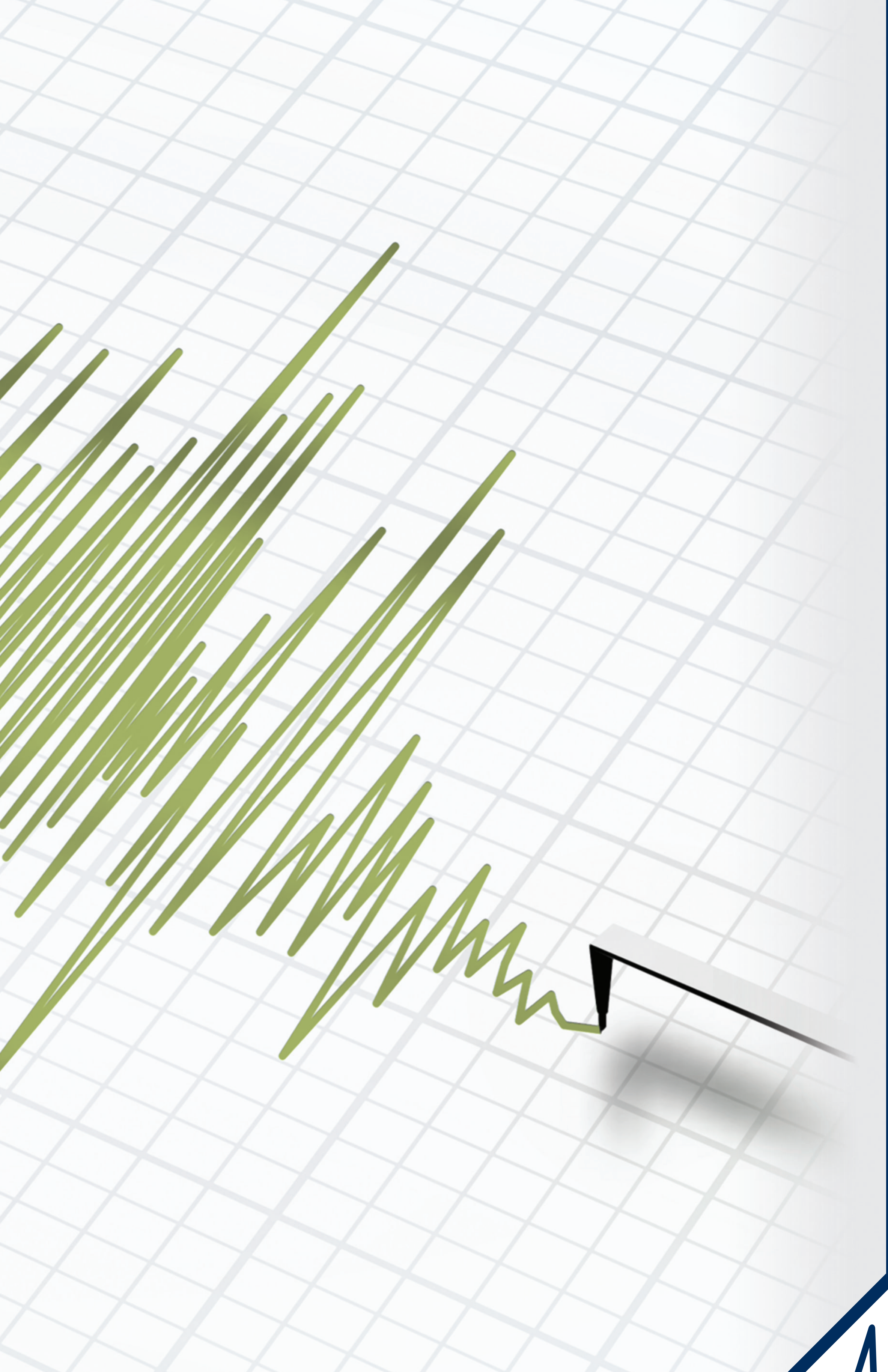
SEiSMOSIGNAL
SEiSMOSIGNAL 3D
SEiSMOSELECT
SEiSMOMATCH
SEiSMOARTIF
SEiSMOSPECT

SEiSMOAPPS



SEISMOSOFT's SUITE
of Earthquake Tools

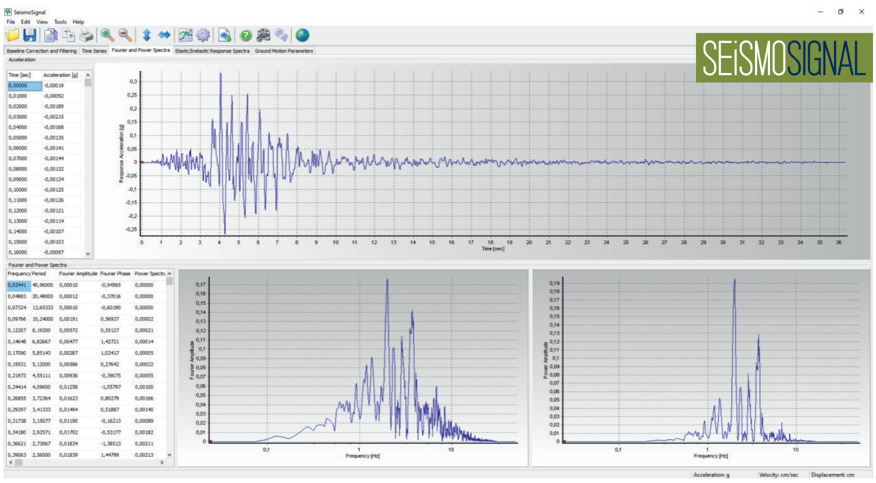
SEiSMOAPPS

copyright

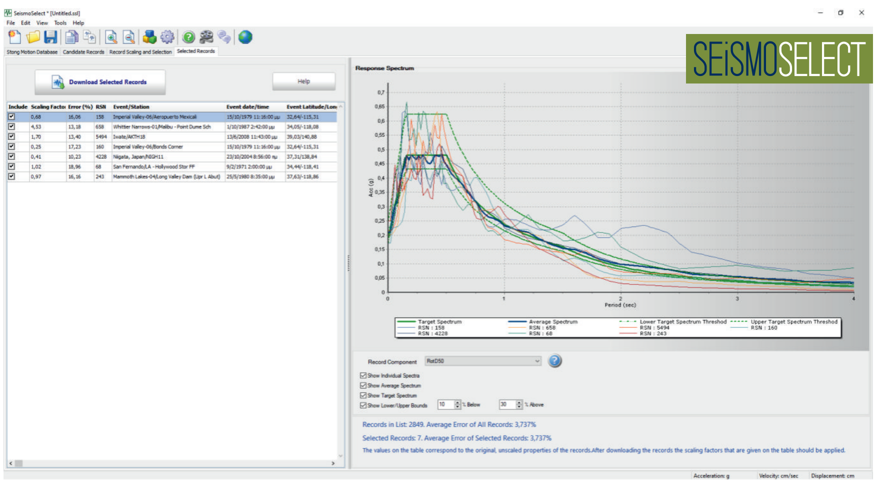
Seismosoft Ltd.
Piazza Castello, 19
27100 Pavia (PV) - Italy
e-mail: info@seismosoft.com
website: www.seismosoft.com

table of contents

SeismoSignal, SeismoSignal 3D, SeismoSelect, SeismoMatch, SeismoArtif and SeismoSpect, constitute a suite of programs that are used to carry out basic earthquake records operations, such as the processing of strong-motion data, the derivation of elastic & inelastic response spectra and Power & Fourier spectra, the calculation of a number of commonly used ground motion parameters, the adjustment of earthquake records to match a specific target response spectrum, or the generation of artificial earthquake accelerograms.



SeismoSignal constitutes a simple, yet efficient, package for the processing of strong-motion data. Amongst other things, it allows for the derivation of elastic and constant ductility inelastic response spectra, the computation of Fourier amplitude spectra, the filtering of high and low frequency record content and the estimation of other important strong-motion parameters, such as the Arias Intensity and the significant and effective durations.

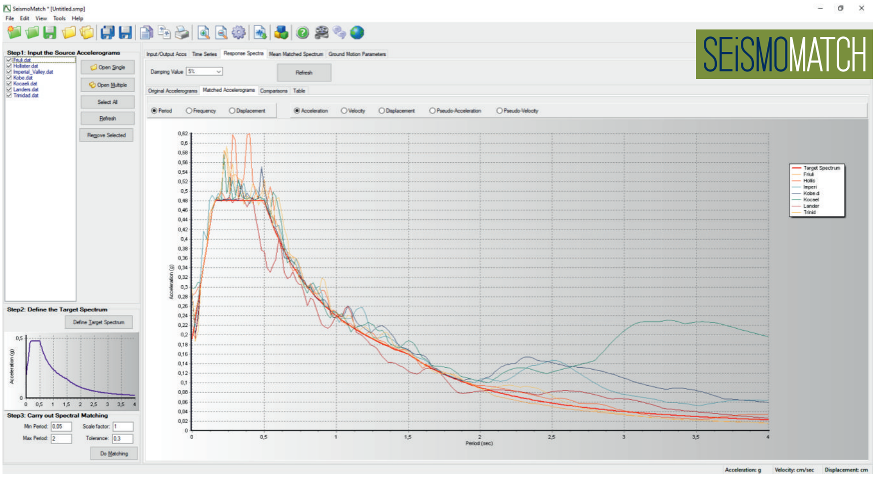


SeismoSignal3D is an extension of SeismoSignal that allows for the simultaneous processing of acceleration components in 2 or 3 dimensions. In addition to the data that are provided for each component separately (ground motion parameters, displacement and velocity time-histories), the program provides the orientation-independent spectra for the ground motion (RotD100, RotD50, RotD00, RotDXX) and the orbit plots, considering the two horizontal components of the records.

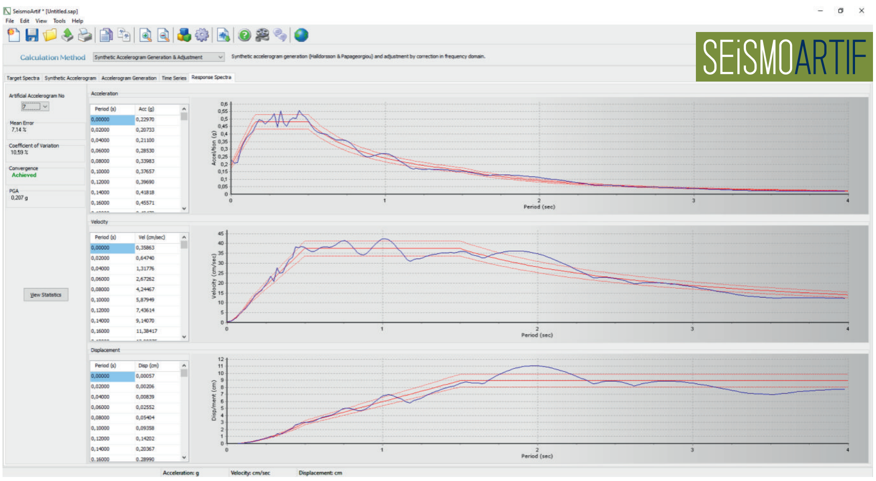
SeismoSelect is an easy and efficient way to search, select, scale and download ground motion data from three of the mostly used strong motion databases that are available on-line: the NGA-West 2 Ground Motion Database, the NGA-East Ground Motion Database and the ESM - Engineering Strong-Motion Database v2.0. Different criteria may be employed for the selection, e.g. target spectral ordinates, different ground motion parameters, and information regarding the event or the recording site. Based on these parameters the software carries out searches for sets of compatible records and provides ways to easily download the selected records.

SeismoMatch is an application capable of adjusting earthquake records, through wavelet addition, to match a specific target response spectrum. Users have the opportunity to simultaneously match a number of accelerograms, and then obtain a mean matched spectrum whose maximum misfit respects a pre-defined tolerance. This software can thus be used in combination with records selection tools and records appropriateness verification algorithms to define adequate suites of records for nonlinear dynamic analysis of new or existing structures.

SeismoMatch is an application capable of adjusting earthquake records, through wavelet addition, to match a specific target response spectrum. Users have the opportunity to simultaneously match a number of accelerograms, and then obtain a mean matched spectrum whose maximum misfit respects a pre-defined tolerance. This software can thus be used in combination with records selection tools and records appropriateness verification algorithms to define adequate suites of records for nonlinear dynamic analysis of new or existing structures.



SeismoArtif is an application capable of generating artificial earthquake accelerograms matched to a specific target response spectrum using different calculation methods and varied assumptions. It is noted that the use of real accelerograms and spectrum matching techniques (i.e. SeismoMatch), together with records selection tools, tends to be recommended for the derivation of suites of records for use in nonlinear dynamic analysis of structures. However, in those cases where access to real accelerograms is, for whatever reason, challenging or inappropriate, then a tool such as SeismoArtif will be of pertinence and usefulness.



SeismoSpect allows users to create their own library of ground motion records and save them all in a single file making it easy to handle and share large numbers of records. This application is then capable of applying several filter types, perform baseline-correction, computing the mean spectral response of a collection of accelerograms and to compare these results with a target spectrum. A number of strong-motion parameters can also be calculated.

The structure of the programs follows a very straight forward methodology with a series of input modules (tabs) from the input definition to the results to be extracted. This rational and intuitiveapproach makes it extremely easy to learn and use; neither manuals, nor tutorial examples or videos are required.

The programs are fully integrated with the Windows environment. All the data can be copied into any other Windows application, i.e. tabled results can be copied into a spreadsheet application like Microsoft Excel, whilst the results plots can be copied into any word-processing application, like Microsoft Word.

The purpose of this document is to provide technical information about the SeismoSignal, SeismoSignal 3D, SeismoSelect, SeismoMatch, SeismoArtif and SeismoSpect packages. This includes information about their capabilities, their fundamental technical features, as well as the planned future developments.

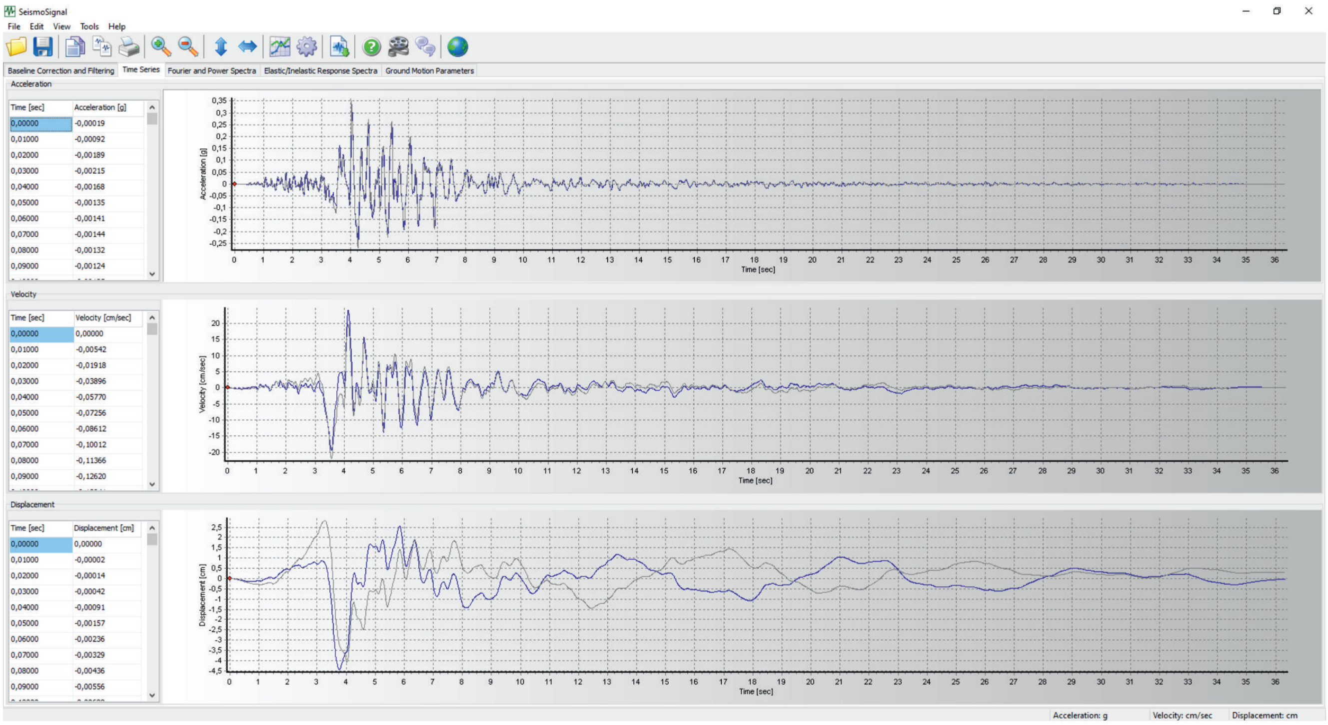
SYSTEM REQUIREMENTS

To use SeismoSignal, SeismoSignal 3D, SeismoSelect, SeismoMatch, SeismoArtif, SeismoSpect, we suggest:

✓ A PC (or a "virtual machine") with one of the following operating systems:
Windows 10, Windows 8 or Windows 7 (32-bit and 64-bit);
✓ 4 GB RAM;
✓ Screen resolution set to 1366x768 or higher (based on web browser statistics, as of 2022 about 96% of computers feature a screen resolution of 1366x768 or higher);
✓ An Internet connection (better if a broadband connection) for the registration of the software.

SeismoSignal - overview

SeismoSignal constitutes an easy and efficient way to process strong-motion data, featuring a user-friendly visual interface and being capable of deriving a number of earthquake records parameters often required by engineer seismologists and earthquake engineers. SeismoSignal is capable of opening an accelerogram from a text file and to process the strong-motion data. Amongst other things, it allows for the derivation of elastic and constant ductility inelastic response spectra, the computation of the Fourier amplitude spectra, the filtering of high and low frequency record content and estimation of other important strong-motion parameters, such as the Arias Intensity and the significant and effective durations. The main characteristics of the program are described below:



✓ **Units:** Units for both the metric and the imperial system are supported; for instance the acceleration units supported are g, milli-g, micro-g, m/sec^2, cm/sec^2, mm/sec^2, in/sec^2, and ft/sec^2.

