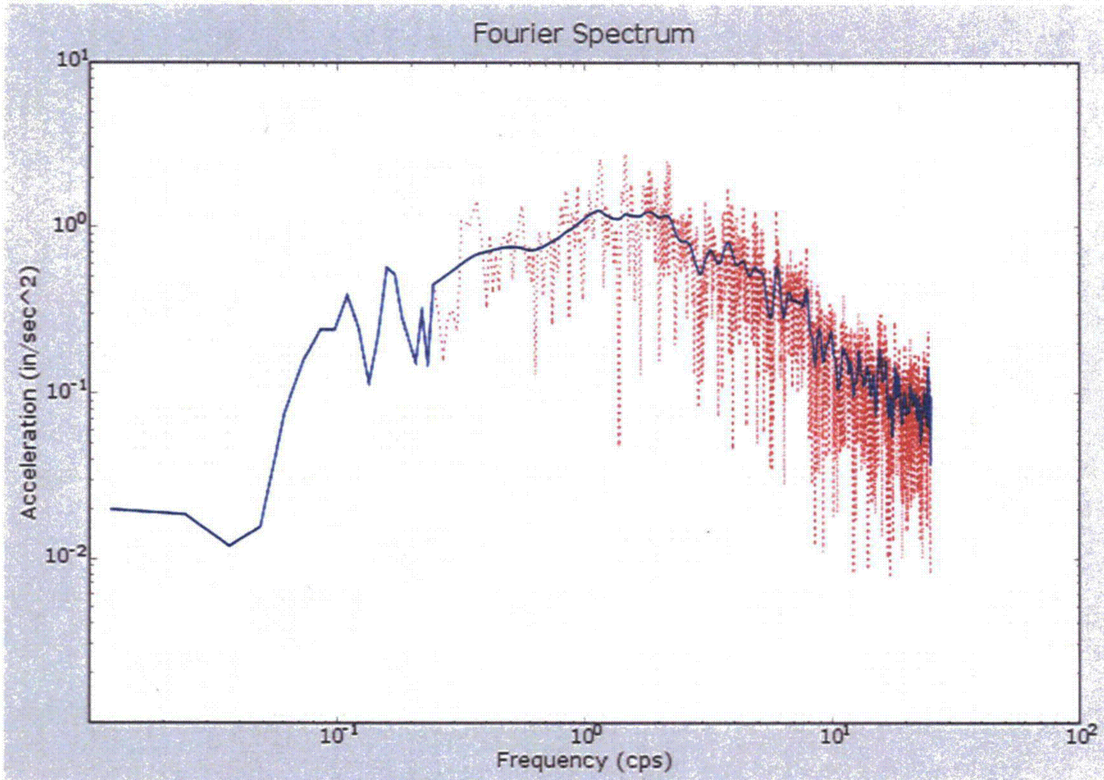


Figure 4-10 After a Fixed Width Window Smoothing (fw=0.5 Hz)

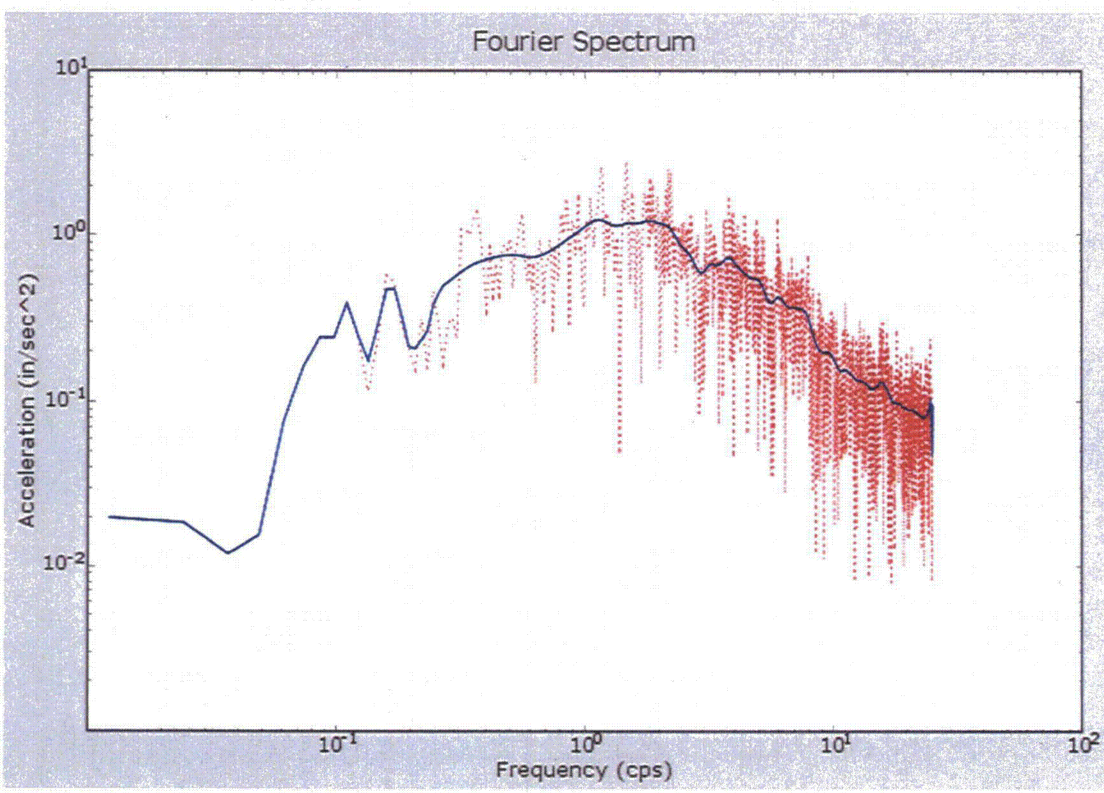
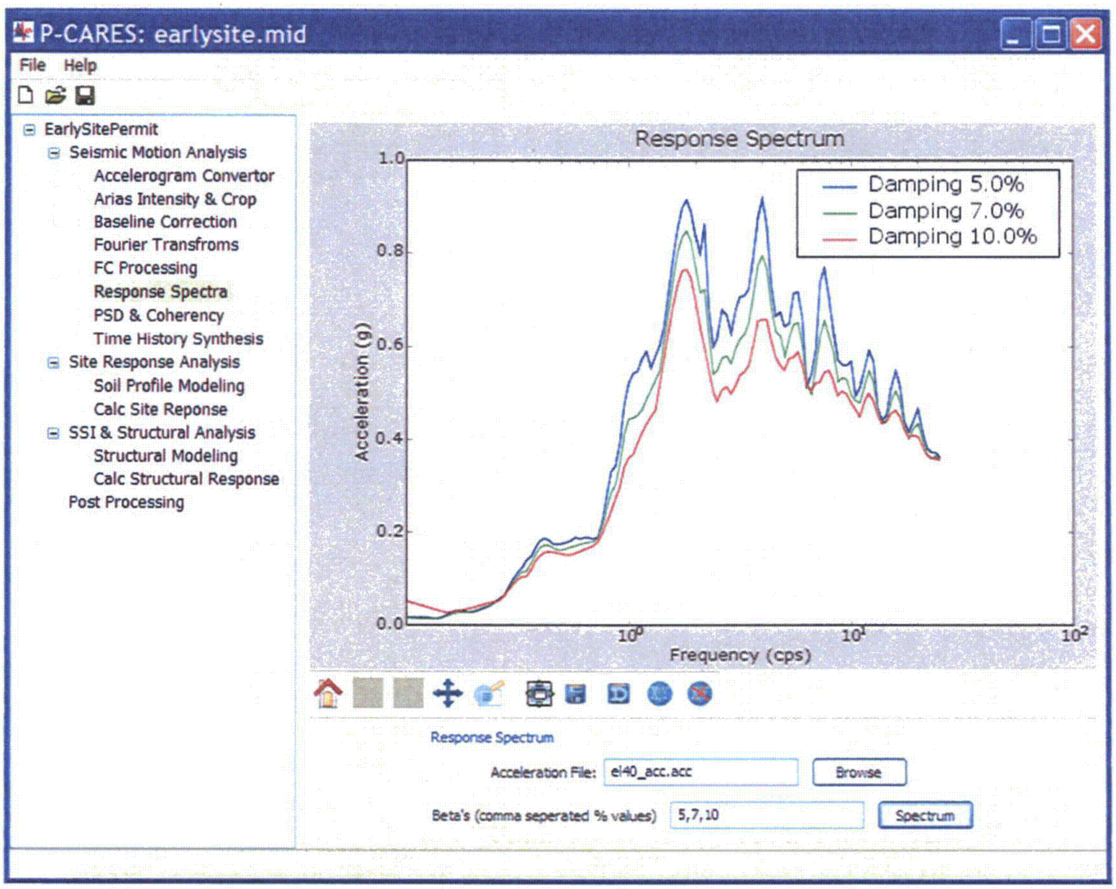


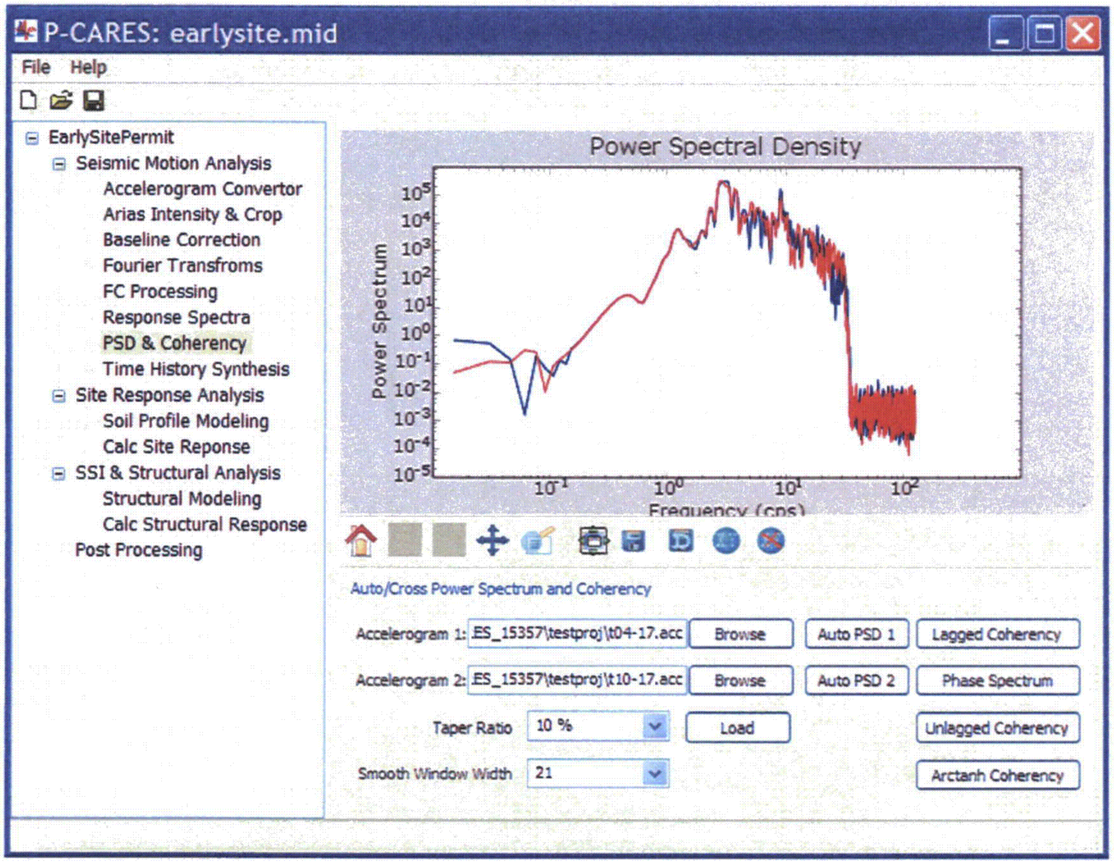
Figure 4-11 After a Varying Width Window Smoothing (fw=20% f_c)

4.5.6 Response Spectra



Description	This utility reads in an accelerogram and generates the response spectra plot for various user-specified dampings. The response spectra curves are identified by different colors and a legend. The generated response spectra are automatically saved to individual files using the general file naming convention. For example, three response spectra files generated in the figure above are el40_acc.acc.rs5, el40_acc.acc.rs7, and el40_acc.acc.rs10.
Beta's	The user can specify an arbitrary number of damping values in a comma separated format.
Spectrum	Clicking this button generates the response spectra, and saves the curves to files.

4.5.7 PSD and Coherency



Description	This utility reads in one or two accelerograms, applies a split cosine bell taper function on them, smoothes their Fourier spectra with Hamming's window, and generates auto power spectra and various coherency plots.
Taper Ratio	The percentage of the whole accelerogram that will be tapered using a split cosine bell function. Half of this ratio is applied at both the beginning and the end of the record.
Smooth Window Width	The number of points of the Hamming's window. This number has to be an odd number and can only be selected from the drop down list.
Load	Clicking this button reads in the accelerograms, applies the taper function to them, transforms them to Fourier spectra using FFT, smoothes the Fourier spectra using the Hamming's window, and generates the auto power spectrum density and the coherency.
Auto PSD 1	Plot the auto power spectrum density for the first accelerogram.
Auto PSD 2	Plot the auto power spectrum density for the second accelerogram.
Lagged Coherency	Plot the lagged coherency.
Phase Spectrum	Plot the phase spectrum of the coherency.

Unlagged Coherency	Plot the unlagged coherency.
Arctanh Coherency	Plot the arctanh coherency.

Examples of the four kinds of coherency plots are shown in the following figures.

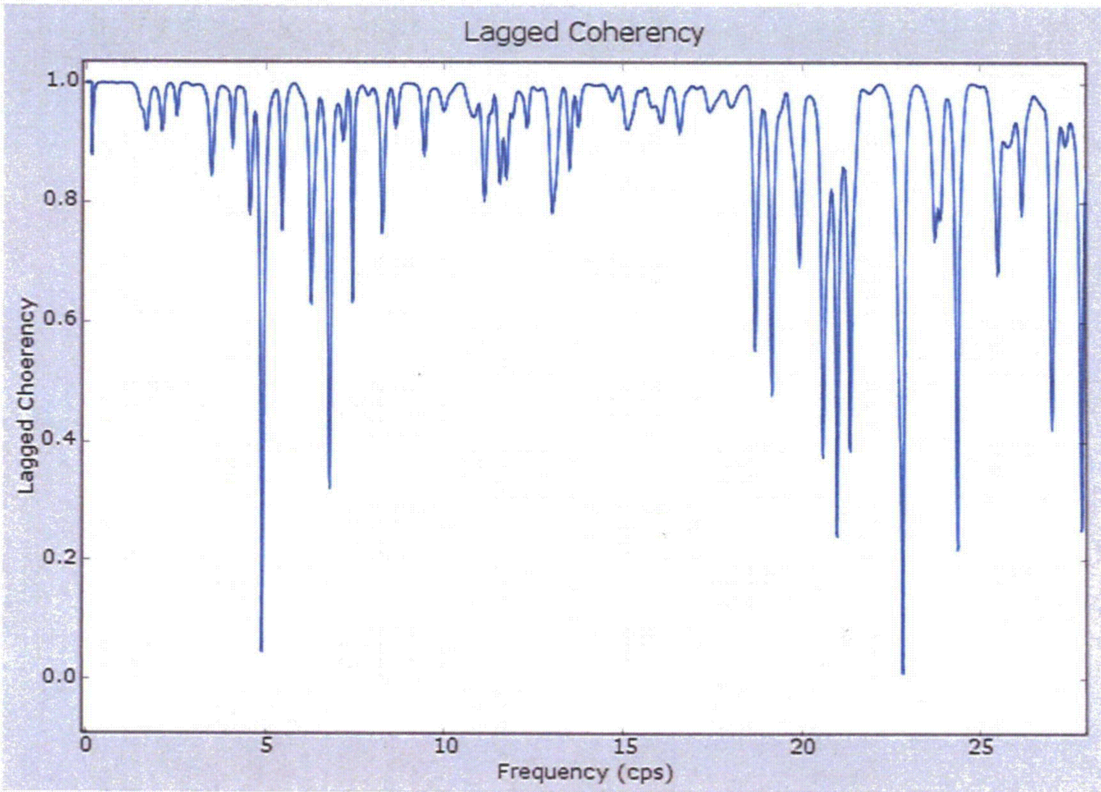


Figure 4-12 Example of Lagged Coherency

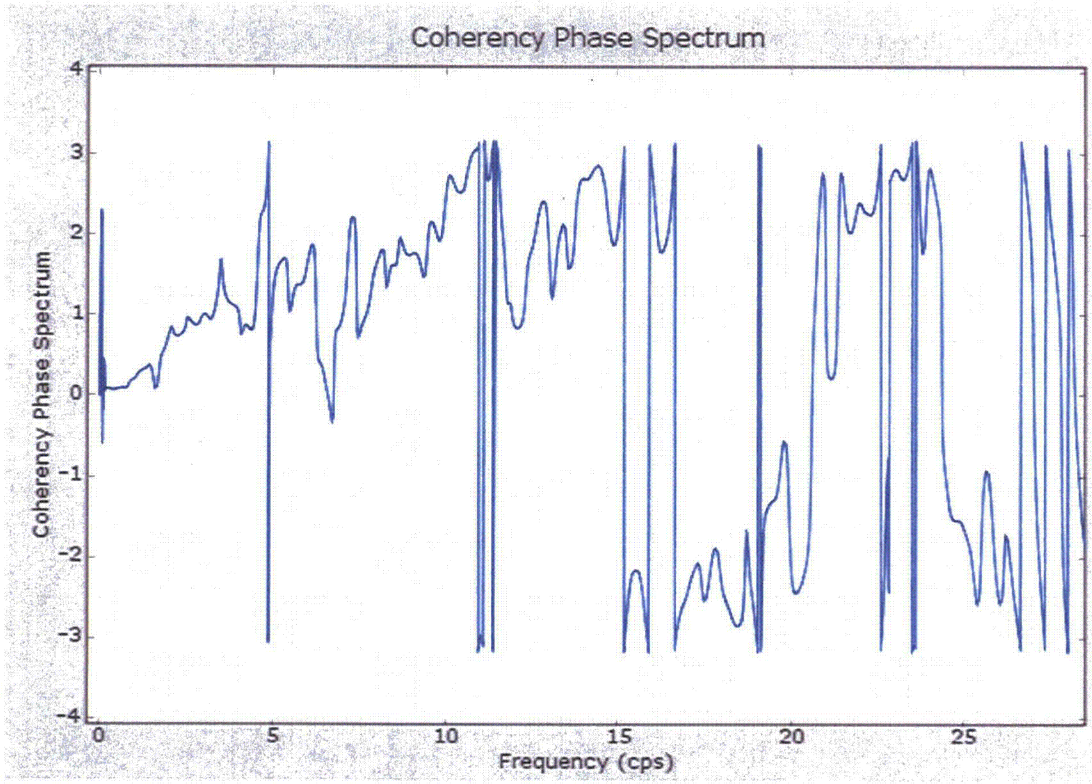


Figure 4-13 Example of Phase Spectrum

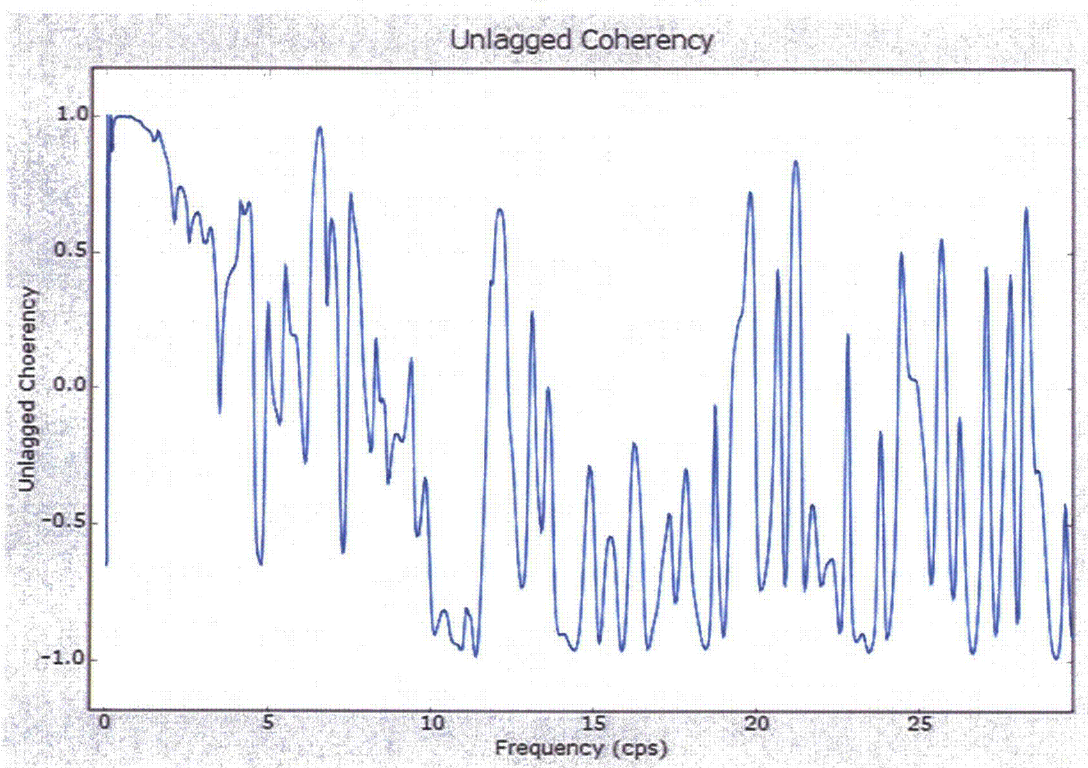


Figure 4-14 Example of Unlagged Coherency

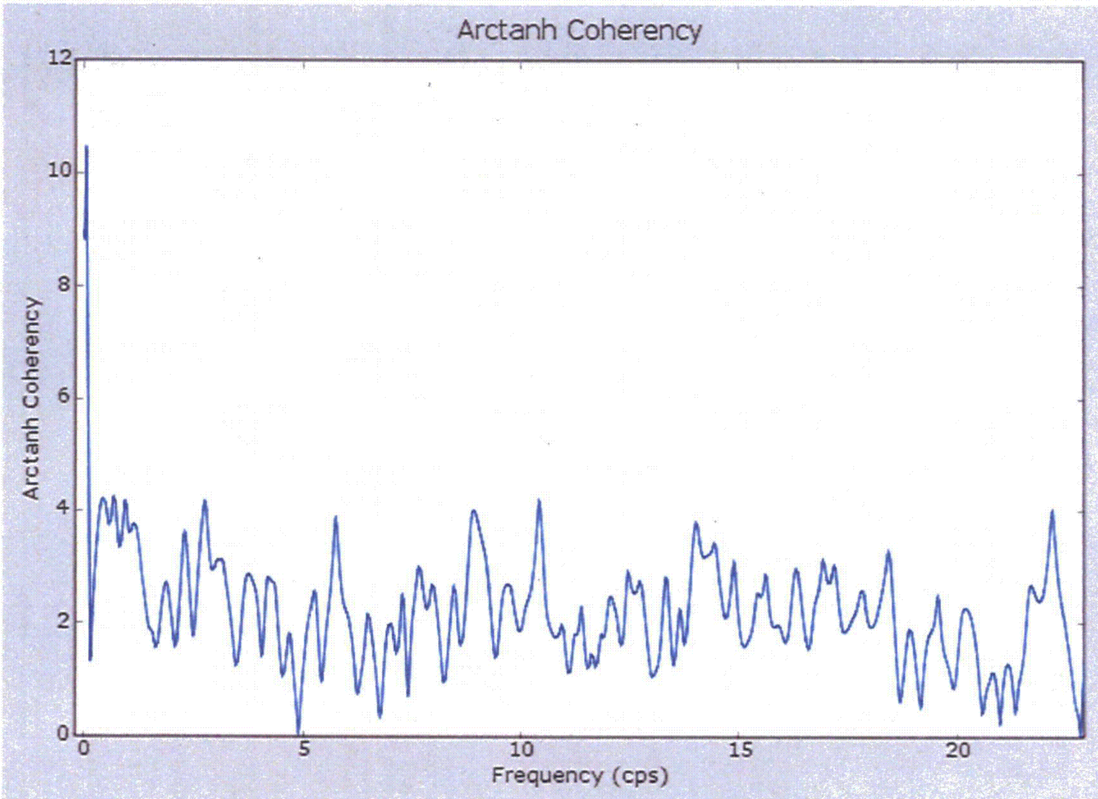
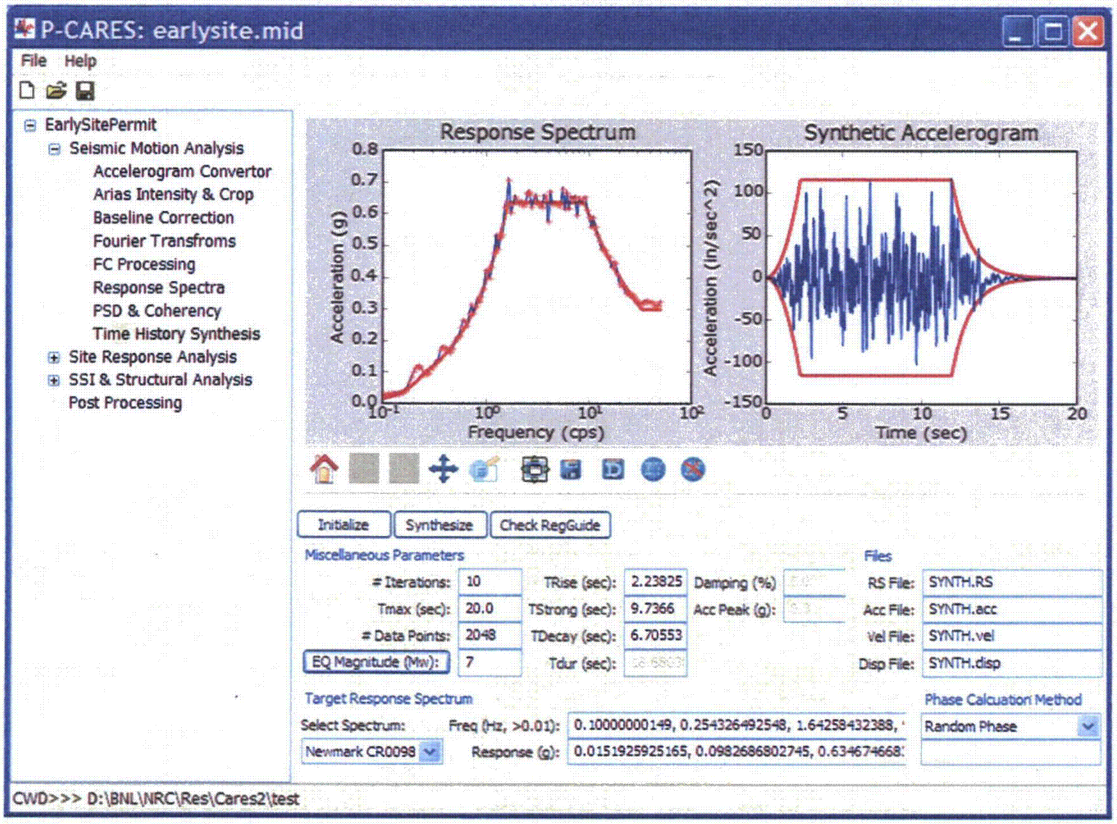


Figure 4-15 Example of Arctanh Coherency

4.5.8 Time History Synthesis



Description

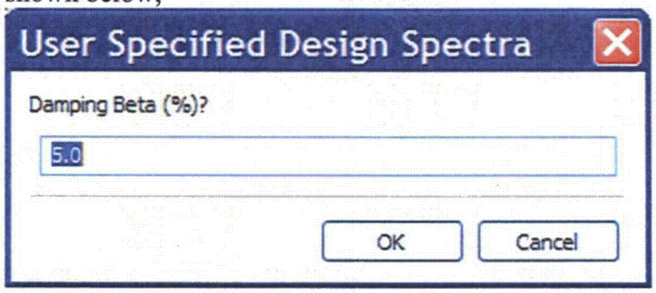
This utility generates an accelerogram that matches a target response spectrum. The shape of the synthetic accelerogram is modified by an envelop function to make it closer to a realistic record. The parameters defining the envelop function can be initialized by using the user-specified earthquake magnitude estimate *M* and be modified as desired. The record is also automatically baseline-corrected and enveloped by the maximum peak ground acceleration, which is defined by the last point of the target response spectrum. The response spectrum of the synthetic accelerogram is plotted over the target response spectrum after specified iterations of generation, and the synthetic time history is plotted with the envelop function. The response spectra are linearly interpolated in the log-log scale.

The user needs to first select a spectrum predefined in P-CARES or to type in a spectrum. A phase calculation method is initially the random phase method but can be chosen as reading from a Fourier spectra or a time history. After providing other parameters, the user can initialize the synthesis process and then apply the specified number of iterations by clicking the "Synthesize" button. The user can also click "Check RegGuide" button to validate the generated time history against the requirement of RegGuide 1.60. If the generated synthetic accelerogram is not satisfied, additional iterations can be performed by clicking the "Synthesize" button for more than one times, or the generation process can be re-initialized with a new set of phase angles if the random phase generation method is selected.

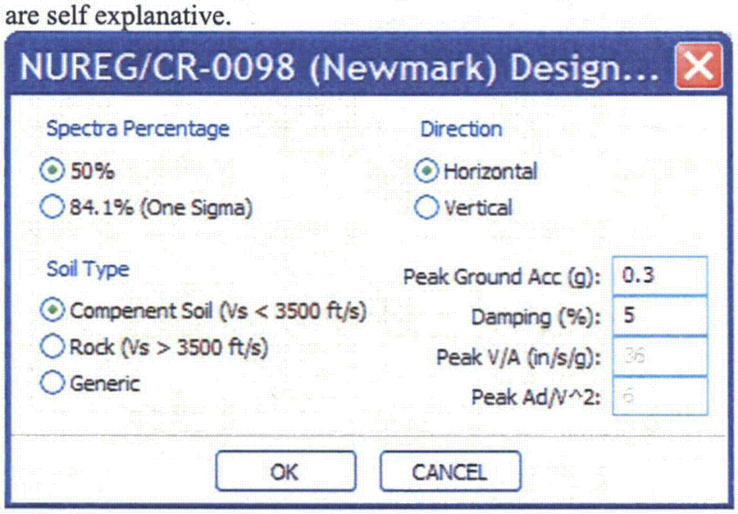
Select Spectrum

Select a predefined target spectrum or type in a spectrum if the "User specified" option is selected. Selecting a predefined spectrum will automatically fill in the input boxes for frequencies and the spectrum values.

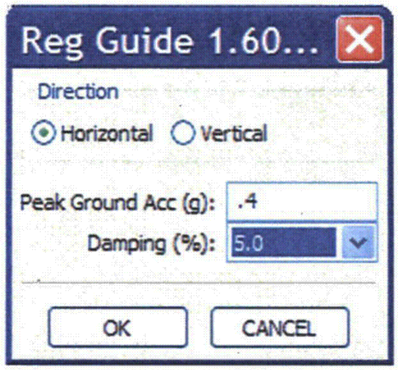
If "User specified" is selected, the user is prompted to provide a damping value and P-CARES also expects the user to type in the frequencies and the response spectral values in the input boxes. The dialog for the damping is shown below,



If the "Newmark CR0098" option is selected, a dialog as in the following is shown for the user to select or provide various parameters to define a Newmark CR0098 spectrum. The parameters required in the following dialog are self explanative.



If the "Reg Guide 1.60" option is selected, a dialog as shown in the following prompts the user to select parameters to define a Regulatory Guide 1.60 spectrum. There are only 5 different damping values are available.



Phase Calculation Method Three methods are available to define the phase angles for the synthetic time history. The first method uses a sequence of randomly generated phase angles, the second method reads in the phase angles from an existing Fourier spectra file, and the third one reads in an accelerogram file and uses FFT to generate the phase angles. When the last two options are selected, a file browser will be shown for the user to select a file. For compatibility, Tmax and the number of points will be set equal to those from the file for the last two options.

 # Iterations The number of iterations to be performed for each click of the "Synthesize" button.

Tmax The maximum duration of the synthetic time history. If the phase angles are read from a Fourier spectra file or a time history file, the Tmax will be the same as the existing record and cannot be modified.

 # Data Points The number of points used for the time history. It must be a power of 2. If the phase angles are read from a Fourier spectra file or a time history file, the number of points is fixed to that of the record and cannot be modified.

EQ Magnitude Enter in the text box an earthquake magnitude estimate M and click this button to calculate the rise time, strong motion duration, and the decay time, which however can be modified. The duration time is simply the summation of these three periods.

Damping Different target spectrum uses different ways to define the damping. This is not editable.

Acc PGA It refers to the last response spectral value in the target spectrum. This is not editable.

Files File names for the synthetic time history, including the acceleration, velocity, displacement, and the response spectra. These files are automatically saved at the end of each click of the "Synthesize" button.

Initialize Initialize the synthesis process after all parameters are set. Clicking this button regenerates the phase angles if a random phase calculation method is used.

Synthesize Applies the specified number of iterations in the generation process. More than one click of this button can be made to apply more iterations. At the end, the synthetic time history and the corresponding response spectrum will be plotted.

Check Clicking this button will check the synthetic time history against the

RegGuide	Regulatory Guide 1.60.

4.6 Site Response Analysis

Clicking the "Site Response Analysis" in the command tree panel shows a window as in Figure 4-16, informing the user the major components of this module. The general procedure for this module is first to prepare the soil column model and SSI model (foundation), and then select the analysis type and perform the calculation. All required information can be entered through a few convenient forms in the soil profile modeling interface. The calculation is highly automated to facilitate the simulation.

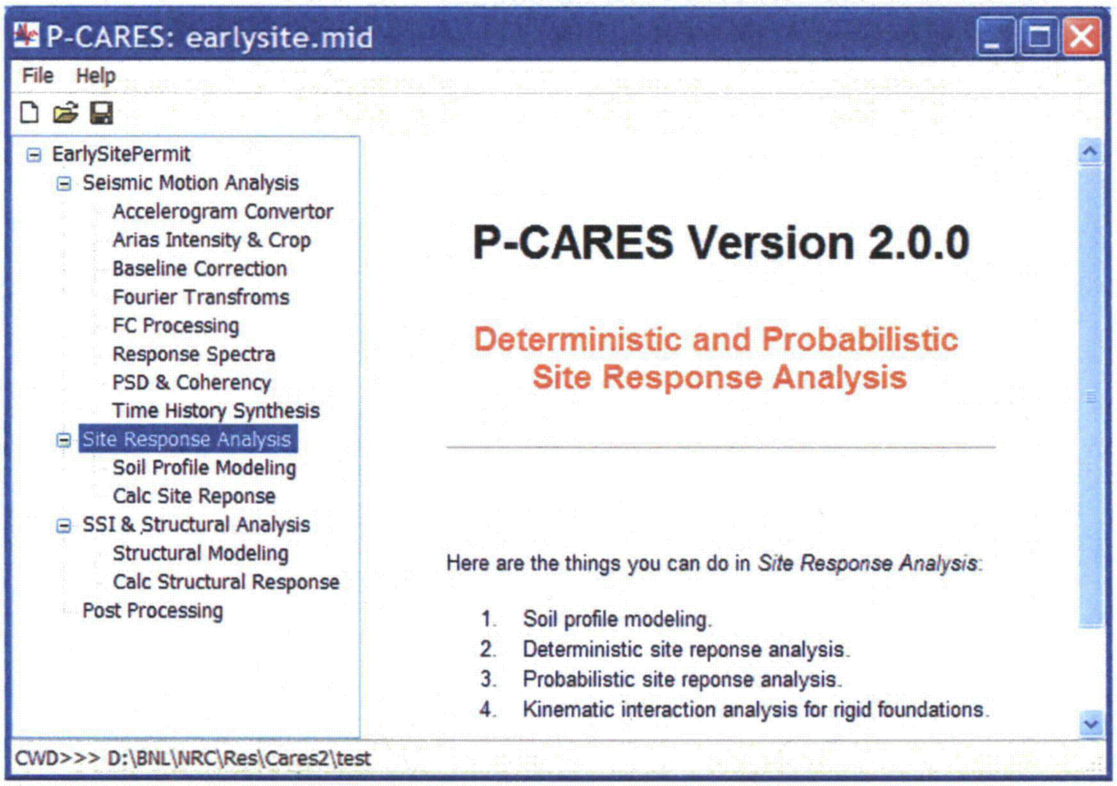
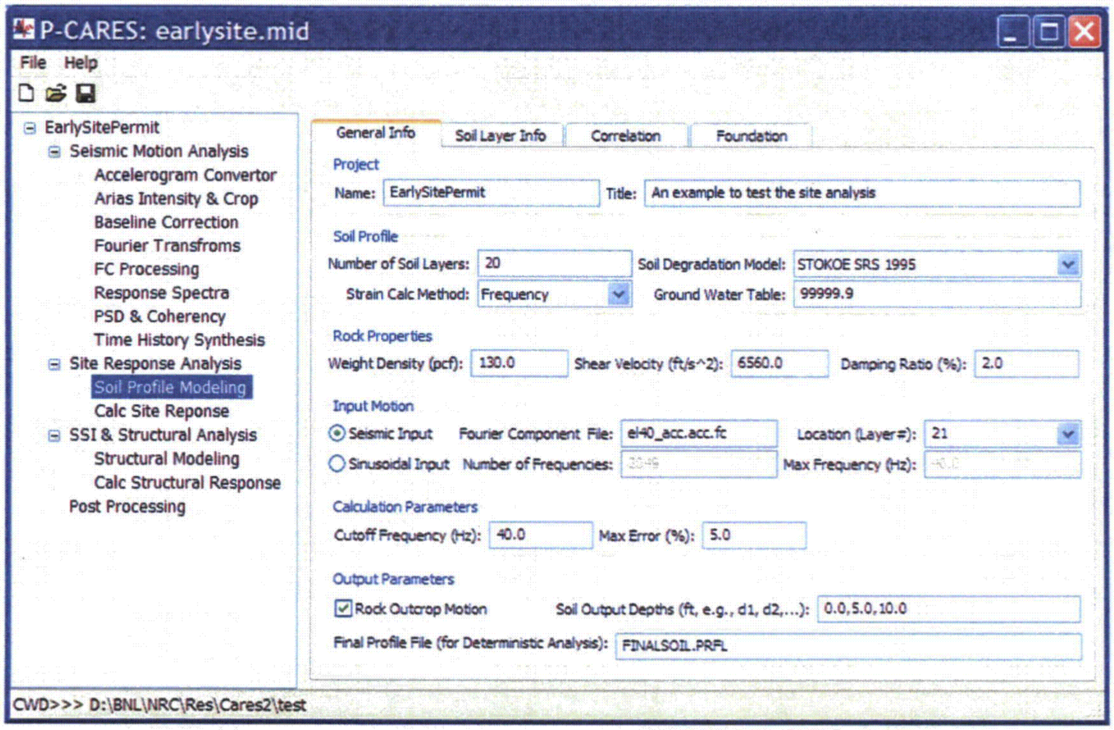


Figure 4-16 Site Response Analysis Interface

There are four forms in the soil profile modeling command. The first one requests the general information of the soil column that is not specific to any soil layers. Through a set of layer navigation commands, the second form can process the soil properties in a layer-by-layer fashion. These layer soil properties include the point values of the layer thickness, low strain soil density, and shear wave velocity for deterministic analysis and the corresponding distribution parameters of these variables for the probabilistic analysis. It also requires the Poisson's ration for SSI analysis. The third form dedicates to assist the layer correlation data input. The fourth form is optional and defines the foundation data if the SSI input motions for the structural analysis is desired. These forms are introduces in sequel in the following.