✓ **Loading & Pre-processing:** The selected record may open from a specially designed window, whereby the parameters for reading the data are input. The following text file formats are supported: (i) Single-value per line, (ii) Time & Acceleration values per line,(iii) Multiple-values per line, (iv) ESM format, (v) SMC format, (vi) PEER NGA format and (vii) SHAKE format. Further, users can take advantage of the Paste command to add additional acceleration values to the loaded time-history. These added values are appended at the end of the existing accelerogram.

✓ **Modifying input time-history characteristics:** Users can change the time-step and/or scale the accelerogram employing the appropriate SeismoSignal commands. Linear interpolation is employed in the former case, whereas scaling up or down by a constant factor is done in the latter.

✓ **Baseline Correction and Filtering:** Users are able to choose, through tick boxes, if they wish, or not, to "correct" the loaded accelerogram, be it through baseline correction and/or frequency filtering. If required, the original "uncorrected" input motion can be visualised in contemporaneous to its post-processed counterpart on all the plots with the processed results.

✓ **Velocity & Displacement time-histories:** Once an accelerogram has been defined, the corresponding velocity and displacement time-histories, as obtained through single and double time-integration, respectively, are automatically computed (using the trapezoidal rule) and plotted.

✓ **Fourier and Power Spectra:** In this module, the Fourier Amplitude Spectrum and the Power Spectrum (or Power Spectral Density Function) are computed by means of Fast Fourier Transformation (FFT) of the input time-history. The Fourier amplitude spectrum shows how the amplitude of the ground motion is distributed with respect to frequency (or period), effectively meaning that the frequency content of the given accelerogram can be fully determined. The power spectral density function, on the other hand, may be used to estimate the statistical properties of the input ground motion and to compute stochastic response using random vibration techniques.

✓ **Elastic and Inelastic Response Spectra:** Elastic and inelastic acceleration, velocity and displacement response spectra can be easily obtained. In addition, and for the case of elastic spectra only, the pseudo-velocity and pseudo-acceleration response values are also given. The results are provided in a plot, and in table format; the Acceleration vs. Displacement spectrum is also available.
Up to six elastic response spectra can be created simultaneously, and users have the possibility of changing the level of viscous damping associated to them. By defining relatively large values of equivalent viscous damping, overdamped elastic spectra can also be readily obtained.
Constant-ductility inelastic spectra may also be derived to reproduce the actual nonlinear structural response by means of an elasto-plastic representation of the system. An iterative process is employed to achieve the target ductility factor considering the hysteretic behaviour of the system.
In this way, energy dissipated through hysteresis is explicitly modelled, with only a relatively small viscous damping quantity (usually not more than 5%) is added to the system, to somehow represent non-hysteretic energy dissipation mechanisms. Up to six levels of displacement ductility can be defined.

✓ **Ground Motion Parameters:** A number of commonly computed ground motion parameters are automatically computed for both the corrected and uncorrected accelerogram.

- Peak ground values of Acceleration (PGA), Velocity (PGV) and Displacement (PGD)
- Peak velocity and acceleration ratio (vmax/amax)
- Root-Mean-Square (RMS) of acceleration, velocity and displacement
- Arias Intensity (Ia)
- Characteristic Intensity (Ic)
- Specific Energy Density (SED)
- Cumulative Absolute Velocity (CAV)
- Acceleration (ASI) and Velocity (VSI) Spectrum Intensity
- Housner Intensity (HI)
- Sustained Maximum Acceleration (SMA) and Velocity (SMV)
- Effective Design Acceleration (EDA)
- A95 parameter
- Predominant Period (Tp)
- Mean Period (Tm)
- Husid plot
- Energy Flux plot

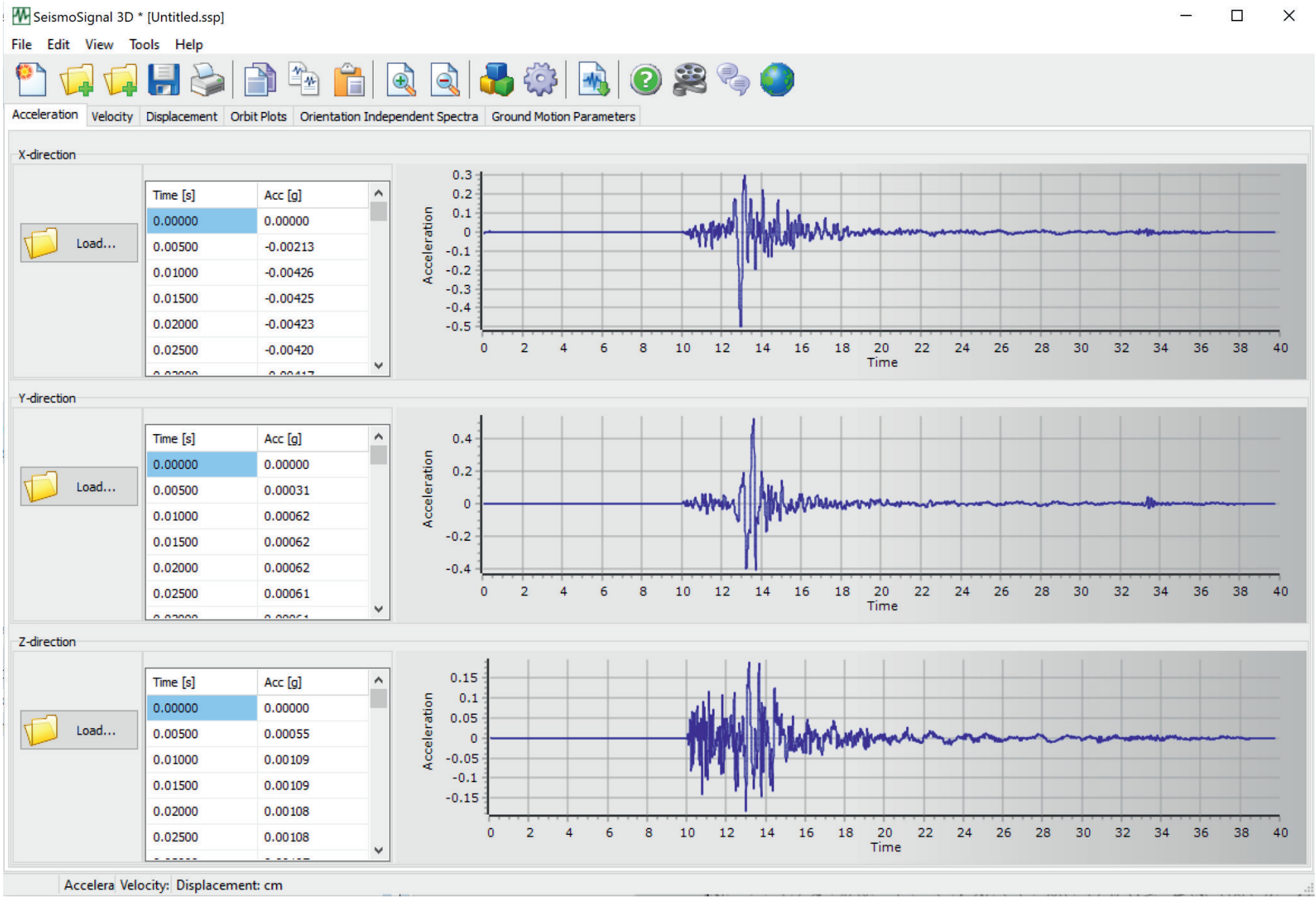
The data points of the Arias Intensity and Energy Flux plots are given only for the corrected accelerogram.

✓ **Record Durations:** Four different types of record durations are computed: (i) the Bracketed duration, (ii) the Uniform duration, (iii) the Significant duration and (iv) the Effective duration.

✓ **Formatting and exporting results:** The vast majority of output results (e.g. displacement time-history, filtered signal, response spectrum, etc.) are made available to the user in both table and graphical formats. The tabled data can be copied to any spreadsheet application (e.g. Microsoft Excel), and all the plots can be copied to word processing programs. Alternatively, these plots can also be printed directly from within the program. Zoom in and out, and formatting of the plot appearance and characteristics (e.g. the background colour, the thickness/style of the line, the font size of the axes legends and plot titles) are available. In addition, users are also able to export in text format the displacement, velocity and acceleration time-histories.

SeismoSignal 3D - overview

SeismoSignal 3D is an extension of SeismoSignal that allows for the simultaneous processing of acceleration recordings in 2 or 3 dimensions. In addition to the data that are provided for each component separately, the program provides the orientation-independent spectra for the ground motion (RotD100, RotD50, RotD00, RotDXX) and the orbit plots, considering the two horizontal components of the records. The main characteristics of the program are described below:



✓ **Units:** Units for both the metric and the imperial system are supported; for instance the acceleration units supported are g, m/sec^2, cm/sec^2, mm/sec^2, in/sec^2, and ft/sec^2.

✓ **Loading acceleration time-histories:** SeismoSignal 3D is capable of opening selected records from text files. The following text file formats are supported: (i) Single-value per line, (ii) Time & Acceleration values per line, (iii) Multiple-values per line, (iv) ESM format, (v) SMC format, (vi) PEER NGA format and (vii) SHAKE format.

✓ **Loading records directly from the ESM and NGA strong motion databases:** The files that are downloaded from these databases are in zip format and, apart from the accelerograms contain several other files and information that are not directly needed by the user. SeismoSignal 3D loads these files, makes the selection of the appropriate information, unzips it and automatically loads the acceleration time-histories to be processed.

✓ **Baseline Correction and Filtering:** SeismoSignal 3D supports baseline correction and filtering of the records. The Baseline Correction and Filtering are common to all the records and can be determined by the program settings window.

✓ **Velocity & Displacement time-histories:** Once the records have been defined, the corresponding velocity and displacement time-histories, as obtained through single and double time-integration, respectively, are automatically computed (using the trapezoidal rule) and plotted. If required, both the original "uncorrected" and the "corrected" input motion may be visualised simultaneously.

✓ **Elastic Response Spectra**: The RotD100, RotD50, RotD00 elastic acceleration response spectra can be automatically obtained with SeismoSignal 3D. RotD100 or the Maximum Rotated Component is the maximum possible Sa value along all orientations between 0 and 360 degrees [Boore, 2010], RotD50 is the Median Rotated Component and RotD00 is the Minimum Rotated Component. Apart from these three standard spectra, any percentile RotDXX can be generated by the program.

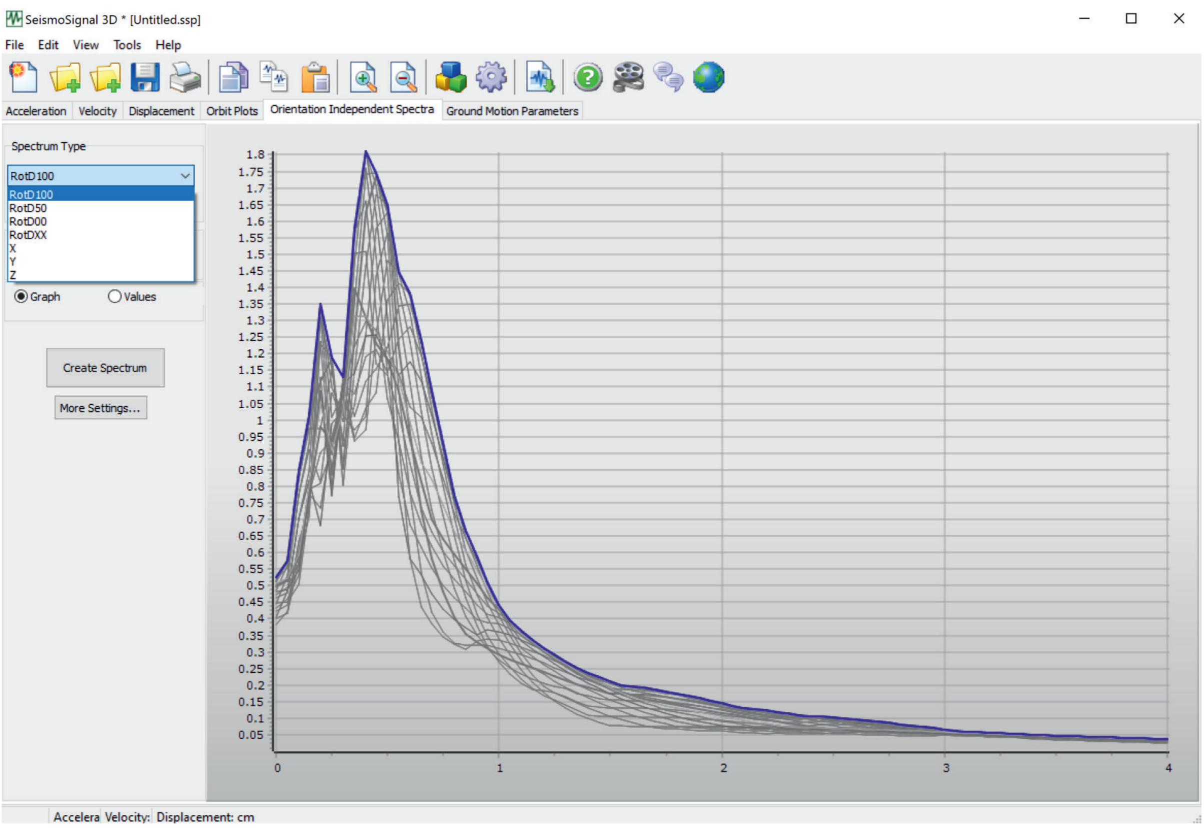
✓ **Orbit Plots:** The orbit plots present the displacement time-histories of the two horizontal components X & Y plotted against each other on the same graph. The orbit plots are automatically generated once a record is loaded.

✓ **Ground Motion Parameters:** A number of commonly computed ground motion parameters are automatically computed for all the components:

- Peak ground values of Acceleration (PGA), Velocity (PGV) and Displacement (PGD) for the X, Y, Z RotD100, RotD50 and RotD00 components
- Arias Intensity (Ia) for the X, Y and Z components
- Cumulative Absolute Velocity (CAV) for the X, Y and Z components

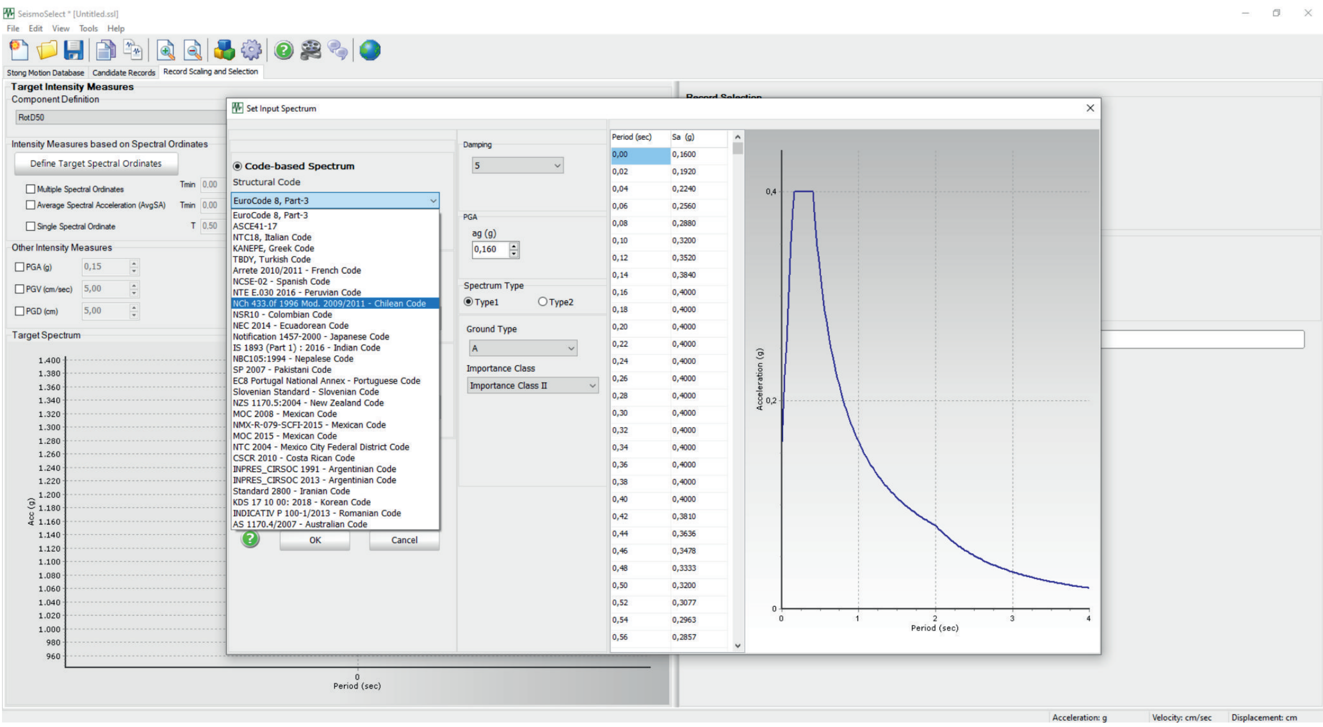
The results are presented on a table.

✓ **Formatting and exporting results:** The vast majority of output results (e.g. displacement time-history, filtered signal, response spectrum, etc.) are made available to the user in both table and graphical formats. The tabled data can be copied to any spreadsheet application (e.g. Microsoft Excel), and all the plots can be copied to word processing programs. Alternatively, these plots can also be printed directly from within the program. Zoom in and out, and formatting of the plot appearance and characteristics (e.g. the background colour, the thickness/style of the line, the font size of the axes legends and plot titles) are available. In addition, users are also able to export in text format the displacement, velocity and acceleration time-histories of all the loaded records.



SeismoSelect - overview

SeismoSelect is an easy and efficient way to search, select, scale and download ground motion data from the three of the best-known strong motion databases that are available on-line. Different criteria may be employed for the selection, e.g. target spectral ordinates, different ground motion parameters, and information regarding the event or the recording site. Based on these parameters the software carries out searches for sets of compatible records and provides ways to easily download the selected records. The main characteristics of the program are described below:



✓ **Units:** Units for both the metric and the imperial system are supported; for instance the acceleration units supported are g, m/sec^2, cm/sec^2, mm/sec^2, in/sec^2, and ft/sec^2.

✓ **Supported Strong-motion Databases:** SeismoSelect can retrieve data from three of the most widely used strong motion databases worldwide:

(I) The NGA West 2 Ground Motion Database (Ancheta et al., 2013) has been developed by the Pacific Earthquake Engineering Research Center (PEER), and features a large set of ground motions recorded in worldwide shallow crustal earthquakes in active tectonic regimes.

(ii) The NGA East Ground Motion Database (Goulet et al., 2014) has been developed by the Pacific Earthquake Engineering Research Center (PEER), and features ground motions from events in Central and Eastern North American (CENA) region, including those from an induced and triggered nature.

(iii) The Engineering Strong Motion Database (Luzi et al., 2020) has been developed in the framework of the European Project NERA (Network of European Research Infrastructure for Earthquake Risk Assessment and Mitigation), Network Activity 3: Networking acceleration networks and SM data users. The database is maintained by WG5 of ORPHEUS.

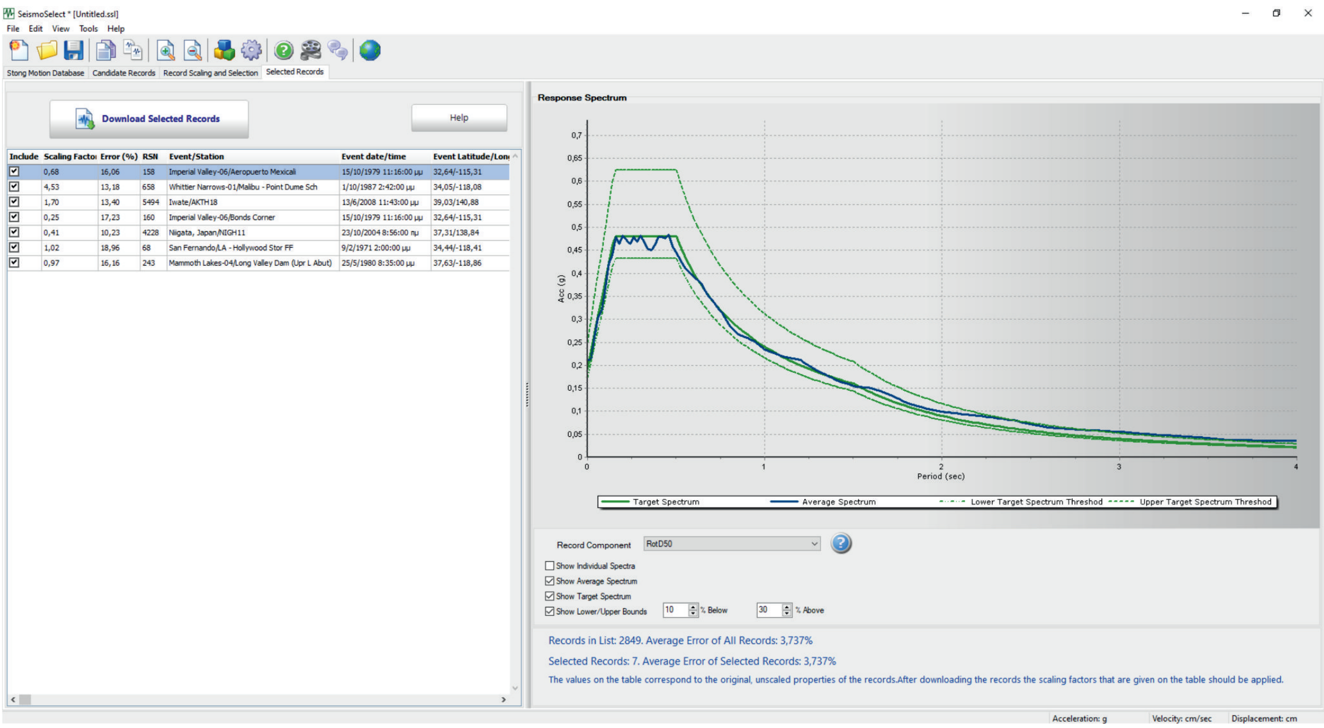
✓ **Criteria for the Selection of Records:** Different criteria may be employed as the parameters of interest, with which to carry out the searches. These include target spectral ordinates, different ground motion parameters (e.g. PGA, PGV, Arias or Housner Intensity), information regarding the event (e.g. magnitude, faulting style location, date) or the recording site (e.g. $V_{S,30}$,epicentral distance).

✓ **Definition of the target spectrum:** A target acceleration spectrum is the most common criterion for the selection of records. The following options are available for creating/loading the spectrum: (i) a code-based spectrum; the spectrum of more than 30 Codes worldwide can be automatically loaded, (ii) a spectrum from a loaded accelerogram, and (iii) a spectrum loaded from a file.

✓ **Selection algorithm:** The selection of the records that match best the provided selection criteria is a two-step process. (i) In the first step the identification of the records, which will be considered as candidates for subsequent selection, is carried out. Although the flat files of the databases contain a plethora of parameters for the selection of the candidate records, only the ones that are deemed of relevance are included in SeismoSelect: Magnitude, distance: $V_{S,30}$, faulting style, significant-duration, PGA, event date and event nation. (ii) In the second step the final selection of the records is done considering different record parameters: specific spectral coordinates or an entire period range of the target spectrum, PGA, PGV, PGD, Arias Intensity, Housner Intensity, Cumulative Absolute Velocity. The records may be scaled with direct scaling in order to achieve a better fit to the target spectrum, depending on the options set by the user.

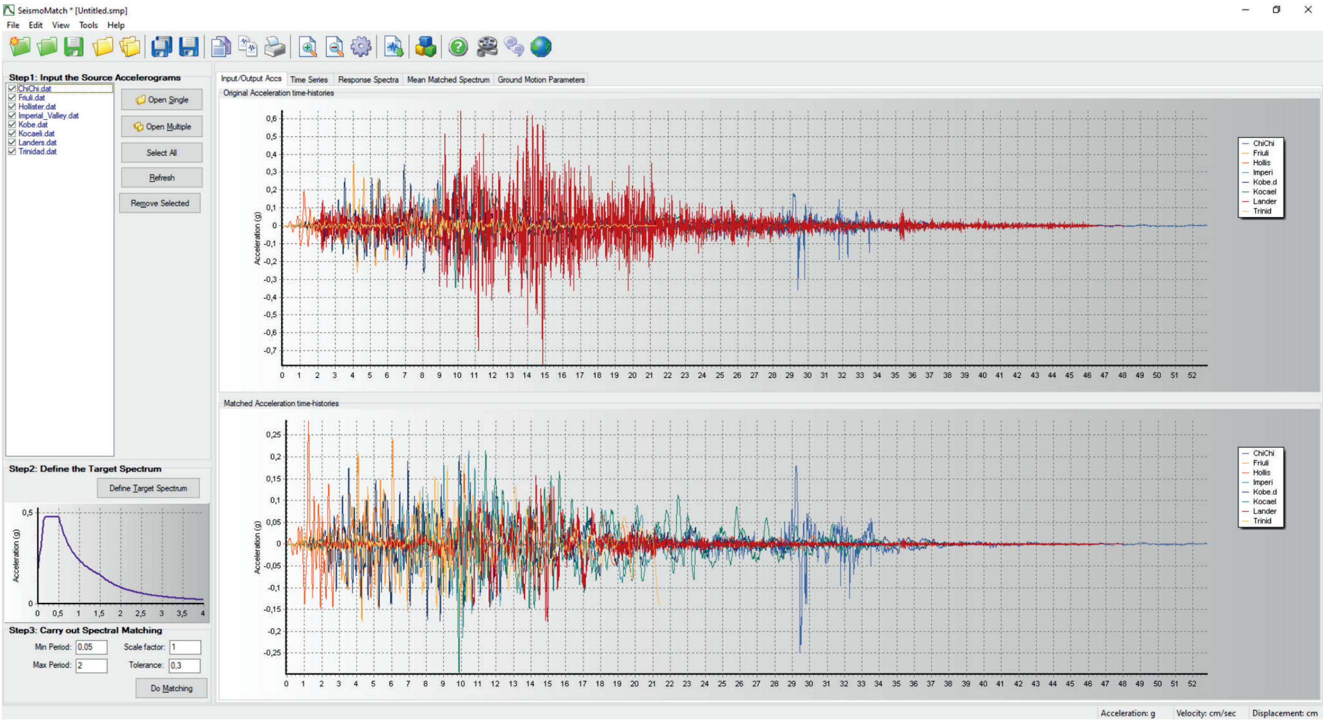
✓ **Visualising and Downloading the Records:** After the selection, the final list with the selected records is given in a table with detailed data for all the records. Users may create a shortlist with some of the records by checking or unchecking them. In order to facilitate the selection, a plot with the spectra of the checked records is given, together with their average spectrum and the target spectrum, as defined in the previous module. Furthermore, the average errors for both the entire list and the shortlist are automatically calculated and output. Finally, the user may download the final list of records, either automatically (if this is permitted by the strong-motion database), or manually with the record IDs that are provided by SeismoSelect.

✓ **Formatting and exporting results:** The vast majority of output results (e.g. displacement time-history, filtered signal, response spectrum, etc.) are made available to the user in both table and graphical formats. The tabled data can be copied to any spreadsheet application (e.g. Microsoft Excel), and all the plots can be copied to word processing programs. Alternatively, these plots can also be printed directly from within the program. Zoom in and out, and formatting of the plot appearance and characteristics (e.g. the background colour, the thickness/style of the line, the font size of the axes legends and plot titles) are available.



SeismoMatch - overview

SeismoMatch is an application capable of adjusting earthquake accelerograms to match a specific target response spectrum, using the wavelets algorithm proposed by Abrahamson [1992] and Hancock et al. [2006] or the algorithm proposed by Al Atik and Abrahamson [2010]. It is also possible to simultaneously match a number of accelerograms, and then obtain a mean matched spectrum whose maximum misfit respects a pre-defined tolerance. The software can hence be used to define adequate suites of records for nonlinear dynamic analysis of new or existing structures.



✓ **Units:** Units for both the metric and the imperial system are supported; for instance the acceleration units supported are g, m/sec^2, cm/sec^2, mm/sec^2, in/sec^2, and ft/sec^2.

✓ **Loading acceleration time-histories:** SeismoMatch is capable of opening selected records from text files. The following text file formats are supported: (i) Single-value per line, (ii) Time & Acceleration values per line, (iii) Multiple-values per line, (iv) ESM format, (v) SMC format, (vi) PEER NGA format and (vii) SHAKE format. Further, users can take advantage of the facility to open simultaneously multiple records of the same format.

✓ **Defining the target spectrum:** The user indicate a target spectrum to which the loaded records are to be scaled, according to the following options: (I) a code-based spectrum; the spectrum of more than 30 Codes worldwide can be automatically loaded, (ii) a spectrum from a loaded accelerogram, and (iii) a spectrum loaded from a file. After loading the suite of accelerograms and the target spectrum, the data can then be saved and retrieved as a SeismoMatch project.

✓ **Spectral matching operation:** In order to adjust the loaded ground-motion to the target response spectrum, the user specifies the matching period range and the required tolerance, amongst other parameters. Once the matching process is triggered, a pop-up window will be displayed showing the progress of each accelerogram as well as information on spectral misfit, iterations and tolerance.

✓ **Velocity & Displacement time-histories:** After the spectral matching, the acceleration time-histories are integrated to derive the velocity & displacement time-histories for both the original and the matched records. The results are presented either separately for the original and the matched records, or together in plots where the comparisons between the former and the latter can be made. Further, tables with all the values are also presented.

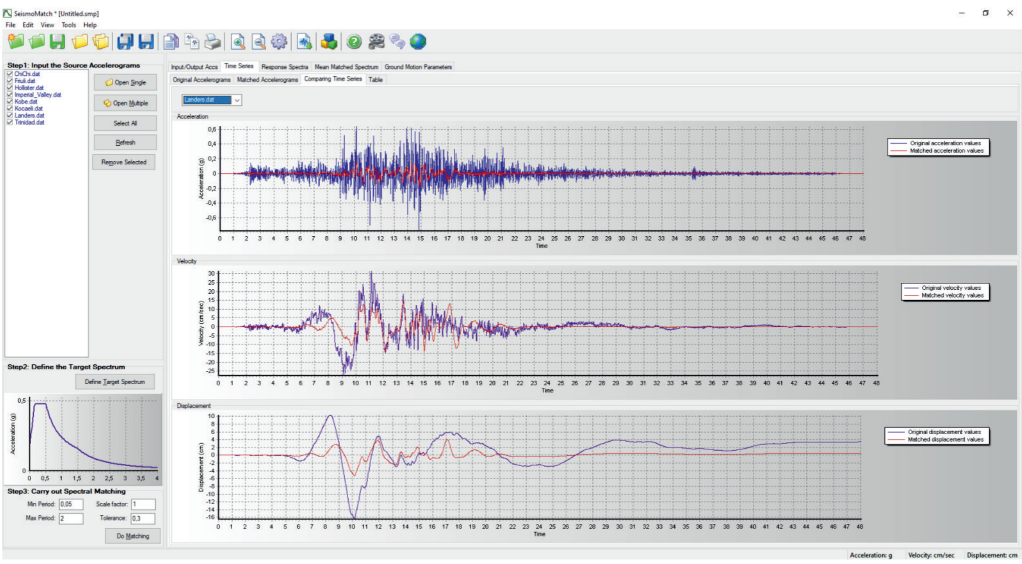
✓ **Elastic and Inelastic Response Spectra:** Similarly to the velocity & displacement time-histories, elastic and inelastic acceleration response spectra can be obtained for the original and the matched records. The results are again presented in plots (separately or together) and tables. Further, the program calculates the mean of selected matched records, and compares it with the target spectrum, so that the user can select the most appropriate sub-group of the generated records.

✓ **Ground Motion Parameters:** A number of commonly computed ground motion parameters are automatically computed for all the accelerograms, both the original and matched.

- Peak ground values of Acceleration (PGA), Velocity (PGV) and Displacement (PGD)
- Peak velocity and acceleration ratio (vmax/amax)
- Root-Mean-Square (RMS) of acceleration, velocity and displacement
- Arias Intensity (Ia)
- Characteristic Intensity (Ic)
- Specific Energy Density (SED)
- Cumulative Absolute Velocity (CAV)
- Acceleration (ASI) and Velocity (VSI) Spectrum Intensity
- Housner Intensity (HI)
- Sustained Maximum Acceleration (SMA) and Velocity (SMV)
- Effective Design Acceleration (EDA)
- A95 parameter
- Predominant Period (Tp)
- Significant Duration

The results are presented both graphically on charts and on table format.

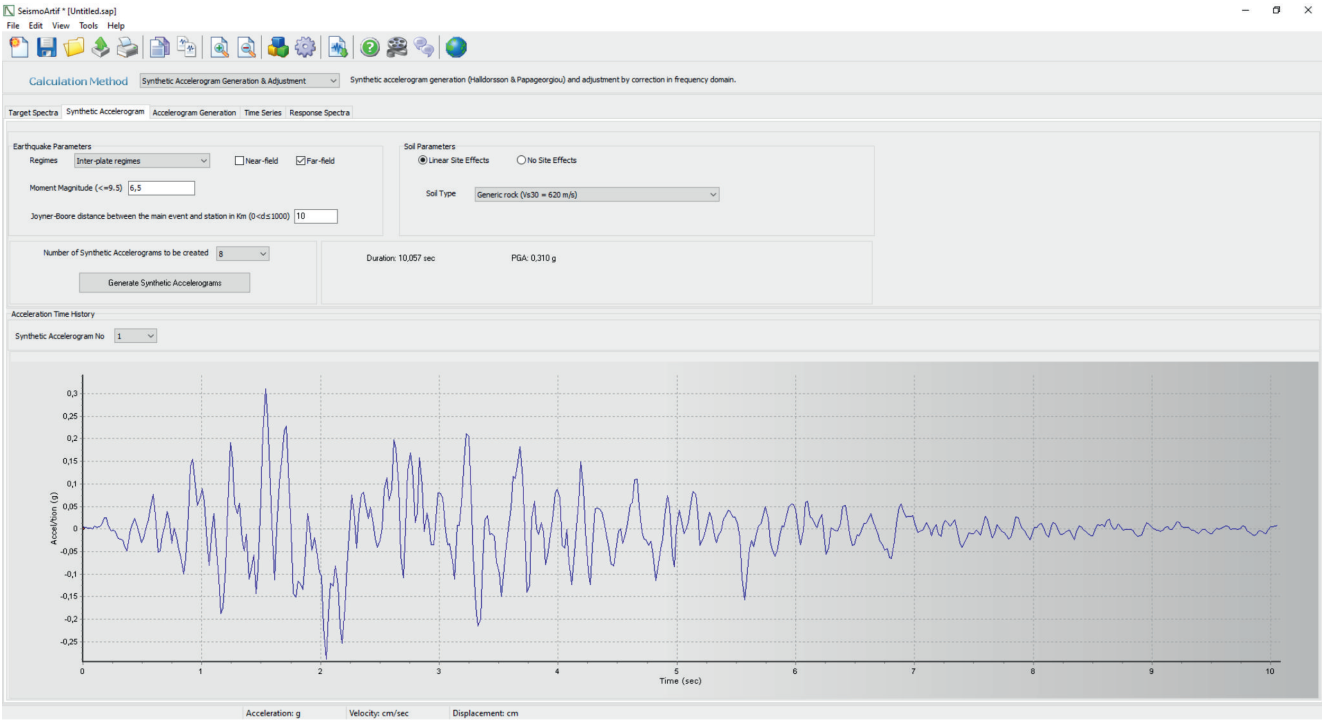
✓ **Formatting and exporting results:** The vast majority of output results (e.g. displacement time-history, filtered signal, response spectrum, etc.) are made available to the user in both table and graphical formats. The tabled data can be copied to any spreadsheet application (e.g. Microsoft Excel), and all the plots can be copied to word processing programs. Alternatively, these plots can also be printed directly from within the program. Zoom in and out, and formatting of the plot appearance and characteristics (e.g. the background colour, the thickness/style of the line, the font size of the axes legends and plot titles) are available. In addition, users are also able to export in text format the displacement, velocity and acceleration time-histories of all the loaded records.