4.6.1 General Information for Soil Column



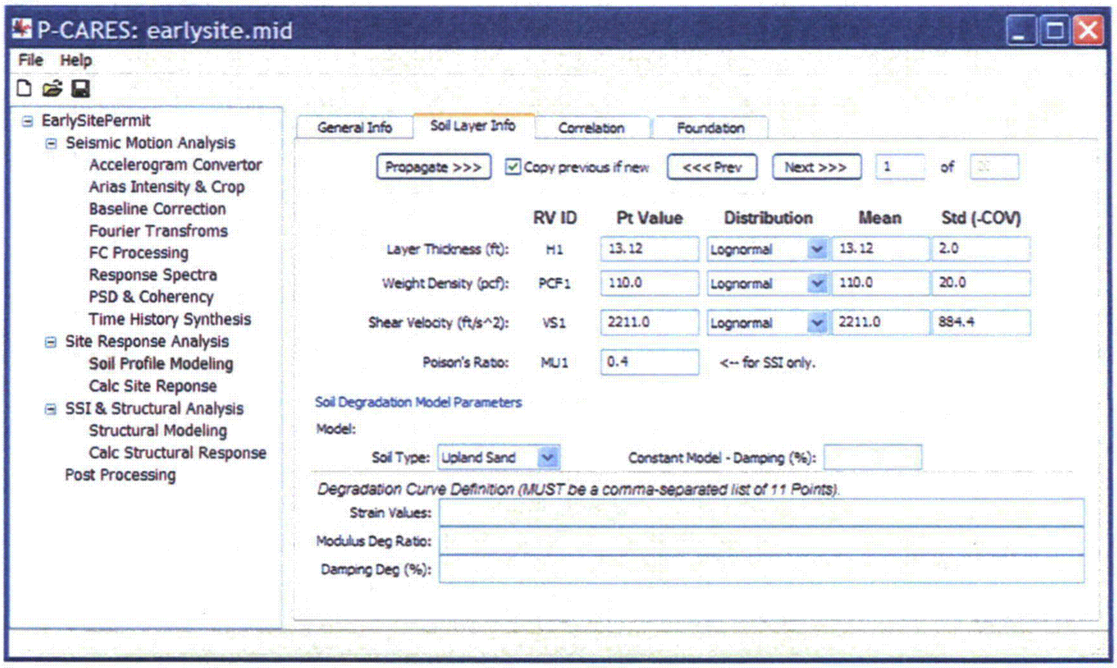
Description	This form accepts user's input for information related to the entire soil column. Related items are grouped together in a rounded box with a blue tag indicating the purpose of the group. The form can dynamically update the status of other items if a changing item incurs other items to change. For example, if the number of layers is changed, the choices for application location of the seismic input motion are updated accordingly. Items irrelevant to the current input data are disabled (grayed out).
Name	The name of the project. It will be displayed at the root of the command tree on the left of the main GUI.
Title	A descriptive string to explain more the nature of current project. It can contain any characters.
Number of Soil Layers	The number of the soil layers in the one dimensional soil column model.
Soil Degradation Model	This is a choice control that provides seven soil degradation models: SEED-IDRISS 1970, IDRISS 1990, GEI ORIGINAL FROM SRS, STOKOE SRS 1995, GEOMATRIX 1990, EPRI-93 COHESIONLESS SOIL, CONSTANT MODEL, and A USER model. The SEED-IDRISS 1970, IDRISS 1990, and the STOKOE SRS 1995 models require the user to provide soil types when defining the soil layer information. The GEI ORIGINAL FROM SRS, GEOMATRIX 1990, and EPRI-93 COHESIONLESS SOIL models determine the soil shear modulus and damping degradation curves by depths and require no more information from the user. The later two requires the user to

	provide the degradation curves for the shear modulus ratio and the damping. This choice updates the options in the soil type in the form for soil layer information.
Strain Calc Method	Specify whether the strain is calculated in the time or frequency domain.
Ground Water Table	The depth to the ground water table (ft). Specifying a big number, e.g. the default value 99999.9, effectively turns off the consideration of water table effect.
Rock Weight Density	Specify the weight density (pcf) of the base rock. If the input motion is not specified at the rock outcrop and no output motions are required for the base rock, all rock properties need not be provided.
Rock Shear Velocity	Specify the rock shear wave velocity (ft/sec/sec) of the base rock. If rock outcrop is not involved in the calculation, this property need not be provided.
Rock Damping Ratio	Specify the rock damping ratio (%) of the base rock. If outcrop is not involved in the calculation, this property need not be provided.
Seismic Input	This option indicates that the type of input motion is a Fourier component file. This option disables the number of frequencies and the maximum frequency controls, which are used for the sinusoidal input option.
Fourier Component File	A valid Fourier component file as the input seismic motion. This file must be in the current project directory.
Location (Layer #)	Specify the layer number at which the seismic motion or sinusoidal input is applied. A layer number 0 means the ground surface, and the number of soil layer plus 1 means the rock outcrop. The user can also select the layer number from the drop down list. For the user's convenience, the ground surface and the rock outcrop always appear at the top of the list.
Sinusoidal Input	This option indicates that the input motion is a series of unit pulses for a range of frequencies defined by the number of frequencies and the maximum interested frequency. This option disables the Fourier Component File text box.
Number of Frequencies	Specify the number of frequencies to be used in the sinusoidal input.
Max Frequency	Specify the maximum frequency (Hz) that the user is interested in for the analysis.
Cutoff Frequency	A cutoff frequency for the strain calculation. A large number effectively turns off the cutoff effect, e.g., the defaut value 0f 1000 Hz.
Max Error	The allowable maximum relative error (%) in strain calculation.
Rock Outcrop Motion	A check box to signify that the rock outcrop motion is requested for output. The rock outcrop motion is only available for a deterministic analysis. The output file name is "ROCKOUTCROP.FC".

Soil Output Depths A list of comma-separated depths (ft) in the soil deposit for the soil output motion, e.g., 0.0, 5.0, 10.0. In deterministic analyses, these output motions are saved in individual files under names like "accout#.fc", where # means the sequence number in the output depth list. In probabilistic analyses, these output motions are stored in a database file named "SOILRESPONSE.DB".

Final Profile File The file to store the final soil profile in the deterministic soil convolution analysis. If a probabilistic analysis is performed, the final profiles are stored in a database file named "SOILPROFILE.DB".

4.6.2 Soil Layer Information



Description This form allows the user to specify the layer properties though a set of convenient navigation commands. The required layer properties include the layer thickness, weight density, low strain shear wave velocity, and the soil type. If kinematic interaction analysis is included in the site response analysis, the user needs to supply the Poisson's ratio as well. If a deterministic analysis is to be performed, the user does not need to specify the distribution information (distribution, mean, and standard deviation). Controls related to the layer properties will be described first in the following, and the description of the navigation commands will be provide after.

RV ID The first three identifiers in this column are the variable names used to identify uniquely the layer thickness, weight density, and shear wave velocity for all layers. The fourth identifier indicates the Poisson's ratio. These identifiers are not editable.

Pt Value — The first three values in this column are the point values for the layer thickness (ft), the weight density (pcf), and the shear wave velocity (ft/sec/sec), which are used in deterministic analysis. These values often equal the mean values, however can take any values for the purpose of parametric studies. The Poisson's ratio is used in the kinematic interaction analysis.

Distribution — This column presents the distribution types as choice controls. Although all random variables are currently assumed of lognormal distribution, implementing these items as choice controls in the GUI facilitates the future adoption of other probabilistic models.

Mean — This column contains the mean value input boxes for the layer thickness (ft), the weight density (pcf), and the shear wave velocity (ft/sec/sec).

Std (-COV) — This column includes the standard deviations for the layer thickness (ft), the weight density (ft), and the shear wave velocity (ft/sec/sec). If a negative number is entered, it is interpreted as the coefficient of variation (COV), and is replaced by the calculated standard deviation. (Std = COV * Mean).

Soil Type — A choice box to specify the type of soil for the current layer. The available choices in this box are determined by the current soil degradation model, which is located in the general information form. This item may be disabled if the soil degradation model does not need a soil type. If the soil degradation model is Seed-Idriss 1970 model or Idriss 1990 model, the available choices are "Sand" and "Clay". The available soil types for Stokoe SRS 1995 model are "Upland Sand", "Tobacco Road", "Dry Branch", "Shallow Clay", "Deep Sand", and "Deep Clay". All other models do not require this choice.

Constant Model = Damping (%) — If the constant soil model is chosen, the user needs to supply a damping value for each layer. The damping and the shear modulus do not change as the strain varies in this model.

Strain Values — If the user soil model is chosen, the user is required to provide the degradation curves for the shear modulus and the damping, which are represented by comma-separated list of 11 values. Use this box to define the strain values. The list of strain values are shared by all layers.

Modulus Deg Ratio — If the user soil model is chosen, use this box to define the 11 values for the degradation ratio on the shear modulus degradation curve. The maximum value of 1 represents the low strain soil.

Damping Deg (%) — If the user soil model is chosen, user this box to define the 11 damping values for the damping degradation curve.

Propagate>>> — Clicking this button propagates the properties of the current layer to all layers below. This is a way to quickly initiate all layer properties.

<<<Prev — Proceed to the previous layer and retrieve its layer properties.

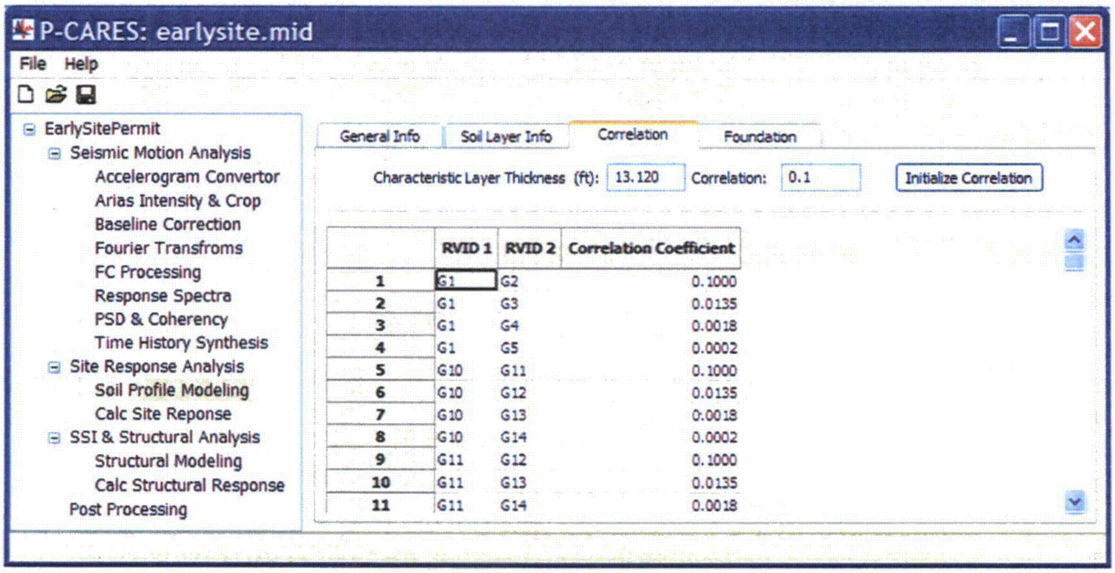
Next>>> — Proceed to the next layer and retrieve its layer properties.

Copy previous if new — If checked, clicking **Next>>>** will copy the current layer properties to the next layer, however only if the next layer is blank.

Current Layer — The editable text box without a label contains the current layer id. The user

Id can type in a valid layer id and press ENTER to proceed to that layer directly.

4.6.3 Correlation of Random Vector



Description This form provides ways to enter the layer-to-layer correlation coefficients for different random variables. It provides a fast way to populate the table using an exponential spatial rule, and a manual way to add, delete, edit the correlation between any two random variables.

Characteristic Layer Thickness Used for specifying the broadness of the exponential rule. For any two layers with a mid-to-mid distance within the characteristic layer thickness (ft), the correlation coefficient equals the value in the correlation input box; otherwise, the coefficient decays exponentially as the distance grows. This value defaults to the average thickness of all layers using their point values. See theoretic basis section for more information on the exponential spatial rule.

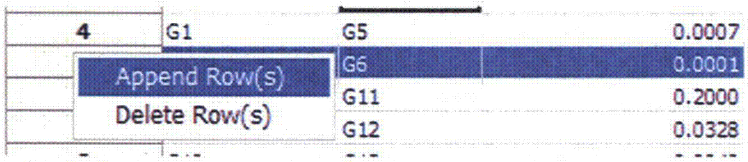
Correlation The maximum coefficient of correlation, with an initial value 0.1.

Initialize Correlation Clicking this button clears the correlation table first, and populates the table with a new set of coefficients according to the exponential rule.

RVID1 This column represents the first random variable in the correlation. Each cell has a drop list for the user to select the random variable id.

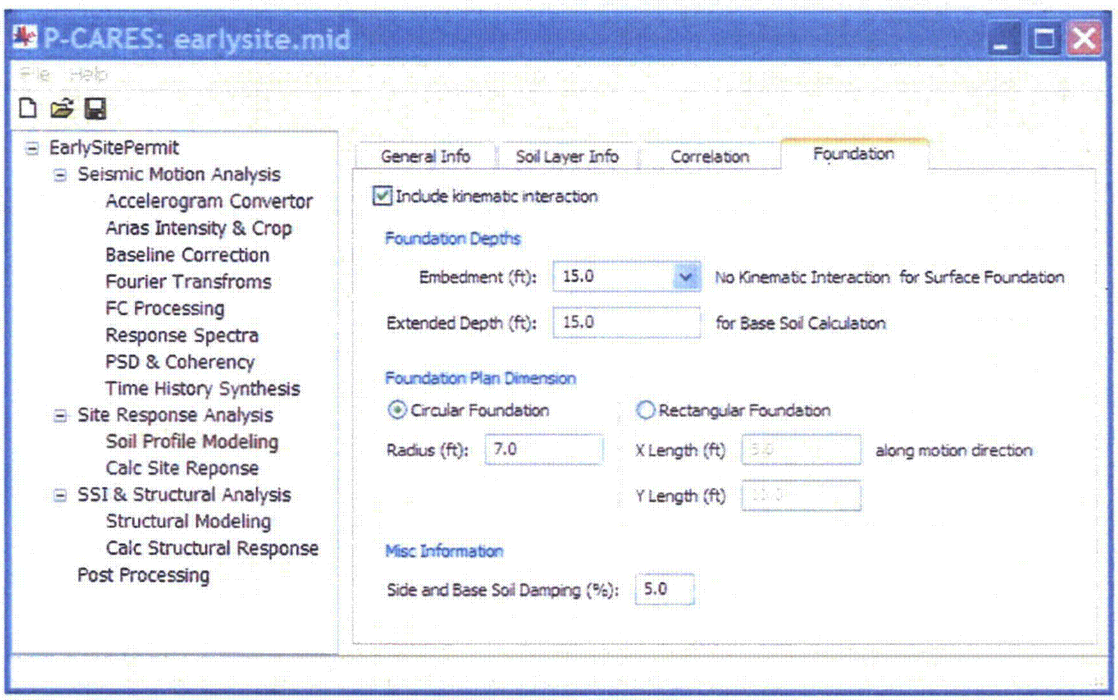
RVID2 Ditto.

Correlation Coefficient A cell accepts a real number for the coefficient.



Description	Right clicking on the left margin brings up a popup menu for manual addition or deletion of rows in the correlation table.
Append Row(s)	If no row is selected, a row will be added after the current row; otherwise, the number of rows added after the current row is the number of selected rows.
Delete Row(s)	Delete the current row if no row has been selected; otherwise, delete all selected rows.

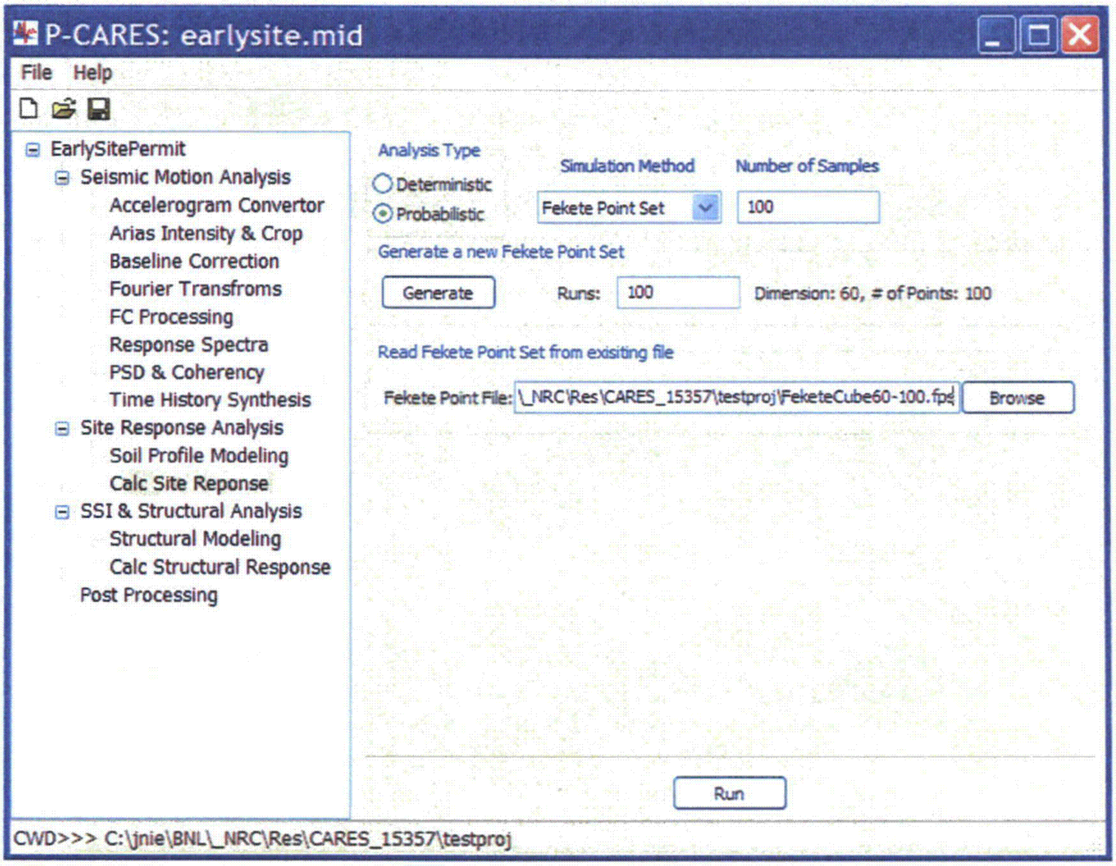
4.6.4 Foundation for Kinematic Interaction



Description	This optional form allows the user to specify whether the SSI motions (translational and rotational motions at the base of the foundation) should be generated. If so, the information about the dimension of the foundation should be provided. A joint SSI analysis should be selected in the SSI & structural analysis module to utilize the generated SSI motions. The files "BASETRAN.FC" and "BASEROT.FC" are used to store the two SSI motions in a deterministic analysis; while a database file "SSIRESPONSE.HDB" is used to store the translational and rotational motions in the probabilistic simulation.
Include Kinematic	A check box to signify that the SSI input motions should be generated

Interaction	for the structural analysis module.
Embedment	A text box for the embedment depth (ft). If the embedment is 0 ft, the surface motion is used as the SSI input motion, and there is no rotational motion.
Extended Depth	The extended embedment depth (ft) is used to calculate the base soil properties from the soil column in kinematic interaction analysis. It is the depth of soil under the basemat of the foundation that will be considered to be the base soil in the SSI context.
Circular Foundation	A radio option control. Clicking it to select the circular foundation type.
Radius	A text box for the radius (ft) of the circular foundation.
Rectangular Foundation	A radio option control. Clicking it to set the rectangular foundation type.
X Length	The length (ft) of the foundation in x direction, which is the particle movement direction.
Y Length	The length of the foundation in y direction, which is perpendicular to the particle movement direction.

4.6.5 Site Response Calculation



Description This command has one form to manage the analysis. The user first selects the type of analysis, and provides the simulation parameters if a probabilistic analysis is activated, and click button Run to start the analysis. A progress dialog will be displayed if a simulation is running (see Figure 4-5). For Fekete point set generation, the dimension means the number of random variables (3 × the number of layers), and the number of points is the number of samples used in the simulation.

Deterministic The radio option "Deterministic" should be selected if a deterministic analysis is desired. Click the button Run to start the analysis. No progress dialog is shown for this analysis. This option disables all other simulation related controls in this interface.

Probabilistic The radio option "Probabilistic" should be selected for a probabilistic site response analysis.

Simulation Method This choice control provides four simulation method, namely Monte Carlo simulation, Latin Hypercube sampling (LHC), Engineering LHC, and the experimental Fekete point set method. For the first three simulation methods, only the number of samples is required; for the Fekete point set method, the user needs to decide either to read from an existing Fekete point set file or to generate a new set. The generated Fekete point set is saved automatically.

Number of Samples	The number of samples used in the simulation.
Runs	The number of iterations used in generating a Fekete point set. It has been determined experimentally that 60 ~ 100 iterations can yields a good Fekete point set (Nie, 2003). However, since the number of points (the same as the number of samples) is typically small in soil structural analyses, more than 100 iterations can be used without a serious concern of performance.
Generate	Clicking this button to start the Fekete point set generation process.
Fekete Point File	The user can use an existing Fekete point set file (e.g., "FeketeCube60-100.fps" as in the picture above).
Run	Clicking this button to start the site response analysis. If a probabilistic analysis is selected, a progress dialog will be shown.

4.7 SSI and Structural Analysis

Selecting "SSI and Structural Analysis" in the command tree panel will activate the structural analysis module including the SSI effect. As shown in Figure 4-17, this module provides the capability to build the structural model and to perform four types of structural analyses. The user should first build a 3-D structural model using the structural modeling command, select the analysis type and provide its related parameters in the structural response calculation panel, and then conduct the intended analysis. For a joint SSI analysis, either a deterministic or a probabilistic analysis, P-CARES automatically transfers the necessary information from the site response analysis to the structural analysis, and the user is not required to manually build this connection.

The structural modeling interface and the structural response analysis interface will be described in the following.

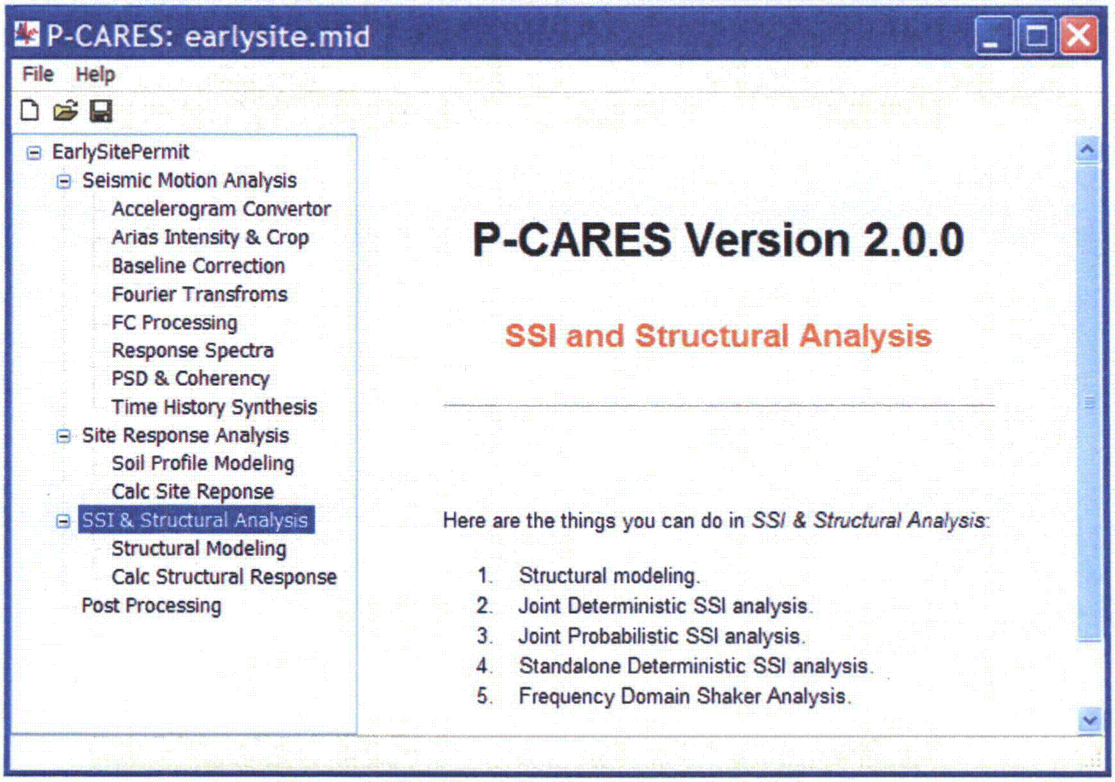
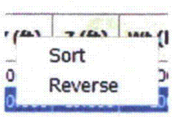


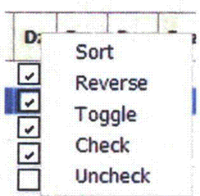
Figure 4-17 SSI and Structural Analysis Interface

4.7.1 Structural Modeling

The four forms for the structural modeling command are the nodes and constraints form, beam form, shear wall form, and the damping form, each of which may contain a few tables (similar to spread sheets). The common behaviors of these grids are introduced in the following.

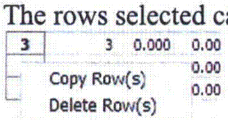
Wherever possible, right clicking the top margin of a table displays either of the following two pop up menus:





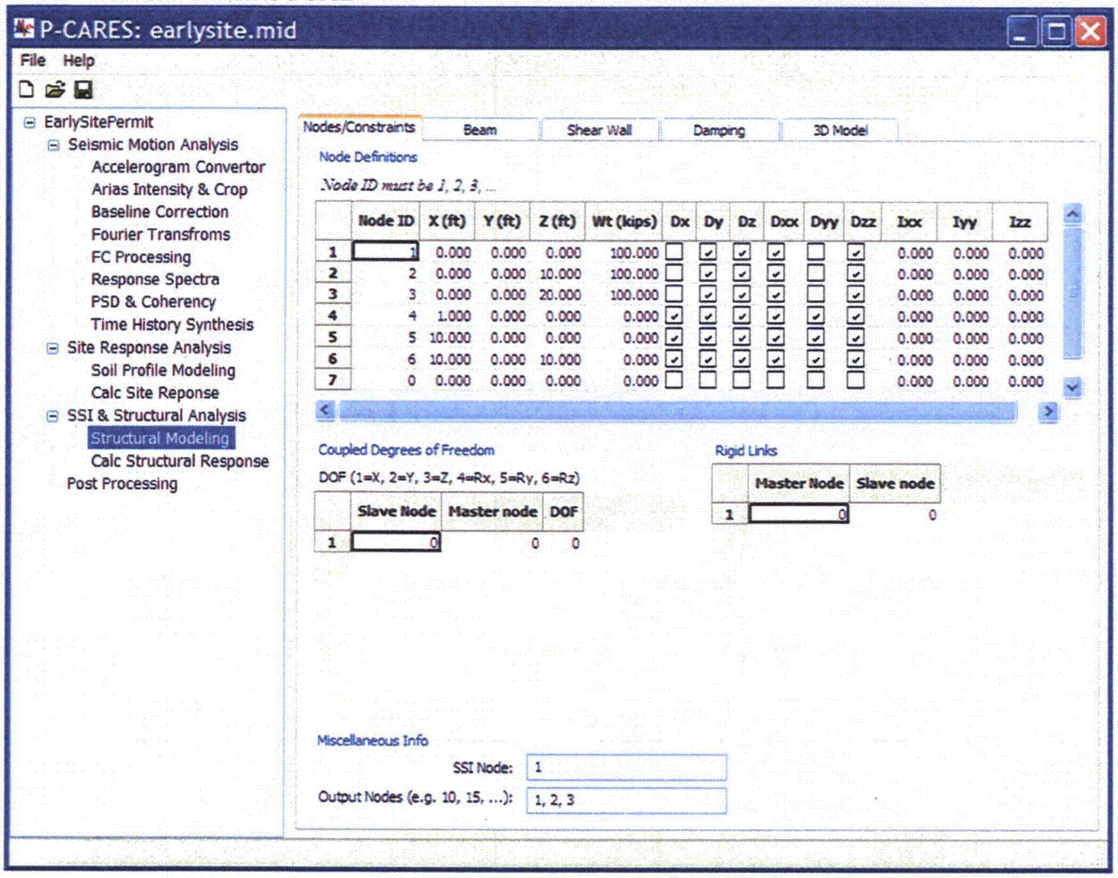
The sort command sorts the current column, while the reverse command reverses the order of the current column. The toggle command reverses the states of the check controls in the current column, while the check and uncheck commands set and unset the check controls respectively.

The rows selected can be copied or deleted using the following pop up menu on the left margin.



The last row of all the tables used in structural modeling does not represent any real structural properties; rather it is a mechanism to append a row at the end of the table. Editing the last row creates a new definition line for the structural model, and appends another empty row at the end of the table.

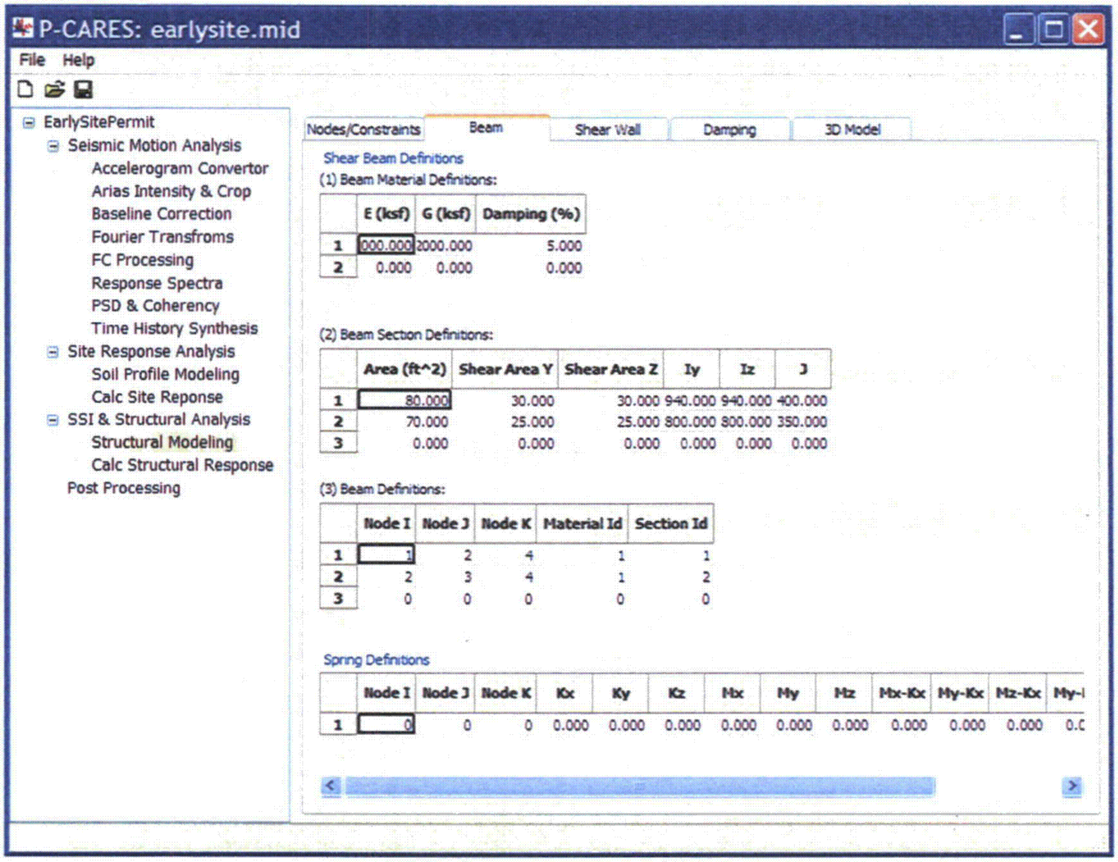
Nodes and Constraints Form



Description	This interface presents a few tables to define the nodes and constraints for the structural model. The SSI node and the output nodes need also be provided in this form.
Node Definitions	Each row in the node definition table holds the properties for one node, which include an integer node id, three coordinates (ft), the lumped weight (kip), six constraint check boxes for all six degree of freedom, and optional three rotational inertias (kip*ft/s^2). Use the pop up menu to set/unset the constraints column-wise, or click the individual constraint check box to set/unset that constraint.
Coupled Degrees of Freedom	This table defines the slave-master couples. Each row of the table holds the slave node in the first cell, the master node in the second cell, the restrained DOF in the third cell.
Rigid Links	This table defines all the rigid links. Each row of the table holds the master and slave node pair.

SSI Node	Provide the SSI node id.
Output Nodes	A list of comma-separated node ids for output.

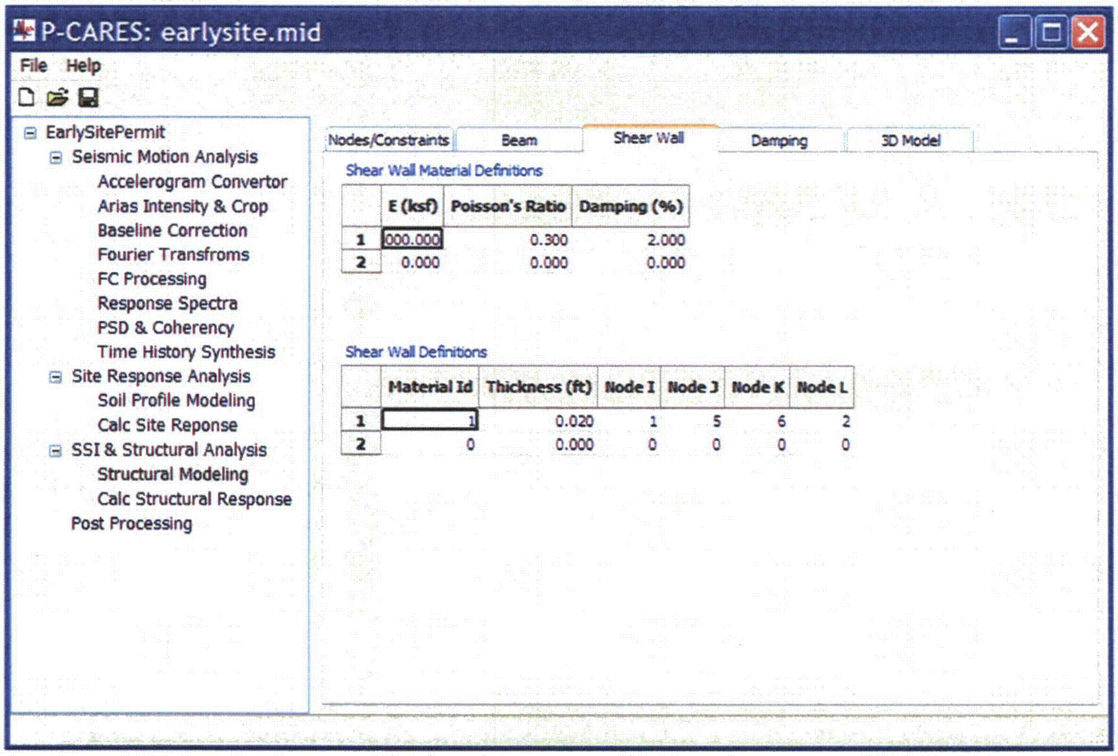
Beam Form



Description	This interface presents four tables to define the beam and spring elements for the structural model. The 3-D beam with shear stiffness is defined using the first three tables, while the spring is defined by the last table.
Beam Material Definitions	Each row of the beam material definition table consists of the Young's modulus (ksf), the shear modulus (ksf), and the damping (%).
Beam Section Definitions	Each row of the beam section definition table consists of the area (ft*ft), Y shear area (ft*ft), Z shear area (ft*ft), and the moments of inertia Iy (ft^4), Iz (ft^4), and J (ft^4).
Beam Definitions	Each row of the beam definition table defines a 3-D beam element, which consists of start node I, end node J, k node, material id, and section id. The k node is used to define the local coordinate system of the beam.

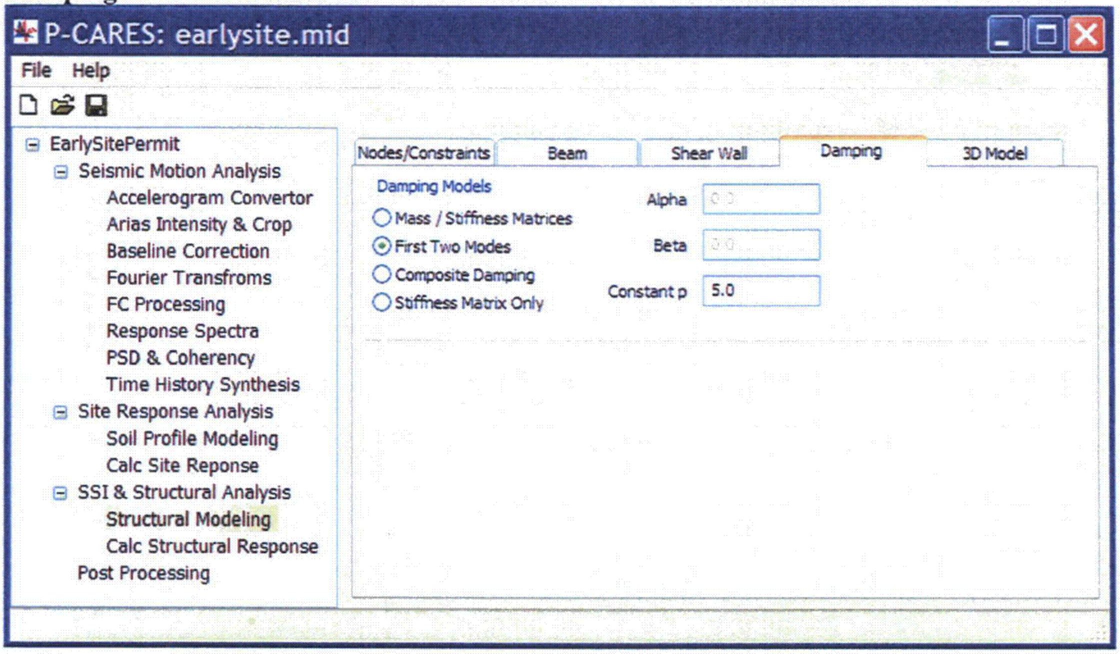
Spring Definitions	Each row of the spring definition table defines a 3-D spring element that does not have the shear stiffness. The definition consists of start node I, end node J, k node, and the entries in the stiffness matrix Kx, Ky, Kz, Kxx, Kyy, Kzz, Kxx-Kx, Kyy-Kx, Kzz-Kx, Kyy-Ky, Kzz-Ky, Kzz-Kz. The k node is used to define the local coordinate system of the spring.

Shear Wall Form



Description	This interface utilizes a table to define the shear wall material and a table to define the shear wall connectivity. The shear wall cannot resist any out-of-plane displacement.
Shear Wall Material Definitions	Each row defines a kind of shear wall material, which consists of Young's modulus (ksf), Poisson's ratio, and damping (%).
Shear Wall Definitions	Each row defines a shear wall element, which consists of the shear wall material id, thickness (Ft), and the element connectivity of nodes I, J, K, and L.

Damping Form



Description This interface presents data items to define the damping of the entire structure. It may or may not use the element damping data depending on the damping model selected (please refer to the theoretical basis for more information).

Damping Models Select which damping model will be used in the structural analysis.

(1) Mass/Stiffness Matrices: this model requires the coefficient α for the mass matrix and the coefficient β for the stiffness matrix. This option disables the input field for the constant p.

(2) First Tow modes: this model requires the critical damping ratio p to define the coefficients α and β in mode (1).

(3) Composite Damping: this model still defines the stiffness matrix as a linear combination of the mass and stiffness matrices, but the damping in each of the first two modes is defined as a weighted average of the damping in each of the structural elements, with the weighting function based on the ratio of the strain energy stored in the element to the total energy stored in all of the elements. The user does not need to provide additional damping values for this model.

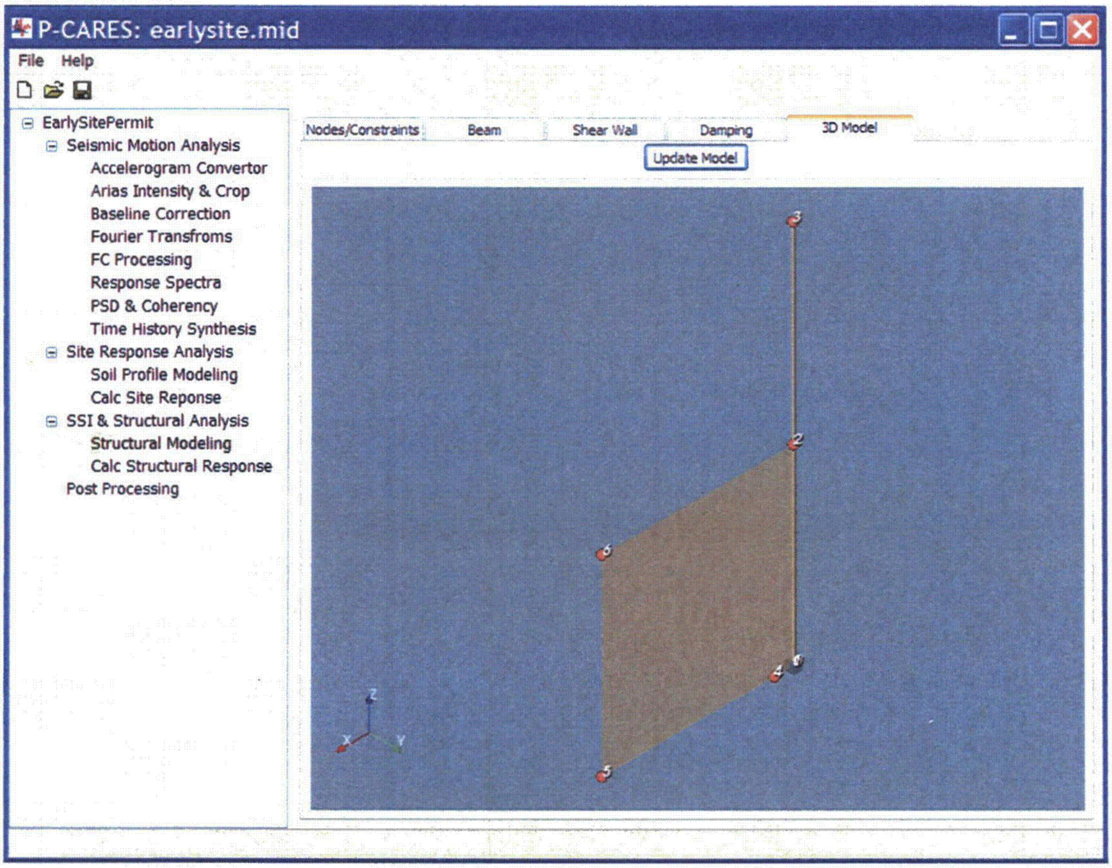
(4) Stiffness Matrix Only: the damping value for each element and its stiffness matrix are combined directly in the formation of the global damping matrix. No further user input is required.

Alpha The coefficient associated with the mass matrix.

Beta The coefficient associated with the stiffness matrix.

Constant p	The critical damping ratio, together with the first two modes, defines the coefficients α and β.

3D Model Form

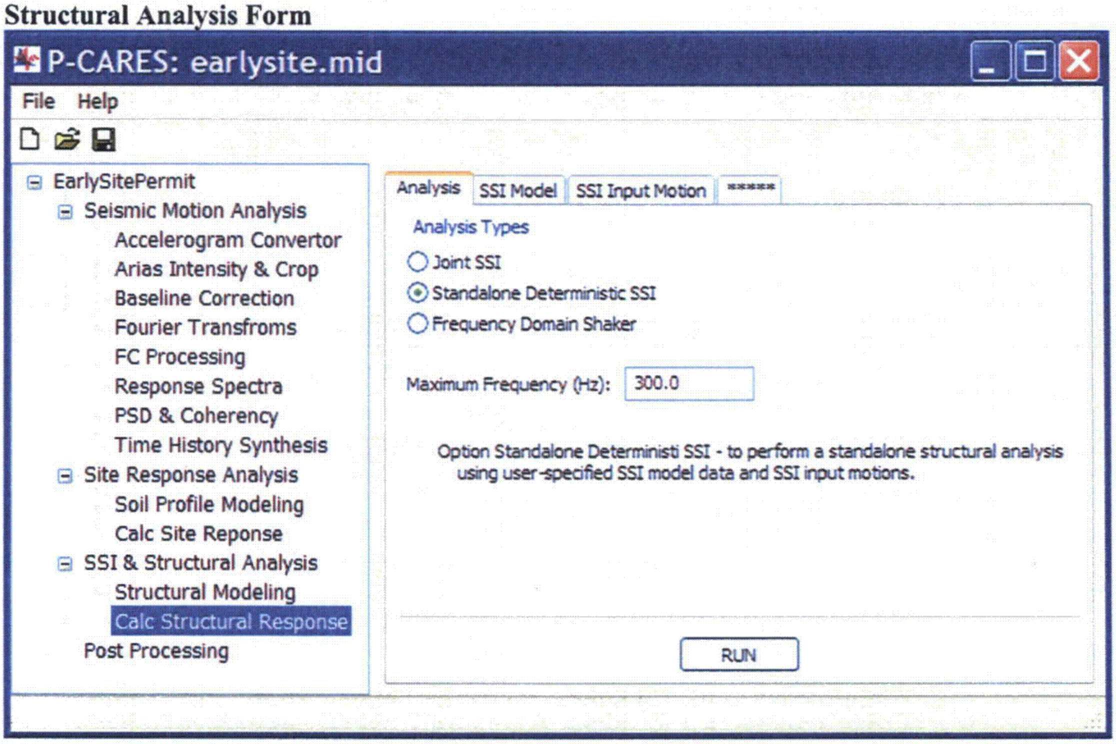


Description	This is a 3D structural model viewer for structural model inspection. Only the node numbers can be shown. The SSI node is shown as a small box, while other nodes are shown as small spheres. The model can be rotated, panned, and zoomed by dragging the left, middle, and right mouse buttons. Ctrl+left button drag rotates the model in the view plane, and Shift+left button drag and Ctrl+Shift+left button drag perform the pan and zoom functions. The mouse wheel can also be used for zooming. Typing key "r" restores to the whole extent of the model, "w" for wireframe representation, "s" for the surface representation.
Update Model	Click this button to refresh the model viewer if the definitions of nodes, beams, and shear walls have changed.

4.7.2 Structural Response Calculation

There are 3 analysis options in the structural response calculation panel, which are the joint (deterministic or probabilistic) SSI analysis, the standalone deterministic SSI analysis, and the frequency domain shaker analysis. The user needs to specify the maximum frequency (Hz) for the structural analysis. For a joint SSI analysis, the required soil properties and the SSI input motions are taken from the site response analysis, therefore, no further user input is needed. For a standalone deterministic SSI, the user needs to supply the SSI model information and the SSI input motion. For a frequency domain shaker analysis, the user needs to provide the SSI model information and the forcing function. The forms used in the structural response calculation command will be introduced in this subsection.

Structural Analysis Form

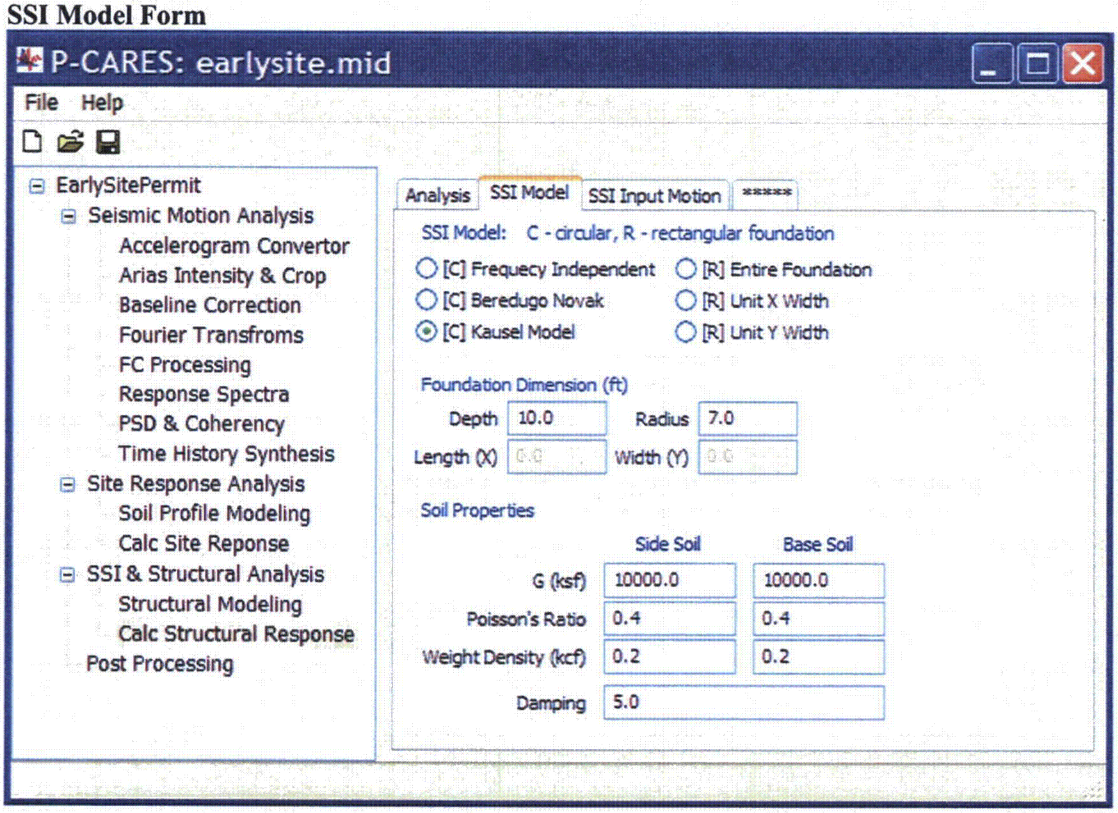


Description This interface includes options for analysis types. The user needs to supply the maximum frequency for the structural analysis for all analyses. If the "Joint SSI" analysis type is selected, all other forms are starred (disabled). If the "Standalone Deterministic SSI" analysis type is selected, the SSI Model and the SSI Input Motion forms will be available. If the "Frequency Domain Shaker" analysis type is selected, the SSI Model and the Shaker Forcing Function forms will be enabled. After selecting the intended analysis type and furnishing the necessary parameters using the available forms, clicking RUN to perform the structural analysis. If a probabilistic analysis is to perform, a progress dialog will show up after clicking the RUN button.

Joint SSI Selecting this option to conduct a consecutive structural analysis after the site response analysis has been performed. The input motion assumes in the x direction. If this is a joint deterministic analysis, the output motions are stored in individual files under names as "JD*n*-*d*.fc", where *n* stands for the node id and *d* stands for the directions, i.e. one of the X, Y, Z, RX, RY, and RZ. If this is a joint probabilistic analysis, the output motions are stored in a database file

	"STRUCRESPONSE.DB".
Standalone Deterministic SSI	Selecting this option enables the forms SSI Model and SSI Input Motion. The output files are under names as "ST*n*-*d*.fc", where *n* stands for the node id and *d* stands for the directions, i.e. one of the X, Y, Z, RX, RY, and RZ.
Frequency Domain Shaker	Selecting this option enables the forms SSI Model and Shaker Forcing Function. The output files are under names as "SH*n*-*d*.fc", where *n* stands for the node id and *d* stands for the directions, i.e. one of the X, Y, Z, RX, RY, and RZ.
Maxim Frequency	The maximum frequency (Hz) used for all structural analysis types.
RUN	Clicking this button to start the intended analysis.

SSI Model Form



Description	This interface includes necessary items used in the standalone deterministic SSI analysis and the frequency domain shaker analysis. The user needs to select the SSI model, foundation information, and the soil properties. This form has many items similar to the foundation definition in the site response analysis, and provides more SSI models than implied in the kinematic interaction analysis, which is embedded in the site response analysis. This form makes the structural analysis independent of the site response analysis, for situations where only SSI and structural responses are of interest.

SSI Model The options starting with "[C]" are for the circular foundation type, while the ones starting with "[R]" are for the rectangular foundation type. Selecting a soil model for a circular foundation type disables the foundation dimensions of a rectangular type, and vice versa.

Depth The embedment (ft) of the foundation.

Radius The radius (ft) of a circular foundation.

Length (X) The dimension of a rectangular foundation in the X direction.

Width (Y) The dimension of a rectangular foundation in the Y direction.

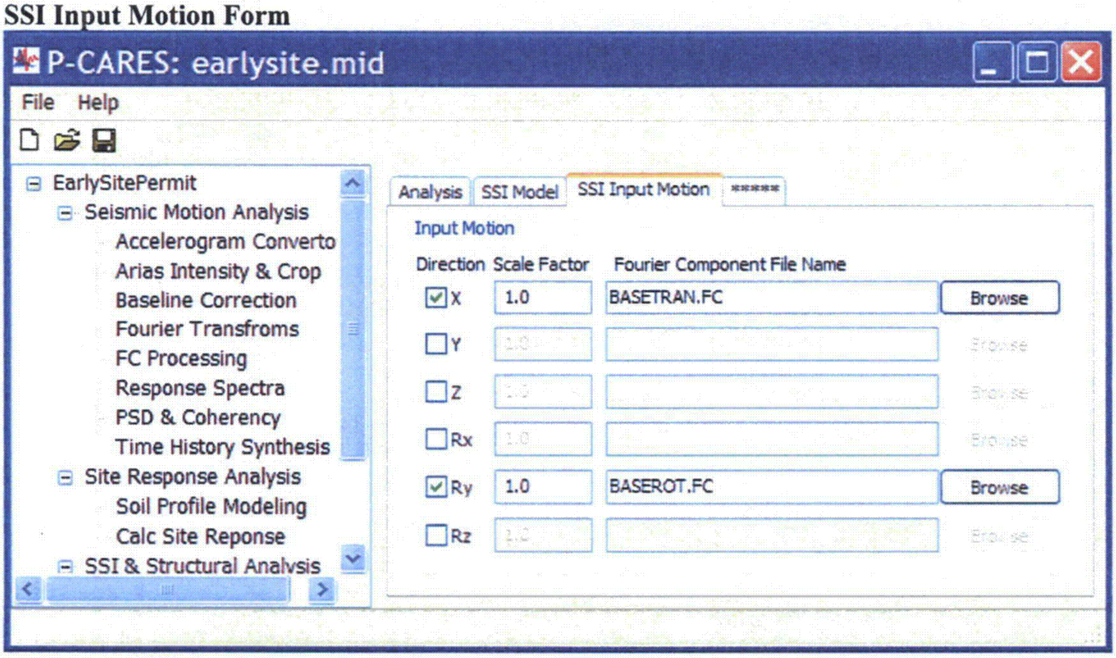
Base G The shear modulus for the soil (ksf), for the base or the side soil.

Poisson's Ratio The Poisson's ratio, for the base or the side soil.

Weight Density The soil weight density (kcf), for the base or the side soil.

Damping Damping value for both the side and base soils.

SSI Input Motion Form



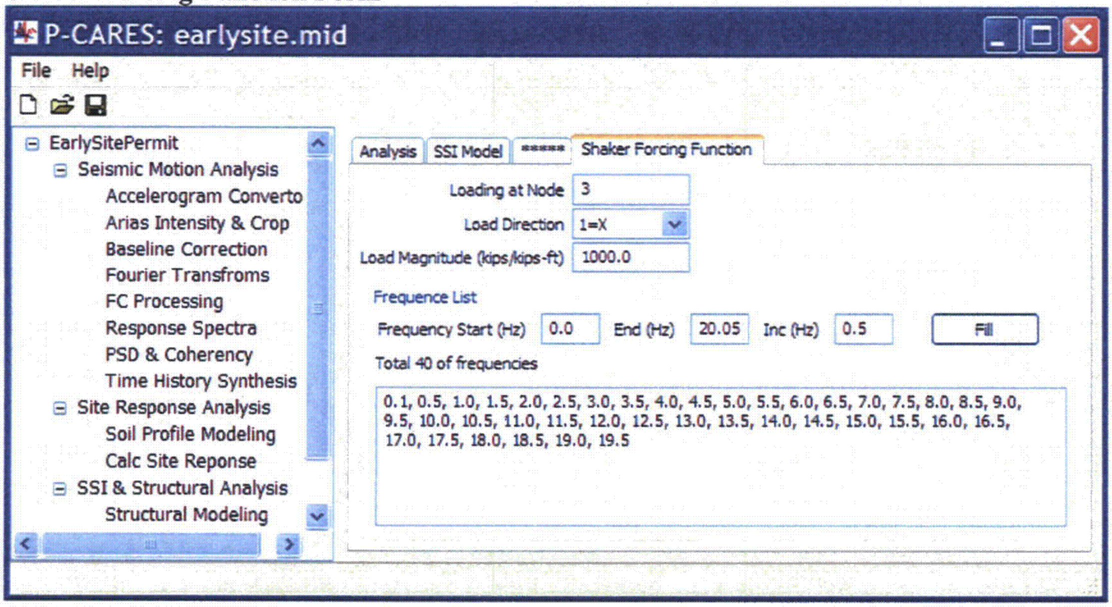
Description This interface defines the input motions for the standalone deterministic SSI analysis. The input motions are applied at the SSI node, which is defined in the structural model. There are 6 possible input motions corresponding to the six degree of freedoms of the SSI node. The input motions are in the format of Fourier component.

Direction Check one or more directions that require an input motion. An uncheck direction has its rest fields disabled (grayed out).

Scale Factor The scale factors applied at each direction. The default value for the scale factor is 1.0.

Fourier Component File Name Type in or browse in a valid Fourier spectrum file for each checked direction.

Shaker Forcing Function Form



Description This interface provides the capability to define a forcing function for the frequency domain shaker analysis. The forcing function is applied at a user specified node and along a user selected direction. The load magnitude and the frequencies to be analyzed need to be provided. Regularly spaced frequencies can be generated using the "Fill" button.

Loading at Node Type in a node id that is defined in the structural model.

Load Direction Select a direction along which the forcing function will apply.

Load Magnitude The magnitude of the load. The unit for a force (along X, Y or Z) is kips, while the unit for a moment (along Rx, Ry, or Rz) is kips-ft.

Frequency Start The start of a frequency range (Hz) that will be generated.

(Frequency) End The end of the frequency range (Hz) that will be generated.

(Frequency) Inc The incremental frequency (Hz) used to generate the regularly spaced frequency range.

Fill Clicking this button will clear the frequency list and then fill the frequency list using the above three parameters.

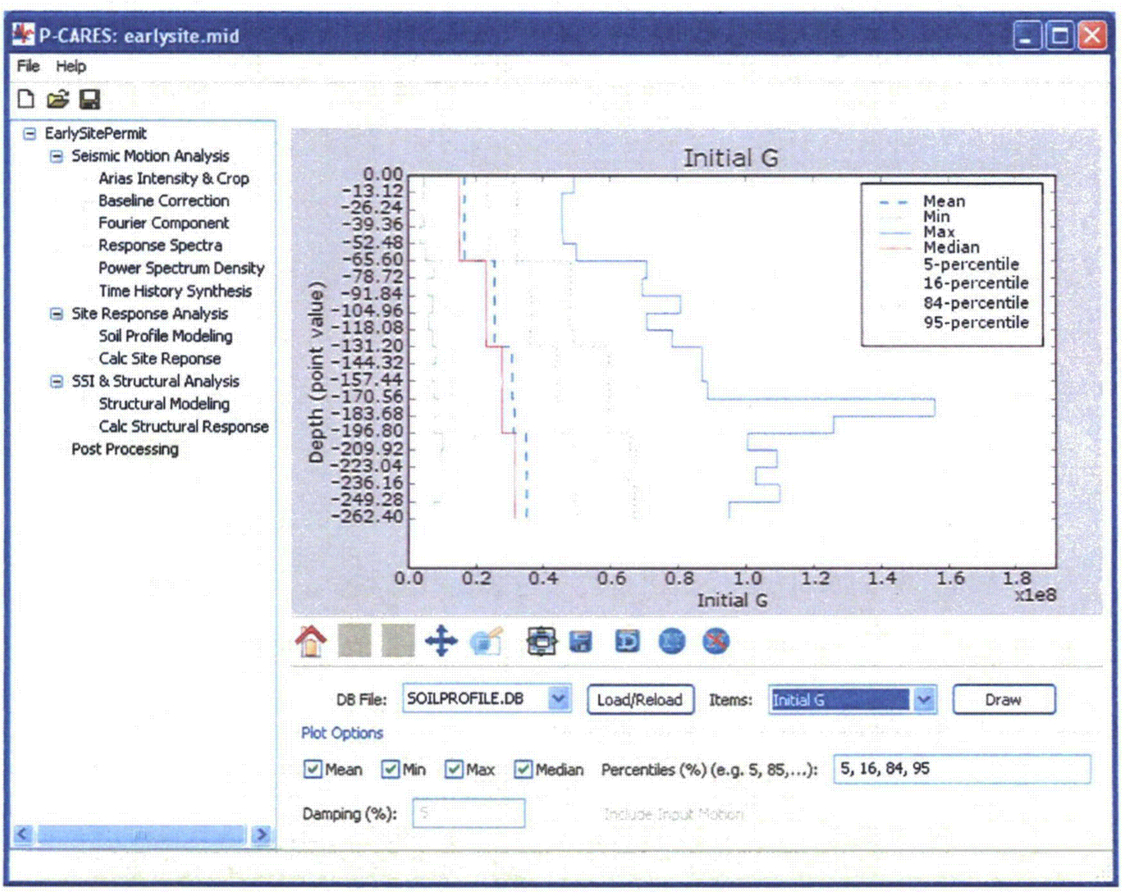
Frequency List This is a comma-separated list of frequencies used to define the forcing function. The list can be quickly filled using button "Fill", or can be manually entered or edited.

4.8 Post Processing

For various deterministic analyses, the outputs are stored in individual text file, and can be processed using the utility tools in the seismic motion analysis module. For probabilistic simulation, the post processing command can be used to process the simulated soil profile, site responses and structural responses. This subsection describes the features of the post processing command. The interface of this command will be described first, and then a few examples will be presented to demonstrate what the post processing command can produce.

The simulated soil profile results are loaded from the database file, and then sorted in ascending order; profiles for the mean, minimum, maximum, median, and various percentiles can then be determined and plotted. As for the soil and structural responses from a probabilistic analysis, a response spectrum is first generated for each response. The response spectra are then sorted and saved to a file with an extension ".POST" to avoid the possible regeneration of the response spectra, since the calculation of response spectra for many samples is a time consuming process. For example, if the soil responses are under consideration, i.e., using the "SOILRESPONSE.DB", then the sorted response spectra are saved in "SOILRESPONSE.DB.POST". If such a file exists before loading a database file, the user is asked whether to use this ".POST" file.

4.8.1 Post Processing Interface



Description	The post processing is a typical console style interface that consists of a plot panel on the top and a bunch of controls at the bottom. It can process both the simulated soil profile and the simulated soil and structure responses. When the interface is started, it will search the current project directory for all available databases and make them available in the database choice control. Plot options include a variety of statistical measures, damping for response spectrum generation, and an option to include the input motion in the figure. The figure can be saved in a few popular image formats or in data file that can readily be imported into Excel. Annotations cannot be saved into a data file.
DB File	A choice box contains all database files available in the current project directory.
Load/Reload	Load/reload the database file. For response databases, the calculation of response spectra for many samples is a time consuming process; therefore, when a POST file exists, the user will be prompted for confirmation of its usage. The user can instruct P-CARES to regenerate the response spectra, for example, when a different damping value is desired.
Items	A choice box containing all the items that P-CARES can plot. For soil profile, it includes layer thickness, soil density, damping, initial shear modulus, final shear modulus, initial shear velocity, and final shear velocity. For soil or structural responses, this choice box provides choices of various locations that may be the depths in the soil column or node ids in the structure.
Draw	Clear the figure canvas and draw the selected item with the current plot options.
Mean	Plot option for the statistical mean (arithmetic average).
Minimum	Plot option for the 0-percentile. This option is not available for response results.
Minimum	Plot option for the 100-percentile. This option is not available for response results.
Median	Plot option for the statistical median that is defined as the 50-percentile.
Percentiles (%)	An arbitrary list of percentiles can be specified. It uses a comma separated format, e.g., 5, 16, 84, ...
Damping	Specify the damping value used in generating the response spectra. This option is meaningless and not available for soil profile results.
Include Input Motion	A check box to indicate if the response spectrum of the input motion should be included in the figure. This option is meaningless and not available for soil profile results.

4.8.2 Post Processing Examples

The post processing command, although using a relatively simple interface, can produce a variety of different plots. This section documents some of the typical examples to demonstrate its capabilities. The caption of the following figures can provide a clear explanation of the figure. For plot items of a soil profile, if the total number of soil layers is less than 50, the vertical axis shows the depths of the soil layer interfaces using the point values of the layer thicknesses; otherwise, the vertical axis shows regular ticks that are evenly separated.

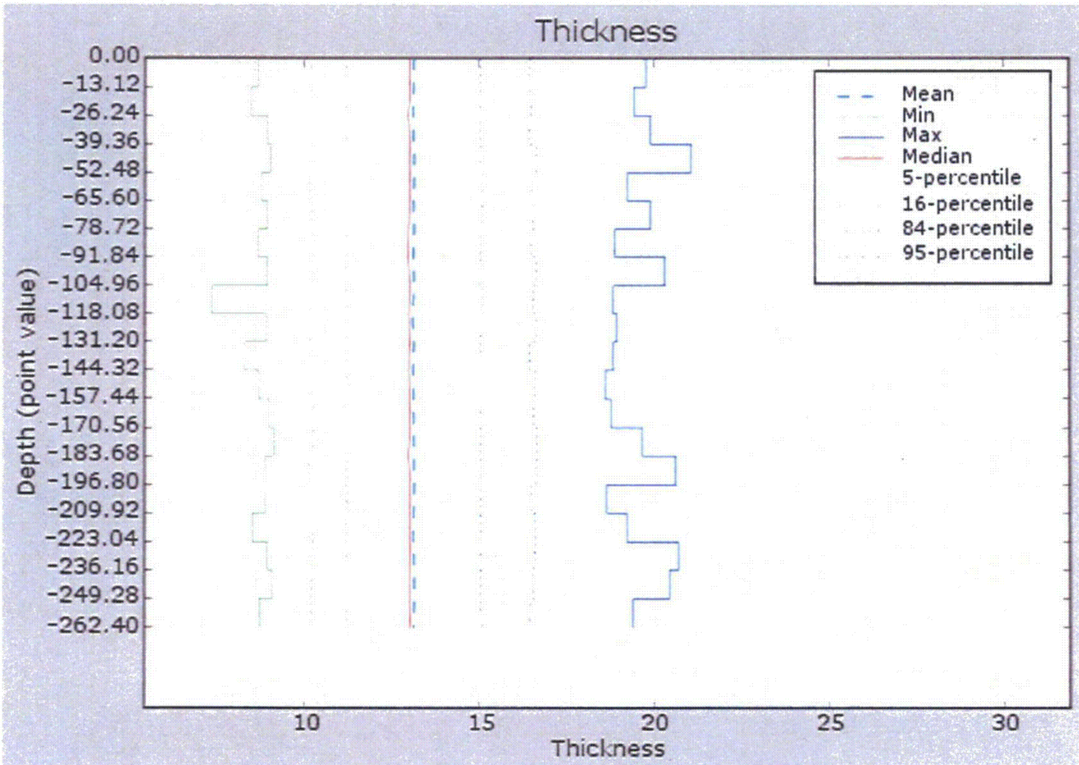


Figure 4-18 Post Processing Example - Layer Thickness

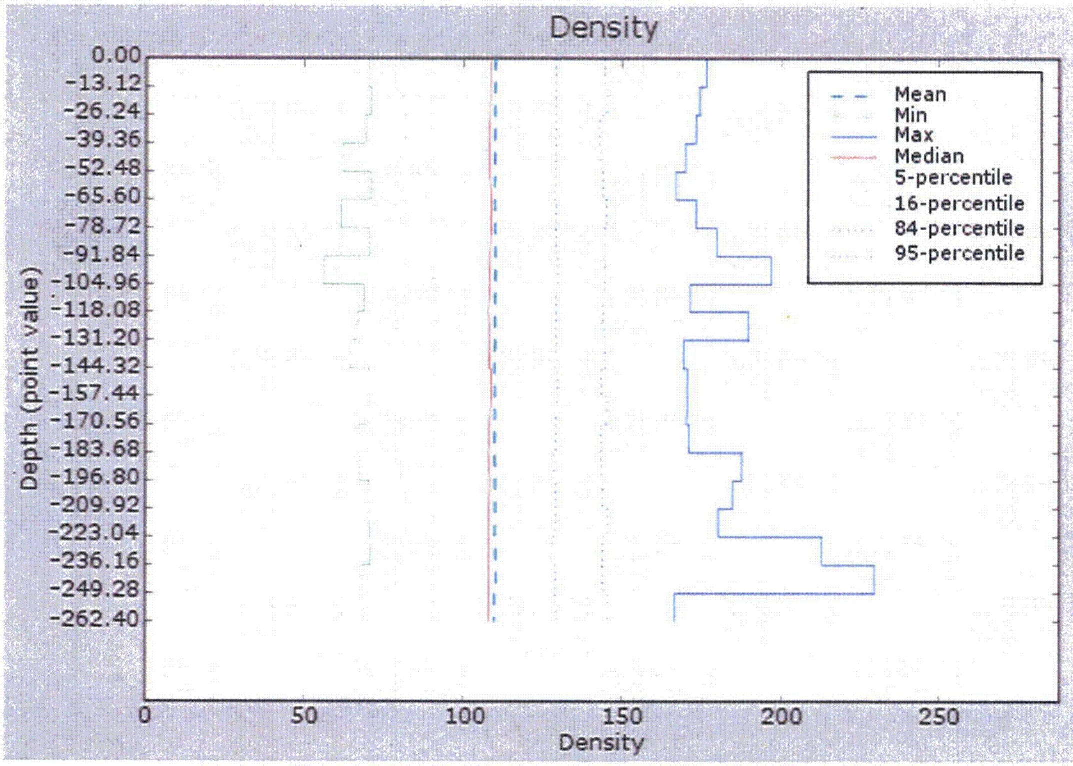


Figure 4-19 Post Processing Example – Soil Weight Density

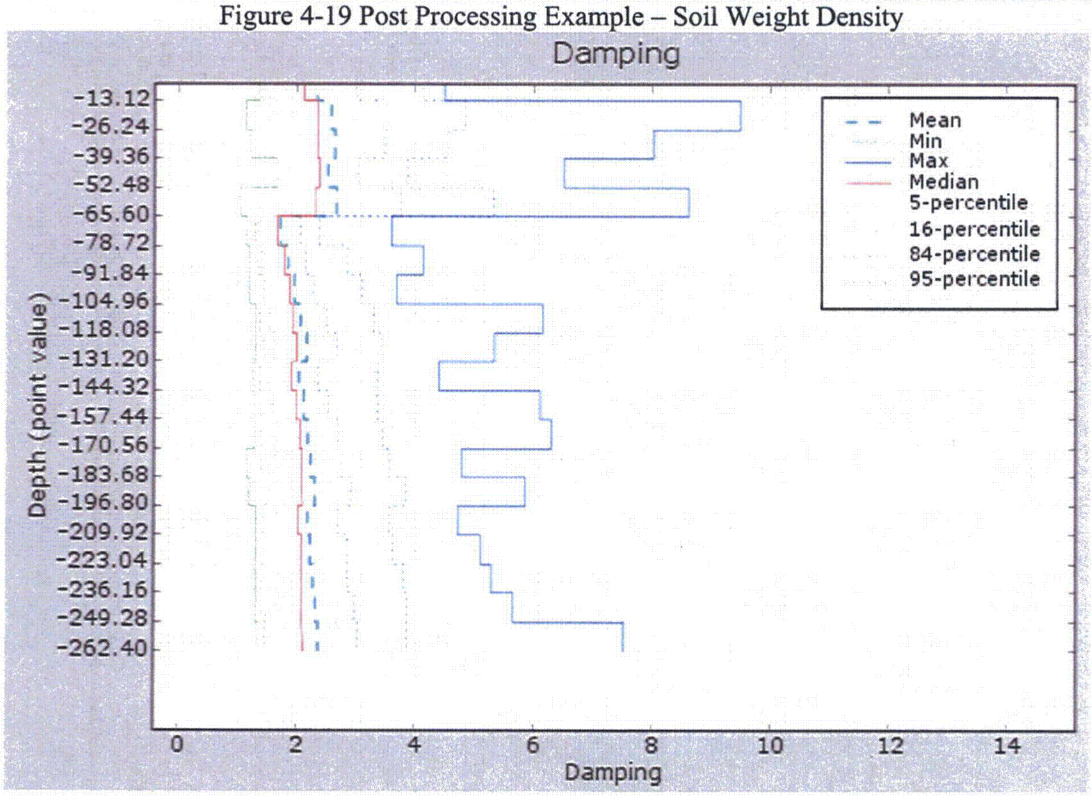


Figure 4-20 Post Processing Example – Soil Damping (Strain-Compatible)