SeismoArtif - overview

SeismoArtif is an application capable of generating artificial earthquake accelerograms matched to a specific target response spectrum, using different calculation methods and varied assumptions. It can thus be used to generate suites of accelerograms for nonlinear dynamic analysis of new or existing structures.

It is noted that the use of real accelerograms and spectrum matching techniques (see SeismoMatch), together with specialised records selection tools, tends to be recommended for the derivation of suites of records for use in nonlinear dynamic analysis of structures. However, in those cases where access to real accelerograms is, for whatever reason, challenging or inappropriate, then a tool such as SeismoArtif will be of pertinence and usefulness.



✓ **Units:** Units for both the metric and the imperial system are supported; for instance the acceleration units supported are g, m/sec^2, cm/sec^2, mm/sec^2, in/sec^2, and ft/sec^2.

✓ **Defining the target spectrum:** The user indicates one or more target spectra, to which the loaded records are to be scaled, from the following available options: (i) a code-based spectrum; the spectrum of more than 30 Codes worldwide can be automatically loaded, (ii) a spectrum from a loaded accelerogram, and (iii) a spectrum loaded from a file. After loading the suite of acceleration response spectra, these can then be saved and retrieved as a SeismoArtif project.

✓ **Calculation methods:** In SeismoArtif, users can choose from four calculation methods for the simulation of artificial ground motions. These methods are listed below:

- Synthetic Accelerogram Generation & Adjustment
- Artificial Accelerogram Generation
- Artificial Accelerogram Generation & Adjustment
- Real Accelerogram Adjustment

The Synthetic Accelerogram Generation & Adjustment method is the default option. Synthetic accelerograms tend to appear realistic and they can be generated with some basic (or more extended) knowledge of earthquake history and soil conditions relative to the region/site of interest. This method is able to efficiently combine simple input data with good results.

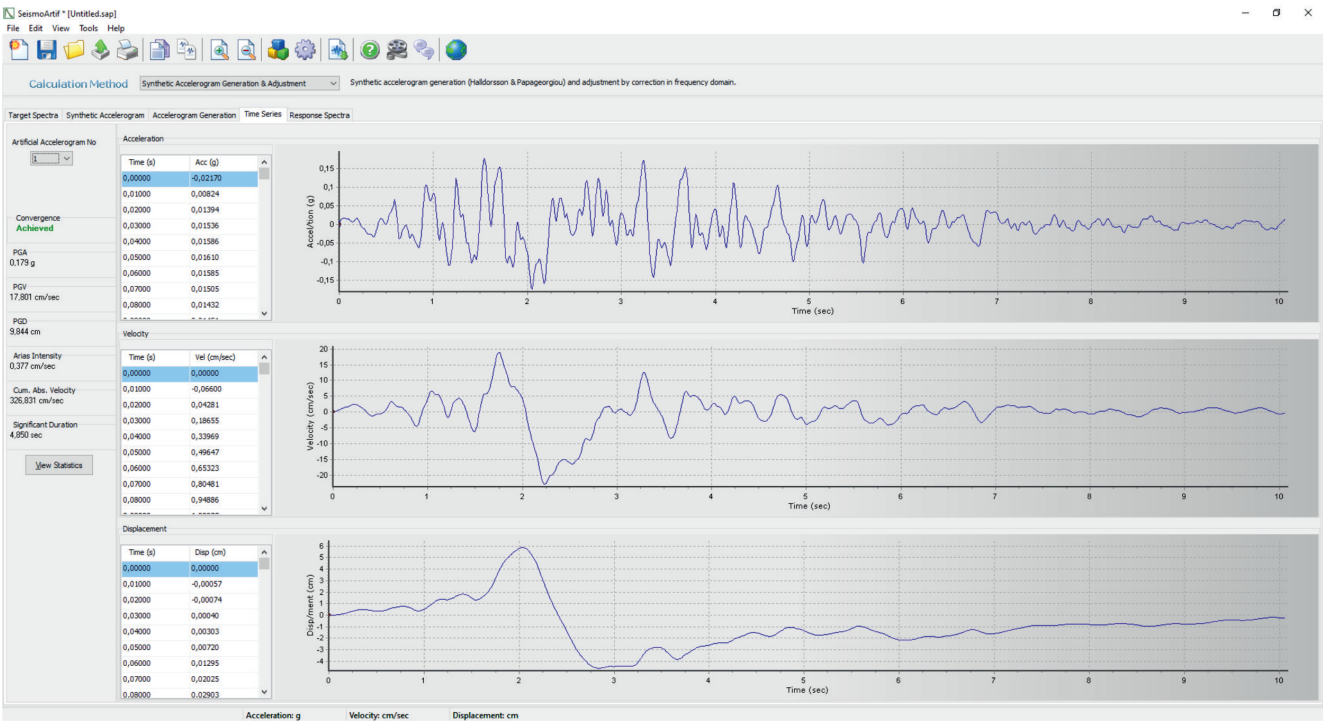
Accelerogram Generation and Artificial Accelerogram Generation & Adjustment methods are based on the adaptation of a random process to a target spectrum. Apart from the target spectrum, an envelope shape should also be defined for the generation of an accelerogram in these cases. It is noted however that with these two methods, engineering judgement and experience is required for the assessment of the appropriateness of the generated accelerogram, since very often the generated records' characteristics differ significantly from real records.

With the Real Acceleration Adjustment method, the artificial accelerogram is defined starting from a real one and adapting its frequency content to match the target spectrum using the Fourier Transformation Method.

✓ **Velocity & Displacement time-histories:** After the accelerogram generation, the time-histories are integrated to derive the velocity & displacement time-histories. The results are presented in table and graphical format.

✓ **Elastic Response Spectra:** Similarly to the velocity & displacement time-histories, the elastic acceleration response spectra can be obtained for the generated records. The results are again presented in plots (separately or together) and tables.

✓ **Formatting and exporting results:** The vast majority of output results (e.g. displacement time-history, filtered signal, response spectrum, etc.) are made available to the user in both table and graphical formats. The tabled data can be copied to any spreadsheet application (e.g. Microsoft Excel), and all the plots can be copied to word processing programs. Alternatively, these plots can also be printed directly from within the program. Zoom in and out, and formatting of the plot appearance and characteristics (e.g. the background colour, the thickness/style of the line, the font size of the axes legends and plot titles) are available. In addition, users are also able to export in text format the displacement, velocity and acceleration time-histories of all the loaded records.



SeismoSpect - overview

SeismoSpect is a platform that allows users to create their own library of ground motion records and save them all in a single file, making it easy to handle and share large numbers of records. Amongst other features, it is capable of applying baseline correction and filtering, and processing the strong motion data. It derives the mean response spectra and compares them to reference spectra. It also computes a number of strong-motion parameters often required by engineer seismologists and earthquake engineers. The most important features of the package are as follows:

✓ **Units:** Units for both the metric and the imperial system are supported; for instance the acceleration units supported are g, m/sec^2, cm/sec^2, mm/sec^2, in/sec^2, and ft/sec^2.

✓ **Loading acceleration time-histories:** SeismoSpect is capable of opening selected records from text files. The following text file formats are supported: (i) Single-value per line, (ii) Time & Acceleration values per line, (iii) Multiple-values per line, (iv) ESM format, (v) SMC format, (vi) PEER NGA format and (vii) SHAKE format. Once an accelerogram has been loaded into SeismoSpect, an entry will be added to the table of records, where removing, editing, viewing and sorting capabilities are available. After loading the suite of accelerograms, the group of records can then be saved and retrieved as a SeismoSpect project.

✓ **Baseline Correction and Filtering:** SeismoSpect supports baseline correction and filtering of the records. The Baseline Correction and Filtering are common to all the records and can be determined by the program settings window.

✓ **Velocity & Displacement time-histories:** Once the records have been defined, the corresponding velocity and displacement time-histories, as obtained through single and double time-integration, respectively, are automatically computed (using the trapezoidal rule) and plotted. If required, both the original "uncorrected" and the "corrected" input motion may be visualised simultaneously.

✓ **Elastic and Inelastic Response Spectra:** Elastic and inelastic acceleration response spectra can be obtained in SeismoSpect. Apart from the individual spectra for each record, the mean spectrum and the mean plus/minus one or two standard deviations spectra are also calculated.

The damping and the ductility values for the calculation of the spectra are specified by the user (the latter only for the inelastic spectra).

✓ **Simplified Inelastic Response Spectra:** Since in SeismoSpect the need to compute hundreds of spectral responses may arise, the following simplified and faster methods to compute the inelastic spectra have also been implemented: (i) Newmark and Hall [1982], (ii) Miranda and Bertero [1994] and (iii) Krawinkler and Nassar [1992].

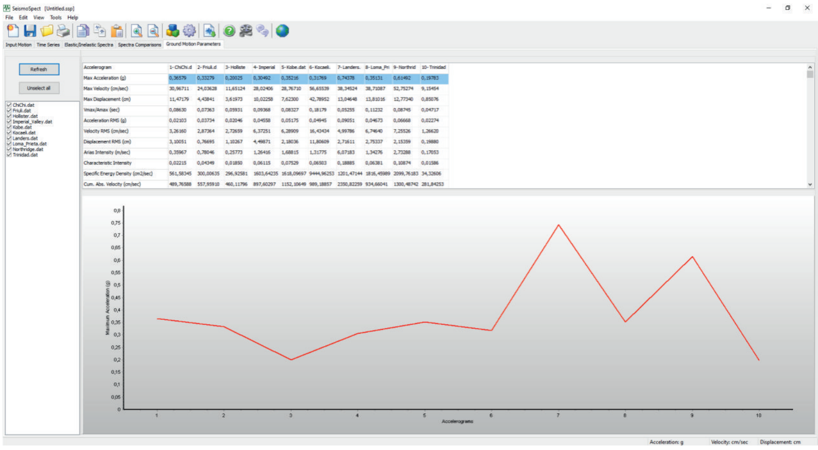
✓ **Comparing Response Spectra:** The user may indicate a reference spectrum between the following choices: (i) current mean spectrum, (ii) a spectrum from a loaded accelerogram, (iii) a spectrum loaded from a file, and (iv) a code-based spectrum; the spectrum of more than 30 Codes can be automatically loaded. The differences might be presented in absolute or relative values and in graphical or tabular format.

✓ **Ground Motion Parameters:** A number of commonly computed ground motion parameters are automatically computed for all the accelerograms.

- Peak ground Values of Acceleration (PGA), Velocity (PGV) and Displacement (PGD)
- Peak velocity and acceleration ratio (vmax/amax)
- Root-Mean-Square (RMS) of acceleration, velocity and displacement
- Arias Intensity (Ia)
- Characteristic Intensity (Ic)
- Specific Energy Density (SED)
- Cumulative Absolute Velocity (CAV)
- Acceleration (ASI) and Velocity (VSI) Spectrum Intensity
- Housner Intensity (HI)
- Sustained Maximum Acceleration (SMA) and Velocity (SMV)
- Effective Design Acceleration (EDA)
- A95 parameter
- Predominant Period (Tp)

The results are presented both on a chart and on a table.

✓ **Formatting and exporting results:** The vast majority of output results (e.g. displacement time-history, filtered signal, response spectrum, etc.) are made available to the user in both table and graphical formats. The tabled data can be copied to any spreadsheet application (e.g. Microsoft Excel), and all the plots can be copied to word processing programs. Alternatively, these plots can also be printed directly from within the program. Zoom in and out, and formatting of the plot appearance and characteristics (e.g. the background colour, the thickness/style of the line, the font size of the axes legends and plot titles) are available. In addition, users are also able to export in text format the displacement, velocity and acceleration time-histories of all the loaded records.



1. They offer enhanced accuracy and reliability

The algorithms employed by all programs have been developed recently and are accepted to be amongst the most sophisticated such algorithms worldwide. Further, the extensive use of the applications for more than 20 years by thousands of users, both in the academia and the industry, ensures that these have been thoroughly quality-checked and are highly reliable. As a result, all programs exhibit great stability, and provide very accurate results, even in the most intricate and demanding cases of analyses.

2. They have very smooth learning curve

Featuring an extremely intuitive graphical environment with a series of input and output modules (tabs) and a very straightforward methodology from the definition of the input to the exporting of selected results, Seismosoft's earthquake tools are extremely easy to learn. No manuals or tutorials are needed, and a user may open the programs and start using them.

3. They offer increased productivity

Particular emphasis has been put on rendering the programs not only intuitive, but also easy and fast to use. Loading and displaying of the acceleration records or spectral shapes is done in a very efficient way, and the calculations are carried out automatically or with the click of a button. Further, the programs are fully integrated with the Windows environment and the vast majority of output results (e.g. displacement time-history, filtered signal, response spectrum, etc.) are made available to the user in both table and graphical formats. The tabled data can be copied quickly to any spreadsheet application (e.g. Microsoft Excel), and all the plots can be copied to word processing programs.

All these facilities result in an extremely user-friendly environment, whereby any operation (e.g. strong motion processing, spectral matching or generation of artificial accelerograms) can be done extremely quickly.

4. They have the guarantee and the reliability of Seismosoft

Seismosoft's earthquake records programs constitute state-of-the-art tools with thousands of users worldwide in academic institutions and in the industry alike. Based on this huge users base, Seismosoft has been established as a worldwide leader in the creation of earthquake tools that combine ease-of-use and high expertise in the same package.

technical features

BASELINE CORRECTION

Baseline Correction, as implemented in the four packages, consists in (i) determining, through regression analysis (least-squares-fit method), the polynomial curve that best fits the time-acceleration pairs of values and then (ii) subtracting from the actual acceleration values their corresponding counterparts as obtained with the regression-derived equation. In this manner, spurious baseline trends, usually well noticeable in the displacement time-history obtained from double time-integration of uncorrected acceleration records, are removed from the input motion.

Polynomials of up to the 3rd degree can be employed, effectively meaning that constant (y=a0), linear ($y=a_0+a_1*x$), quadratic ($y=a_0+a_1*x+a_2*x^2$) and cubic ($y=a_0+a_1*x+a_2*x^2+a_3*x^3$) baseline correction can be used. Further information and discussion on baseline correction can be found in the work by Boore [2001], amongst others.

FREQUENCY FILTERING

Filtering is employed to remove unwanted frequency components from a given signal; (i) lowpass filtering suppresses frequencies that are higher than a user-defined cut-off frequency (Freq1), (ii) highpass filtering allows frequencies that are higher than the cut-off frequency (Freq1) to pass through, (iii) bandpass filtering allows signals within a given frequency range (Freq1 to Freq2) bandwidth to pass through and (iv) bandstop filtering suppresses signals within the given frequency range (Freq1 to Freq2) - note that Freq2 cannot be higher than 1/2 of the record's time-step frequency.

To create any of the above four filtering configurations, three classical infinite-impulse-response (IIR) filter types are available: Butterworth, Chebyshev and Bessel filters. The choice of digital IIR filters over their FIR counterparts is motivated by the fact that the former usually can achieve a given set of filtering characteristics (e.g. smoothness, roll-off steepness, etc.) with a much lower filter order than a corresponding FIR filter, thus minimising computing requirements. Evidently, these digital IIR filters are initially designed in analogue form and then transformed into their digital version through a bilinear transformation, so as to overcome the current impossibility of directly designing digital IIR filters (please refer to the available literature, e.g. Stearns & David [1996] and Lynn & Fuerst [1998] for further information and discussion on the topic). It is also noted that filtering is carried out in the time-domain and that the employed filters described above are of causal type (e.g. see Boore and Akkar [2003] for further information on this topic).

In addition to choosing the type of filter to be used and its configuration, users can also define the order and frequency range to be adopted. It is also highlighted that the pre-defined filtering range corresponds, with some approximation, to the filtering configuration usually employed by strong-motion databases to obtain corrected accelerogram records.

ELASTIC AND INELASTIC RESPONSE SPECTRA

Elastic and inelastic acceleration, velocity and displacement response spectra are obtained by means of time-integration of the equation of motion of a series of single-degree-of-freedom systems, from which the peak displacement, velocity and acceleration response quantities are then obtained and plotted in period vs. amplitude graphs, commonly known as response spectra. In addition, and for the case of elastic spectra only, the pseudo-velocity and pseudo-acceleration response values, obtained through multiplication of the displacement response values by ω and ω^2, respectively, are also given ("ω" stands for angular frequency). Users are referred to the literature [e.g. Clough and Penzien, 1994; Chopra, 1995] for further details on these procedures.

Numerical integration parameters Determination of elastic and inelastic response spectra requires the computation of peak response values of SDOF oscillators with varying periods of vibration that are subjected to the acceleration time-history under consideration. Therefore, linear and nonlinear dynamic analysis needs to be carried out, and a numerical direct integration scheme is employed in order to solve the system of equations of motion [e.g. Clough and Penzien, 1994; Chopra, 1995]. Such integration is carried out by means of the Newmark integration scheme [Newmark, 1959].

The Newmark integration scheme requires the definition of two parameters; beta (β) and gamma (γ). Unconditional stability, independent of time-step used, can be obtained for values of $\beta \geq 0.25\ (\gamma+0.5)^2$. In addition, if $\gamma = 0.5$ is adopted, the integration scheme reduces to the well-known non-dissipative trapezoidal rule, whereby no amplitude numerical damping is introduced, a scenario that is clearly advantageous within the scope of the current application. The default values are therefore $\beta = 0.25$ and $\gamma = 0.5$.

Elastic spectrum The level of viscous damping associated to an elastic spectrum is defined as a percentage of the critical damping value, and usually featuring values ranging from 0 to 5% [e.g. Chopra, 1995]. By defining relatively large values of equivalent viscous damping, overdamped elastic spectra can also be readily obtained.

Constant-ductility inelastic spectra (SeismoSignal and SeismoSpect specific) Constant-ductility inelastic spectra attempt to reproduce actual nonlinear structural response by means of an elasto-plastic representation of the system. In this way, energy dissipated through hysteresis comes explicitly modelled, and only a relatively small viscous damping quantity (usually not more than 5%) is added to the system, to somehow represent non-hysteretic energy dissipation mechanisms.

For the computation of constant-ductility inelastic spectra, the post-yield hardening ratio typically needs to be defined. Further, when carrying out nonlinear dynamic analysis (needed in this case), it is required for a convergence criterion to be set, in order for the nonlinear analysis to progress from one step to the other. For this reason, a 'Ductility Tolerance' and an 'Out-of-balance Force Tolerance' are defined, with default values sufficiently small to warrant very good accuracy (users who wish to speed their analysis may obviously define larger tolerances).