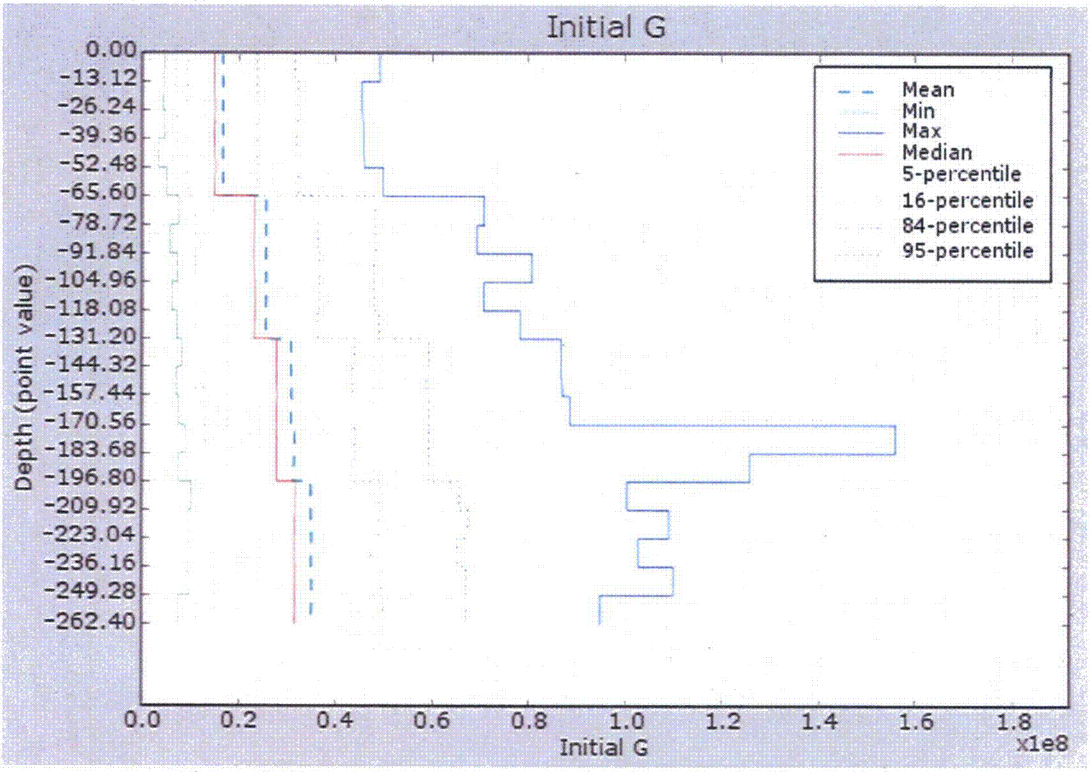


Figure 4-21 Post Processing Example – Low Strain Shear Modulus

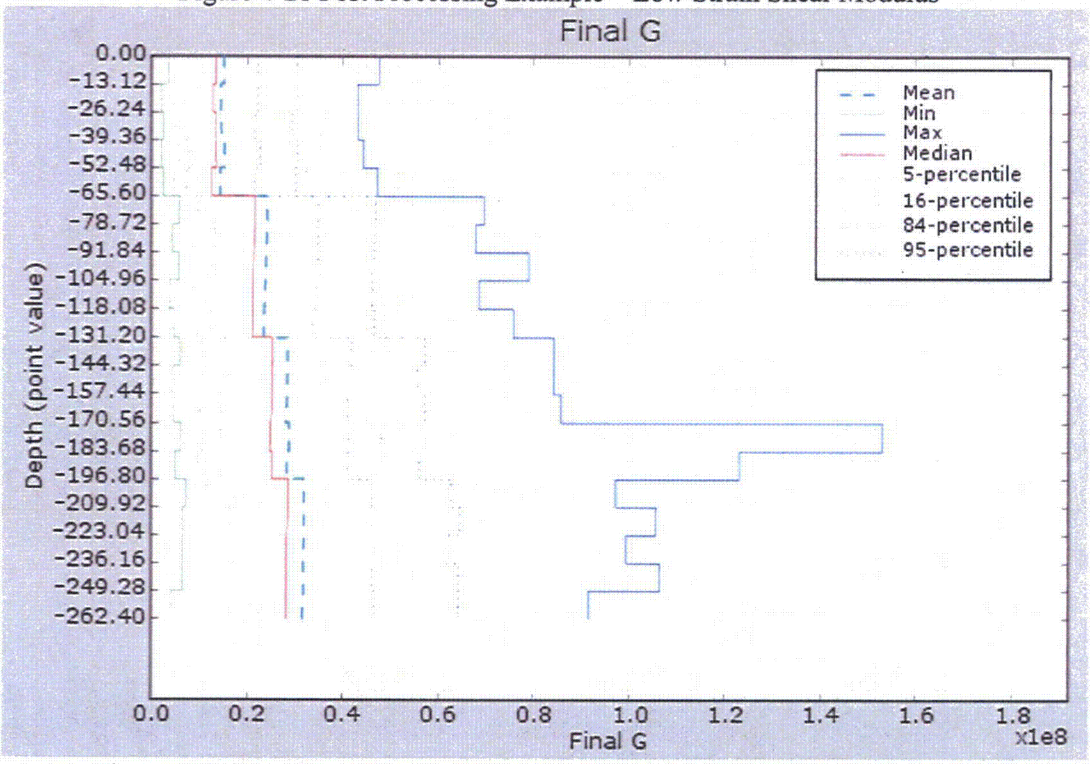


Figure 4-22 Post Processing Example – Final Shear Modulus (Strain Compatible)

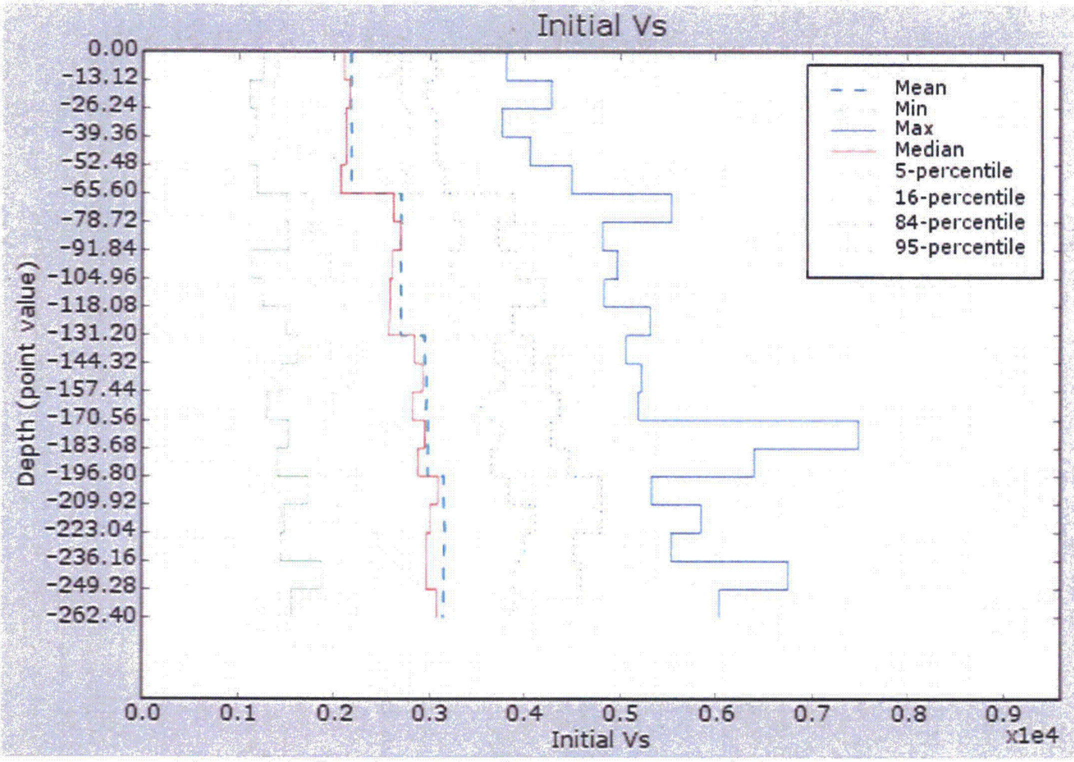


Figure 4-23 Post Processing Example – Low Strain Shear Velocity

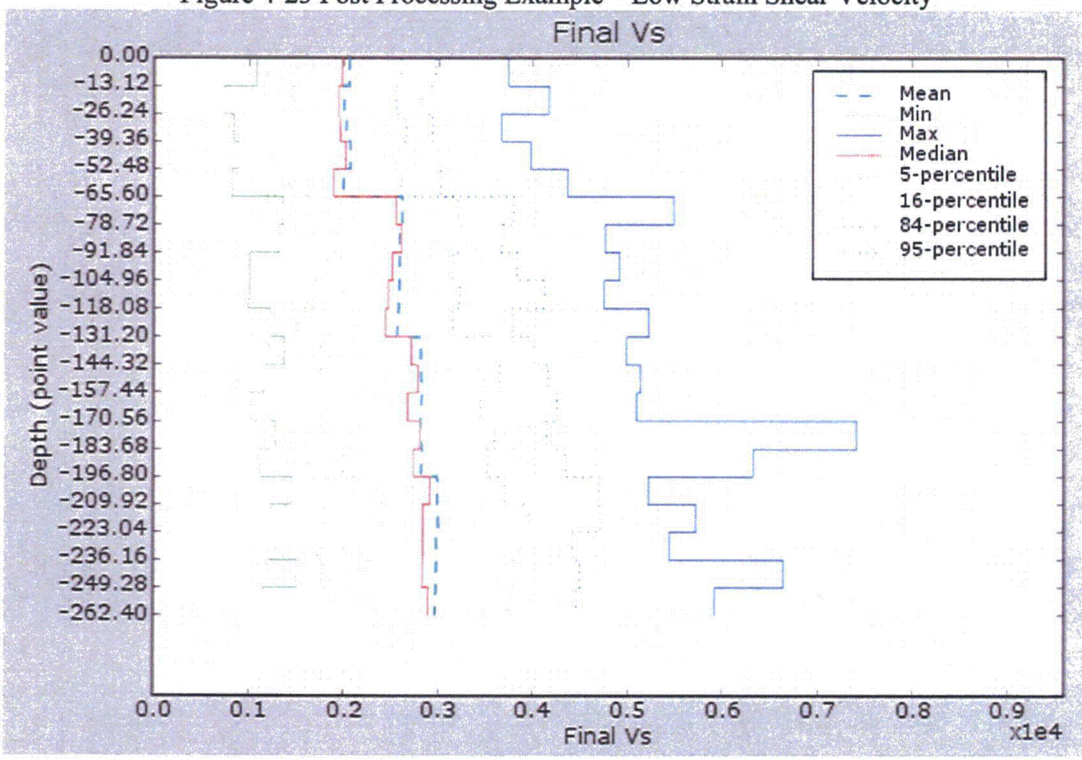


Figure 4-24 Post Processing Example – Final Shear Velocity (Strain Compatible)

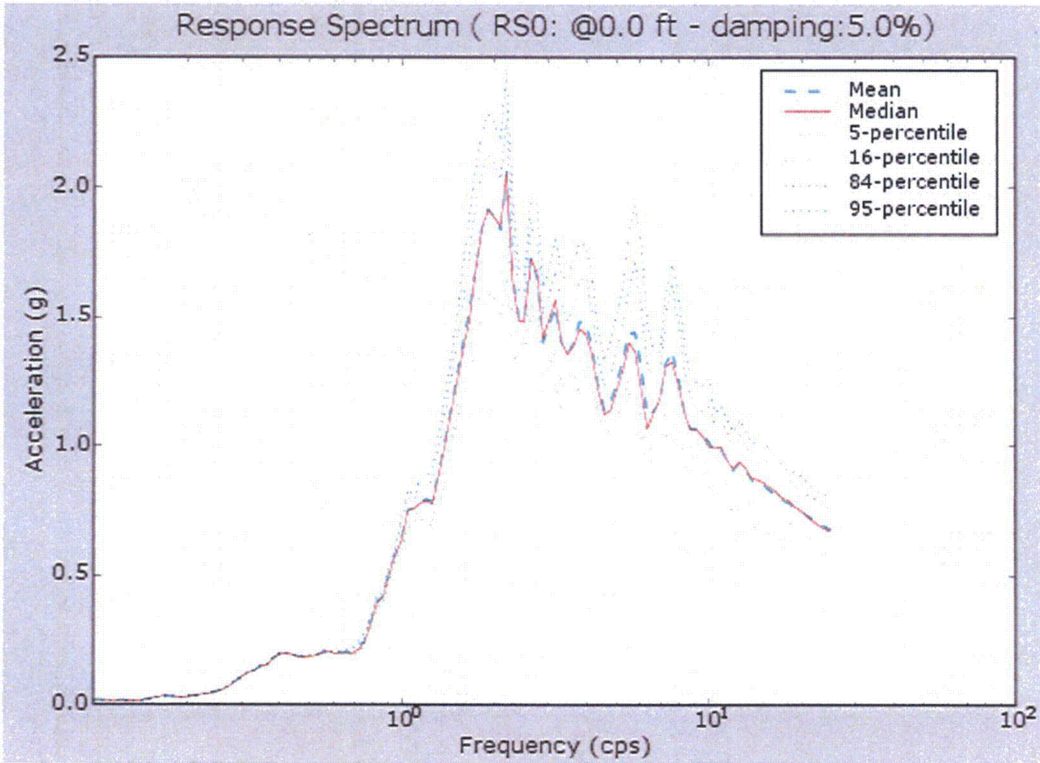


Figure 4-25 Post Processing Example – Statistics of Response Spectra

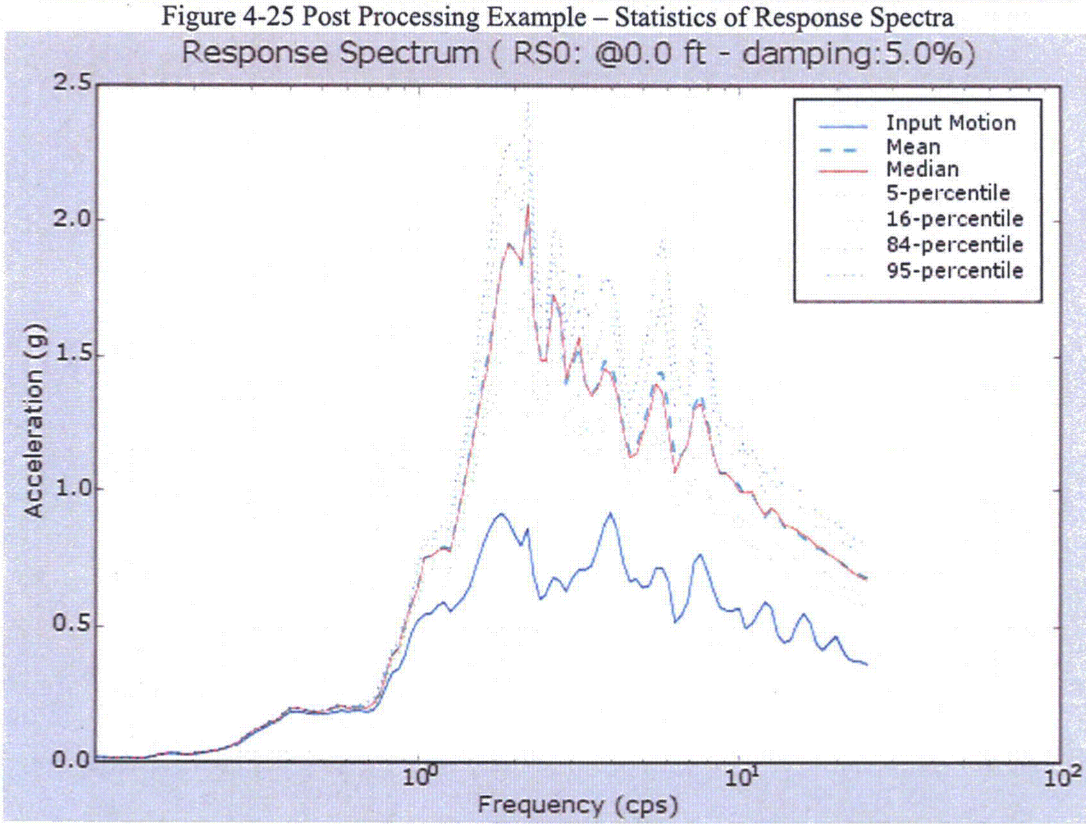


Figure 4-26 Post Processing Example – Statistics of Response Spectra With Input Motion

5 SUMMARY

The objective of this report is to describe the theoretical basis, the usage, and the development of the P-CARES software such that the prospective users will have confidence with the application of the software, the soundness of theories underlying the computation, and the results and their presentation generated in the software. This section summarizes this report with the major components of the P-CARES software and the achievements in its development.

The existing CARES Ver. 1.3 has been upgraded to FORTRAN 90/95 to add clear interfaces between subroutines that are necessitated by the probabilistic simulation, to remove many input/output states that are not suitable for simulation, to take advantage of the dynamic memory allocation for problem size, and to improve the logic and the code quality, among many other improvements. The upgraded version of CARES becomes a few compiled modules that are accessed in Python, and constitutes the computational core in the P-CARES. Building around this computational core, probabilistic simulation and a graphical user interface (GUI) have been developed to form the integrated software package. The software architecture of P-CARES follows the object-oriented approach, the current state-of-the-art programming technique, which enables it to be very flexible and extensible for future upgrades. A rapid application development (RAD) aspect of P-CARES is the mixed programming in Python and FORTRAN, with Python serving as a powerful glue language while FORTRAN is used for the computational core involving heavy number crunching.

P-CARES provides the capabilities to perform deterministic and probabilistic site response and soil-structure interaction (SSI) analyses based on relatively simplified soil and structural models. It automatically manages data and calculations in the probabilistic simulation with any arbitrary number of samples. The sample soil profiles and the response spectra of the simulated soil and structural responses can be aggregated statistically in terms of mean, median, and different percentiles curves. These statistical measures may provide more valuable insights and inferences than those in deterministic soil and structural analysis, in the process of review and evaluation of nuclear power plant (NPP) structure designs. The probabilistic analysis capability in P-CARES becomes especially important as the nuclear industry is gaining wider acceptance of the probabilistic approach to account for the uncertainties inherent in the natural and built environments.

P-CARES also provides a set of utility functions for seismic motion analysis, which include the Arias Intensity calculation, accelerogram manipulation, Fast Fourier Transformation and its inverse, baseline correction of accelerograms, Butterworth low pass / high pass / band pass filtering, window smoothing, response spectrum generation, power spectrum density and coherency generation, and time history synthesis. The utility functions can be used to preprocess an accelerogram for the site response and SSI analysis, and can also be used for post processing for deterministic analysis. Another well-suitable application of these utilities is to simply examine the characteristic of a given accelerogram.

The P-CARES GUI integrates all the above-mentioned functions in one package, instead of a few stand-alone programs in the traditional CARES. It provides convenient on-screen model building capability for soil and structural models, automatic analysis management, and intuitive feedback of instant display of figures. The generated figures can be saved in various popular image formats or in data files that can be readily imported into any spreadsheet programs such as Excel for further processing. It can therefore greatly improve the productivity and makes P-CARES a valuable tool to assist the staff in evaluation of the site and structural analysis data submitted by the applicants.

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APPENDIX A SAMPLE PROBLEM

This section describes a sample problem that covers time history synthesis, site response analysis, and soil-structure interaction and structural analysis, and typifies a common application scenario of P-CARES for confirmatory analysis of nuclear power plant structures. This sample problem has been developed based on the one presented in Xu, et al (1990), volume 3. Section A.1 describes the simulation procedure in P-CARES to synthesize a ground acceleration time history compatible to Reg. Guide 1.60 spectra. This synthetic time history is then applied in Section A.2 for deterministic and probabilistic site response analyses that calculate the strain-compatible soil properties of a layered soil profile, generate the output motions at various locations in the soil column, and optionally create the SSI motions to be used in the structural analysis. Section A.3 describes deterministic and probabilistic SSI and structural analyses that automatically carry over the sample strain-compatible soil profiles and the SSI motions from the site response analyses, perform the structural analyses, and generate the in-structure output motions and response spectra.

P-CARES utilizes the US customary unit system except that the response spectra are represented in terms of the gravity constant g.

A.1 Synthetic Time History

Although any existing seismic record can serve well the demonstration of capability of the site response analysis and SSI and structural analysis, a record synthesized to match the Reg. Guide 1.60 spectra may demonstrate better the goal of P-CARES, which is to facilitate the quick assessment of nuclear power plant structures in the regulatory activities. The horizontal Reg. Guide 1.60 spectrum with a peak ground acceleration (PGA) of 0.2g and a damping ratio of 5% is selected as the target response spectrum. As a general rule for time history synthesis in P-CARES, the time increment should be set smaller than 1/5 of the minimum period of interest; and the duration is recommended to be greater than 4 times of the maximum period of interest to achieve a reasonable frequency resolution. The number of data points in the time history needs to be a power of 2 to allow the fast Fourier transform (FFT) that is used in this utility. In this example, the time increment is set to 0.005 seconds, the number of points is selected to be 4096, and the duration is then determined to be 20.48 seconds. An envelop function consisting of build up, strong motion, and decaying periods is applied to the generated time history for a reasonable resemblance of the nonstationary characteristics of a realistic earthquake record. The parabolic buildup time parameter *Trise* is set to 3 seconds, the strong motion duration *Tstrong* is set to 5 seconds, and exponential decay time *Tdecay* is set to 12 seconds.

Figure A-1 shows the parameters described above. The target response spectrum is selected by clicking the "Select Spectrum" option box and entering the parameters in the popup dialog for Reg. Guide 1.60 spectrum (shown in Figure A-2). After clicking the "OK" button, the "Freq" and "Response" fields are automatically filled up to define the target spectrum, the "Damping" and the "Acc Peak" boxes are set as well. The response spectra are linearly interpolated in the log-log scale. The phases of the time history are to be generated randomly in this example, while the other choices include reading from a Fourier component file or a time history file. However, if the phases are read from files the duration and the number of points will be the same as in the files. The maximum duration Tmax and the number of data points are entered as 20.48 seconds and 4096. Although using the "EQ Magnitude" button can generate the envelop function parameters, the user can provide arbitrary numbers for Trise, Tstrong, and Tdecay. After clicking the "Initialize" button, the target response spectrum and the envelop function are plotted side by side in the top portion of Figure A-1. The response spectrum, acceleration, velocity, and displacement of the generated time history are stored in files as "sample.rs", "sample.acc", "sample.vel", and "sample.disp" respectively.

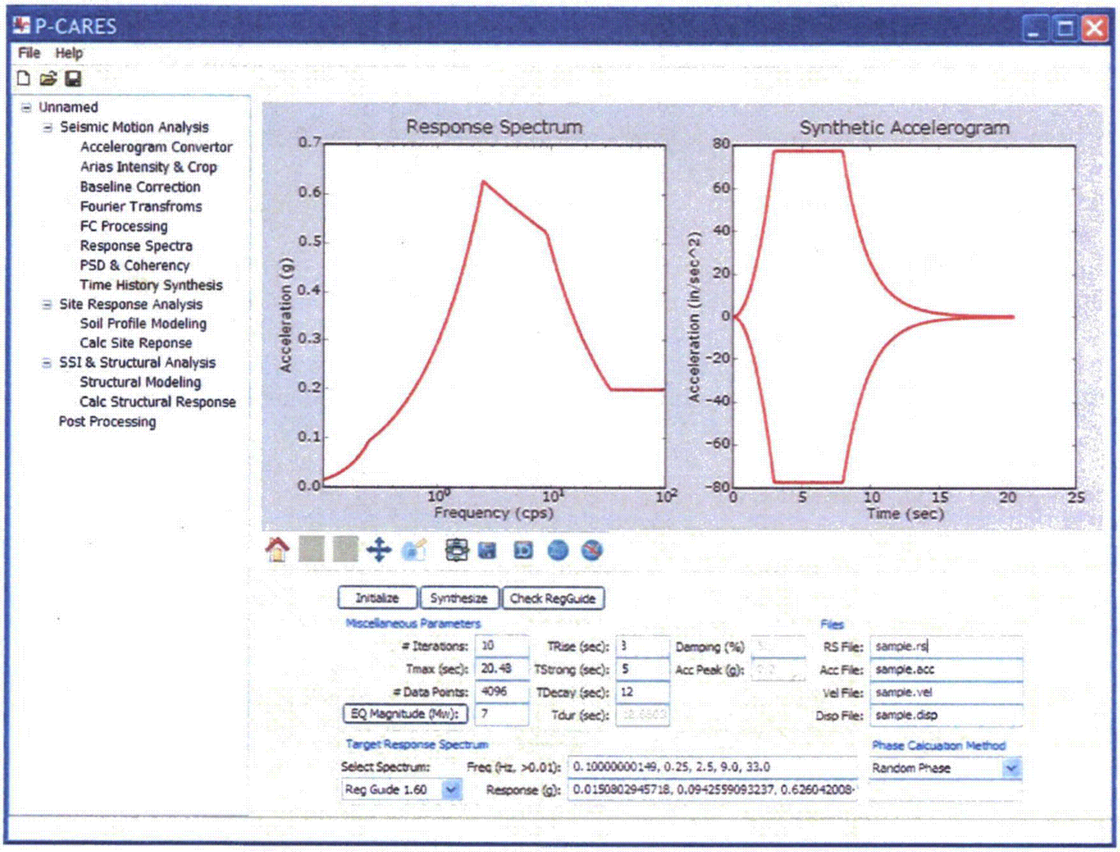


Figure A-1 Parameters for Time History Synthesis

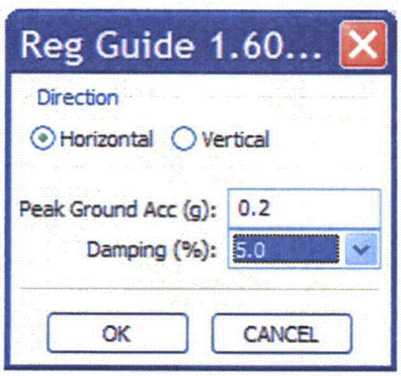


Figure A-2 Design Spectrum Dialog for Reg. Guide 1.60

The time history synthesis is an iterative process as described in the theoretical basis section. The user-specified number of iterations, 10 as in Figure A-1, is carried out for each click of the button "Synthesize". After each cycle, i.e., a click of the "Synthesize" button, the generated time history and its response spectrum are plotted overlapping the envelop function and the target response spectrum respectively, and the associated files are saved. If the generated response spectrum does not match the target well, more cycles can be applied by more clicks of "Synthesiz". A satisfactory time history (by visual check) can usually be obtained in a few cycles; however, if a reasonably good match has not been achieved after a few cycles, the random phases can be reinitialized by clicking "Initialize" and the time history can be regenerated. The user has an option to perform the Reg. Guide check on a satisfactory time history, which requires there can only be at most 5 points below and no point less than 90% of the target spectrum for the 75 Reg. Guide frequencies. Figure A-3 shows the generated time history and its response spectrum after applying the Reg. Guide check. Figure A-4 and Figure A-5 show plots of the time history and its Fourier spectrum respectively, the later of which was generated using the "Fourier Transforms" tool. The Fourier spectrum is stored in file "sample.acc.fc" and will be used as input in the site response analysis in the next subsection.

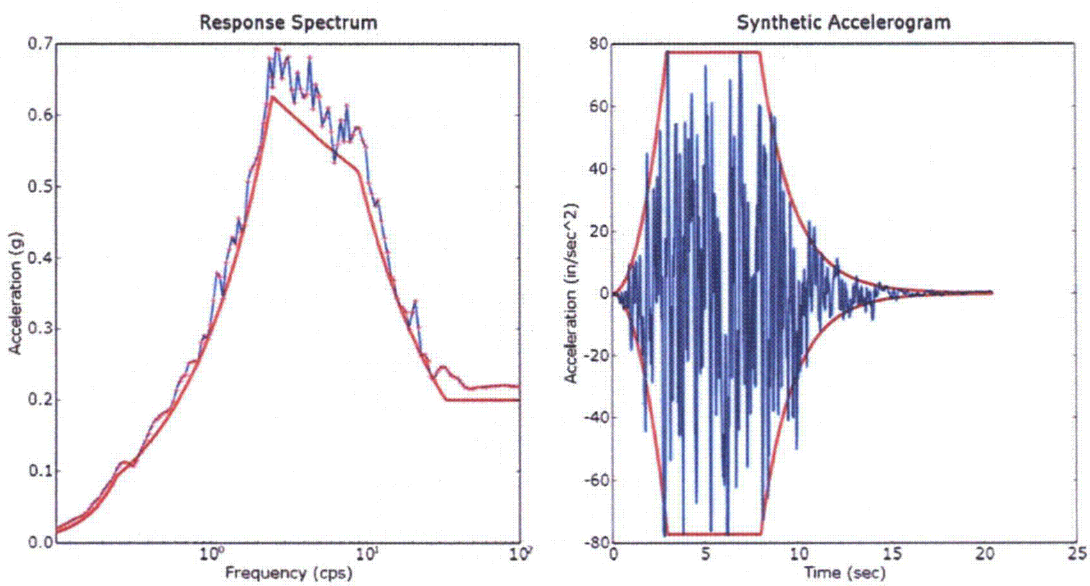


Figure A-3 The Synthetic Time History And Its Response Spectrum

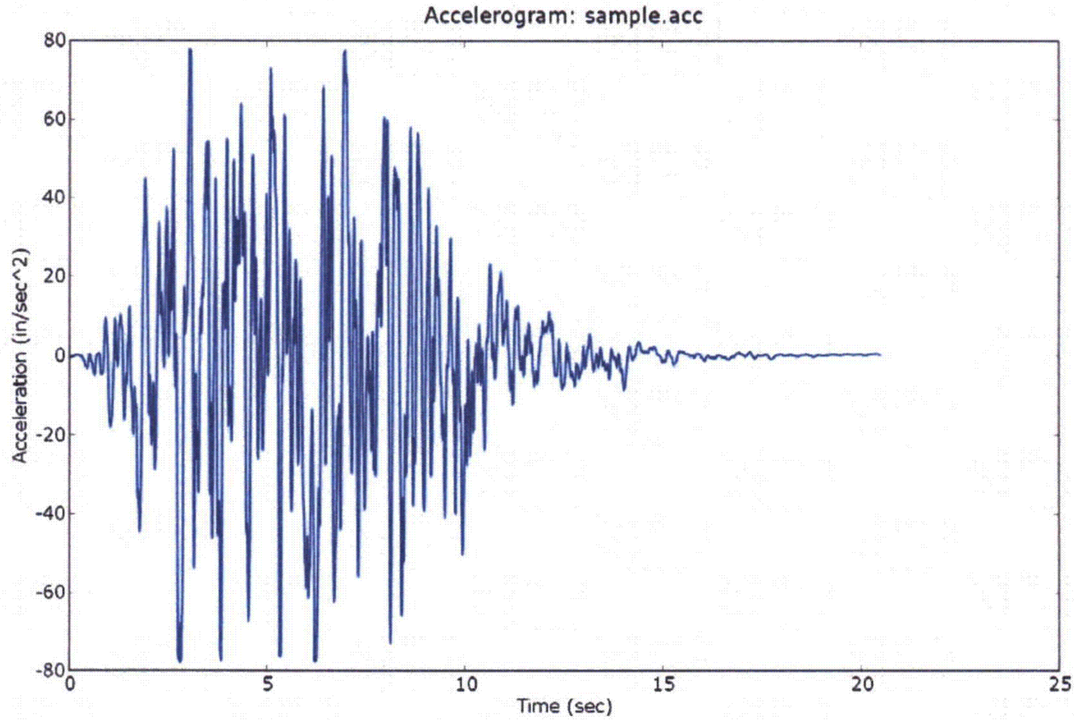


Figure A-4 Synthetic Time History

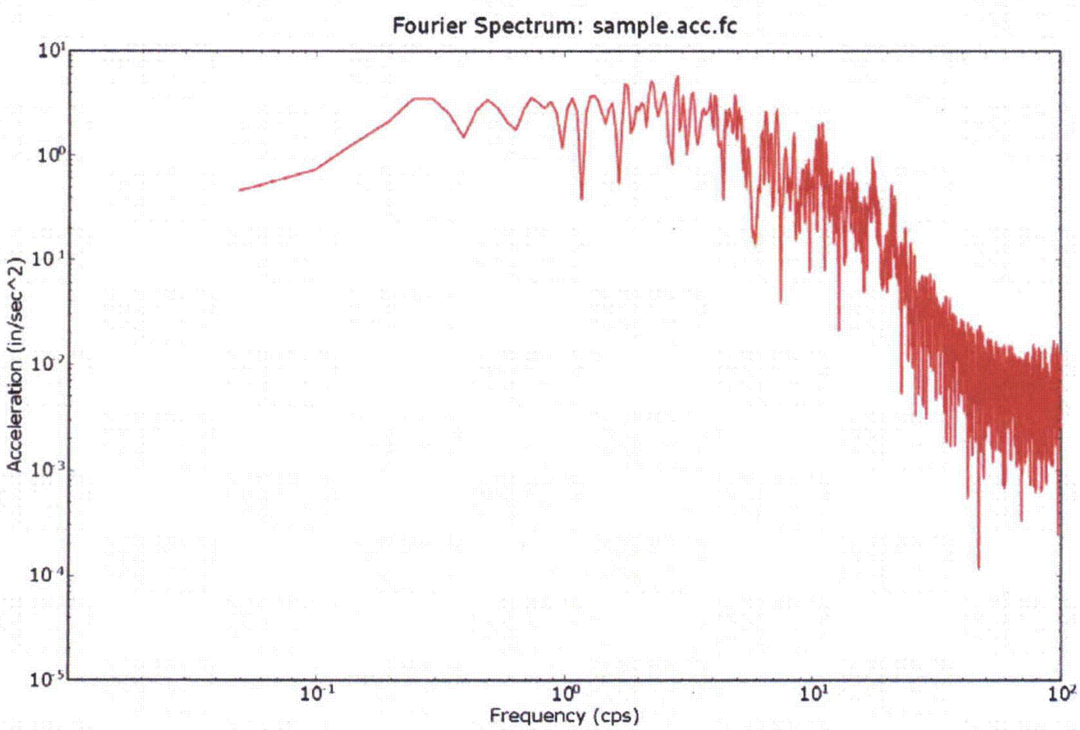


Figure A-5 Fourier Spectra of the Synthetic Time History

A.2 Site Response Analysis

This subsection continues this demonstrative example with a simulation of a layered soil column subjected to vertical propagation of the synthetic time history, which has been generated in the previous subsection. As described in the theoretical basis section, the soil is modeled in P-CARES as horizontally layered 1-D column and the seismic motion is simulated as shear waves propagating vertically through the soil column. The degradation of the soil shear modulus and damping properties as functions of the soil strain can be calculated through deconvolution/convolution analysis, and the responses at various depths in the soil column due to the input seismic motion can then be obtained using the strain-compatible soil column. In addition to the site response analysis, P-CARES also include an option to calculate the SSI motions due to kinematic interaction at the base of the foundation. The site response analysis operates in the frequency domain and requires the input motion be represented as Fourier components. However, the strain calculation can also be specified to be carried out in the time domain, requiring the input motion be temporarily transformed to the time domain using FFT. The computational cost for strain calculation in the time domain is higher than in the frequency domain.

As shown in Figure A-6, the soil column used in this example consists of 4 layers of medium to dense sandy soils. The low strain properties of soil layers are tabulated in Table A.1. The soil degradation relations are assumed to be the SEED-IDRISS model, and the soil types of the four layers are assumed to be "Sand" in this model. The water table is about 10 ft below the ground surface. The layer thickness, the weight density, the low-strain shear velocity, and the low-strain shear modulus (used internally in P-CARES) are considered to be lognormally distributed. The means of these random variables are assumed as values shown in Table A.1, and the coefficient of variation (COV) is assumed to be 10% for the layer thickness and weight density and 20% for the shear wave velocity. The parameters defining the probabilistic distributions of the layer properties are summarized in Table A.2. It is important to note that the deterministic values of the shear moduli (as in Table A.1) derived from the weight density and the shear velocity are different than the means of the shear moduli (as in Table A.2), because the shear moduli are derived random variables from the weight density and the shear velocity. The resultant COV of the shear modulus is about 42.6%. The weight densities or the shear velocities between layers are assumed to be correlated according to a function exponentially decaying as the distance between two layers increases; other feasible correlation can be arbitrarily specified in P-CARES but is not considered in this example. The maximum correlation coefficient is assumed to be 0.2 for the soil column. More specific description of the various parameters used in the site response analysis will be provided when the step by step soil profile modeling is described.

Applied at the bottom of the 4th layer is the acceleration time history previously generated to match the Reg. Guide 1.60 horizontal wave with a PGA of 0.2 g and a damping ratio of 5%. The degraded soil profile is calculated in an iterative fashion. In each iteration, the soil strains due to the input motion are computed using the current constant soil properties and the soil properties for the next iteration are then determined to be matching the strain state from the degradation model. This iterative process stops when the strains computed in two consecutive iterations converge to a user-specified tolerance level. The soil properties of the last iteration become the properties of the strain-compatible soil profile, and are used to compute the output motions at various depths in the soil column. These output motions, which are represented in Fourier components format, include the user requested motions and the motions automatically generated over the embedment of the foundation in kinematic interaction analysis.

The site response analysis of P-CARES will be demonstrated step by step in the following using this simple soil profile. Six subsections will be presented in sequel to describe the features of soil profile modeling, namely the general information, the soil layer information, correlation modeling, and the foundation information, and the analysis options. The P-CARES GUI assists the user to efficiently and conveniently prepare the soil column model and the foundation information for SSI calculation and to manage the deterministic and/or probabilistic analyses. Saving the project periodically during the model preparation is a good practice to avoid the loss of data.

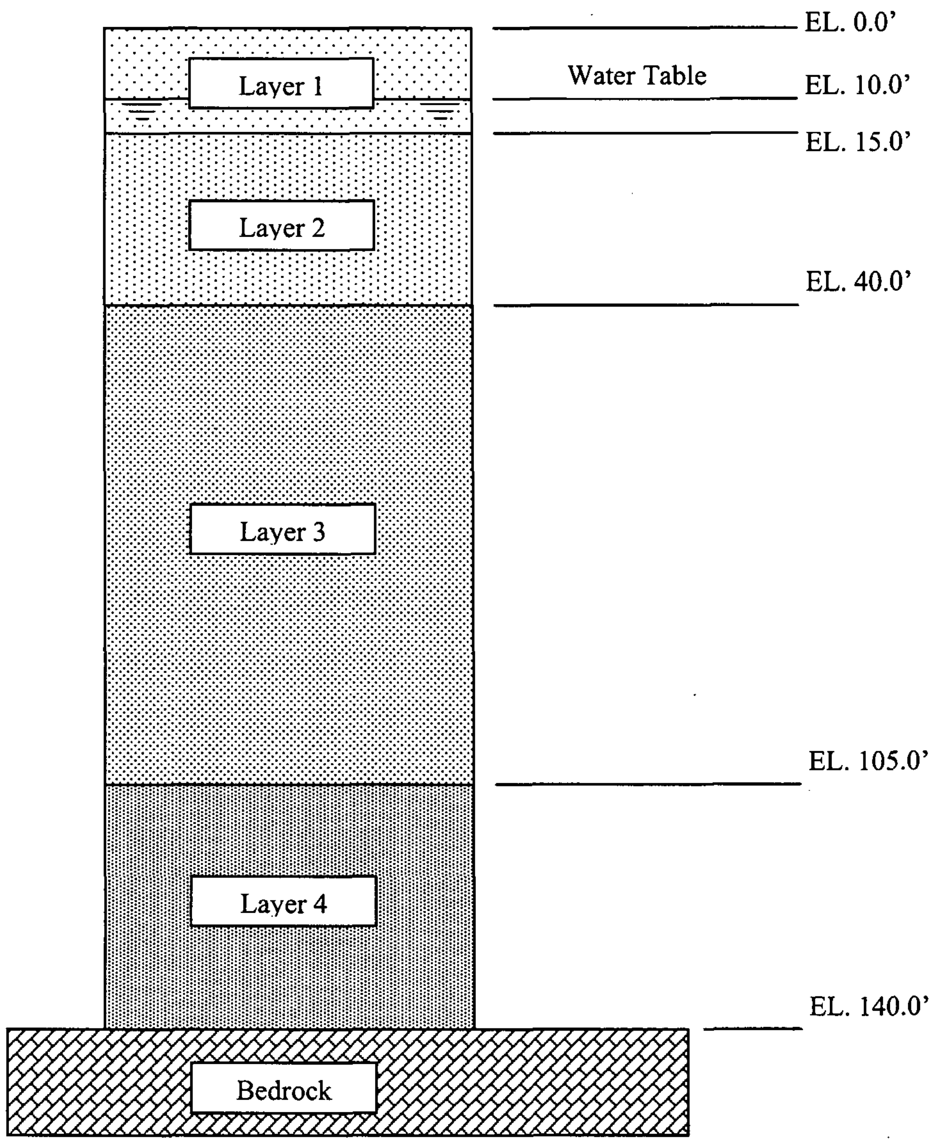


Figure A-6 Soil Profile Used for Site Response Analysis (After Xu, et al 1990)

Table A.1 Low-strain Soil Properties

Layer Id.	Thickness (ft)	Weight Density (pcf)	Poisson's Ratio	Low Strain Shear Velocity (ft/sec)	Shear Modulus (×1000 psf)
1	15	120	0.39	600	1342
2	25	120	0.48	1000	3727
3	65	120	0.48	1200	5366
4	35	120	0.47	1400	7304

Table A.2 Distribution Parameters for Soil Layer Properties

Layer Id.	Thickness (ft)		Weight Density (pcf)		Shear Modulus (×1000 psf)		Low Strain Shear Velocity (ft/sec)	
	Mean	Std	Mean	Std	Mean	Std	Mean	Std
1	15	1.5	120	12	1395	595	600	120
2	25	2.5	120	12	3876	1651	1000	200
3	65	6.5	120	12	5581	2378	1200	240
4	35	3.5	120	12	7597	3237	1400	280

A.2.1 General Information

This modeling feature is located at the "Site Response Analysis/Soil Profile Modeling" within the command tree.. Figure A-7 shows the "General Info" form that defines various parameters for the soil column as a whole. The input parameters are grouped into boxes for the user's convenience. The necessary information is entered as follows,

+ The project name "Example" is also shown as the root of the command tree to signify the current project. The project title can be any descriptive statement about the project.
+ In the box "Soil Profile", the number of soil layers is specified as 4, the soil degradation model is selected as "SEED-IDRISS 1970", the strain calculation method is selected to be "Frequency" domain calculation (default), and the water table is set as 10 ft.
+ The rock properties are omitted in the box "Rock Properties", therefore the input motion cannot be specified in the rock outcrop and no rock outcrop motion can be generated in this example.
+ The input motion is chosen as "Seismic Input", and the input motion data will be read from the file "sample.acc.fc". It is specified at the interface between the soil layer 4 and the bedrock.
+ In "Calculation Parameters" box, specify the cutoff frequency as 30 Hz, and the maximum error (convergence criteria) in calculating the strain as 5%.
+ In "Output Parameters" box, the rock outcrop motion should not be selected because the rock properties were not provided. A list of depths, 0, 10, 80, 120 ft, are specified as locations in the soil column for output motions. The strain-compatible soil profile will be stored in file "FINALSOIL.PRFL", as specified.

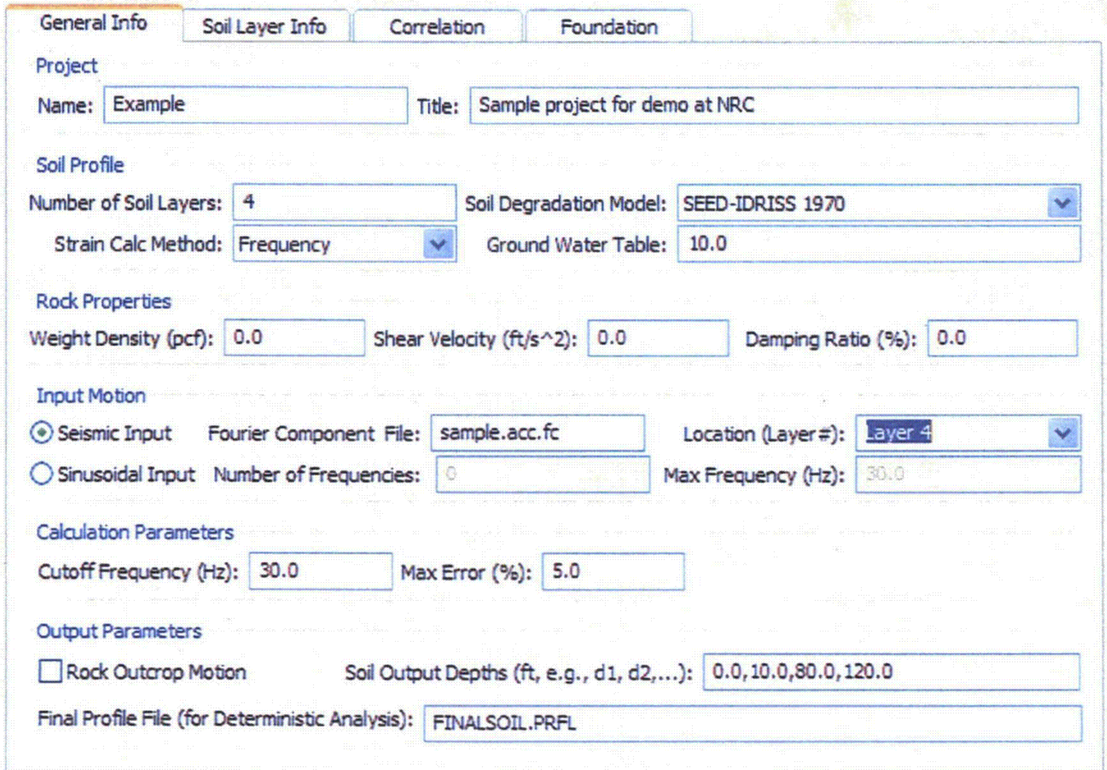


Figure A-7 Soil Profile Modeling - General Information

A.2.2 Soil Layer Information

Figure A-8 to Figure A-11 show the input forms for the 4 soil layers. The user can navigate through layers using the buttons and other controls at the top of these forms. After the data entry for a layer is completed, clicking "Next>>>" with the "Copy previous if new" checked copies the data of the current layer to the next layer if the next layer has not been entered. Using "Propagate>>>" copies the current layer information to and *overwrites* all layers after it. Entering the layer number can directly jump to that layer.

The point values of the soil layer thickness, weight density, and the shear velocity are used for deterministic analysis, while the distributions defined by the mean and the standard deviation (std) are used for probabilistic analysis. A negative number in the boxes under "**Std(-COV)**" is interpreted as the COV, and the corresponding standard deviation is then computed internally. The shear modulus of each layer, which is used internally in P-CARES for the computation, is a derivative quantity from the layer weight density and the shear velocity. The Poisson's ratios are used only in the kinematic interaction analysis. All data in these forms can be found in Table A.1 and Table A.2.

The soil type of the SEED-IDRISS soil degradation model is selected as "Sand" for all 4 layers; the other possible soil type in this model is "Clay". The gray boxes are used for defining the relevant parameters for the constant or user degradation model.

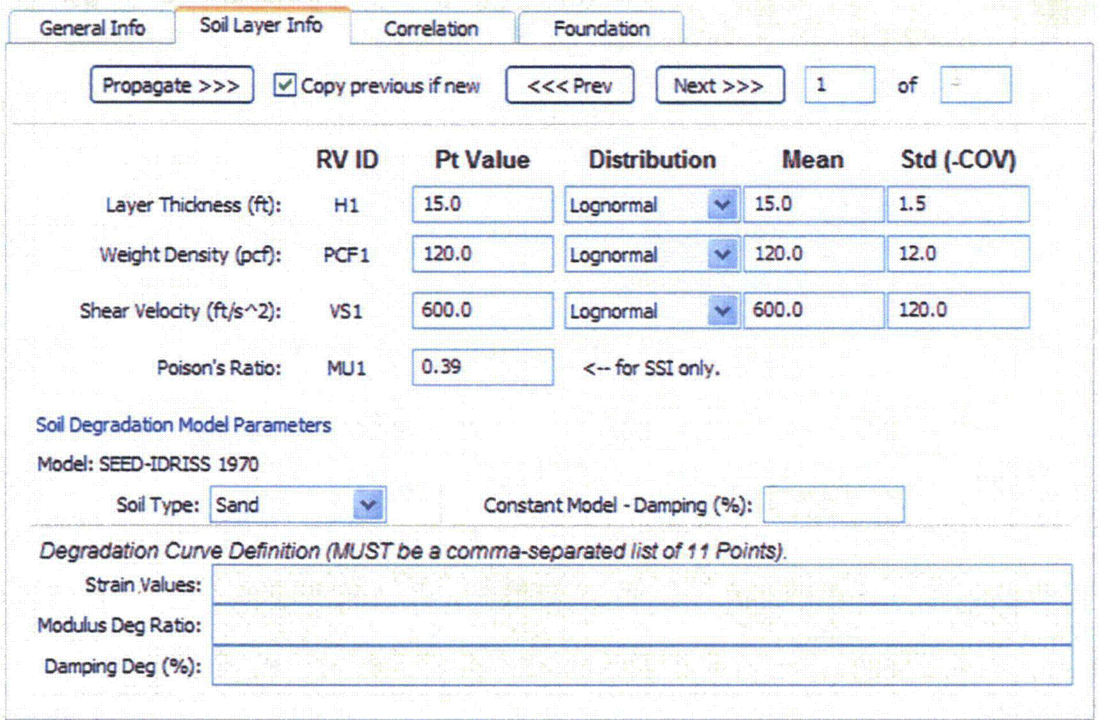


Figure A-8 Soil Profile Modeling - Soil Layer Information for Layer 1

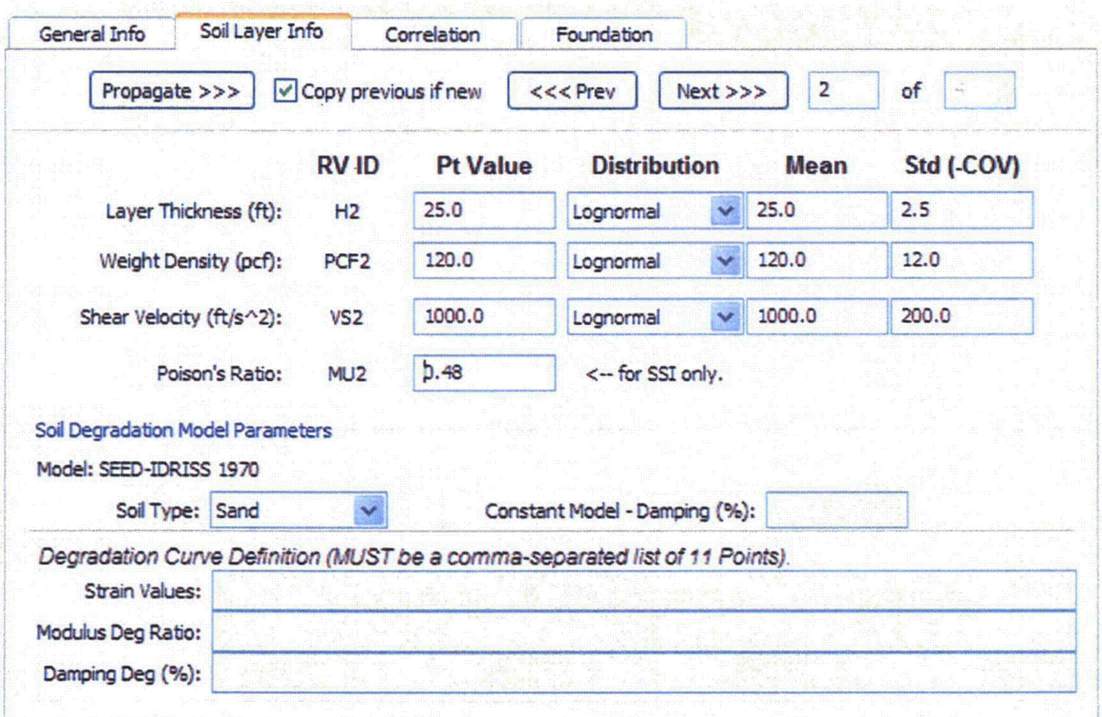


Figure A-9 Soil Profile Modeling - Soil Layer Information for Layer 2

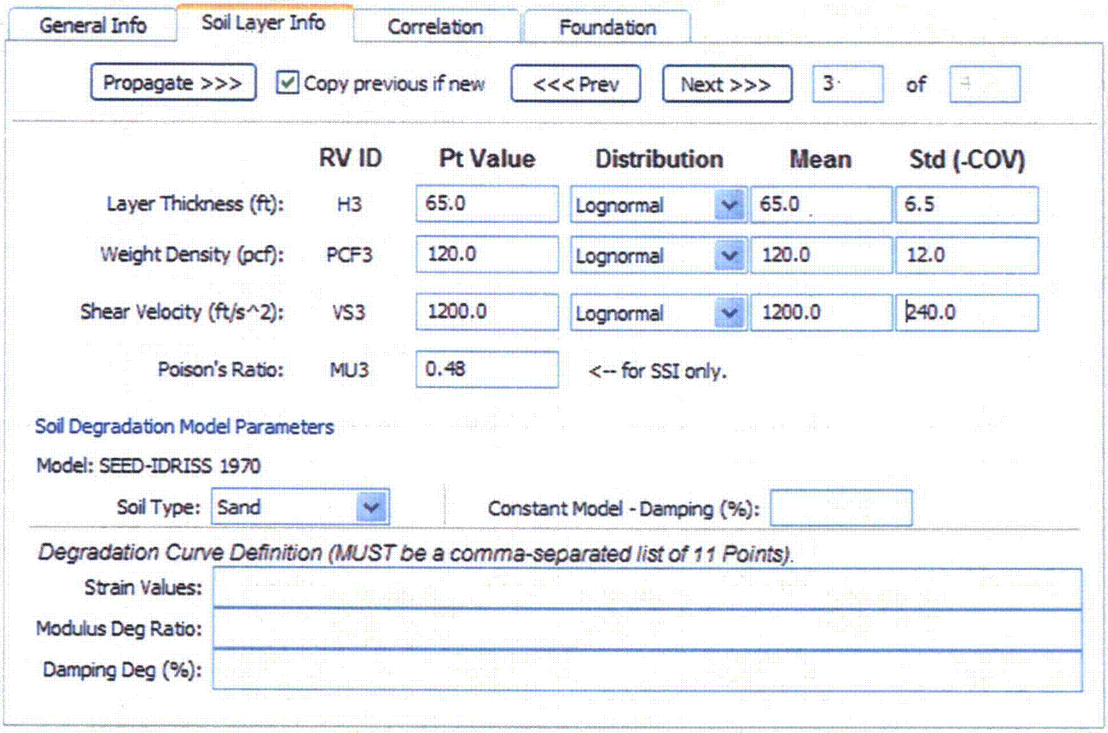


Figure A-10 Soil Profile Modeling - Soil Layer Information for Layer 3

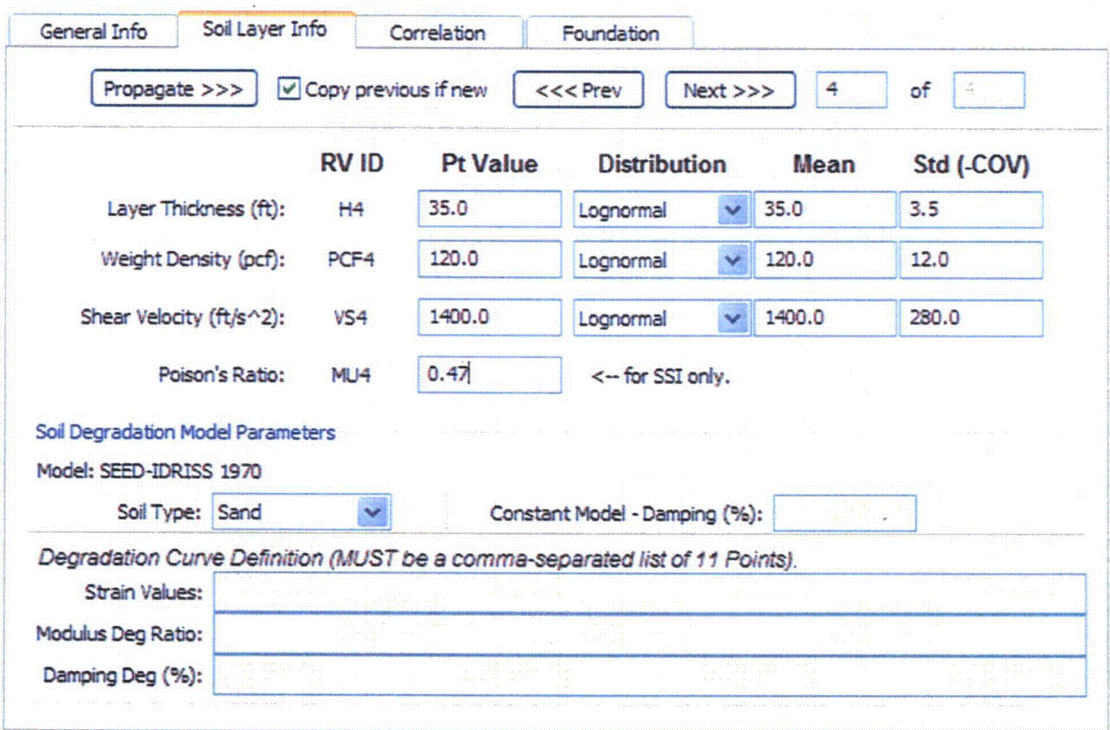
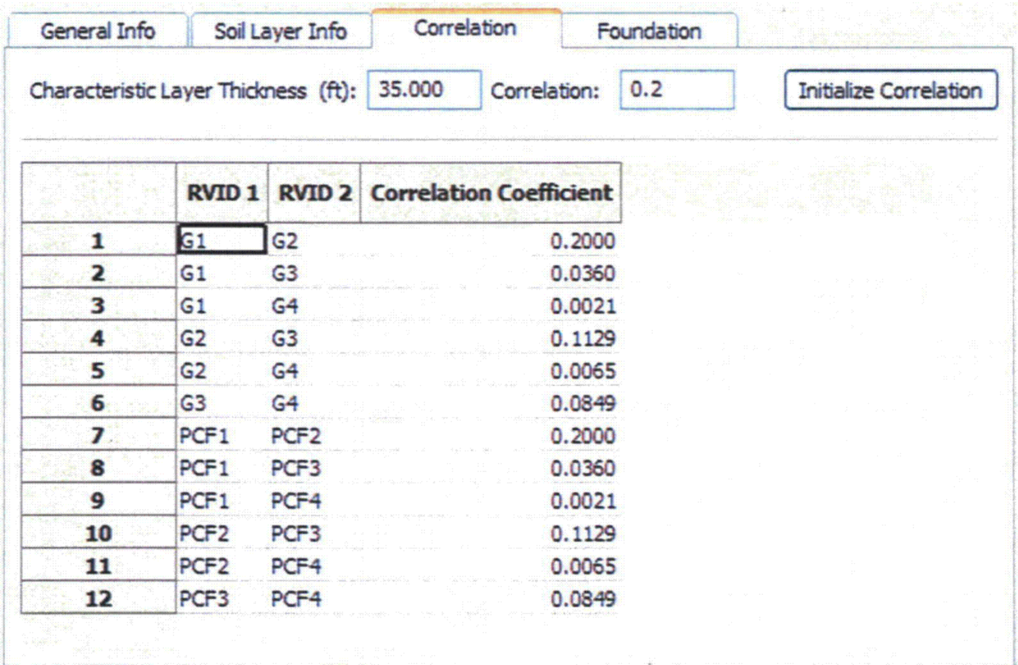


Figure A-11 Soil Profile Modeling - Soil Layer Information for Layer 4

A.2.3 Correlation

Figure A-12 shows the correlation definition form. The correlation table can be populated using a spatial exponential rule as described in the theoretical basis section. The characteristic layer thickness used in this rule is initialized as the average thickness (35 ft), though it can be entered as any positive value. A larger characteristic layer thickness makes the correlation decay slower as the distance between two layers increases. The maximum correlation coefficient is set to 0.2 in this example. Clicking "Initialize Correlation" fills out the correlation table after deleting any previous coefficients. It should be noted that this initialization only considers correlation between layer shear moduli or between weight densities. However, the user can specify any feasible coefficient between any two random variables. Right click on the row ids displays a popup menu for appending and deleting rows, each of which defines a correlation pair. Click any RVID field will show a list of all random variable ids for the user to choose. As an example from the correlation table, the correlation coefficient for the shear moduli between the first layer and the rest layers decays from 0.2, to 0.036, and then to 0.0021.



	RVID 1	RVID 2	Correlation Coefficient
1	G1	G2	0.2000
2	G1	G3	0.0360
3	G1	G4	0.0021
4	G2	G3	0.1129
5	G2	G4	0.0065
6	G3	G4	0.0849
7	PCF1	PCF2	0.2000
8	PCF1	PCF3	0.0360
9	PCF1	PCF4	0.0021
10	PCF2	PCF3	0.1129
11	PCF2	PCF4	0.0065
12	PCF3	PCF4	0.0849

Figure A-12 Soil Profile Modeling - Correlation Definition

A.2.4 Foundation

Figure A-9 shows the foundation definition form. With a single check box "Include kinematic interaction", the user can choose to include or exclude the kinematic interaction analysis during the site response analysis. The kinematic interaction analysis generates the translational and the rotational SSI motions to be used in the SSI and structural analysis. Since the SSI and structural analysis is included in this example, the kinematic interaction analysis is enabled as shown in Figure A-9.

The foundation information is taken from the structural model to be introduced in a late section. The embedment is 10 ft and the radius of the circular foundation is 75 ft. As described in the theoretical basis section, the soil in the context of SSI analysis is modeled as a two-layered soil system (side soil and base soil) in P-CARES. The damping of the side and base soil is assumed as 10% (Xu, et al, 1990). The extended depth, a distance extending downward from the base of the structure for automatic base soil approximation in P-CARES, is set to 30 ft.

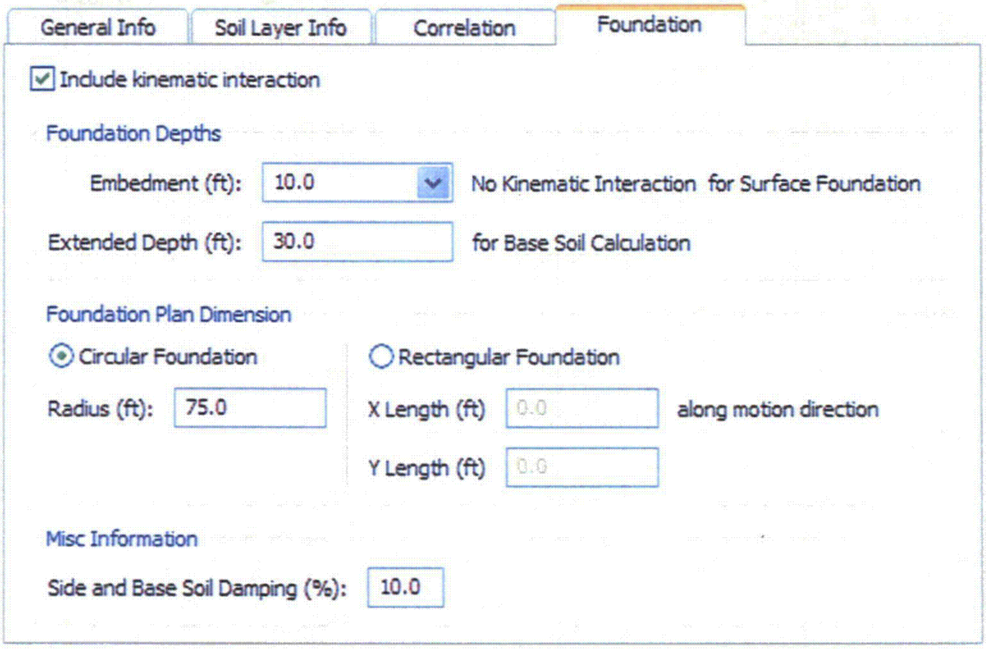


Figure A-13 Soil Profile Modeling – Foundation

A.2.5 Deterministic Site Response Analysis

Figure A-14 shows the form for site response analysis, which is located at the "Site Response Analysis/Calc Site Response" within the command tree. Selection of deterministic type in this form is the only requirement to perform a deterministic site response analysis. Click the button "Run" to start the analysis.

The outputs from the deterministic analysis are stored as text files. In this example, the outputs from the deterministic site response analysis are the strain-compatible soil profile in file "FINALSOIL.PRFL", and four Fourier component files, namely "accout01.fc", "accout02.fc", "accout03.fc", and "accout04.fc", for the output motions at depths of 0, 10, 80, and 120 ft respectively. Another two files, "BASETRAN.FC" and "BASEROT.FC", are the translational and rotational motions from the kinematic interaction analysis and will be used as input motions in the deterministic SSI and structural analysis.

Key soil properties are extracted from the strain-compatible soil profile file ""FINALSOIL.PRFL" and are summarized in Table A.3. Significant degradation in shear velocity and shear modulus has been observed due to the synthetic input motion. For example, the shear modulus and shear wave velocity reduce to about 26.5% and 51.5% of the low-strain values for the 4th layer.

The post processing of the deterministic site responses can be achieved using the seismic motion analysis tools. The time histories and the Fourier spectra shown in Figure A-15 to Figure A-18 are generated using the "Fourier Transforms" tool, for the output depths of 0, 10, 80, and 120 ft in the soil column respectively. Figure A-19 to Figure A-22 show the response spectra generated using the "Response Spectra" tool, using various damping values for the four output depths.

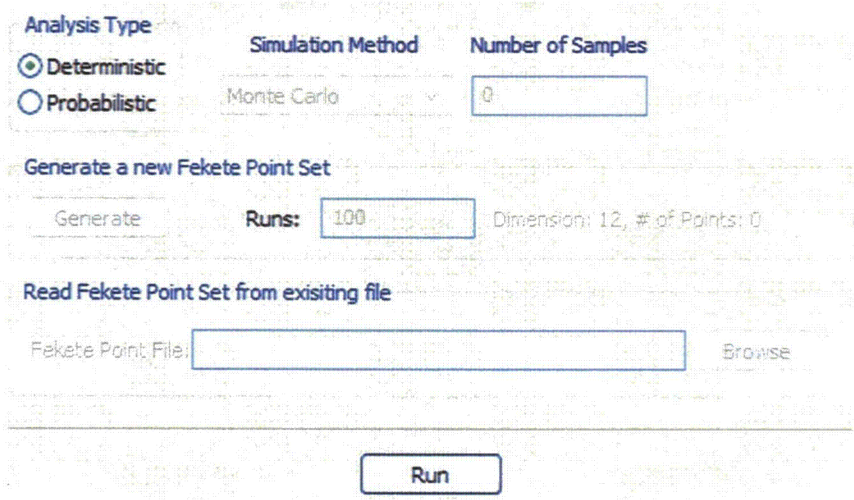


Figure A-14 Calc Site Response - Deterministic Analysis

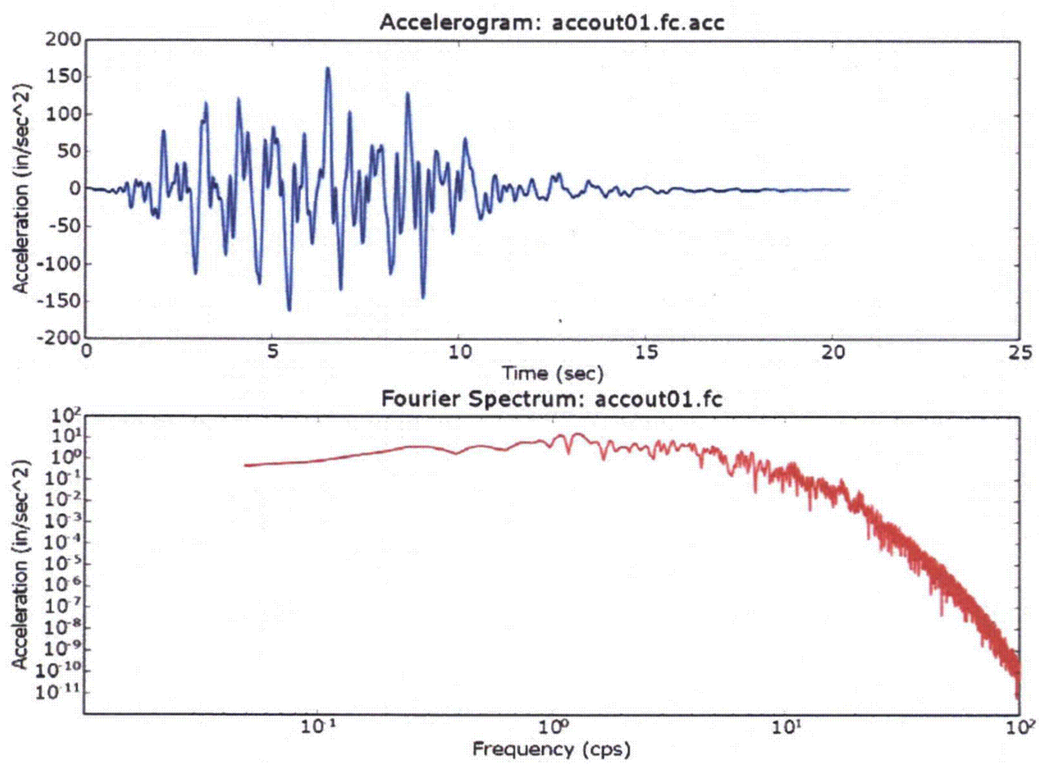
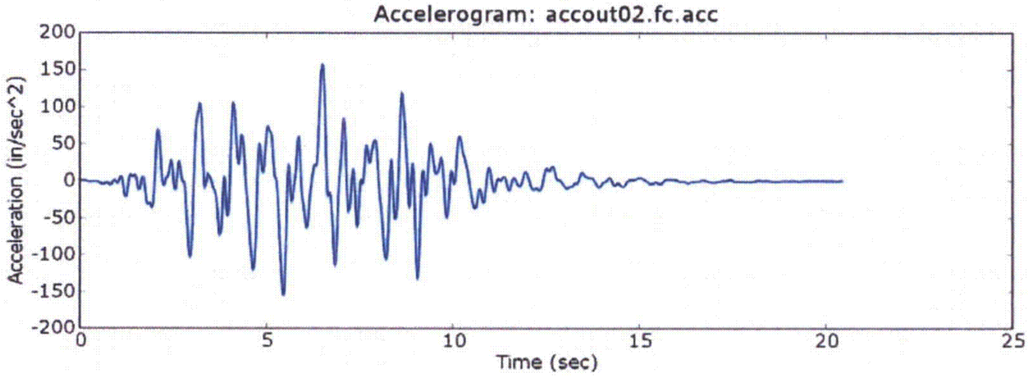


Figure A-15 Deterministic Site Response at 0 ft - Time History and Fourier Spectrum



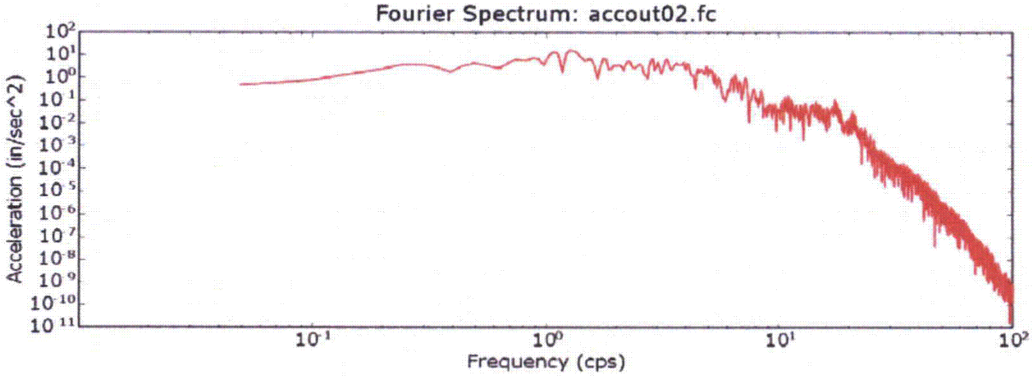
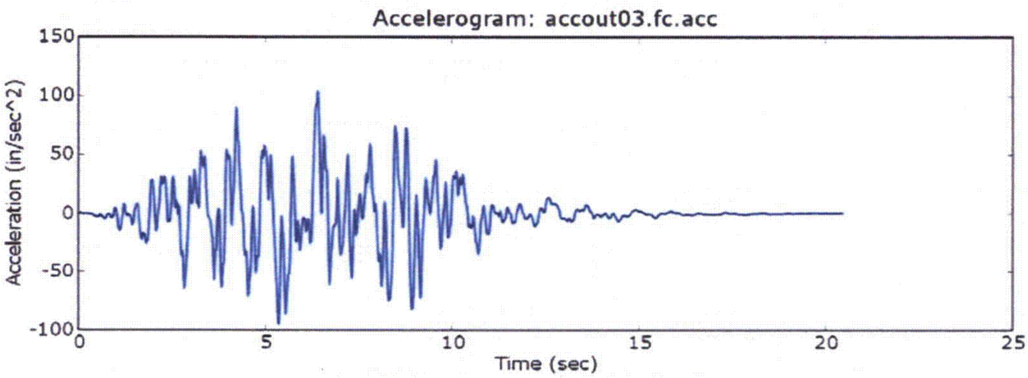