Simplified Expressions for inelastic spectra (SeismoSpect and SeismoMatch specific) Whilst in SeismoSignal constant-ductility inelastic spectra is always computed through nonlinear dynamic analyses of elasto-plastic hysteretic systems, in SeismoSpect for reasons of efficiency and because the need to compute hundreds of spectral responses may arise the following simplified proposals are also available:

Newmark and Hall [1982]: The force reduction factor given by this classic method is parameterized as a function of the yield level and three different formulas are provided depending of the natural period of the structure. The inelastic spectra computed using this method is similar to the elastic spectra for low periods and for higher periods.

Miranda and Bertero [1994]: The equation that gives the reduction factor in this method was obtained from a study of 124 ground motion records on a wide range of soil conditions and therefore, users need to select which type of soil should be considered (rock site, alluvium site or soft site). The yield level was taken into account to compute the parameters of each formula whilst a 5% critical damping was assumed.

Krawinkler and Nassar [1992]: This method uses a reduction factor that was obtained from a study of a set of ground motion records with magnitude varying between 5.7 and 7.7, recorded on alluvium and rock sites. The yield level and post-yield hardening coefficient were taken into account and a 5% damping value was assumed to create the formulas that compute the reduction factor.

These simplified methods provide estimates of acceleration response spectra ordinates (Sa), with (very approximate) displacement response spectra values being then computed through the product of the latter by the square of the angular frequency (ω^2) and a ductility correction factor ($\mu/(\mu+\alpha*\mu-\alpha)$), whereby "μ" is the target ductility and "α" the post-yield hardening ratio. Velocity response spectra ordinates, on the other hand, are estimated through the product of their acceleration counterparts by the angular frequency (ω) - it is noted, however, that such velocity spectral estimates are very unreliable, and users are advised to use the constant-ductility method instead, when velocity spectra (and, albeit to a more limited extent, also displacement spectra) are desired, even at the cost of longer analyses.

GROUND MOTION PARAMETERS

A number of commonly computed ground motion parameters are provided in Seismosoft's applications. Users are referred to the work by Kramer [1996] for a detailed description and discussion on the employment of such ground motion quantities.

Peak ground values of acceleration (PGA), velocity (PGV) and displacement (PGD)

$$PGA = \max|a(t)| \qquad PGV = \max|v(t)| \qquad PGD = \max|d(t)|$$

Peak velocity and acceleration ratio (v_{max}/a_{max})

$$v_{max} / a_{max} = \frac{\max|v(t)|}{\max|a(t)|}$$

Root-mean-square (RMS) of acceleration, velocity and displacement

$$a_{RMS} = \sqrt{\frac{1}{t_{tot}}\int_0^{t_{tot}} [a(t)]^2 dt} \qquad v_{RMS} = \sqrt{\frac{1}{t_{tot}}\int_0^{t_{tot}} [v(t)]^2 dt} \qquad d_{RMS} = \sqrt{\frac{1}{t_{tot}}\int_0^{t_{tot}} [d(t)]^2 dt}$$

Arias Intensity (Ia)

$$I_a = \frac{\pi}{2g}\int_0^{t_{tot}} [a(t)]^2 dt$$

Characteristic Intensity (Ic)

$$I_c = (a_{RMS})^{\frac{3}{2}}\sqrt{t_{tot}}$$

Specific Energy Density (SED)

$$SED = \int_0^{t_{tot}} v[(t)]^2 dt$$

Cumulative Absolute Velocity (CAV)

$$CAV = \int_0^{t_{tot}} [a(t)] dt$$

Acceleration (ASI) and Velocity (VSI) Spectrum Intensity [Von Thun et al., 1988]

$$ASI = \int_{0.1}^{0.5} S_a(\xi = 0.05, T) dT \qquad VSI = \int_{0.1}^{2.5} S_v(\xi = 0.05, T) dT$$

Housner Intensity (HI)

$$HI = \int_{0.1}^{2.5} PSV(\xi = 0.05, T) dT$$

Sustained maximum acceleration (SMA) and velocity (SMV) Introduced by Nuttli [1979], this parameter gives the sustained maximum acceleration/velocity during three cycles, and is defined as the third highest absolute value of acceleration/velocity in the time-history (note: in order for an absolute value to be considered as a "maximum", it must be larger than values 20 steps before and 20 steps after).

Effective Design Acceleration (EDA) This parameter corresponds to the peak acceleration value found after lowpass filtering the input time history with a cut-off frequency of 9 Hz [Benjamin and Associates, 1988].

A95 parameter [Sarma and Yang, 1987] The acceleration level below which 95% of the total Arias intensity is contained. In other words, if the entire accelerogram yields a value of Ia equal to 100, the A95 parameter is the threshold of acceleration such that integrating all the values of the accelerogram below it, one gets an Ia=95.

Predominant Period (Tp) The predominant period (Tp) is the period at which the maximum spectral acceleration occurs in an acceleration response spectrum calculated at 5% damping.

Mean Period (Tm) According to Rathje et al. [1998] the mean period (Tm) is the best simplified frequency content characterisation parameter, being estimated with the following equation, where Ci are the Fourier amplitudes, and fi represent the discrete Fourier transform frequencies between 0.25 and 20 Hz.

$$T_m = \frac{\Sigma C_i^2/f_i}{\Sigma C_i^2}$$

Husid plot [Husid, 1969] The Husid plot represents the build-up of the Arias Intensity.

Energy Flux plot The Energy flux plot represents the build-up of Specific Energy Density. In this module, four different types of record durations are also computed. Users are referred to the work by Bommer and Martinez-Pereira [1999] for a thorough and pertinent discussion on the topic.

Bracketed duration The total time elapsed between the first and the last excursions of a specified level of acceleration.

Uniform duration The total time during which the acceleration is larger than a given threshold value .

Significant duration The interval of time over which a proportion (percentage) of the total Arias Intensity is accumulated.

Effective duration It is based on the significant duration concept but both the start and end of the strong shaking phase are identified by absolute criteria.

FOURIER AND POWER SPECTRA (SEISMOSIGNAL SPECIFIC)

The Fourier Amplitude Spectrum and the Power Spectrum (or Power Spectral Density Function) are computed by means of Fast Fourier Transformation (FFT) of the input time-history. The Fourier amplitude spectrum shows how the amplitude of the ground motion is distributed with respect to frequency (or period), effectively meaning that the frequency content of the given accelerogram can be fully determined. The power spectral density function, on the other hand, may be used to estimate the statistical properties of the input ground motion and to compute stochastic response using random vibration techniques [e.g. Clough & Penzien, 1994; Vanmarcke, 1976; Yang, 1986].

The Fourier Amplitude is computed as the square root of the sum of the squares of the real and imaginary parts of the Fourier transform: SQRT(Re^2+Im^2)

The Fourier Phase (given only in table format) is computed as the angle given by the real and imaginary parts of the Fourier transform: ATAN(Re/Im)

The Power Spectral Amplitude is computed as $FourierAmpl^2$/(Pi*duration*$RmsAcc^2$), where duration is the time length of the record, RmsAcc is the acceleration RMS and Pi is 3.14159.

The computation of the Fourier and Power Spectra can be carried out only for records featuring not more that 2^{15} data points (i.e. 32768 points).

ROTDXX RECORD COMPONENTS (SEISMOSELECT AND SEISMOSIGNAL 3D)

The RotD100, RotD50 and RotD00 measures are computed according to Boore [2010] from the two orthogonal horizontal components of the time series. The two components can be combined into a single time series, which is the combination of the projections of the two time-series on an axis that has a rotation angle θ, with respect to the X-axis:

$$a_{ROT}(t;\theta) = a_1(t)\cos(\theta) + a_2(t)\cos(\theta)$$

where $a_1(t)$ and $a_2(t)$ are the as-recorded horizontal component acceleration time series, and θ is the rotation angle. The response spectrum and the other strong motion parameters for each single time series $a_{ROT}(t;\theta)$ (i.e. for each single angle θ) can be then easily computed.

The process is repeated for a range of azimuths from 0° to 180° (for instance, 0° to 180° with an angle step of 10°). The spectral values at each oscillator period for all values of θ are sorted by amplitude, and the n^{nth} fractiles define the measure of ground motion for that oscillator period. The RotD100 value is the maximum value of the distribution of each intensity measure, the RotD50 value is the median value, and the RotD00 value is the minimum. In the example above (0° to 180° with a step of 10°) and for the case of the PGA, the RotD100 measure would be the largest PGA of all 19 time-series (1st value), RotD00 would be the minimum (19th value), and RotD50 would be the median (10th value).

RECORD SELECTION PROCESS (SEISMOSELECT SPECIFIC)

The selection of the records that best match the provided selection criteria is a two-step process.

Step 1 - Finding Candidate Records:

In the first step the identification of the records, which will be considered as candidates for subsequent selection, is carried out. The user herein defines the criteria, with which the candidate records will be selected from the database. Although the flat files contain a plethora of parameters, only the ones that are deemed of relevance are included in SeismoSelect.
Magnitude: the magnitude of the earthquake event.
Distance: the distance in km from the recording site to the hypocenter (epicentral, rupture or Joyner-Boore).
$V_{S,30}$: the average shear wave velocity $V_{S,30}$ in m/sec.
Faulting Style: Different options are available in the databases (normal, reverse, strike-slip, reverse-oblique or normal-oblique).
Pulse: it is an indicator for the near-fault directivity; the records can be pulse-like or non pulse-like.
Significant-Duration (D5-95): the duration in seconds of the time interval between the points of 5% and 95% of the total energy accumulation for the selected record component.
PGA: The peak ground acceleration of the selected record component.
Event date: The date of the earthquake event.
Event nation: The country, where the earthquake took place.
Maximum number of records per event: The maximum number of records that are to be used from each event. This parameter is introduced, in order not to have many records from a unique event in the list of candidate records.
Maximum number of required candidates: The maximum number of the required candidates sought.
It is noted that some of the parameters specified in the Candidate Records page are not available in all three databases.

The selection of the candidate records is carried out considering directly the values of the intensity measures that are given in the flat file. In ESM the following six options are available: (i) Horizontal U component; this is the 1st component of the record, (ii) Horizontal V component; this is the 2nd component of the record, (iii) Vertical W component; this is the 3rd component of the record, (iv) RotD100 component, (v) RotD50 component and (vi) RotD00 component. In the NGA databases instead, only the RotD50 component is available.

Step 2 - Record Scaling and Selection:

In the second step of the process the selection of the final list of records is carried out from the list of candidate records. This may be done with or without scaling of the selected ground motions. Noting that the matching can be done employing any of the given record components (U or V horizontal, W vertical, RotD100, RotD50, RotD00 for the case of ESM, only RotD50 for NGA), the user may define one or more from the following target intensity measures:
Intensity Measures IM based on a spectral shape
(I) the Multiple Spectral Ordinates: for which the user specifies a period range, in which the program tries to find the best match to the target spectrum,
(ii) the Average Spectral Acceleration: the user specifies a period range, and the program carries out matching for the average of all spectral ordinates within this range,
(iii) Single Spectral Ordinate: the matching is carried out considering the spectral ordinate at a single specific period.
Other Intensity Measures IM:
(i) Peak-ground acceleration PGA,
(ii) Peak-ground velocity PGV,

(iii) Peak-ground displacement PGD,
(iv) Arias Intensity,
(v) Housner Intensity,
(vi) Cumulative Absolute Velocity CAV.

The records selection may be carried out using one of the following three criteria:

Select and Sort All Records: With this option the records are ranked in terms of their error to the given IMs. The error is computed through the square root of sum of squares of the errors for all the Intensity Measures.
Select only Records with Error Smaller than a percentage: This is similar to the previous option, but only the records with an error smaller than the specified value are output. The default value of the error is 20%.
Select the XX records for which the average spectrum has the best fit: A greedy optimization algorithm (Baker & Lee [2018]) is used to identify the specified number of records for which the average spectrum features the smallest error with respect to the target spectrum. It is noted that in this case the selected records are not necessarily those with the smallest individual errors with respect to the target spectrum, as happens instead with the two selection options above, but rather those whose average spectrum has the smallest error.
The selection of the records may be carried out with or without their linear scaling. Whilst the application of scaling will naturally decrease the selection error, users should take care to avoid the use of excessively large/small scaling factors, in order not to introduce undue bias in the selection.

The existence of data for both horizontal components in the ESM flat file enables the availability of additional options, on which the records selection may be based: (i) Single Horizontal, that is the horizontal component U or V, which has the maximum IM,(ii) Geo Mean of the two horizontal components, that is the square root of the product of the two horizontal components U and V, (iii) RotD100 component, (iv) RotD50 component, (v) SRSS of the two horizontal components, that is the square root of the sum of squares of the two horizontal components U and V and (vi) Vertical W component.

SPECTRAL MATCHING (SEISMOMATCH SPECIFIC)

In order to adjust ground-motion records to match a target response spectrum, SeismoMatch uses the wavelets algorithm proposed by Abrahamson [1992] and Hancock et al. [2006], based on the time-domain method of Lilhanand and Tseng [1988], with some modifications to conserve non-stationarity at long periods by using different functional forms for the adjustment time history. The input parameters required by the algorithm are the following:

Mismatch tolerance: This parameter specifies the tolerance for maximum mismatch which controls the convergence process.

Maximum iterations: If convergence is not achieved within the number of iterations specified here, the matching process is stopped (a relatively large default value of 30 is set).

Scale Factor: Factor that can be used to scale the original time-history (e.g. 9.81, if the original accelerogram is defined in "g" and the target spectrum in m/s^2).

Min eigenvalue: Minimum normalized eigenvalue used in singular value decomposition. A smaller value provides more rapid but less stable convergence (recommended value is 1.0e-4).

Max number of waves: Maximum number of waves for wavelet model. The smaller the value, the poorer the matching. Typically, a value higher than the default (10) has no significant effect on the results.

Number additional waves: Maximum number of "additional wavelet" iterations/sub-iterations used to prevent divergence by adding wavelets or reducing correction amplitude (recommended value is 20).

Off diagonal reduction: Reduction in the off diagonal elements provide better convergence, though a value smaller than 0.7 (default) may corrupt the velocity and displacement time series.

Group size: Further control on convergence can be achieved by splitting the design spectrum into a number of sub-groups. The recommended default value is 250.

Min and Max period: Lower and upper period bounds within which spectral matching is carried out.

a1, a2, f1, f2: These so-called alpha model parameters are recommended to feature the values 1.25, 0.25, 1.0 and 4.0, since other combinations may change the frequency dependency of the model and render it inconsistent with the reference time-history, thus resulting in large misfit.

Target PGA, Adjustment frequency, Damping and Cycles number: PGA correction parameters that may be left unchanged for typical applications.

It is noted that with the exception of the 'Matching period range', the 'Scale factor' and the 'Mismatch Tolerance' (all of which are also readily available from the main program window), the remaining of the parameters described below are really intended for expert users that may be very familiar with the algorithm and the corresponding scientific publications.

ARTIFICIAL ACCELEROGRAMS GENERATION (SEISMOARTIF SPECIFIC)

SeismoArtif can be used to generate suites of accelerograms for nonlinear dynamic analysis of new or existing structures, as discussed in several references on the issue of random processes and artificial accelerograms [e.g. Yang, 1986; Clough and Penzien, 1994; Lynn and Fuerst, 1998], as well as to publications on the topics of records appropriateness verification algorithms [e.g. Bradley, 2010].The possible calculation methods are the following:

- Synthetic Accelerogram Generation & Adjustment
- Artificial Accelerogram Generation
- Artificial Accelerogram Generation & Adjustment
- Real Accelerogram Adjustment

Synthetic Accelerogram Generation & Adjustment method is the default option. Synthetic accelerograms tend to appear realistic and they can be generated with some basic (or more extended) knowledge of earthquake history and soil conditions relative to the region/site of interest. This method is able to efficiently combine simple input data with good results.

The Artificial Accelerogram Generation and Artificial Accelerogram Generation & Adjustment methods are based on the adaptation of a random process to a target spectrum. The target spectrum is the only data necessary for the generation of an accelerogram in these cases. However, they require experience for the assessment of the appropriateness of the generated accelerogram.

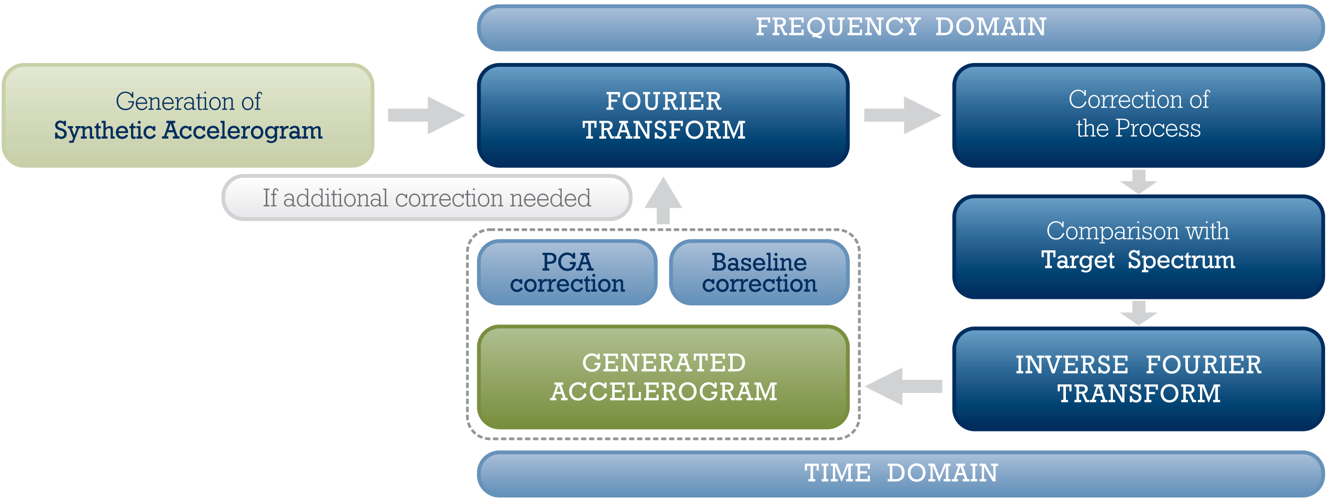
In the Real Acceleration Adjustment method, the artificial accelerogram is defined starting from a real one and adapting its frequency content to match the target spectrum using the Fourier Transformation Method.