Figure A-16 Deterministic Site Response at 10 ft - Time History and Fourier Spectrum



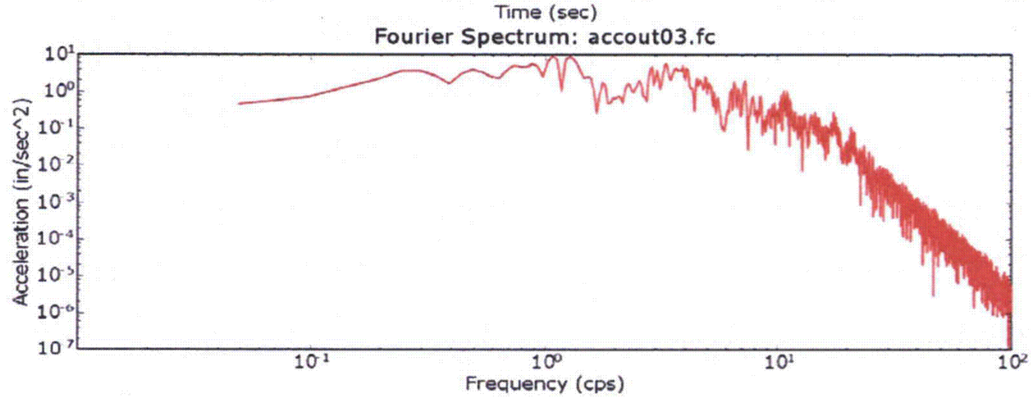


Figure A-17 Deterministic Site Response at 80 ft - Time History and Fourier Spectrum

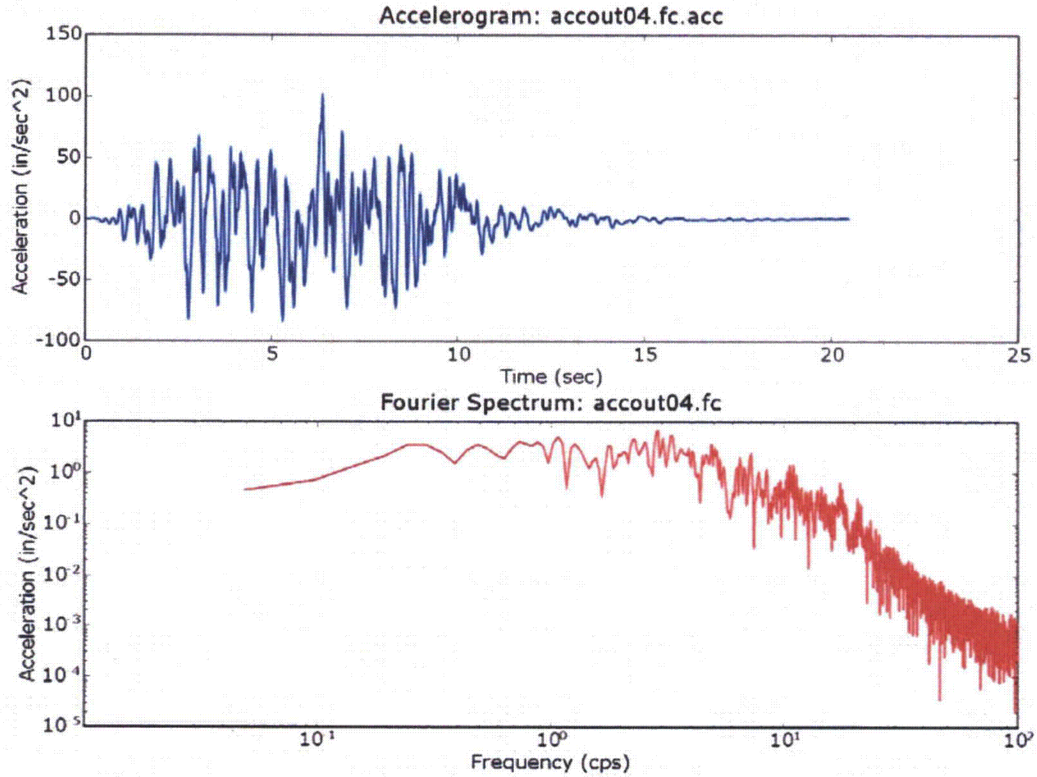


Figure A-18 Deterministic Site Response at 120 ft - Time History and Fourier Spectrum

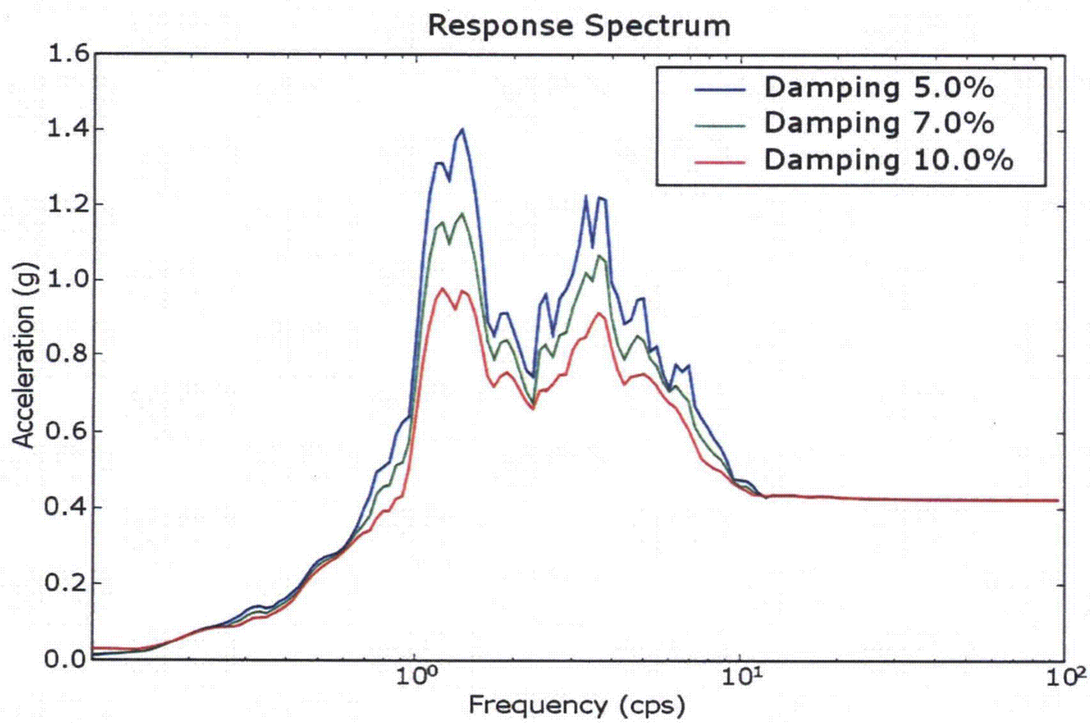


Figure A-19 Deterministic Site Response at 0 ft - Response Spectra

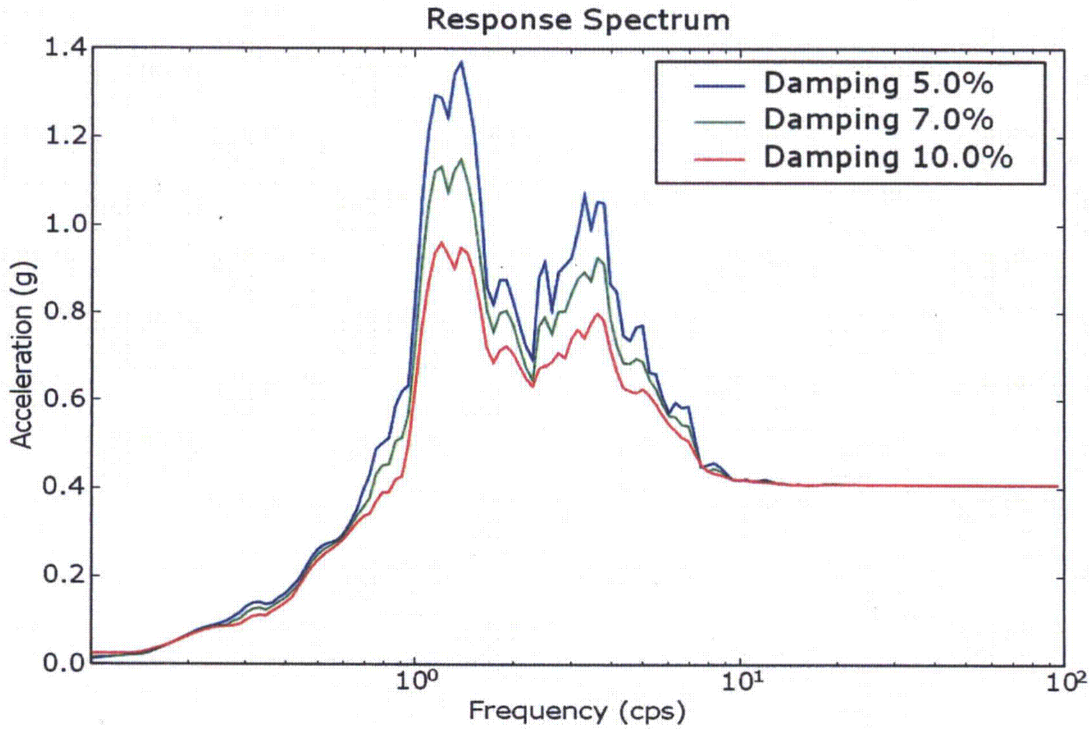


Figure A-20 Deterministic Site Response at 10 ft - Response Spectra

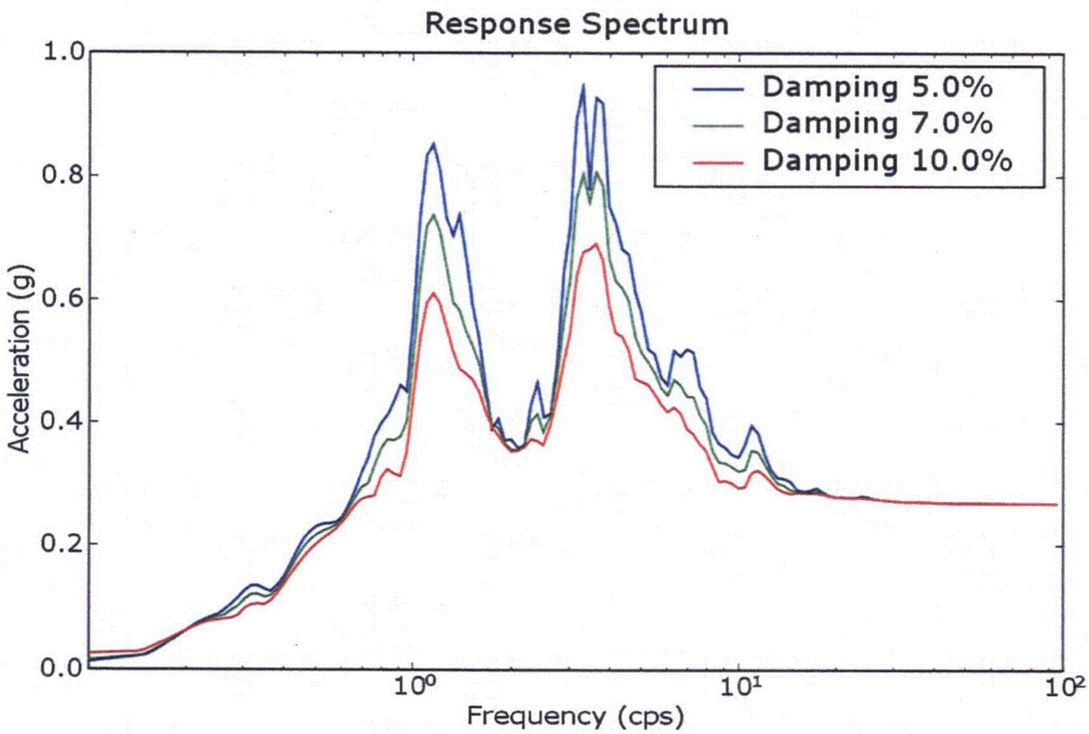


Figure A-21 Deterministic Site Response at 80 ft - Response Spectra

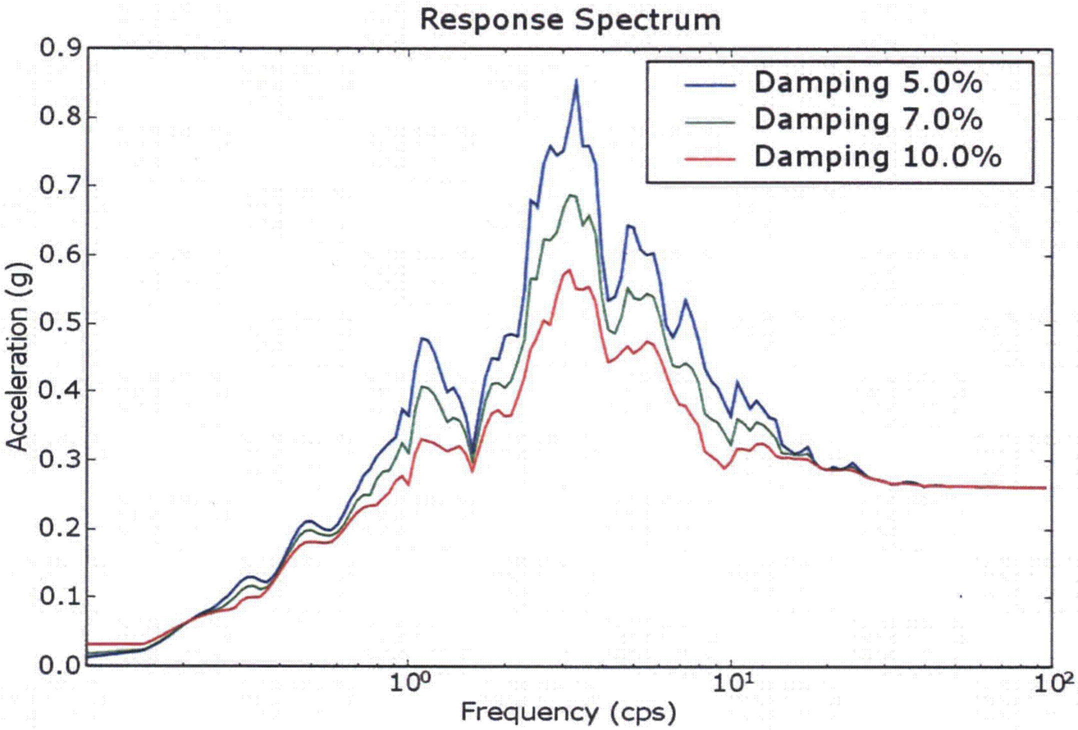


Figure A-22 Deterministic Site Response at 120 ft - Response Spectra

Table A.3 Strain-compatible Soil Profile

Layer Id.	Effective Shear Strain (%)	Shear Modulus (×1000 psf)	Shear Velocity (ft/sec)	Damping Ratio (%)
1	0.0340	578.4	393.8	10.34
2	0.0458	1414.7	616.2	11.77
3	0.0857	1460.0	626.3	14.76
4	0.0893	1936.0	721.3	14.96

A.2.6 Probabilistic Site Response Analysis

Figure A-23 shows the form for site response analysis with the probabilistic analysis type enabled. P-CARES implements four simulation methods Monte Carlo simulation, Latin Hypercube sampling (LHC), Engineering LHC, and the experimental Fekete point set method; details on these simulation methods can be found in the theoretical basis section. If the Fekete point set method is used, the number of samples must be greater than the number of random variables, which is the triple of the number of soil layers. The LHC sampling method with a hundred samples is used in this example. Click button "Run" to start the probabilistic analysis. After the calculation is done, the strain-compatible soil profile samples and the output motions at the four specified locations are stored in databases "SOILPROFILE.DB" and "SOILRESPONSE.DB". Another database file "SSIRESPONSE.HDB" that stores the SSI motions from the kinematic interaction analysis is generated as requested in this example.

The output processing for the probabilistic simulation of the site responses requires the use of the "Post Processing" tool in the command tree, as shown in Figure A-24. This tool can handle the simulated soil profile, the soil responses, and the nodal responses of the super structure. For soil profile data, the statistic measures include minimum, maximum, mean, median, and a number of user-specified percentiles. For both soil and structural responses, the statistics measures for the response spectra include the mean, median, and a number of user specified percentiles. The response spectrum of the input motion can also be plotted on top of other response spectra. After loading the selected database file, the items available for plotting are shown in the drop down list. Click "Draw" to plot the selected item using the current plot options. For response spectra plotting, the user will be prompted to use a previously generated response spectra file if there is one, for the sake of the regeneration effort.

Figure A-25 to Figure A-31 show the statistics plots for the simulated layer thickness, weight density, damping ratio, low strain shear velocity, strain-compatible shear velocity, low strain shear modulus, and strain-compatible shear modulus. Since the damping ratios are obtained from the soil degradation model, their sample distributions do not appear lognormally distributed because the mean can be smaller than the median for some layers. The variation of the shear modulus is larger than that of the other variables, and consequently its statistical plot of the shear modulus reveals a sample distribution more like a lognormal distribution. It is worth noting that a lognormal distribution tends to appear close to a normal distribution when the COV of the random variable is small.

Figure A-32 to Figure A-35 present the response spectra plots for the four output depths of 0, 10, 80, and 120 ft respectively. These figures show that the response of the soil is magnified and the peak of the response spectra shifts to lower frequencies as the wave propagate up vertically through the soil column. Even in a close distance between the output depth of 120 ft and the input motion location at 140 ft, the response spectrum of any individual sample does not resemble that of the input motion (e.g. as in Figure A-22). However, the mean and the median of the simulated responses at a depth of 120 ft are sufficiently close to the response spectrum of the input motion (see Figure A-35).

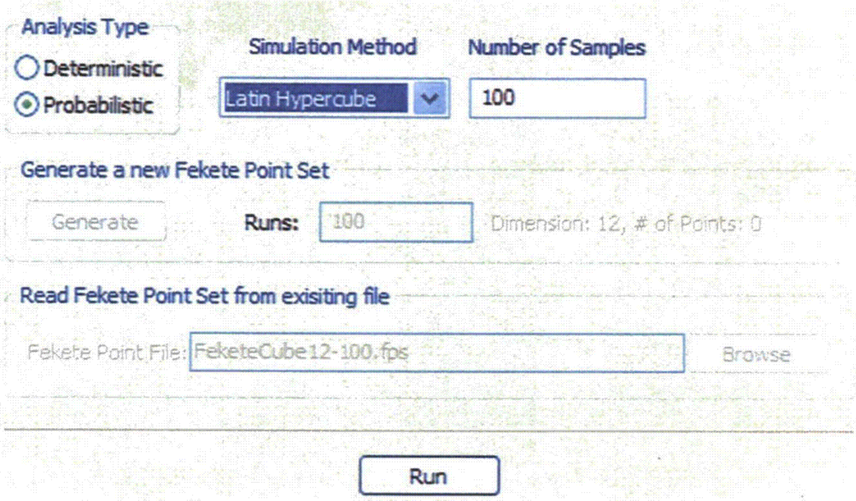


Figure A-23 Calc Site Response - Probabilistic Analysis

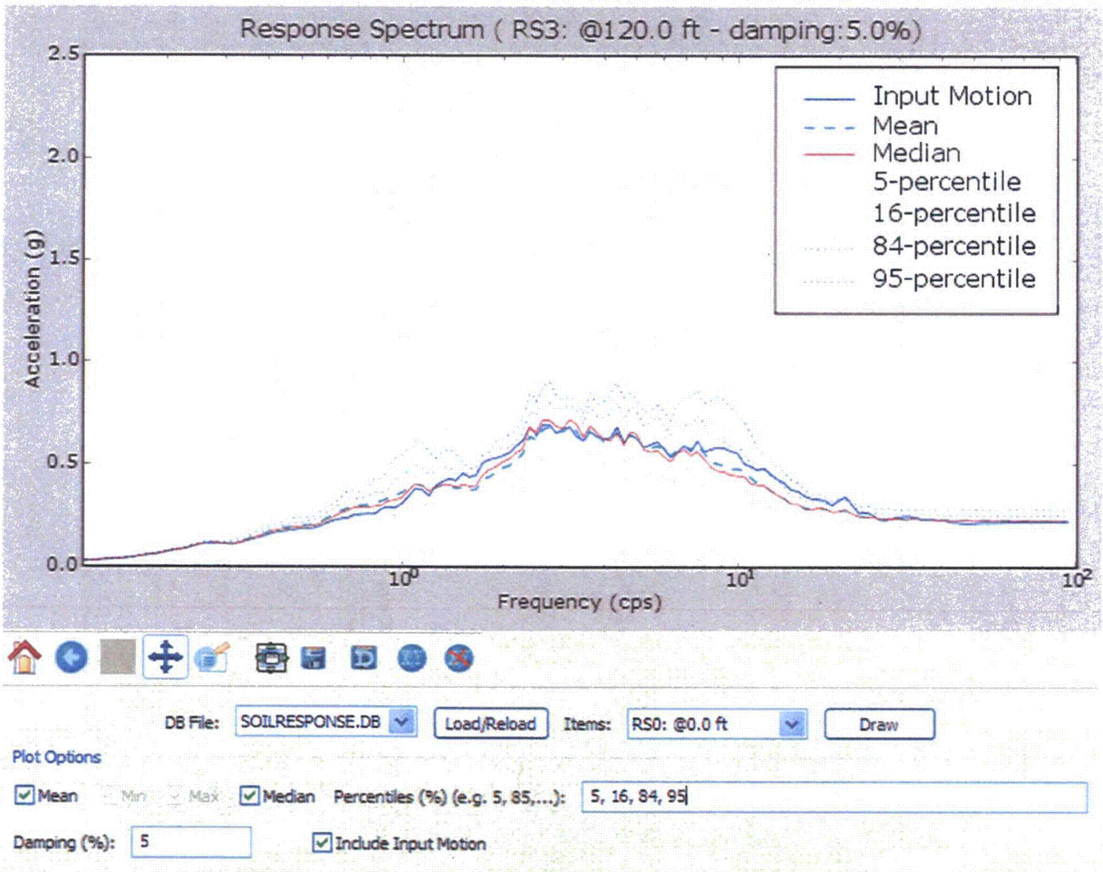


Figure A-24 Post Processing Tool for Simulation Results

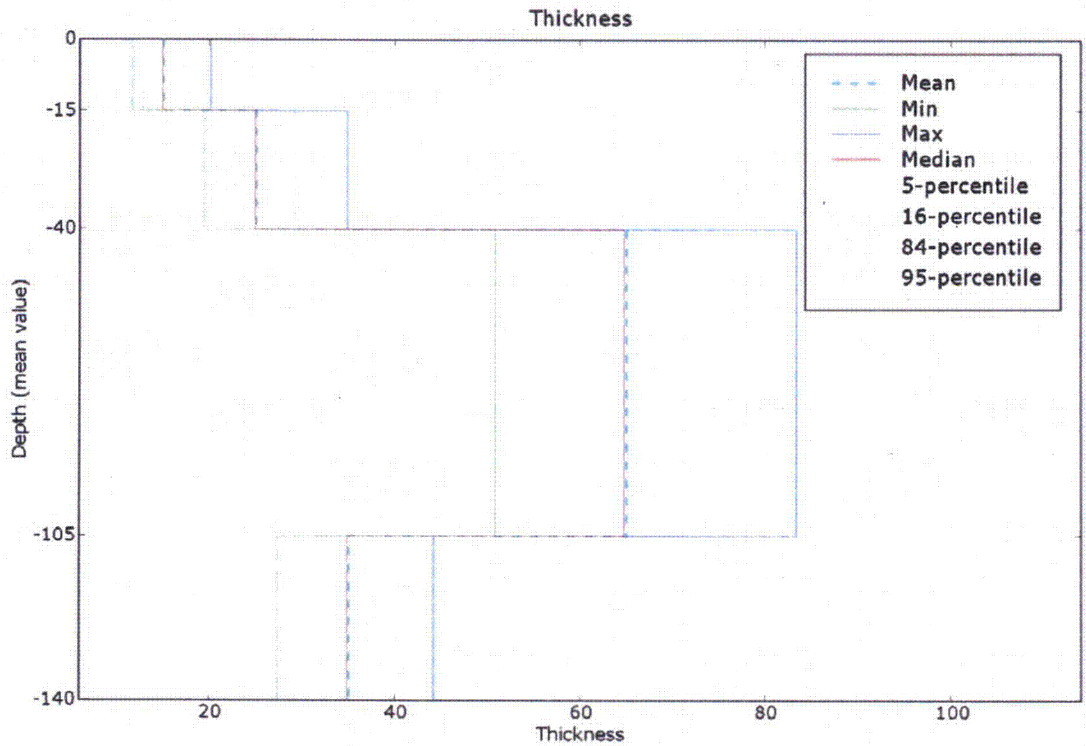


Figure A-25 Probabilistic Soil Profile – Thickness

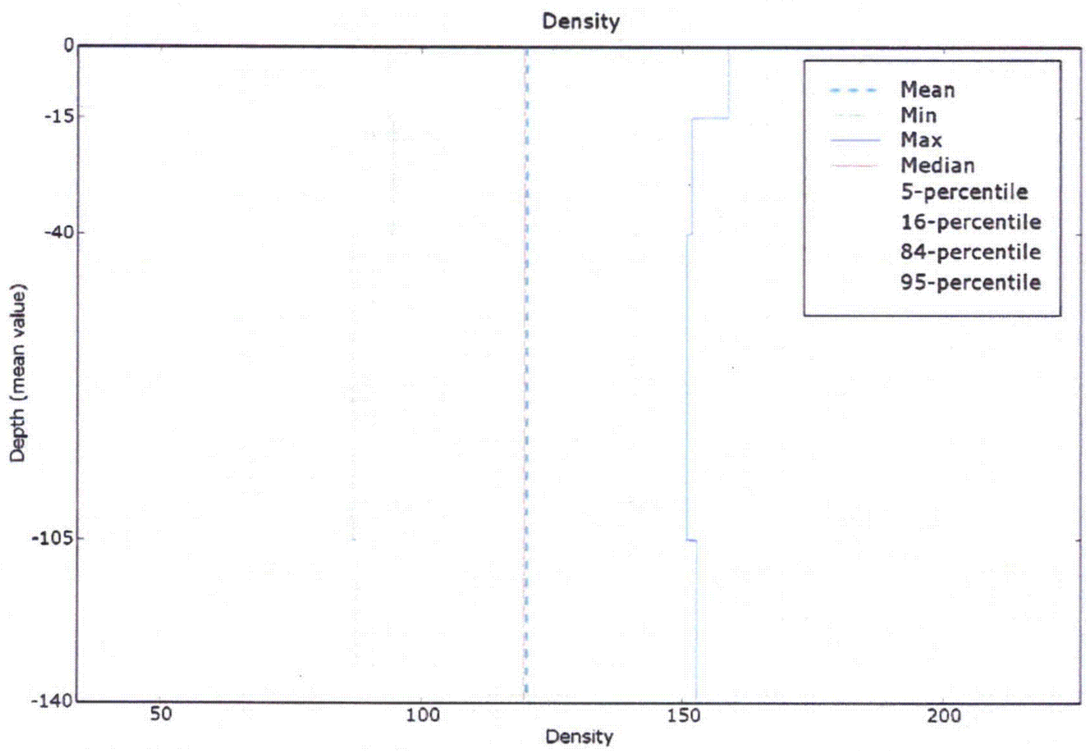


Figure A-26 Probabilistic Soil Profile – Weight Density

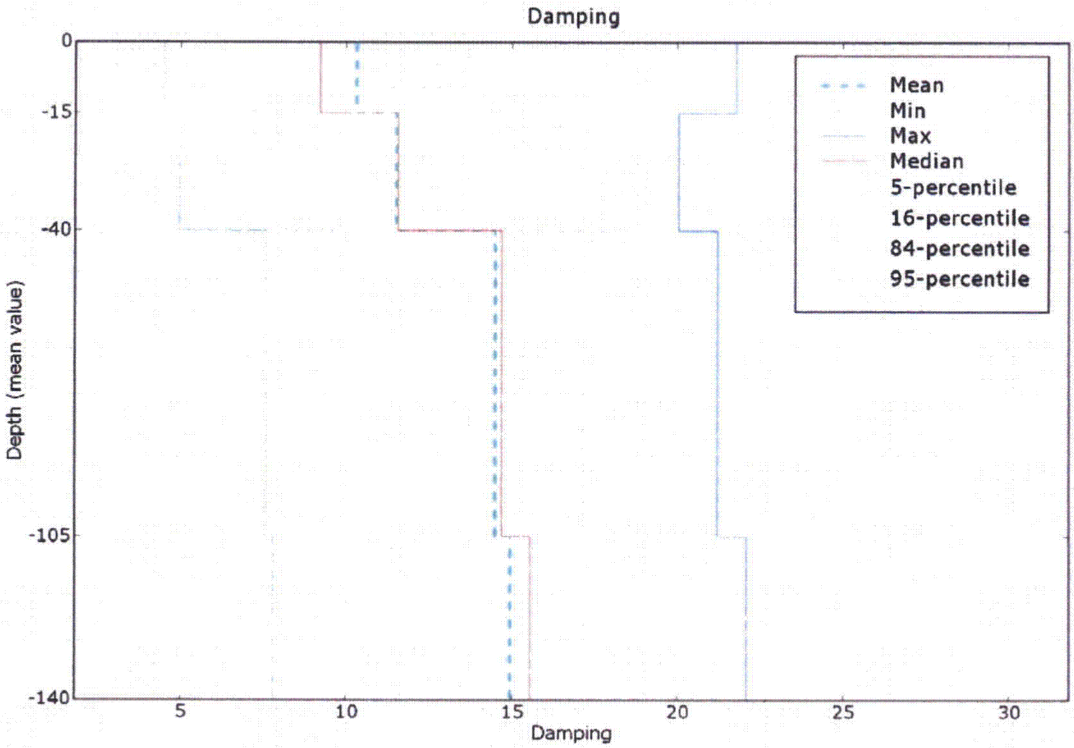


Figure A-27 Probabilistic Soil Profile – Damping

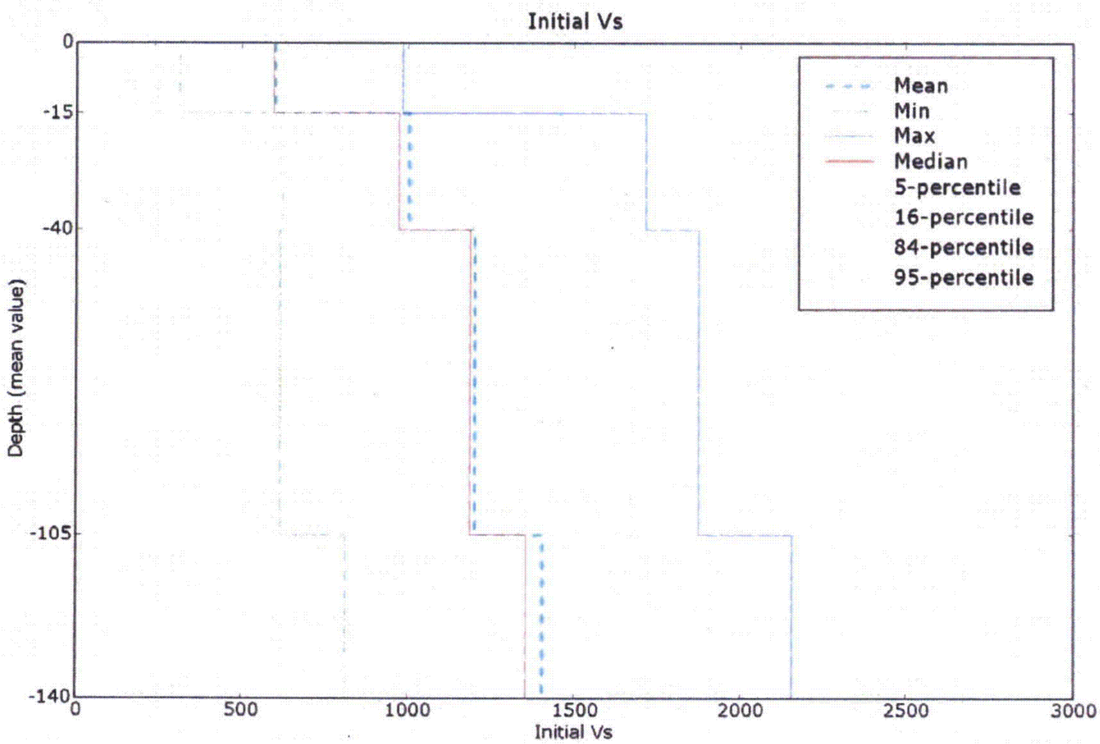


Figure A-28 Probabilistic Soil Profile – Low Strain Shear Velocity

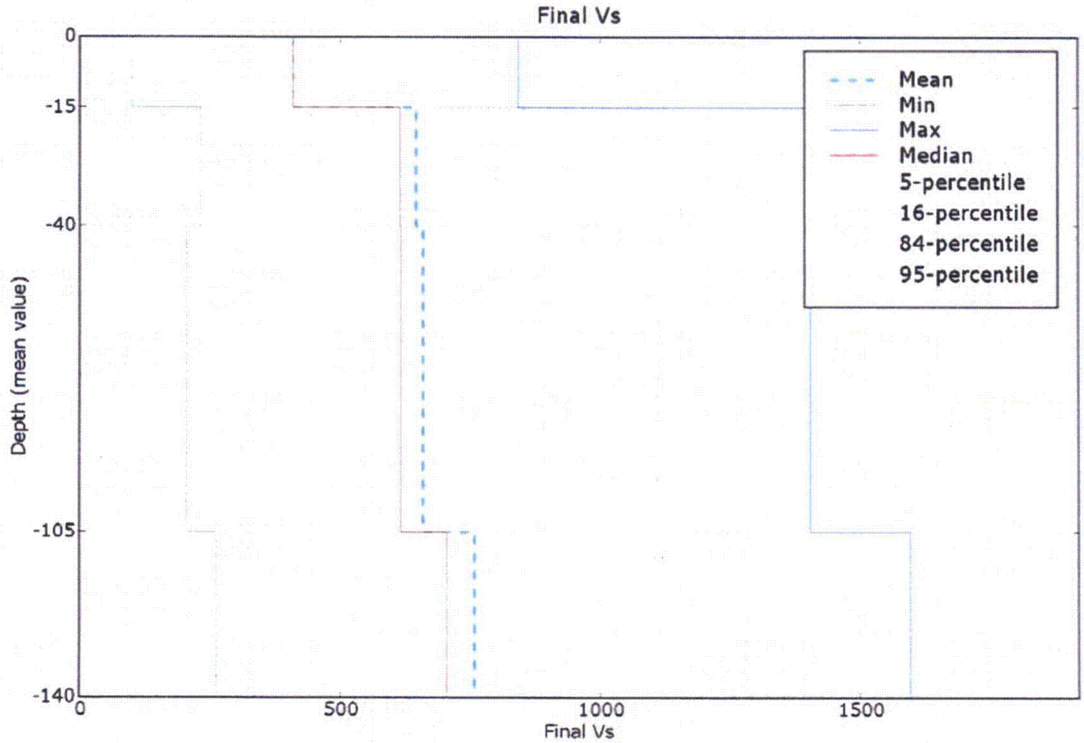


Figure A-29 Probabilistic Soil Profile – Strain-compatible Shear Velocity

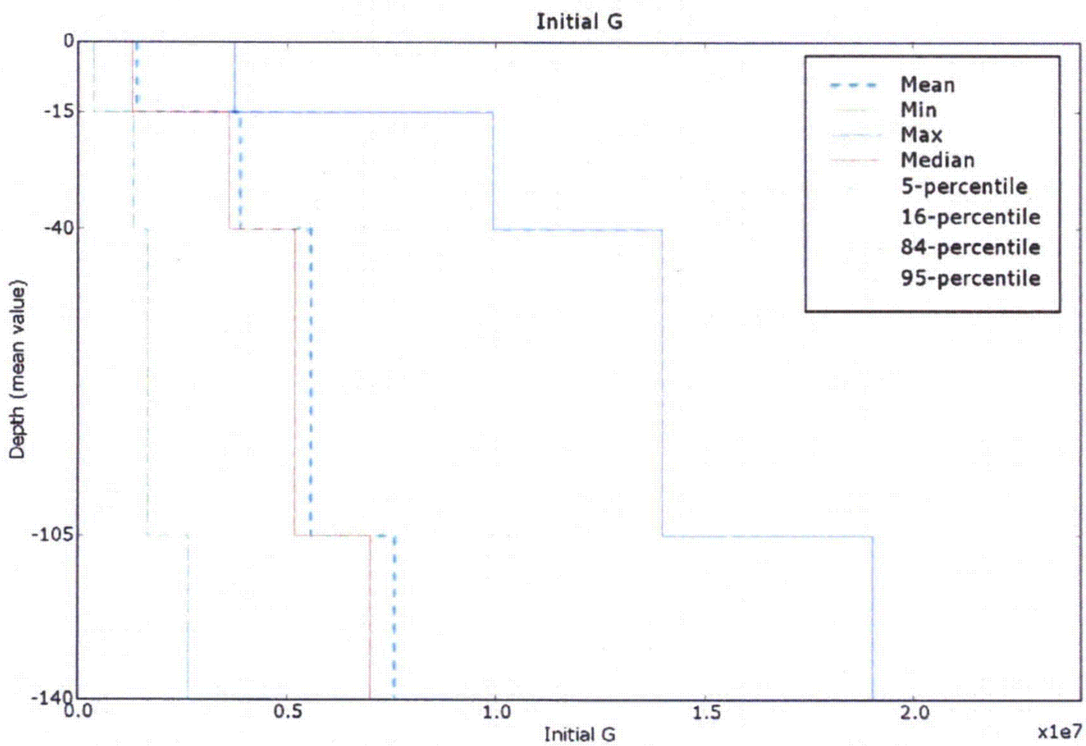


Figure A-30 Probabilistic Soil Profile – Low Strain Shear Moduli

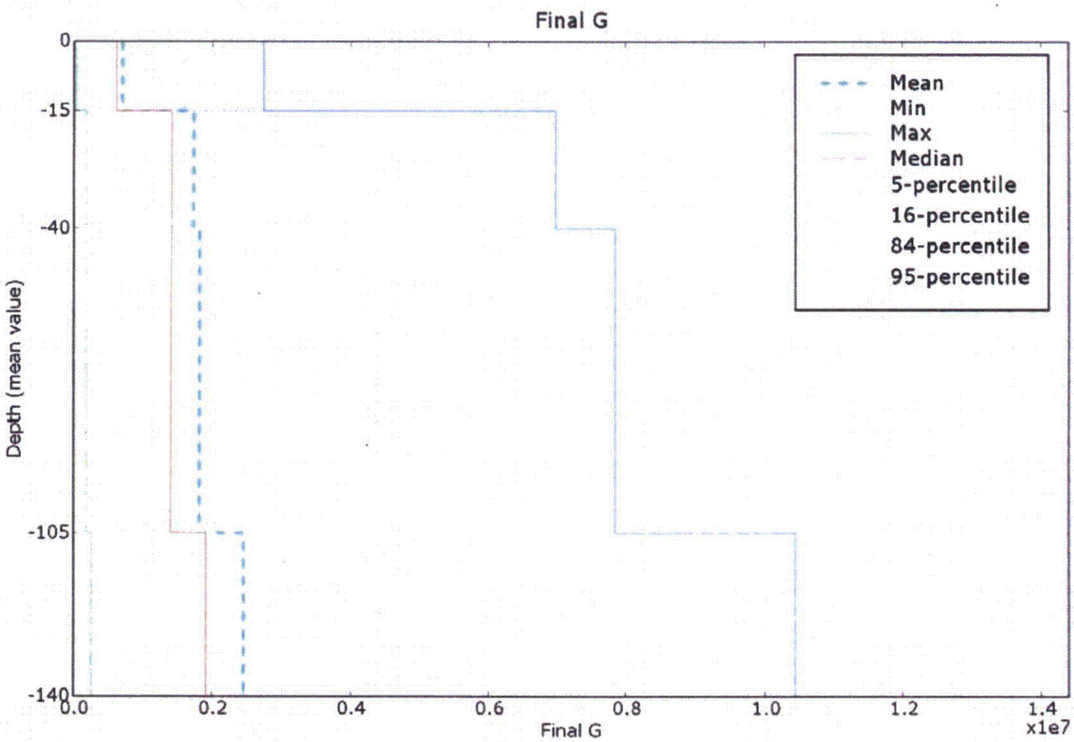


Figure A-31 Probabilistic Soil Profile – Strain-compatible Shear Moduli

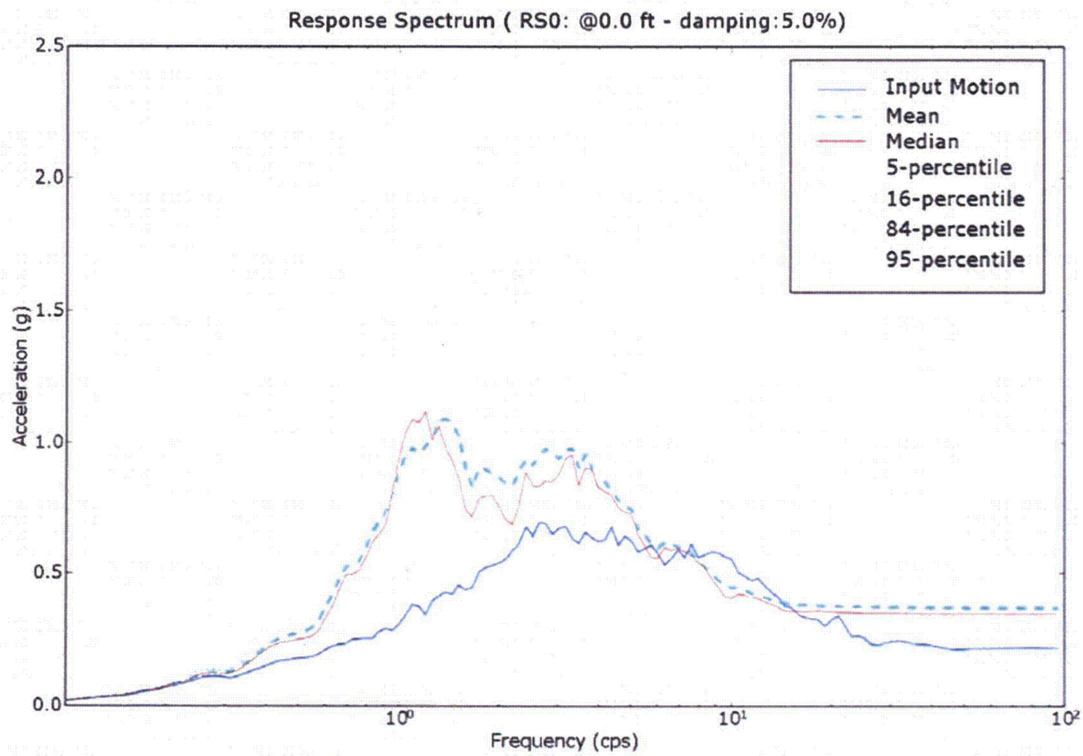


Figure A-32 Probabilistic Site Response Spectra - at 0 ft (Ground Surface)

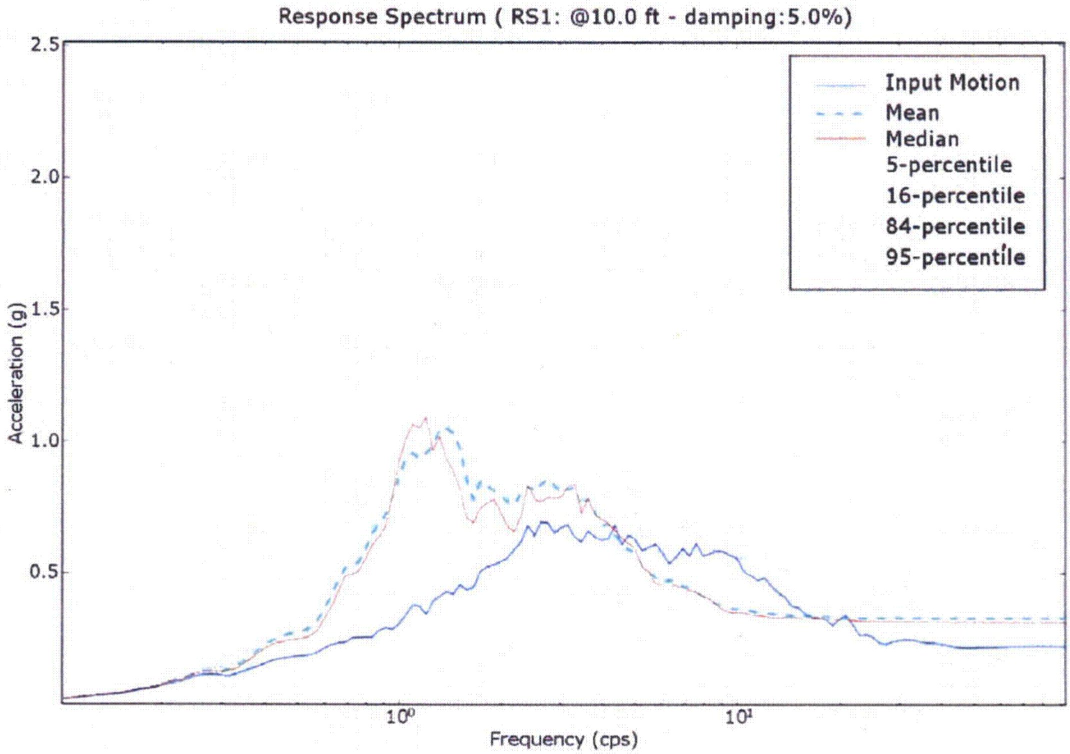


Figure A-33 Probabilistic Site Response Spectra - at 10 ft below Ground Surface

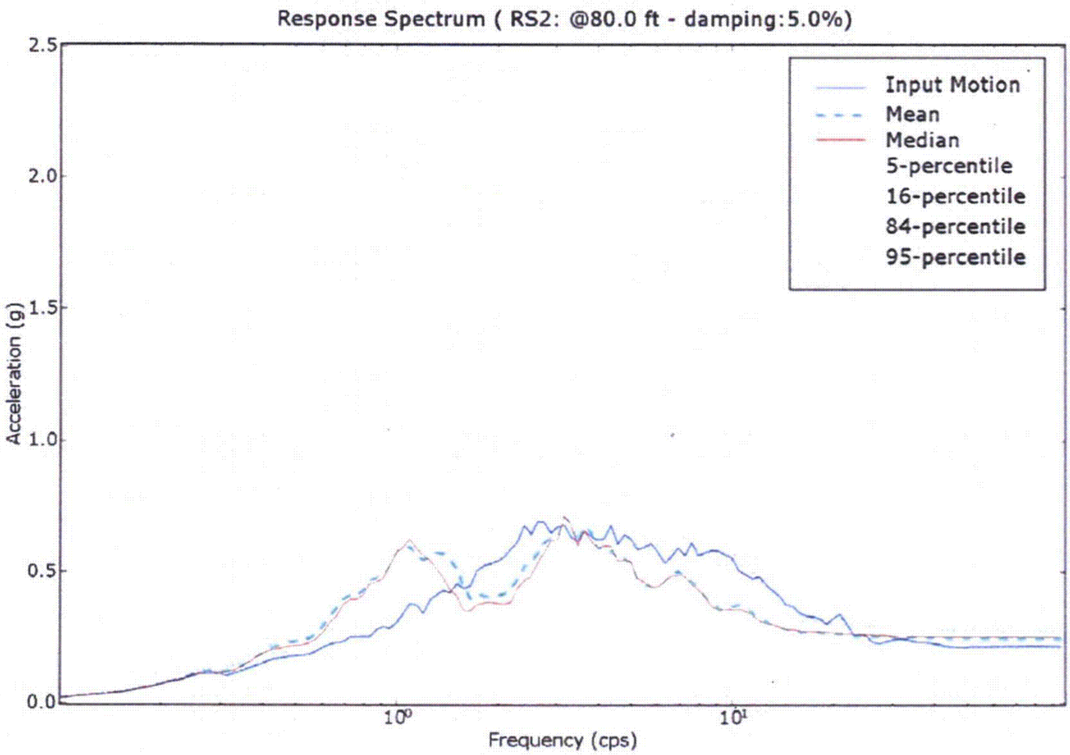


Figure A-34 Probabilistic Site Response Spectra - at 80 ft below Ground Surface

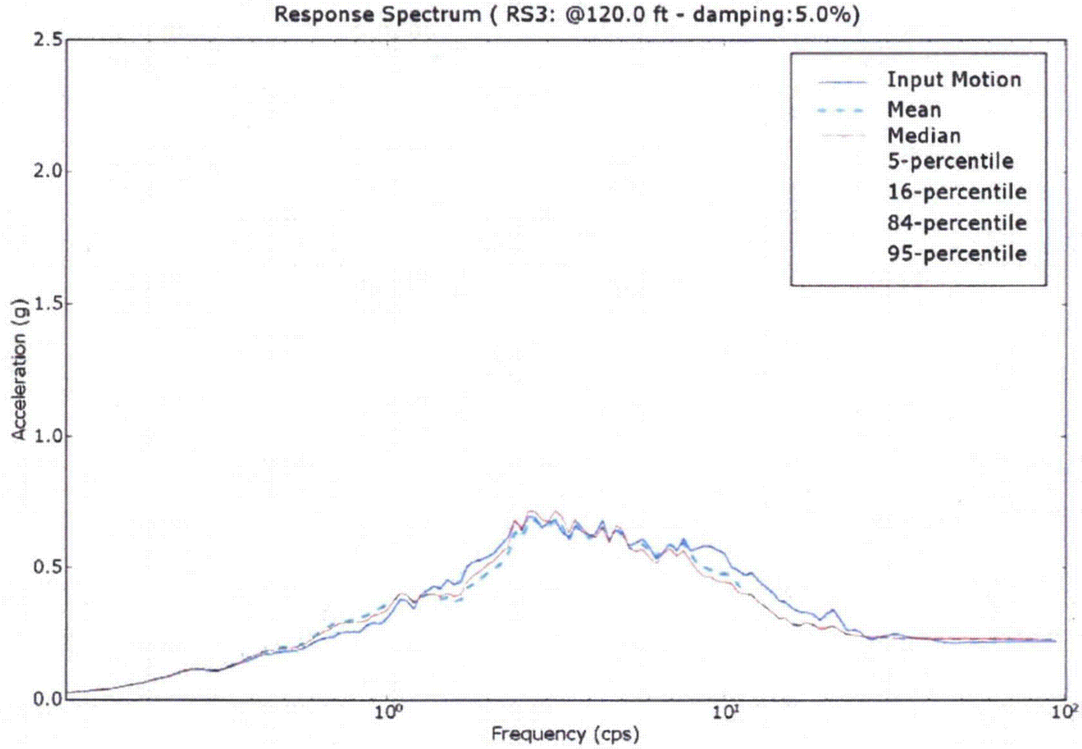
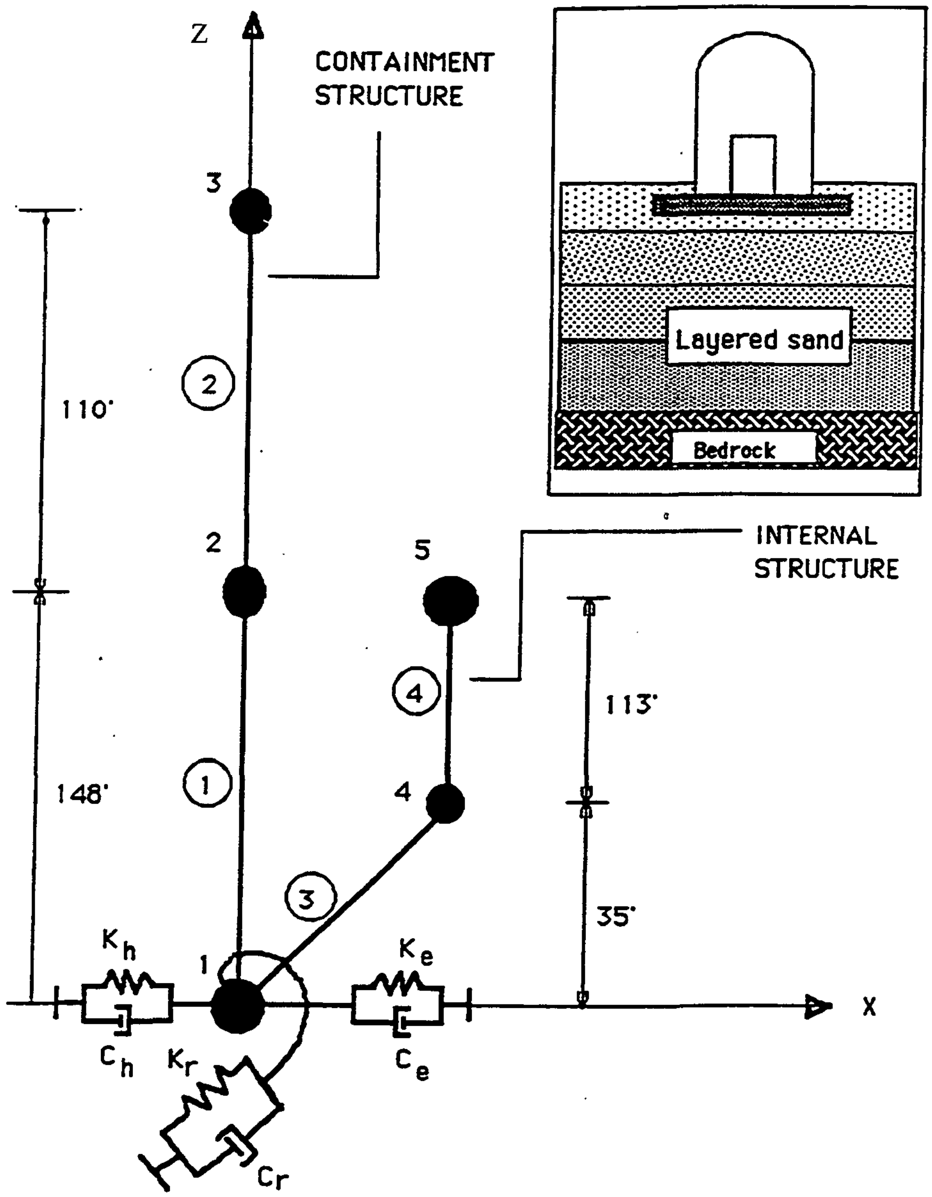


Figure A-35 Probabilistic Site Response Spectra - at 120 ft below Ground Surface

A.3 SSI and Structural Analysis

This section demonstrates the SSI and structural analysis function of P-CARES using a stick model representation of a containment structure and results from the deterministic and probabilistic site response analyses. The containment structure shown in Figure A-36 is about 248 ft high and is supported on a circular foundation basemat of 10 ft thickness and with a radius of 75 ft. The basemat is embedded in the 4-layer soil profile analyzed previously in the site response analyses. The containment building and the internal structures are modeled as a stick model as shown in Figure A-36. The seismic motion of one translational component and one rotational component is obtained automatically from the site response analyses and is applied at the bottom center of the basemat. The properties of the beams and the masses are discussed later when the structural modeling forms are described.

The inputs for the structural model are in units kips, feet, and seconds, which are internally converted to lbs, inches, and seconds. The SSI and structural analysis is conducted in the frequency domain. Results of the deterministic analysis are stored in individual text files that can be post-processed using various seismic motion analysis tools; and the results of the probabilistic analysis are stored in a database file that requires the special "Post Processing" tool.



Note: K_h = Horizontal stiffness ; C_h = Horizontal radiation damper;

K_r = Rocking stiffness ; C_r = Rocking radiation damper;

K_e = Embedment stiffness ; C_e = Embedment damper ;

Figure A-36 Stick Model of A Containment Structure for SSI Analysis [after Xu, et al, 1990]

A.3.1 Nodes/Constraints

As shown in Figure A-37, the stick model of the containment and the internal structures consists of 5 structural nodes and one auxiliary node (the 6th node) that is used to define the beam sectional orientations. The coordinates of the 5 structural nodes in Figure A-37 matches the stick model in Figure A-36, and the node 6 are arbitrarily located on the positive X axis. All nodes are defined in the X-Z plane. The 5 structural nodes are constrained such that only the motions in the X-Z plane are allowed because the SSI motions generated in the site response analysis have only two components in this plane. Node 6 is fixed in all 6 degrees of freedom. The nodal weights and the rotary inertias around the Y axis at the structural nodes are the same as in reference Xu. et al, 1990.

There are no coupled degrees of freedom and rigid links in this example. The SSI motions are applied to node 1, to which the soil springs and dampers are attached as well. It is worth noting that, although the SSI springs and dampers are shown only available in the X-Z plane in Figure A-36, they are indeed applied in P-CARES to all 6 degrees of freedom at the SSI node. The nodal constraints and the input motions obtained from the site response analysis effectively convert a 3D problem into a 2D problem in this example. However, the structural model in P-CARES is a true 3D model, and the input motions can include all 6 components if a standard alone deterministic SSI and structural analysis is performed. As in Figure A-37, output motions are requested for all 5 structural nodes.

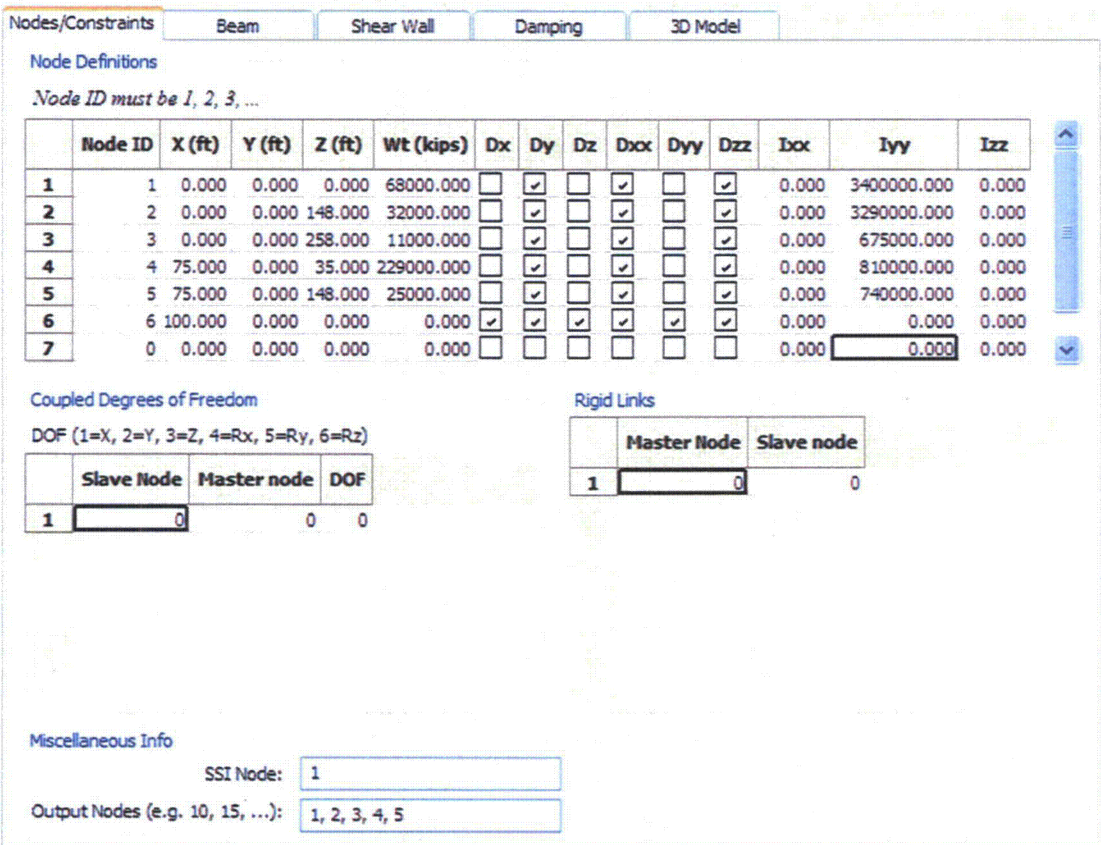
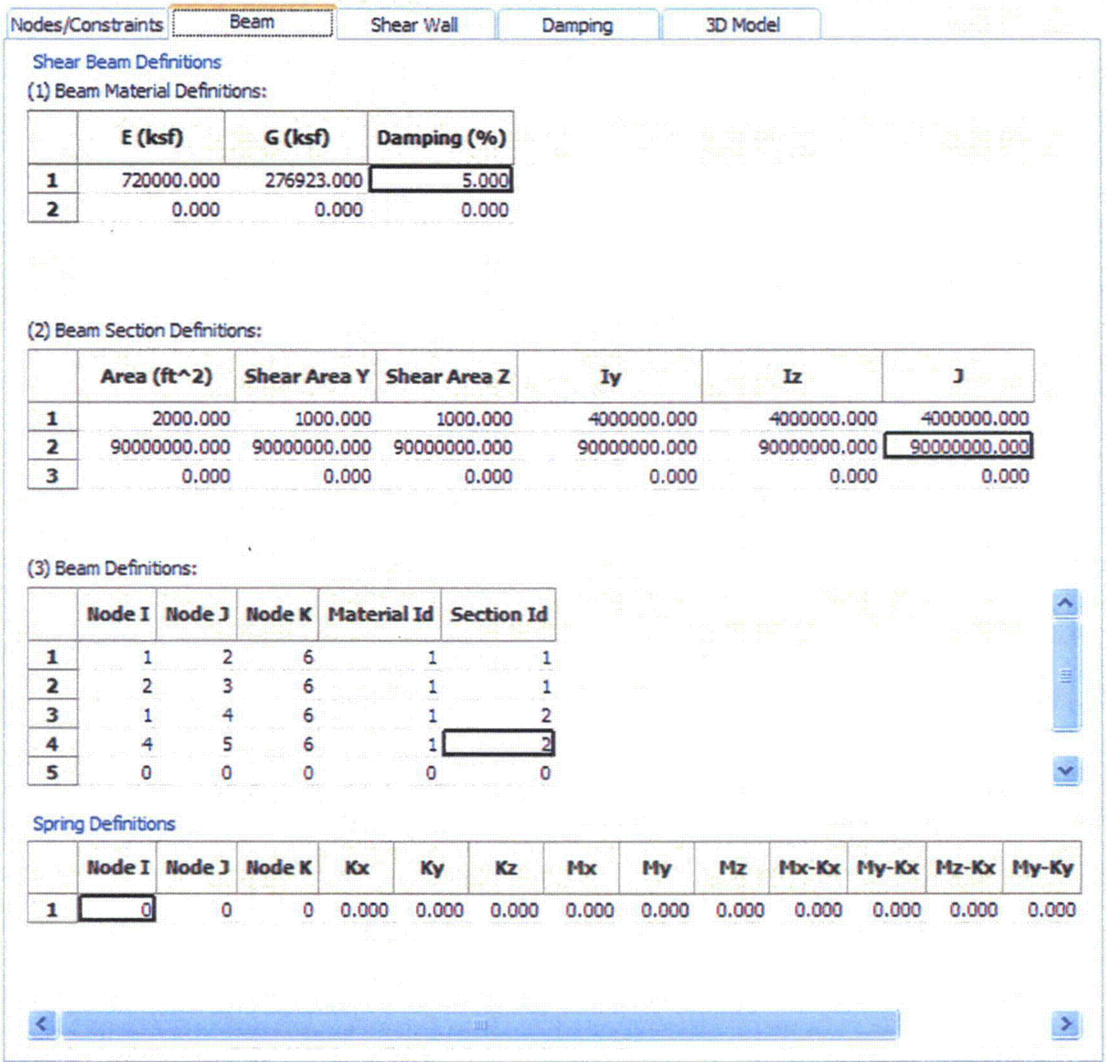


Figure A-37 Structural Model - Nodes/Constraints

A.3.2 Beam

Figure A-38 shows the beam definition form, where shear beams and the flexural beams (springs in P-CARES terms) can be defined. The same material, defined by the Young's modulus, shear modulus, and the damping ratio, is used for all 4 beams. The damping ratios defined in the material definitions are used for the composite or the stiffness matrix only damping model, and are not used if any of the first two structural damping models is used. The containment structure is modeled with beams 1 and 2 that have realistic section properties as shown in Figure A-38; while the internal structural is modeled with beams 3 and 4 that have fictitious large section properties effectively turning them into rigid members. Beam connectivity information is entered through the "Beam Definitions" table. No springs and shear walls (use "Shear Wall" form, not shown) are defined in this example.



Nodes/Constraints | Beam | Shear Wall | Damping | 3D Model

Shear Beam Definitions

(1) Beam Material Definitions:

	E (ksf)	G (ksf)	Damping (%)
1	720000.000	276923.000	5.000
2	0.000	0.000	0.000

(2) Beam Section Definitions:

	Area (ft^2)	Shear Area Y	Shear Area Z	Iy	Iz	J
1	2000.000	1000.000	1000.000	4000000.000	4000000.000	4000000.000
2	90000000.000	90000000.000	90000000.000	90000000.000	90000000.000	90000000.000
3	0.000	0.000	0.000	0.000	0.000	0.000

(3) Beam Definitions:

	Node I	Node J	Node K	Material Id	Section Id
1	1	2	6	1	1
2	2	3	6	1	1
3	1	4	6	1	2
4	4	5	6	1	2
5	0	0	0	0	0

Spring Definitions

	Node I	Node J	Node K	Kx	Ky	Kz	Mx	My	Mz	Mx-Kx	My-Kx	Mz-Kx	My-Ky
1	0	0	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Figure A-38 Structural Model – Beam Definition

A.3.3 Damping

The second damping model is selected for this example, as shown in Figure A-39. In this model, the coefficients for the mass matrix and the stiffness matrix in the Raleigh damping formulation are computed based on the first two modes of the structure (with the SSI node fixed) and requires a critical damping ratio p, which is set to 5% in this example.

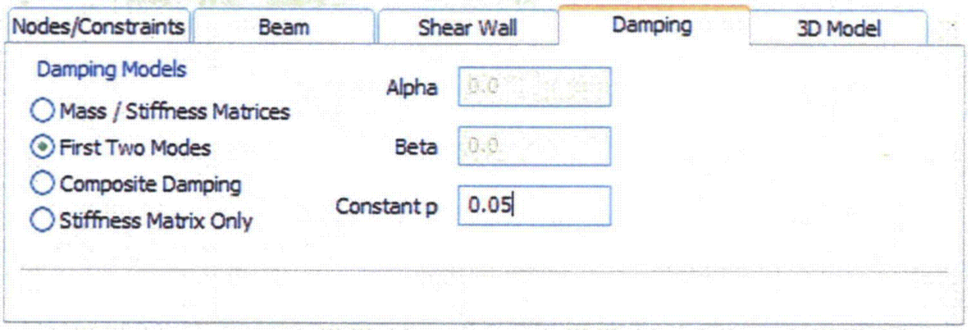


Figure A-39 Structural Model – Structural Damping

A.3.4 3D Model Viewer

The structural model built using the nodes/constraints, beam, and shear wall forms can be visualized using this form. Figure A-40 shows the stick model for the containment and the internal structures, in which nodes are represented by balls, beams by cylinders, and the SSI node by a small cube. Since the stick model is simple, only the nodal ids are shown. The model can be rotated, panned, and zoomed by dragging the left, middle, and right mouse buttons. A marker at the lower left corner showing the orientation of the axes is dynamically updated as the model is rotated.

Figure A-40 Structural Model – 3D Structural Model Viewer

A.3.5 Deterministic SSI and Structural Analysis

Figure A-41 shows the form for SSI and Structural analysis, which is located at the "SSI & Structural Analysis/Calc Structural Response" within the command tree. There are three options in this form: the Joint SSI choice is for SSI and Structural Analysis using the soil profile and the SSI motions generated in the site response analysis, the Standalone Deterministic SSI choice for an analysis using user-specified side and base soil properties and SSI input motions, and the Frequency Domain Shaker is for an analysis using the user-specified side and base soil properties and a forcing function at a specified node. This example demonstrates the most common use of the SSI and Structural analysis, in which the site responses and structural responses are calculated in a consecutive fashion. The "starred" (disabled) forms are for the other two analyses. In a joint deterministic SSI and structural analysis, the deterministic analysis type is required to be selected in the site response analysis. The maximum frequency is set to 100 Hz in this example. Click button "Run" to start the analysis.

The translational and rotational motions from the deterministic site response analysis, "BASETRAN.FC" and "BASEROT.FC", are used in the deterministic joint SSI and structural analysis, and the SSI model is selected internally by P-CARES as Beredugo and Novak model (1972) for the circular foundation. The side and base soil properties are generated automatically from the strain-compatible soil profile file ""FINALSOIL.PRFL". The deterministic analysis generates its output as text files for each unconstrained degree of freedom at requested output nodes. In this example, three Fourier component files, namely "JD*n*-X.fc", "JD*n*-Z.fc", and "JD*n*-RY.fc", are generated for the node *n*. These files can be processed using the seismic motion analysis tools. The vertical displacement and the rotational displacement are not significant for all nodes because the input motion to the entire soil-structure system has only the horizontal component.

As an example, using the "Fourier Transforms" tool, plots of the time histories and the Fourier spectra for the X direction at the five structural nodes can be generated (as shown in Figure A-42 to Figure A-46). The response spectra for various dampings for the same motions can be generated using the "Response Spectra" tool (as shown in Figure A-47 to Figure A-51). From this figures, it is obvious that the output motions at nodes 1, 4, and 5 vary very little because beam 3 and 4 are essentially rigid, although the motions at nodes 1, 2, 3 vary considerably.