The different methods call for different input modules, as a function of the parameters required for the artificial accelerograms generation. The Target Spectra module is common to all of the methods.

Synthetic Accelerogram Generation & Adjustment
Synthetic accelerogram generation [Hallodorson & Papageorgiou, 2005] and correction in frequency domain.
This calculation method is based on Halldorsson & Papageorgiou [2005] algorithm. The artificial accelerogram is defined starting from a synthetic one (simulated by the user), compatible with the target spectrum, and adapting its frequency content using the Fourier Transformation Method.
The correction of the random process is carried on at every iteration using the relationship below [Mucciarelli et al., 2004]:

$$F(f)_{i+1} = F(f)_i[SRT(f)/SR(f)_i]$$

SRT(f) is the value of the target spectrum and $SR(f)_i$ is the value of response spectrum corresponding to the accelerogram of the current iteration for frequency f. $F(f)_{i+1}$ and $F(f)_i$ are the values of the accelerogram in the frequency domain for the current and previous iteration respectively. At each iteration a Fourier Transformation is applied to move from time domain to frequency domain, where the correction to the accelerogram is carried on. Then an Inverse Fourier Transformation is applied in order to return to the time domain, where the corresponding spectrum is calculated, convergence is checked, and it is evaluated whether or not further correction is needed. A schematic summary is given below.



In this calculation method framework, the Envelope Shape module is not required, since the procedure does not start from a random process, but rather from a synthetic accelerogram.

The generation of the synthetic accelerogram starts from a Gaussian white noise which is multiplied by Saragoni & Hart [1974] envelope shape and then adapted to a certain source spectrum. The duration of the ground motion is calculated from the input parameters.

Artificial Accelerogram Generation
Random set of phase angles with amplitudes calculated by power density function [Gasparini & Vanmarcke, 1976].

This method defines each artificial ground motion modifying the starting random process, through the use of a selected envelope shape and a Power Spectral Density Function (PSDF). The PSDF is calculated from the velocity target spectrum (S_v), which is selected before the execution.
This calculation method is based on the fact that each periodic function can be expressed as a series of sinusoidal waves as given in the following formula:

$$X(t) = \sum_n A_n \cdot \sin(\omega_n t + \Phi_n)$$

where A_n is the amplitude and Φ_n is the phase angle of the n^{th} sinusoidal wave. Defining a vector of amplitudes and simulating different arrays of phase angles, it is possible to obtain different processes with the same general aspect but with different characteristics. Such processes are stationary (or steady-state) and their characteristics do not change with time.

To simulate the transient nature of the earthquakes, the steady state motions are multiplied by a deterministic envelope shape (or intensity function) I(t), selected by the user in corresponding Envelope Shapes module.

The artificial ground motion is then defined as:

$$Z(t) = I(t) \cdot \sum_n A_n \cdot \sin(\omega_n t + \Phi_n)$$

These amplitudes are calculated using the PSDF. In this calculation method, the phase angles are generated in the interval [0 2π], following a Uniform probability distribution. The amplitudes (i.e. A_n) are related to the (one-sided) PSDF G(ω) as follows:

$$G(\omega)\Delta\omega = \frac{A_n^2}{2}$$

$G(\omega)\Delta\omega$ represents the contribution to the total power of the motion from the sinusoid with frequency ω_n. If the number of sinusoidal waves considered in the motion is very large, the total power will become the area under the continuous curve $G(\omega)$, as given in the formula below:

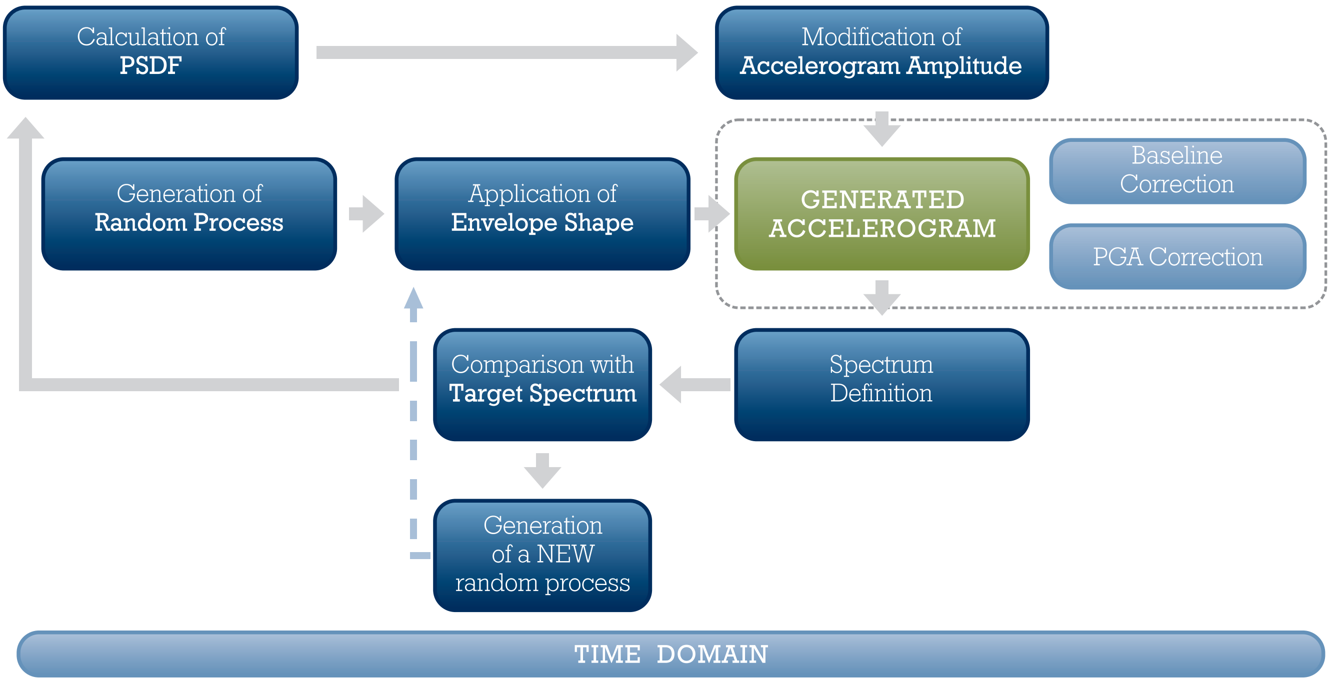
$$\sum \frac{A_n^2}{2} = \sum G(\omega)\Delta\omega \approx \int G(\omega)d\omega$$

The resulting motion is stationary in frequency content, with a peak acceleration close to the target one. The response spectra, relative to the generated motion, are then computed and the program will attempt to match them against the selected target spectrum.

This artificial accelerogram generation method is iterative. For each cycle (i), the response spectrum generated for the simulated ground motion, is compared with the target (at a set of control frequencies). The ratio between the desired response and the computed response is defined at each cycle and the corresponding Power Spectral Density Function (PSDF) is recalculated as a function of the square of the aforementioned ratio as indicated in the following formula:

$$G(\omega)_{i+1} = G(\omega)_i \left(\frac{S_v^{(\omega)}}{S_{v(\omega)}^{(i)}} \right)^2$$

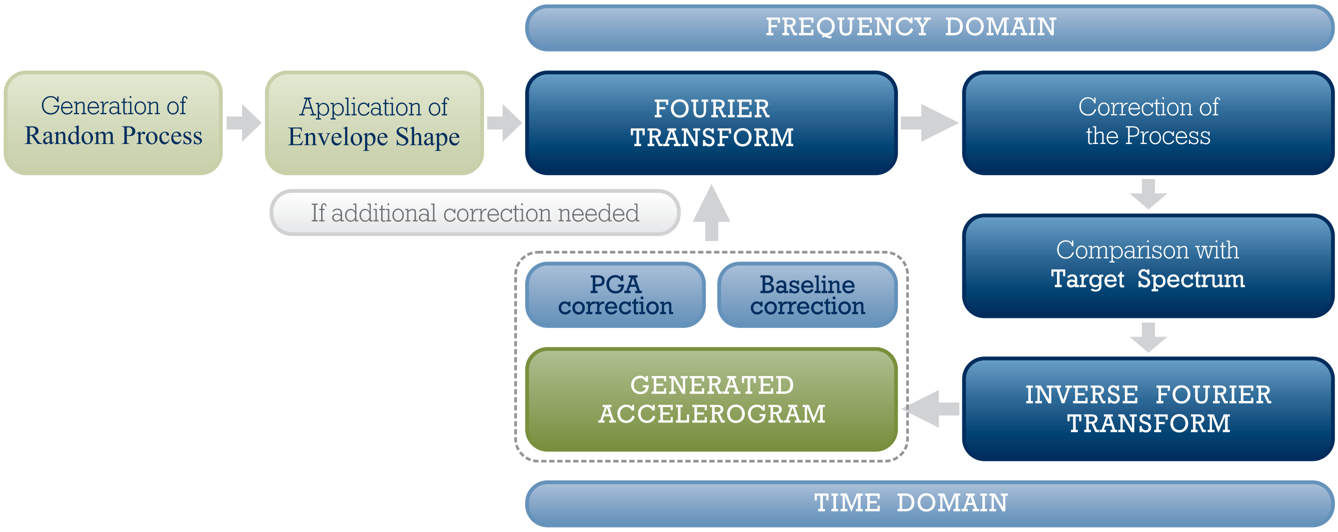
where S_v is the target spectrum value (i.e. desired response values) and $S_v^{(i)}$ (i.e. computed response values). Using the modified PSDF, a new motion is simulated and a new response spectrum is calculated or, otherwise, the procedure can be repeated automatically with new random processes until convergence. A schematic summary of this method is given in the figure below.



The software automatically carries on the entire iterative procedure. N executions with different (N_ω) phase angles are performed until convergence is reached. The default values are N=3 and N_ω=100 as can be noted in the Program Settings module of the software. If convergence cannot be reached, SeismoArtif will output the best solution.

Artificial Accelerogram Generation & Adjustment:
Random process adjustment by correction in frequency domain.

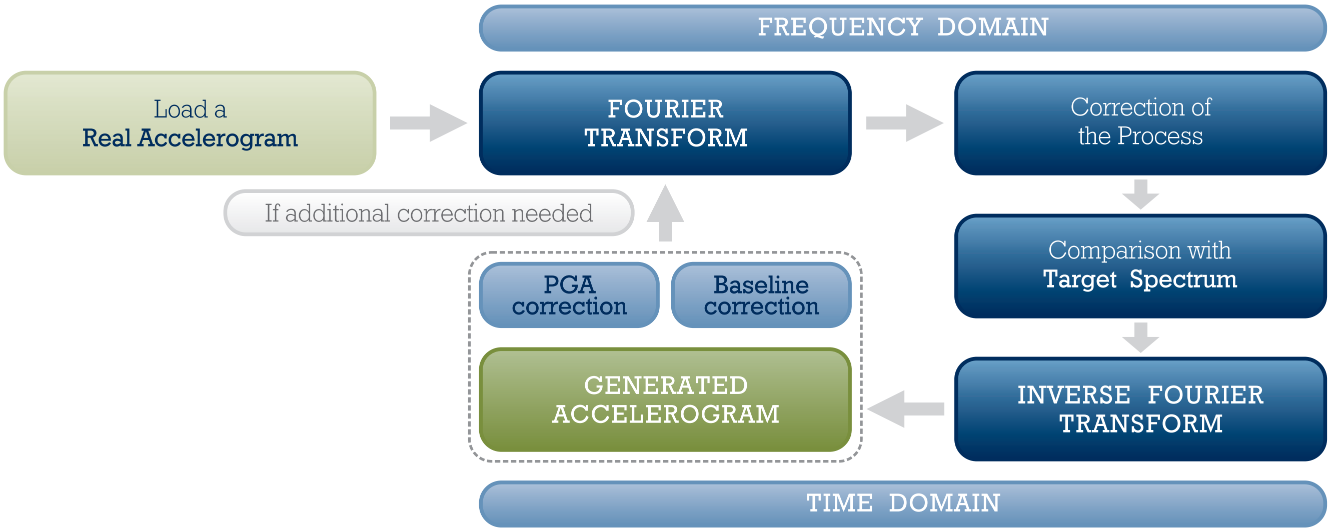
This method defines the artificial ground motions considering a target spectrum and adapting the frequency content using the Fourier Transformation Method. It can be considered as an evolved version of the one described above. Indeed, the generation of the random process and the application of the envelope shape are common to the Artificial Accelerogram Generation method, with its main distinctive feature being the correction (at each iteration) of the random process in the frequency domain. A schematic summary is given below.



Input parameters and output results are the same of the Artificial Accelerogram Generation method, but this is more stable and one-sided and more likely to lead to a very good convergence (error less than 7-8%), at the expense of a higher number of iterations, however.

Real Accelerogram Adjustment
Real accelerogram adjustment by correction in frequency domain.

The artificial accelerogram is defined starting from a real one and adapting its frequency content to match the target spectrum using the Fourier Transformation Method as described in more detail here. This method may lead to reasonable results, however the more the target response spectrum differs from the real accelerogram's spectrum, the less realistic the artificial accelerogram will be. Indeed, users who wish to employ existing real accelerograms in the derivation of spectrum-compatible ground motions, something which is certainly recommended, are strongly suggested to use SeismoMatch instead, a more valid and appropriate tool for this purpose.



company overview

Seismosoft was founded in 2002 with the aim of providing the earthquake engineering community with access to powerful and state-of-the-art analytical tools, and is now recognised as a leading enterprise in this field.

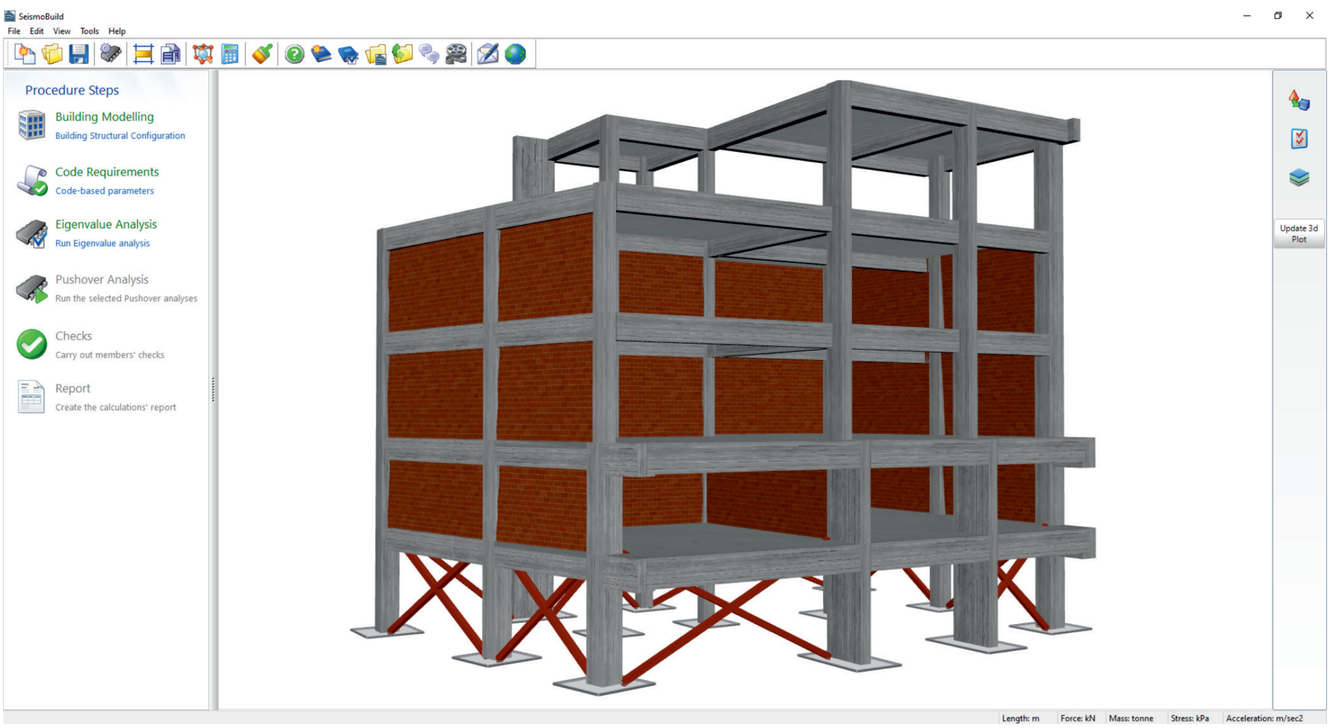
It has always focused not only on technical advancement but also on ease-of-use, so as to facilitate effective adoption and employment by both researchers and practitioners. As a result, its software applications are requested at a rate of 1000 downloads per month, from more than 110 countries, and are employed in hundreds of international academic/research institutions, practicing companies and governmental bodies.

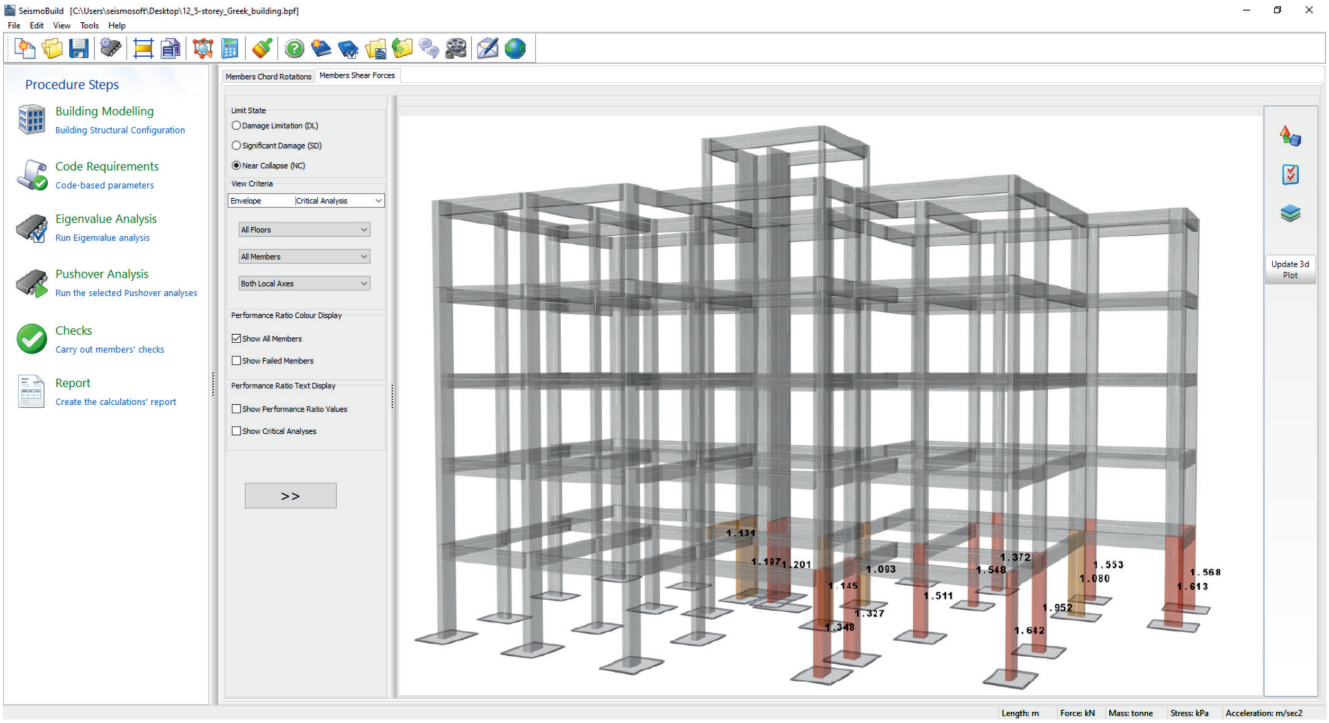
Ultimately, by rendering readily available to the full spectrum of earthquake engineering stakeholders tools and methods that feature not only technical excellence but also efficiency and user-friendliness, Seismosoft hopes to somehow contribute, even if modestly, to the continuous search for higher mitigation of the risks that earthquakes pose to humankind.

Seismosoft goal in having a place in earthquake engineering field has led in the development of ten programs, including SeismoSignal, SeismoSignal 3D, SeismoSelect, SeismoMatch, SeismoArtif and SeismoSpect. A brief reference of the other four programs and their capabilities is exhibited below:

SEISMOBUILD

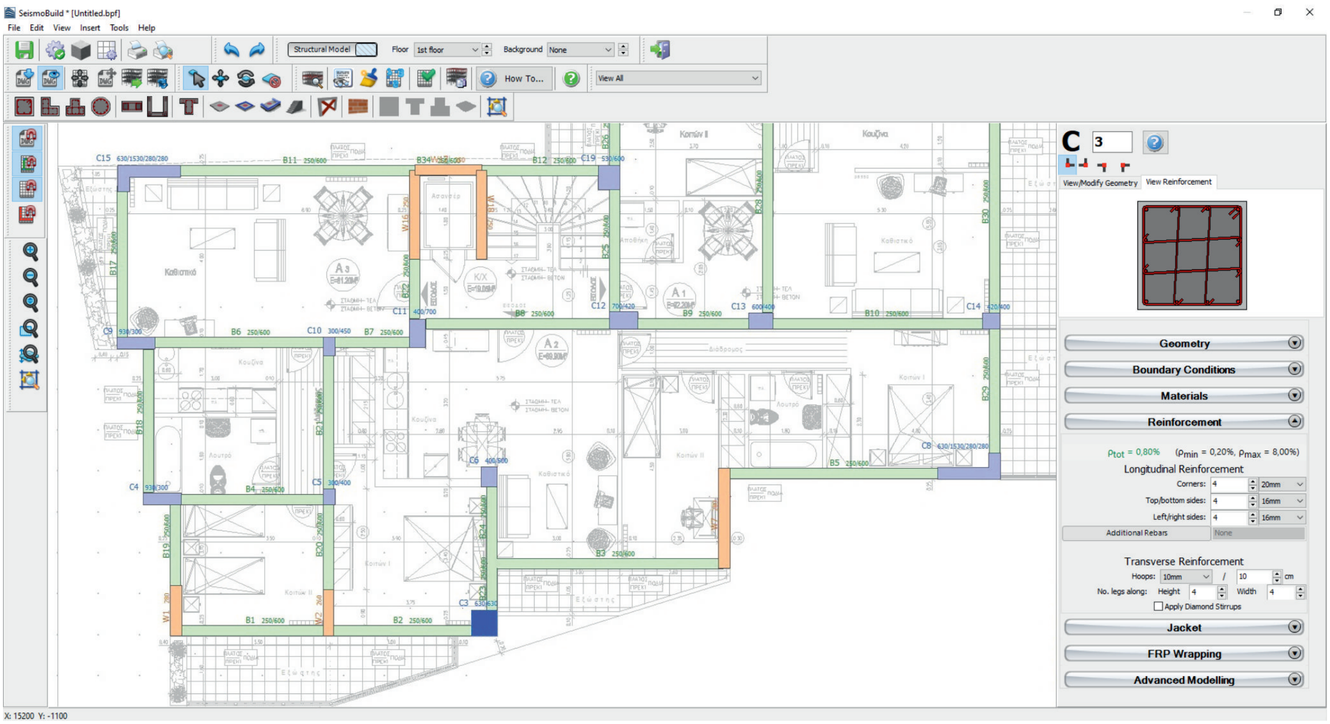
SeismoBuild is an innovative Finite Element package wholly and exclusively dedicated to seismic assessment and strengthening of reinforced concrete buildings. The program is capable of fully carrying out the code defined assessment methodologies from the structural modelling through to the required analyses and the corresponding member checks. Currently five Standards are supported (Eurocode 8 and the Eurocodes framework, American Code for Seismic Evaluation and Retrofit of Existing Buildings ASCE 41, Italian National Seismic Code NTC-18, Greek Seismic interventions Code KANEPE and Turkish Seismic Evaluation Building Code TBDY). Both metric and imperial units, as well as European and US reinforcing bars types are supported.
The rational and intuitive structure of the package, which are mainly attributed to the fact that it is the only software worldwide that is totally committed to seismic assessment, result in a very smooth learning curve even

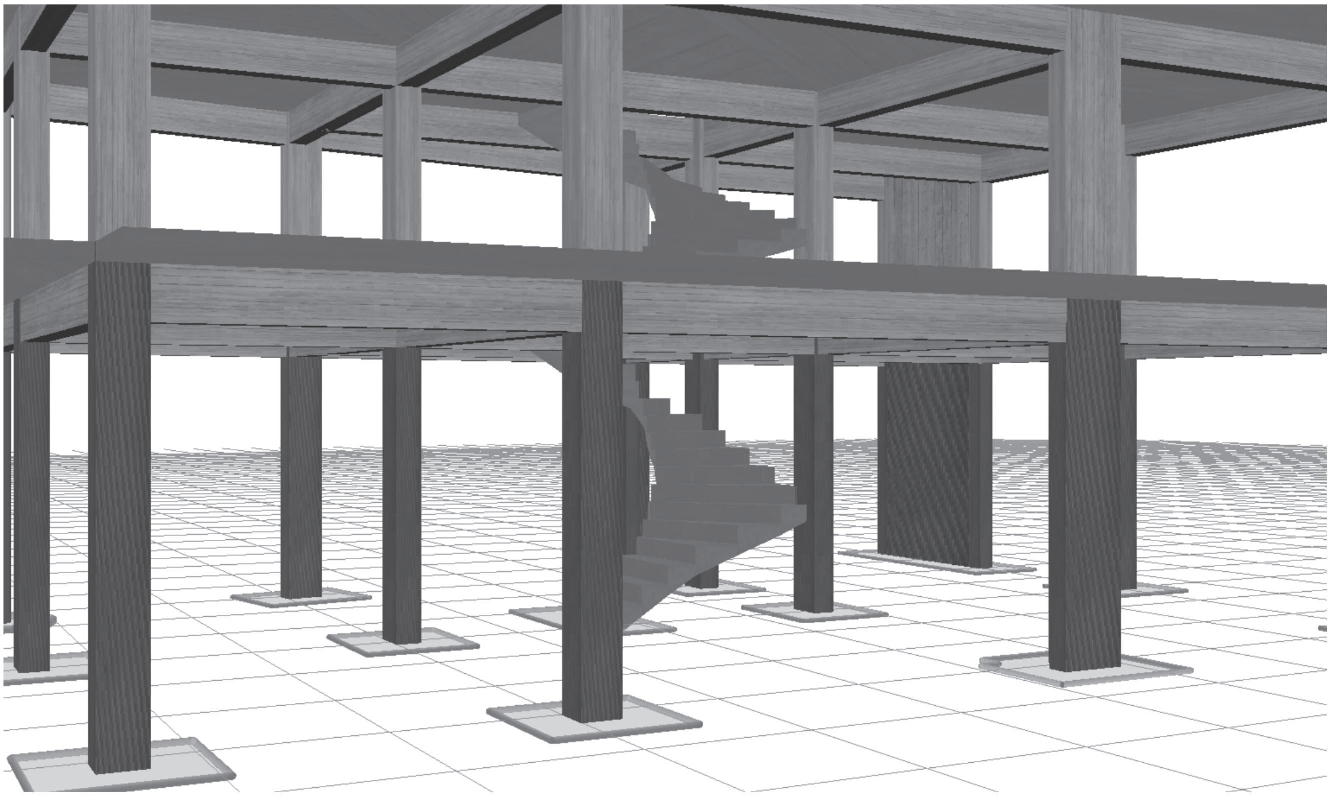




for engineers that are not familiar with the Finite Elements method. Further, the user-friendly,CAD-based, graphical user interface may increase the productivity significantly, to the point that the assessment of a multi-storey RC building can be completed, within a few minutes, including the creation of the report and the CAD drawings to be submitted to the client.

The structural model is introduced with the so-called Building Modeller, which constitutes a special CAD-based module that facilitates significantly the input. With the help of the program's predefined built-in sections, columns and beams of different shapes (rectangular, circular, L-shaped and T-shaped columns, beams and walls, as well as their 1, 2, 3 or 4-sided jacketed counterparts), any RC building configuration can be easily modelled. The reinforcement, the other modelling parameters (e.g. new or existing member, material





strengths, lap splices, members' detailing, cover thickness) and Code-defined settings (e.g. primary/secondary member, with/without detailing for earthquake resistance) may be easily introduced with a couple of mouse clicks. Slabs and stairs can be effectively introduced, whereas inclined slabs and beams are also supported. Furthermore, foundations, infill panels and the strengthening with steel braces of different configurations (X-braces, V-braces or diagonal braces) may also be defined. Finally, a large built-in library of FRP wrapping sheets is available for the strengthening of reinforced concrete members. It is important to note that the input provided by users is only related to either the structural details (geometry, materials, and reinforcement), or clearly defined code-based parameters, such as the limit states, the seismic action, or the knowledge level. The entire structural model (including the material models parameters, the nodes location and the FE mesh, the elements geometry and offsets, the mass distribution and the loading patterns) is automatically created by the program without any intervention by the user.

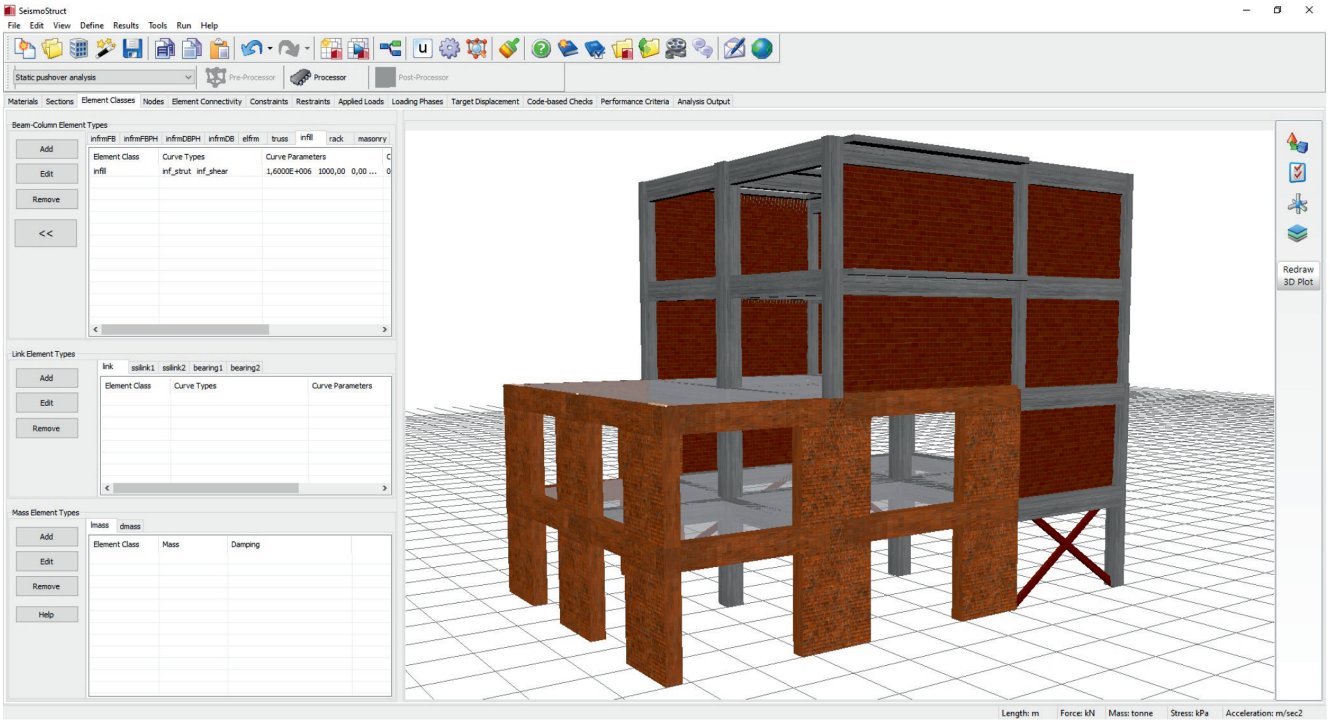
The Code requirements (limit states, knowledge levels, seismic input, types of checks to be performed, safety factors, etc.) according to the selected Standard, as well as the analysis parameters, can be easily introduced from a series of specially designed modules.

All the analysis types proposed by the Standards are supported: (i) linear static procedure LSP, (ii) linear dynamic procedure LDP, (iii) nonlinear static procedure NSP, (iv) nonlinear dynamic procedure NDP. The nonlinear analysis solver features both geometric nonlinearities and material inelasticity, and is based on the advanced solution algorithms of SeismoStruct. Carrying out the analyses, including the calculation of the target displacement in pushover analysis (NSP) and the creation and matching of the input accelerograms in dynamic analysis (NDP) is straightforward. Similarly, the extraction of the results and the creation of the envelopes of the demand-to-capacity ratios for all the analyses is done automatically by the program. The results for all the selected checks can be viewed both in tabular format and graphically, where the members, for which the demand has exceeded the capacity, are displayed in colour. The checks available in SeismoBuild pertain to the members' chord rotations, bending moment and shear capacities, the inter-storey drift levels, as well as the checks for the beam-column joints.

Finally, the technical report of the analysis can be created on-the-fly in PDF, RTF or HTML file formats, whereas a variety of CAD drawing files of the building structural model (plan views, cross sections and reinforcement tables) may be quickly created and exported.

SEISMOSTRUCT

SeismoStruct is an award-winning Finite Element package capable of predicting the large displacement behaviour of space frames under static or dynamic loading, taking into account both geometric nonlinearities and material inelasticity. Concrete, steel, masonry, FRP and superelastic shape-memory alloy material models are available, together with a large library of 3D elements that may be used with a wide variety of pre-defined steel, concrete and composite section configurations. The program has been extensively quality-checked and validated, as described in its Verification Report. Some of the more important features of SeismoStruct are summarised in what follows:



✓ Completely visual interface. No input or configuration files, programming scripts or any other time-consuming and complex text editing requirements.

✓ Full integration with the Windows environment. Input data created in spreadsheet programs, such as Microsoft Excel, may be pasted to the SeismoStruct input tables, for easier pre-processing. Conversely, all information visible within the graphical interface of SeismoStruct can be copied to external software applications (e.g. to word processing programs, such as Microsoft Word), including input and output data, high quality graphs, the models' deformed and undeformed shapes and much more.

✓ With the Wizard facility users can create regular/irregular 2D or 3D models and run all types of analyses on the fly. The whole process takes no more than a few seconds.

✓ With the Building Modeller the user can create real regular or irregular 3D reinforced concrete models within minutes.

✓ Ten different types of analysis: dynamic and static time-history, conventional and adaptive pushover, incremental dynamic analysis, eigenvalue, non-variable static loading, response spectrum analysis, buckling and tsunami analysis.

✓ The applied loading may consist of constant or variable forces, displacements and accelerations at the nodes, as well as distributed element forces. The variable loads can vary proportionally or independently in the pseudo-time or time domain.

✓ The program accounts for both material inelasticity and geometric nonlinearity.

✓ A large variety of reinforced concrete, steel, masonry and composite sections are available.

✓ The spread of inelasticity along the member length and across the section depth is explicitly modelled in SeismoStruct allowing for accurate estimation of damage accumulation.

✓ Numerical stability and accuracy at very high strain levels enable precise determination of the collapse load of structures.

✓ SeismoStruct possesses the ability to smartly subdivide the loading increment, whenever convergence problems arise. The level of subdivision depends on the convergence difficulties encountered. When convergence difficulties are overcome, the program automatically increases the loading increment back to its original value.