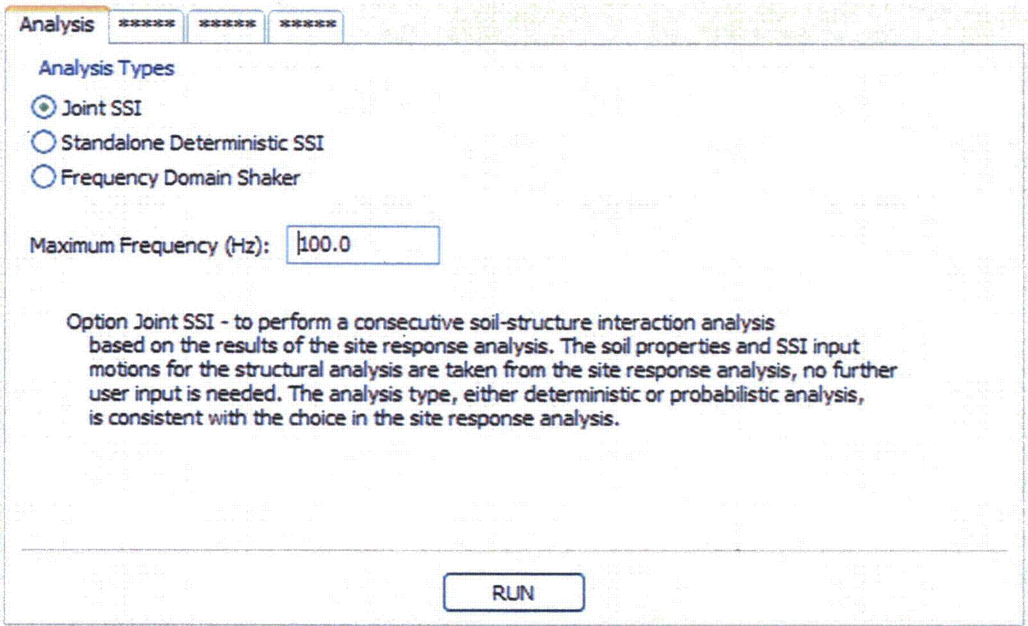


Figure A-41 Calc Structural Response – Joint SSI

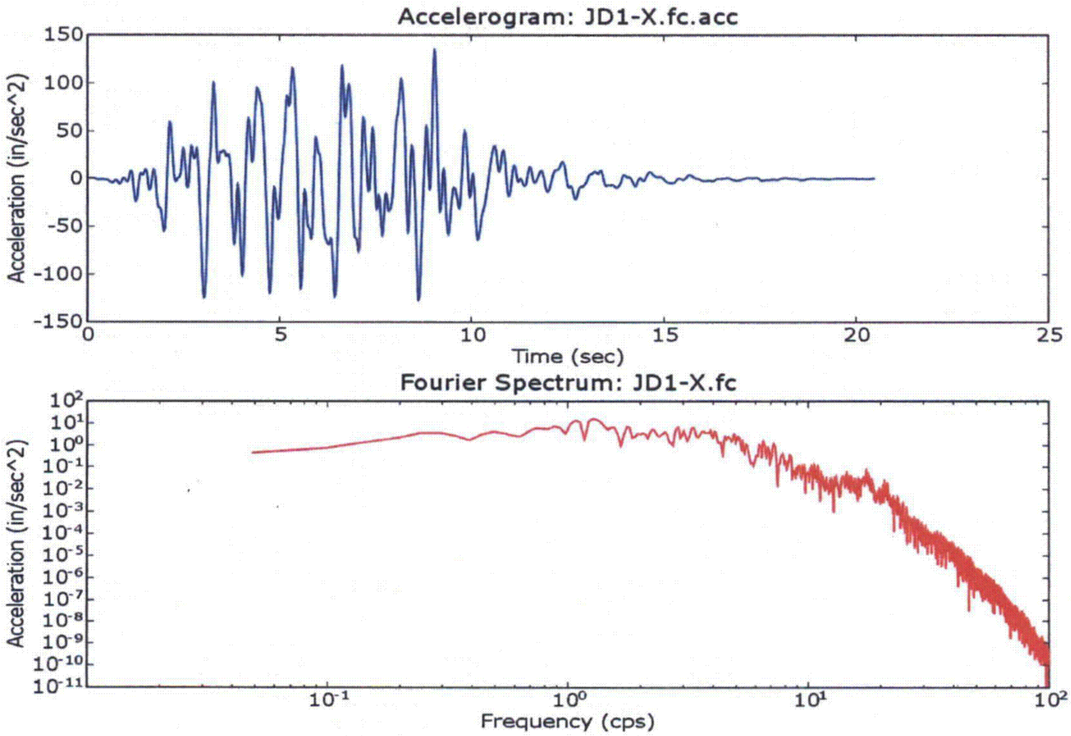


Figure A-42 Deterministic SSI & Structural Analysis at Node 1 - Time History and Fourier Spectrum for the X Direction

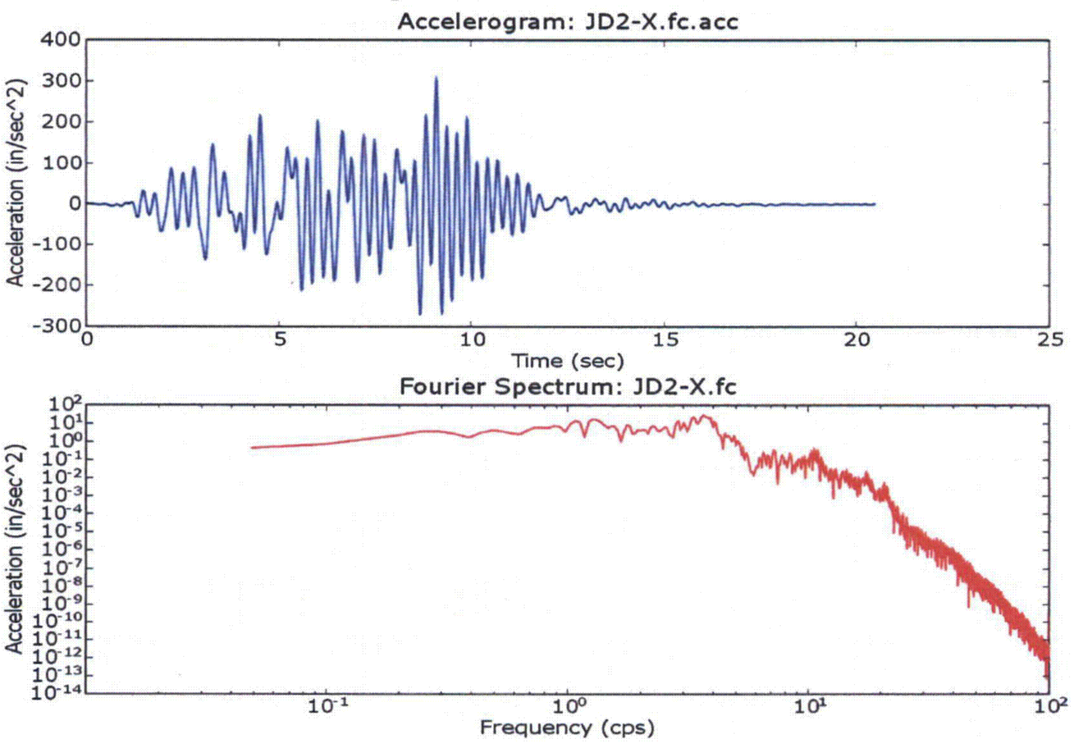


Figure A-43 Deterministic SSI & Structural Analysis at Node 2 - Time History and Fourier Spectrum for the X Direction

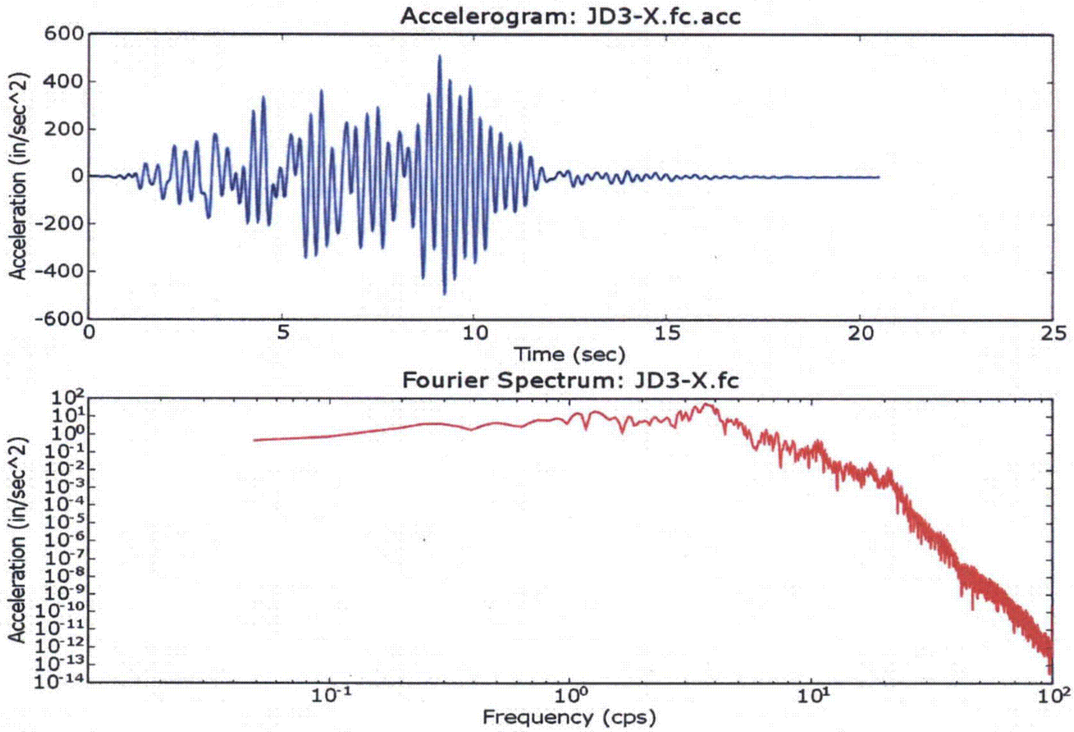


Figure A-44 Deterministic SSI & Structural Analysis at Node 3 - Time History and Fourier Spectrum for the X Direction

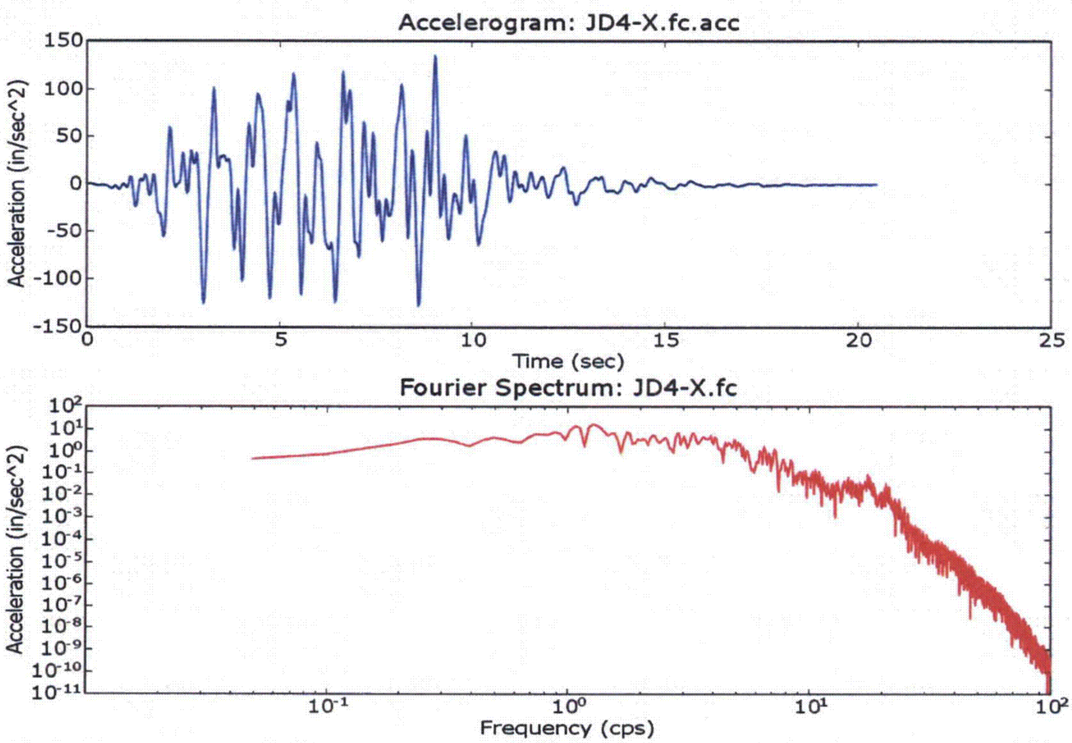


Figure A-45 Deterministic SSI & Structural Analysis at Node 4 - Time History and Fourier Spectrum for the X Direction

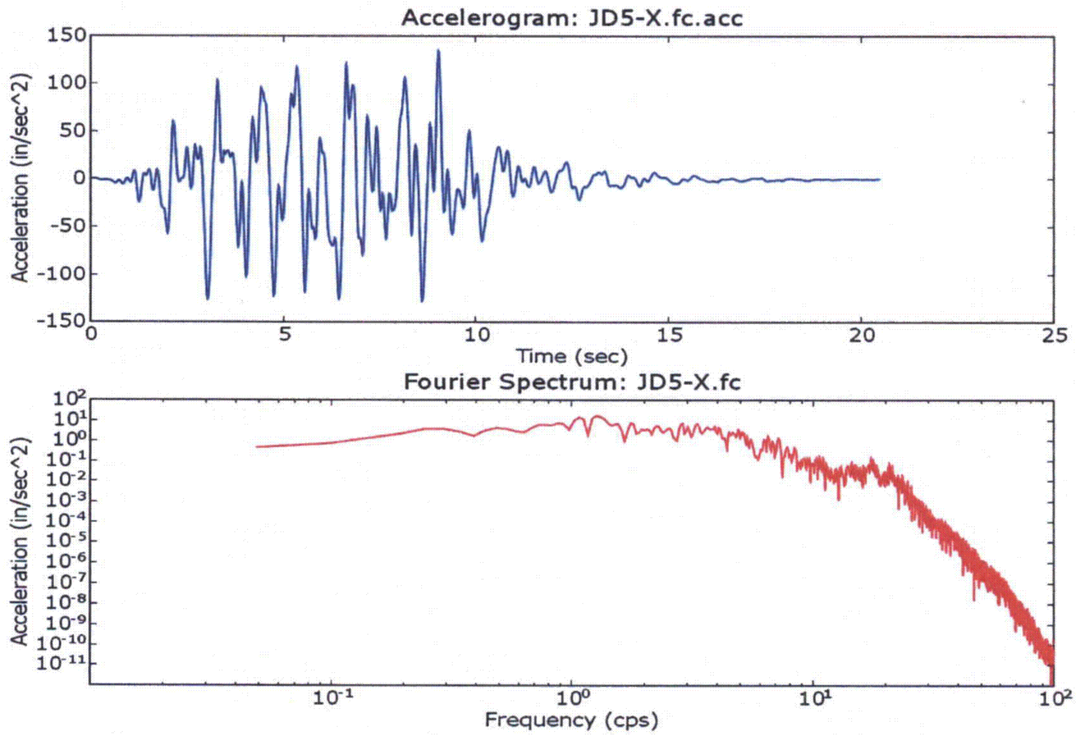


Figure A-46 Deterministic SSI & Structural Analysis at Node 5 - Time History and Fourier Spectrum for the X Direction

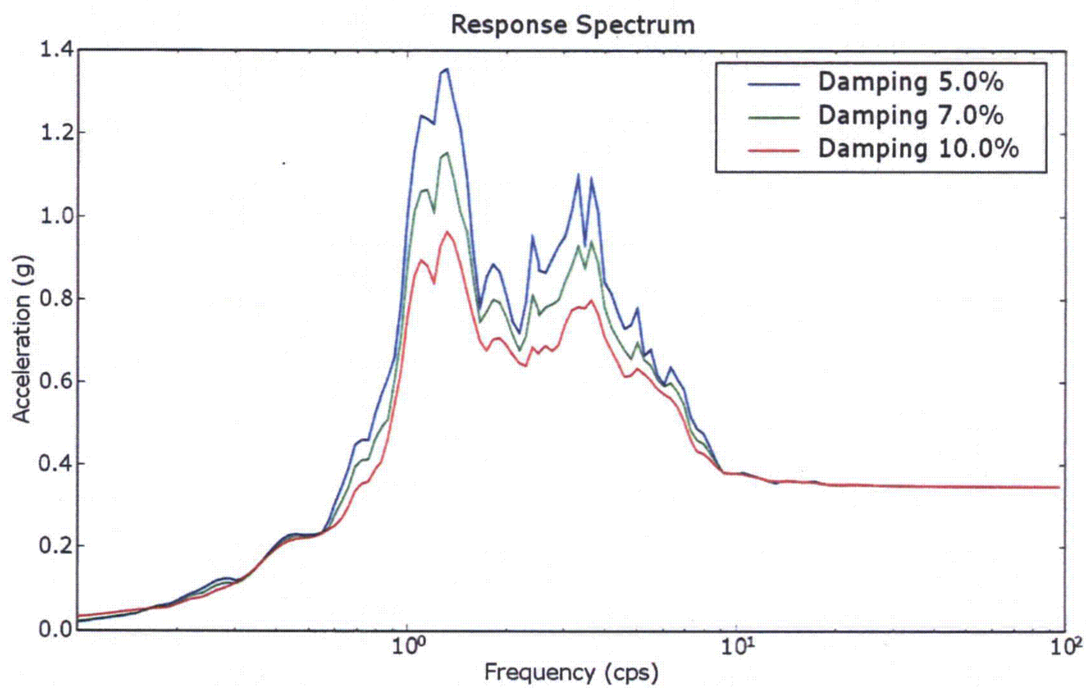


Figure A-47 Deterministic SSI & Structural Analysis at Node 1 - Response Spectra the X Direction

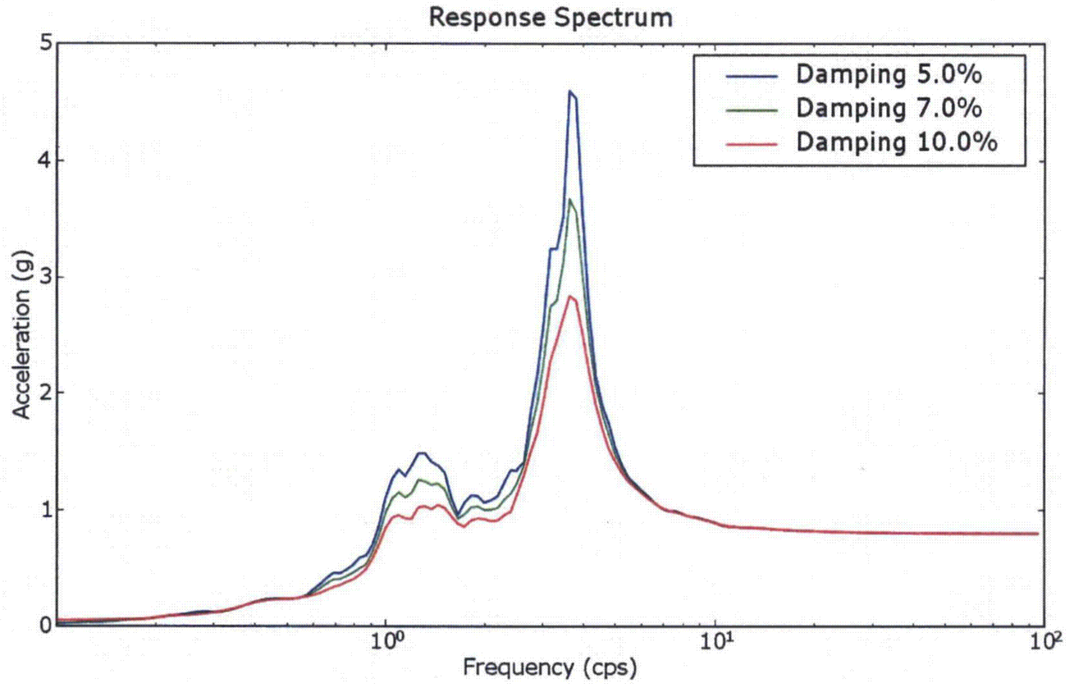


Figure A-48 Deterministic SSI & Structural Analysis at Node 2 – Response Spectra for the X Direction

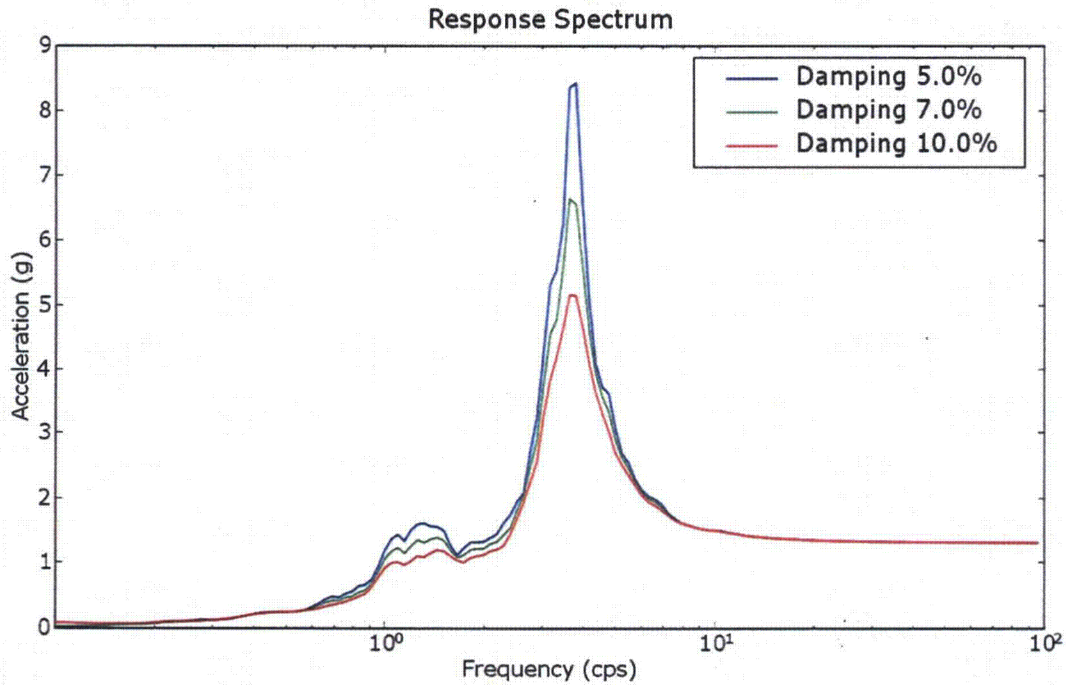


Figure A-49 Deterministic SSI & Structural Analysis at Node 3 – Response Spectra for the X Direction

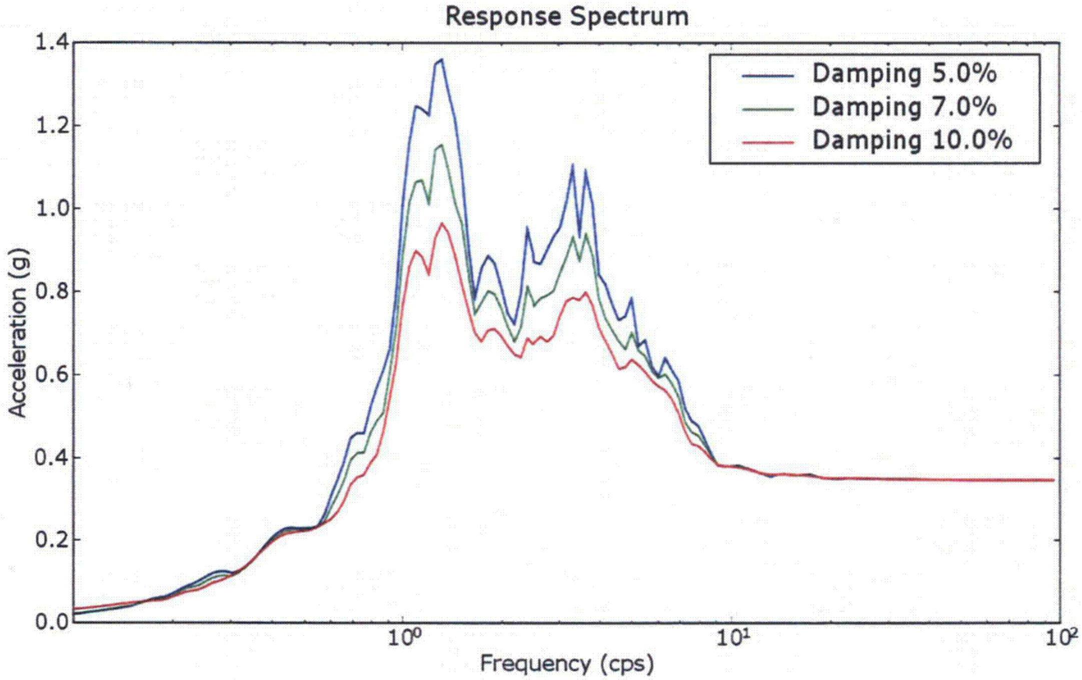


Figure A-50 Deterministic SSI & Structural Analysis at Node 4 – Response Spectra for the X Direction

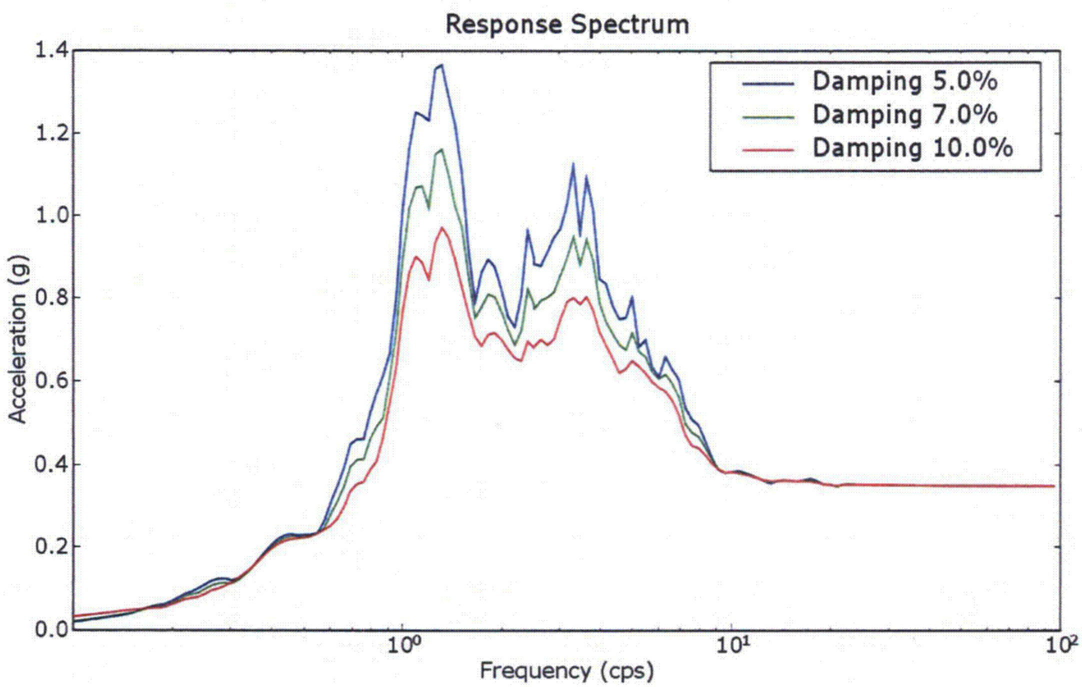


Figure A-51 Deterministic SSI & Structural Analysis at Node 5 – Response Spectra for the X Direction

A.3.6 Probabilistic SSI and Structural Analysis

When the "Probabilistic" analysis type is selected in the site response analysis, the "Joint SSI" analysis option in SSI and Structural analysis signifies the probabilistic simulation, in which the effects of the uncertainties in the soil properties will propagates to the structural responses although the small uncertainties in the structural properties are not considered in P-CARES. The sample soil profiles used to define the side and the base soil properties in the SSI analysis are retrieved from the database file "SOILPROFILE.DB", and the SSI input motions are retrieved from the database file "SSIRESPONSE.HDB". The simulated output motions for unconstrained degrees of freedom at the output nodes are saved in database file "STRUCTRESPONSE.DB".

The "Post Processing" tool in the command tree, as shown in Figure A-24, can be used to process the results of the probabilistic SSI and structural analysis. Figure A-52 to Figure A-56 show plots of the response spectra for the X direction at the 5 structural nodes. The input motion, shown as solid blue lines in these figures, propagates through the 4-layer soil column and then through the containment structure and has been magnified significantly. The frequency characteristics of the responses of the containment structures are also clearly revealed through these figures. On the other hand, because the internal structure is essentially modeled as rigid beams, the response spectra of nodes 4 and 5 resemble that of the basemat node 1 (SSI node). The influence of the soil uncertainties on the structural response is significant as manifested by the large diversity between the various percentiles of the response spectra.

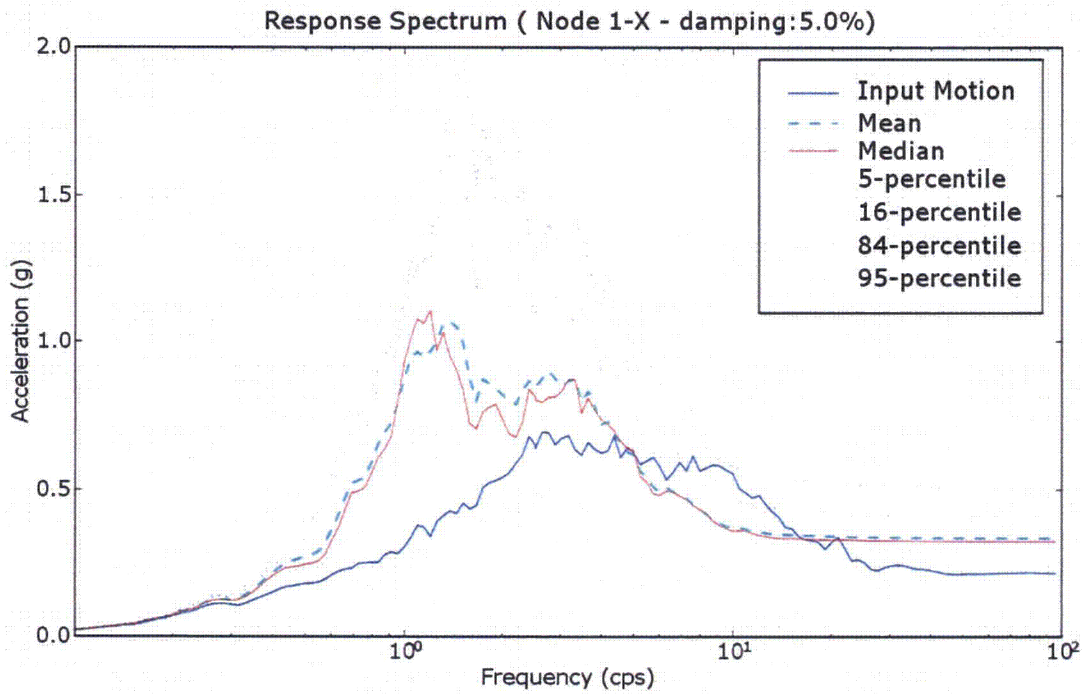


Figure A-52 Probabilistic Structural Response Spectra - For X Direction at Node 1

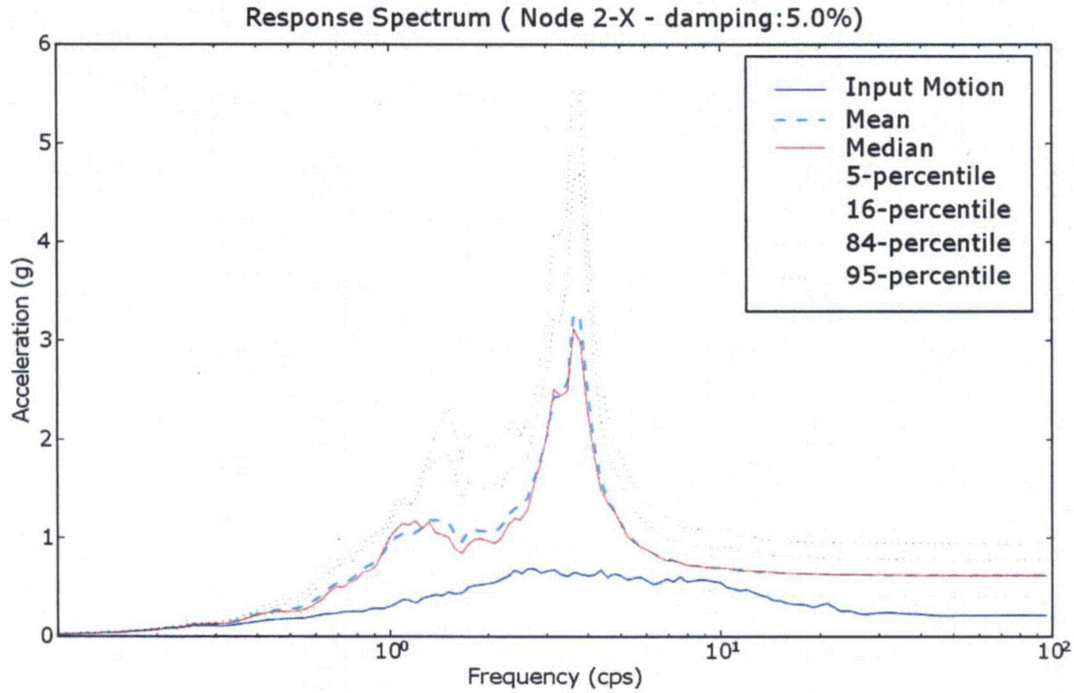


Figure A-53 Probabilistic Structural Response Spectra - For X Direction at Node 2

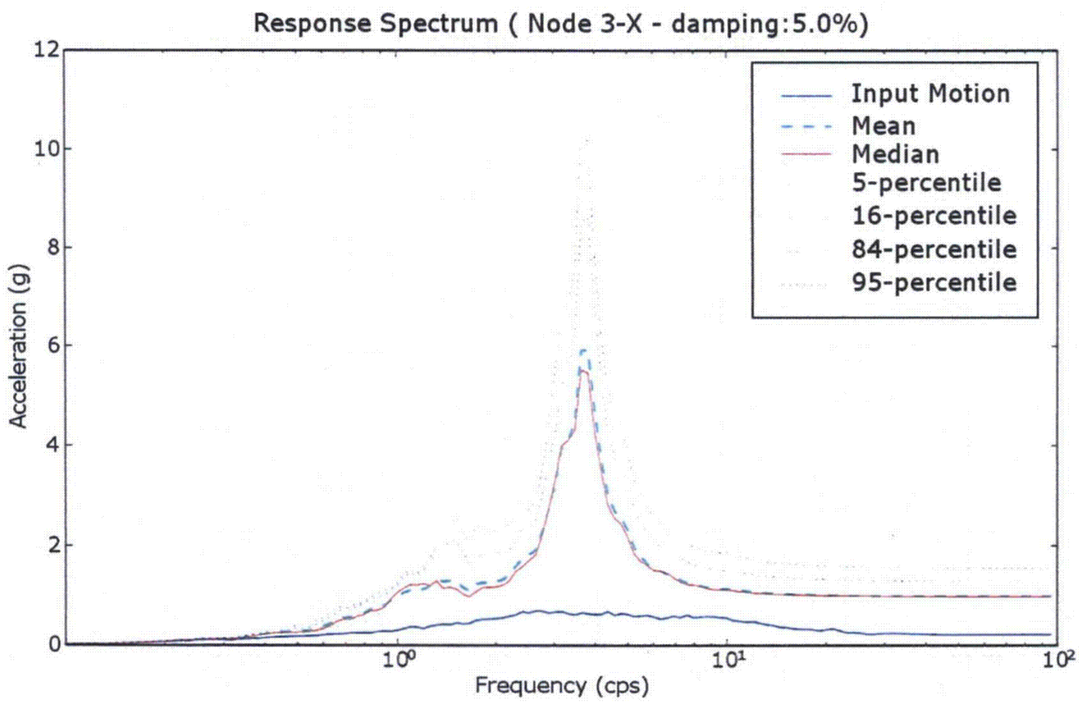


Figure A-54 Probabilistic Structural Response Spectra - For X Direction at Node 3

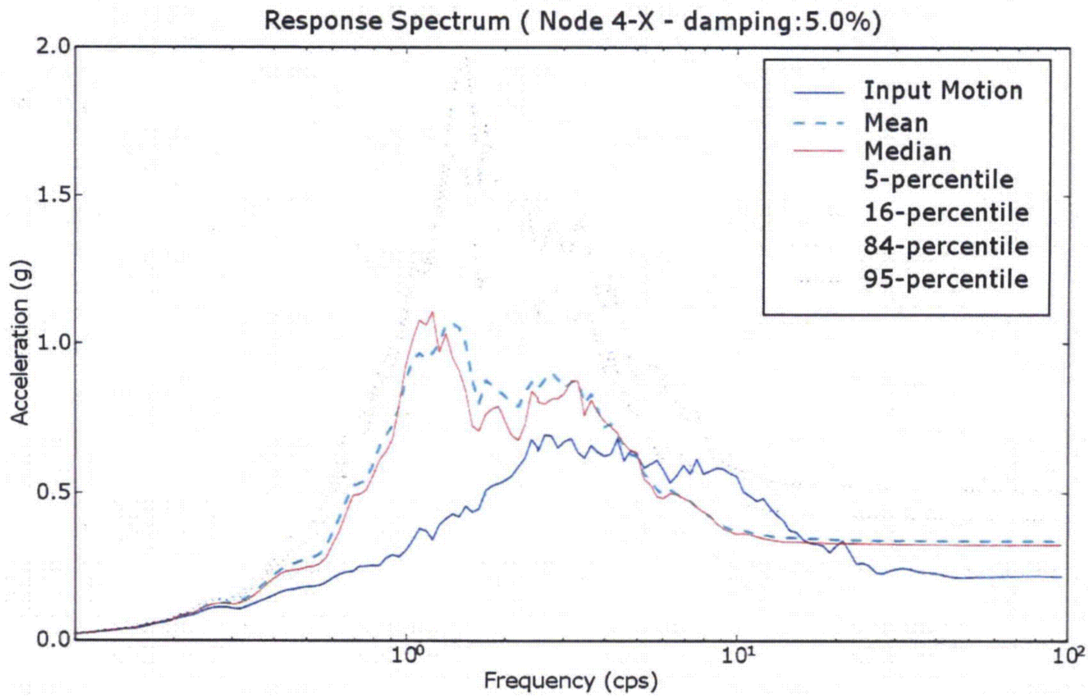


Figure A-55 Probabilistic Structural Response Spectra - For X Direction at Node 4

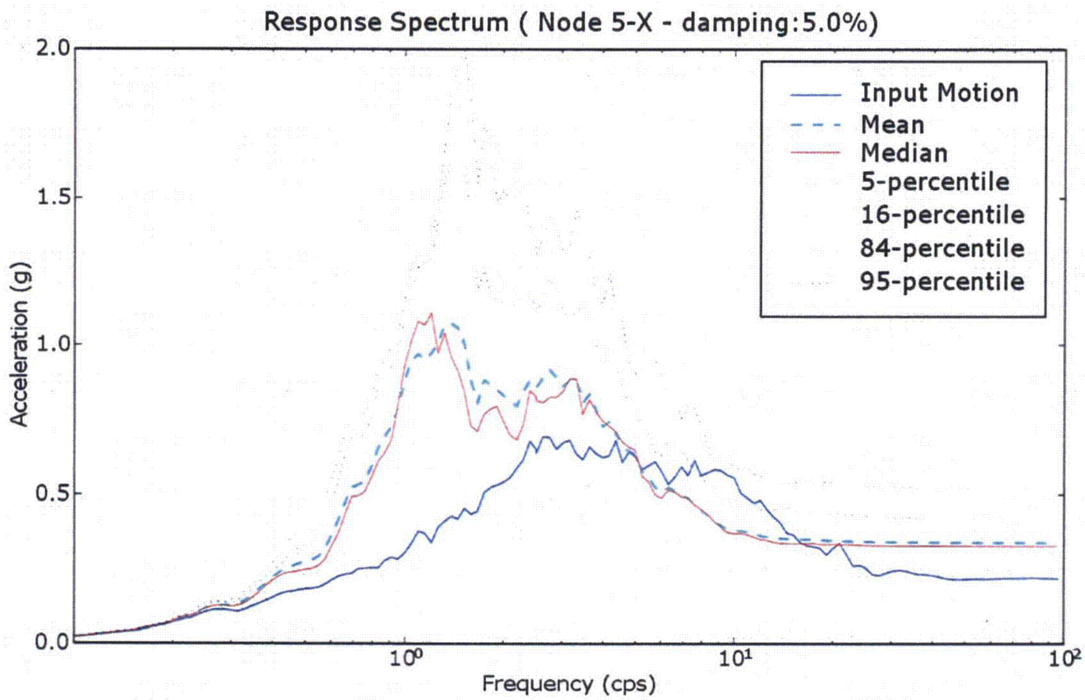


Figure A-56 Probabilistic Structural Response Spectra - For X Direction at Node 5

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10. SUPPLEMENTARY NOTES

Vaughn V. Thomas, NRC Project Manager

11. ABSTRACT *(200 words or less)*

Brookhaven National Laboratory undertook an effort to revise the CARES program under JCN N-6103, referred to as P-CARES in this report. It includes many improvements over the existing CARES, e.g., the enhanced analysis capability in which a probabilistic algorithm has been implemented to perform the probabilistic site response and soil-structure interaction (SSI) analyses.

This report describes the theoretical basis, probabilistic and deterministic site response and SSI analysis capabilities and many user-friendly features which have been implemented in P-CARES. Although the execution of P-CARES is driven by on-screen commands powered by the GUI and is self-explanatory, a user's guide is included in this report to serve either as a quick start or as a reference material for navigating through the program.

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