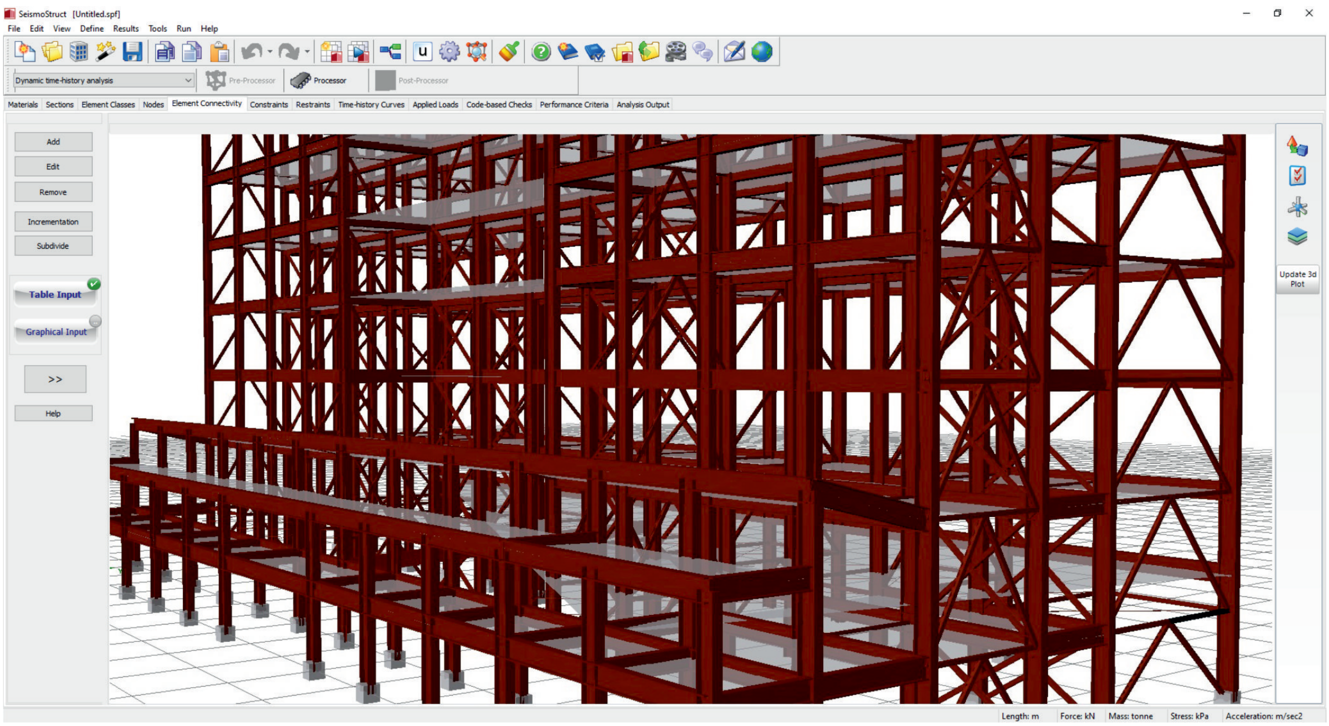
✓ SeismoStruct's processor features real-time plotting of displacement curves and deformed shape of the structure, together with the ability of pausing and re-starting the analysis.

✓ Capacity checks for the frame and masonry elements can be performed, according to Eurocode 8, ASCE 41, NTC-18, KANEPE and TBDY and for all the limit states of the specified Codes.

✓ Performance criteria can also be set, allowing the user to identify the instants at which different performance limit states (e.g. non-structural damage, structural damage, collapse) are reached. The sequence of cracking, yielding, failure of members throughout the structure can also be, in this manner readily obtained.

✓ Advanced post-processing facilities are available, including the ability to custom-format all derived plots and deformed shapes, thus increasing productivity of users.

✓ AVI movie files can be created to better illustrate the sequence of structural deformation.



FRP DESIGNER

FRP Designer is a simple and efficient application for the analysis and design of the strengthening of reinforced concrete members with fibre-reinforced polymers (FRPs).

The input of the structural data for the existing member and for the FRP strengthening is done easily with a completely visual interface. A large library of the most common FRP fabrics and laminates available in the market has been included in the program, whereas user-defined FRP materials can also be defined by specifying their very basic characteristics (e.g. thickness, width, strength, stiffness and maximum elongation).

The program is capable of automatically carrying out all the calculations for the determination of the member capacity with and without the retrofit interventions. Currently interventions in shear and bending have been included. The supported Standards are: (i) the US guidelines of ACI PRC-440.2-17, (ii) Eurocode 8, Part-3, (iii) the Italian guidelines CNR-DT 200 R1/2013 and (iv) the fib Bulletin 90. The results and the checks can be exported in a technical report in PDF, RTF or HTML file format.

SEISMORACK

SeismoRack is Finite Element package wholly and exclusively dedicated to analysis and assessment of structures with members with thin-walled, open, cross-sections. Consequently, the program is ideal for the modelling of steel storage pallet racks, as well as scaffolding structures, which are generally composed by uprights with mono-symmetric lipped channel cross-sections.

Any thin-walled open section configuration can be modelled, and different thicknesses may be assigned at the different parts of the section. The analysis can be performed with either 6 or 7 degrees of freedom per node. In the latter case, the displacements and the internal stresses, including warping displacements and bi-moment stresses, can be correctly estimated and the flexural-torsional and lateral-torsional buckling, derived by the coupling between flexure and torsion, may be accurately predicted. The modelling also accounts for the eccentricity of the shear centre from section centroid, and it considers all the Wagner coefficients, which makes it suitable for use with non-symmetric cross-sections. Finally, the flexibility of the supports at the edges of the rack elements may be modelled with linear or nonlinear springs.

The rational structure of the program, which is mainly attributed to the fact that it is the only software worldwide that is totally committed to racks and scaffoldings, results in a very smooth learning curve even for engineers that are not familiar with the Finite Elements method. Furthermore, the user-friendly graphical user interface increases the productivity significantly, to the point that the assessment of a large rack structure can be completed within a few minutes including the creation of the technical report.

Currently the European Standards for steel static storage systems and adjustable pallet racking systems are supported (EN 15512). The Code requirements (limit states, seismic input, types of checks to be performed, loading combination coefficients, member imperfections etc.), as well as the analysis parameters, can be easily introduced from a series of specially designed modules. The program is capable of running the following analyses specified by the Standard: linear static analysis, eigenvalue analysis, buckling analysis and nonlinear pushover analysis.

The extraction of the results and the creation of the envelopes of the demand-to-capacity ratios for all the analyses is done automatically by the program. The results for all the selected checks can be viewed both in tabular format and graphically, where the members, for which the demand has exceeded the capacity, are displayed in colour. The checks available in SeismoRack are the following: axial tension, axial compression, biaxial bending, shear, combined tension and bending, combined compression and bending, combined shear axial force and bending, lateral torsional buckling of beams, flexural buckling, flexural-torsional buckling, bending and axial compression without lateral-torsional buckling, bending and axial compression with lateral-torsional buckling, deflection of beams, vertical deflection and twist in beams.

The technical report of the analysis with all the checks can be created and exported on-the-fly in PDF, RTF or HTML file formats.

available documentation

Users are provided full documentation for SeismoApps in different formats. The sources of information currently available are:

- ✓ The applications' Help System provided with the program installation
- ✓ Video tutorials available in Seismosoft's page and YouTube channel
- ✓ Seismosoft's Forum available at www.seismosoft.com/forum/
- ✓ Seismosoft's Assessment and Strengthening Blog available at www.seismosoft.com/blog
- ✓ Seismosoft's pages in the social media (Facebook, Twitter and LinkedIn page)

Abrahamson N.A. [1992] "Non-stationary spectral matching," Seismological Research Letters, Vol. 63, No. 1, p. 30.

Ancheta, T.D., Darragh, R.B., Stewart, J.P., Seyhan, E., Silva, W.J., Chiou, B.S.J., Woodell, K.E., Graves, R.W., Kottke, A.R., Boore, D.M., Kishida, T. and Donahue, J.L., [2013]. PEER NGA-West 2 database, PEER Report 2013/03, Pac. Earthq. Eng. Res. Ctr, Berkeley, CA.

Baker JW & Lee C [2018]. An improved algorithm for selecting ground motions to match a conditional spectrum. Journal of Earthquake Engineering 22 (4), 708-723.

Benjamin J.R. and Associates [1988] "A criterion for determining exceedance of the Operating Basis Earthquake," EPRI Report NP-5930, Electric Power Research Institute, Palo Alto, California.

Bommer J.J., Martvnez-Pereira A. [1999] "The effective duration of earthquake strong motion," Journal of Earthquake Engineering, Vol. 3, No. 2, pp. 127-172.

Boore D.M. [2001] "Effects of baseline corrections on displacements and response spectra for several recordings of the 1999 Chi-Chi, Tawian, earthquake," Bulletin of the Seismological Society of America, Vol. 92, No. 4, pp. 1199-1211.

Boore D.M., Akkar S. [2003] "Effects of causal and acausal filters on elastic and inelastic response spectra," Earthquake Engineering and Structural Dynamics, Vol. 32, pp. 1729–1748.

Boore D.M. [2010]. Orientation-Independent, Nongeometric-Mean Measures of Seismic Intensity from Two Horizontal Components of Motion. Bulletin of the Seismological Society of America, Vol. 100, No. 4, pp. 1830–1835, August 2010, doi: 10.1785/0120090400.

Bradley B.A. [2010] "A generalized conditional intensity measure approach and holistic ground-motion selection," Earthquake Engineering and Structural Dynamics, Vol. 39.

Chopra A.K. [1995] "Dynamics of Structures: Theory and Applications to Earthquake Engineering," Prentice-Hall.

Clough R.W., Penzien J. [1994] "Dynamics of Structures," 2nd Edition, McGraw Hill.

Cook R.D., Malkus D.S., Plesha M.E. [1989] "Concepts and Applications of Finite Elements Analysis," John Wiley & Sons.

Crisfield M.A. [1991] "Non-linear Finite Element Analysis of Solids and Structures," John Wiley & Sons.

EN 1998-3 (English) [2004]: Eurocode 8: Design of structures for earthquake resistance -Part 3: Assessment and retrofitting of buildings.

Gasparini D., Vanmarcke E.H. [1976] "Simulated Earthquake Motions Compatible with Prescribed Response Spectra," M.I.T. Department of Civil Engineering research report.

Goulet C.A., Kishida T. Ancheta T D., Cramer C.H., Darragh R.B., Silva W.J., Hashash Y.M.A., Harmon J., Stewart J.P., Wooddell K.E., Youngs R.R. [2014]. PEER NGA-East database, PEER Report No. 2014/17, Pacific Earthquake Engineering Research Center, University of California, Berkeley, CA.

Halldorsson B., Papageorgiou A.S.[2005]"Calibration of the specific barrier model to earthquake of different tectonic regions," Bulletin of the Seismological Society of America, Vol.95, No.4, pp.1276-1300.

Hancock J., Watson-Lamprey J., Abrahamson N.A., Bommer J.J., Markatis A., McCoy E., Mendis R. [2006] "An improved method of matching response spectra of recorded earthquake ground motion using wavelets." Journal of Earthquake Engineering, Vol. 10 pp. 67–89.

Husid L.R. [1969] "Characteristicas de terremotos. Analisis general," Revista del IDIEM, Vol. 8, pp. 21-42.

KANEPE [2022]: Code of Structural Interventions, 3rd revision.

Kramer S.L. [1996]"Geotechnical Earthquake Engineering," Prentice-Hall.

Krawinkler H., Nassar A. A. [1992] "Seismic design based on ductility and cumulative damage demand and capacities," Nonlinear Seismic Analysis and Design of Reinforced Concrete Buildings, Elsevier Applied Science, New York, NY, USA.

Lilhanand K., Tseng W.S. [1988] "Development and application of realistic earthquake time histories compatible with multiple-damping design spectra," Proceedings of the 9th World Conference on Earthquake Engineering, Tokyo, Japan, Vol II, 819-824.

Lynn P.A., Fuerst W. [1998] "Introductory Digital Signal Processing with Computer Applications," Wiley & Sons.

Luzi L, Puglia R, Russo E & ORFEUS WG5 [2016]. Engineering Strong Motion Database, version 1.0. Istituto Nazionale di Geofisica e Vulcanologia, Observatories & Research Facilities for European Seismology. https://doi.org/10.13127/ESM.

Miranda E., Bertero V.V. [1994] "Evaluation of strength reduction factor for earthqauke-resistance design," Earthquake Spectra, 10(2), 357-379.

Mucciarelli M., Spinelli A., Pacor F. [2004]"Un programma per la generazione di accelerogrammi sintetici “fisici” adeguati alla nuova normativa," Proceedings of XI Congresso Nazionale “L'Ingegneria Sismica in Italia”, Genova, Italy.

Newmark N.M. [1959] "A method of computation for structural dynamics," Journal of the Engineering Mechanics Division, ASCE, Vol. 85, No. EM3, pp. 67-94.

Newmark N.M., Hall W.J. [1982] "Earthquake Spectra and Design," EERI Monograph Series, EERI, Oakland, CA, USA.

NTC [2008]: Norme Techniche Construzoni.

Nuttli O.W. [1979] "The relation of sustained maximum ground acceleration and velocity to earthquake intensity and magnitude," Miscellaneous Paper S-71-1, Report 16, U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, Mississippi.

Rathje E.M., Abrahamson N.A., Bray J.D. [1998] "Simplified frequency content estimates of earthquake ground motions," Journal of Geotechnical and Geoenvironmental Engineering, Vol. 124, No. 2, pp. 150-159.

Saragoni, G. R. and Hart,G. C. [I974]"Simulation of artificial earthquakes," Earthquake Engineering-and Structural Dynamics,Vol.2, pp.219-267.

Sarma S.K., Yang K.S. [1987] "An evaluation of strong motion records and a new parameter A95," Earthquake Engineering and Structural Dynamics, Vol. 15, pp. 119-132.

Stearns S., David R. [1996]Signal Processing Algorithms, Prentice-Hall.

Vanmarcke E.H. [1976] "Structural response to earthquakes," Chapter 8 in Seismic Risk and Engineering Decisions (eds. C. Lomnitz and E. Rosenblueth), Elsevier, Amsterdam, pp. 287-338.

Von Thun J.L., Rochim L.H., Scott G.A., Wilson J.A. [1988] "Earthquake ground motions for design and analysis of dams," Earthquake Engineering and Soil Dynamics II - Recent Advances in Ground-Motion Evaluation, Geotechnical Special Publication, Vol. 20, pp. 463-481.

Yang C.Y. [1986]"Random Vibration of Structures," John Wiley and Sons.

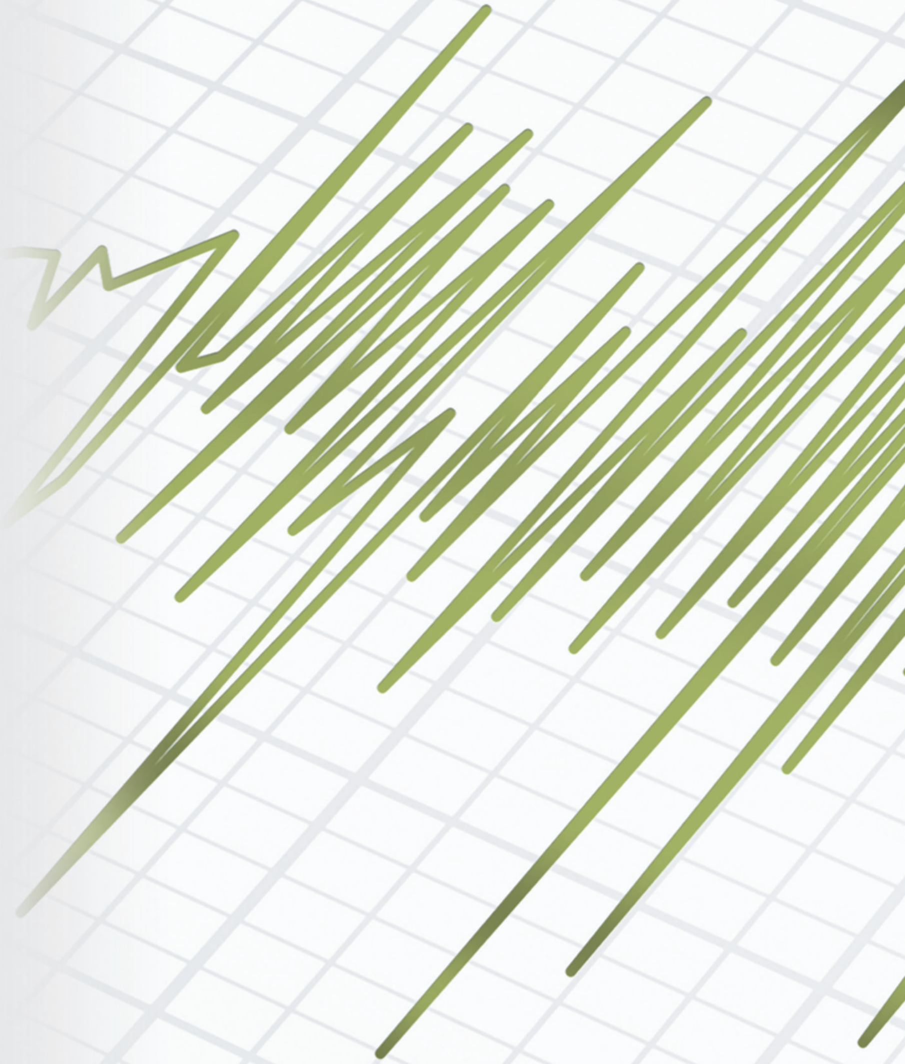
SEiSMOAPPS

Seismosoft in brief

Founded in 2002,
Seismosoft provides the earthquake engineering community with access to powerful and state-of-the-art analytical tools, such as SeismoBuild, SeismoStruct, SeismoSignal, SeismoSelect, SeismoMatch, SeismoArtif, SeismoSpect and FRP Designer.

With more than 1000 software license requests per month, and users in thousands of international academic/research institutions and practicing companies in more than 110 countries worldwide, Seismosoft is now recognised as a leading enterprise in this field. Seismosoft provides the full spectrum of earthquake engineering stakeholders, tools and methods that feature not only technical excellence but also efficiency and user-friendliness.

Ultimately, we hope to somehow contribute, even if modestly, to the continuous search for higher mitigation of the risks that earthquakes pose to humankind.



SEiSMOSOFT
EARTHQUAKE ENGINEERING SOFTWARE SOLUTIONS

How to Contact
Up to date Seismosoft contact details are always available on our website at

www.seismosoft.com

https://seismosoft.com/blog/