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The online graphical user interface of REXELweb for the selection of accelerograms from the Engineering Strong Motion database (ESM)

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Selection and spectrum-matching of ground-motion records is a key issue for dynamic analysis of structures performed by practitioners worldwide. In fact, this is an explicit requirement of several seismic building codes, such as the Italian code and Eurocode 8 (CEN 2003, CS.LL.PP. 2018). Although these accelerograms can be in principle artificial, that is obtained via random vibration theory or simulating seismic rupture and wave propagation, the recent increasing availability of real strong-motion records in online repositories, has shifted the attention of the community mostly towards the use of natural accelerograms (e.g., Bommer and Acevedo, 2004; Iervolino and Cornell, 2005). This has, in turn, led to the development and dissemination of dedicated software for selecting these records from within the databases. One of the most recognized attempts of providing computer-aided selection of accelerograms, compliant (on average) with design spectra, was the standalone program REXEL (Iervolino et al., 2010) still available at the website of the *Rete dei Laboratori Universitari di Ingegneria Sismica* (ReLUIIS – www.reluis.it) which is based on static waveform datasets; i.e. the European Strong-motion Database (ESD) updated up to 2007, ITACA (*Italian Accelerometric Archive*; 2010 version) and SIMBAD datasets (Smerzini and Paolucci, 2011).

More recently, further REXEL-based tools (i.e., based on the same source-code) have been developed, mostly in order to extend the database from which records can be selected: (i) REXELite (Iervolino, 2011) that implemented some basic functionalities of REXEL within the old web-interface of the daily-updated pan-European *Engineering Strong Motion database* (ESM, <http://esm.mi.ingv.it>; Luzi et al., 2016); (ii) REXEL-DISP to select record sets compatible with displacement spectra (Smerzini et al. 2014); and (iii) the recent application REXELweb v1.0 (Sgobba et al., 2019) which is shared through a set of web-services (https://esm-db.eu/#/data_and_services/web_services) as well as in the form of a Mathworks-Matlab® executable linked to the new ESM and ITACA (http://itaca.mi.ingv.it/ItacaNet_31/#/data_and_services/tools/rexel) websites (D'Amico et al. 2021; Lanzano et al. 2021). Although the latter provides computer-friendly access to data, it is strongly limited by the lack of a dynamic user-interface, thus being mostly accessible to advanced users.

To enhance REXELweb, a graphical user interface has been developed and made available online (https://esm-db.eu/#/data_and_services/tools/rexel). It has several advantages and novelties compared to existing tools: (i) a guided web-interface that makes the application user-friendly; (ii) integration within the ESM website, which provides both a continuous availability of new high-quality records and a modern and effective front-end for user needs; (iii) the implementation of all of REXEL's options, with novel features for the definition of the target spectrum. The program is able to search for spectrum-compatible combinations of 1-, 2- or 3-component ground-motion records, compatible - on average - with the assigned target spectrum. It addresses the input options specified by the user through the web-interface and returns data from the ESM database by invoking automatically the set of underlying Web-Services (WSs), specifically developed for REXELweb analysis.

The three main steps of the selection procedure are similar to those of the other tools of the REXEL family:

1. Definition of the target spectrum: this first step allows the user to define a 5%-damping elastic spectrum, which is the target spectrum to match (on average). This can be automatically built according to user-definition or design provisions; i.e. Eurocode 8, Italian Building code or uniform hazard spectra (UHS). A new feature entails the selection of the site of interest directly from an

interactive map. This also allows to retrieve automatically the corresponding peak ground acceleration (PGA) necessary to anchor the target spectrum, from the hazard maps made available both for Italy (MPS04 map; esse1.mi.ingv.it) and Europe (ESHM13 map; SHARE, EU-FP7 project *Seismic Hazard Harmonization in Europe*; <http://www.efehr.org/en/home/>). Once all input options have been entered, one can go ahead and generate the horizontal and vertical design spectra for 30 vibration periods, ranging from 0.01s to 4.00s.

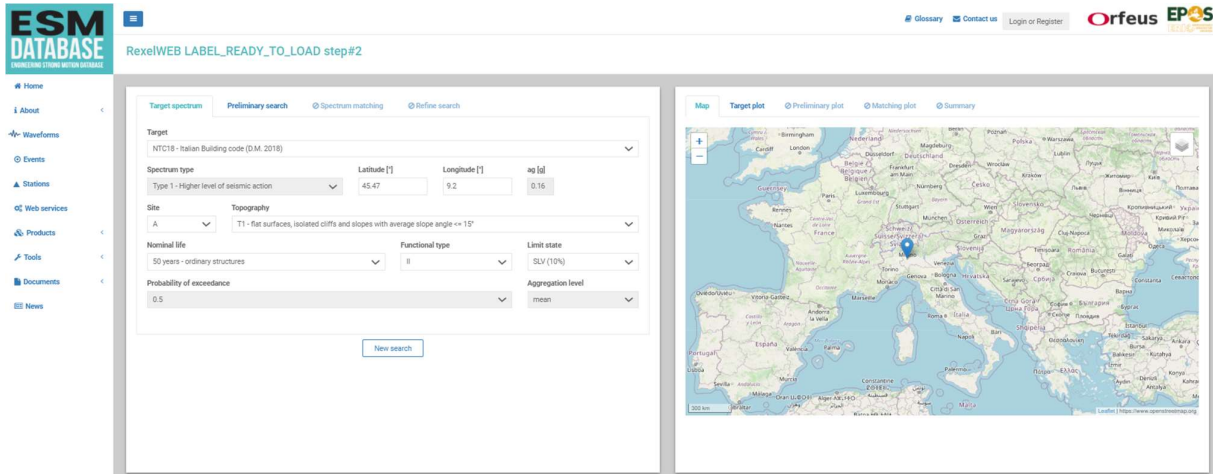


Figure 1. Target Spectrum Tab (panel on the left) and Map (panel on the right)

2. Preliminary search: the second step allows the user to specify the record-selection criteria, as well as the number and type of ground-motion components to consider (1-, 2- or 3-component analysis), providing access to response spectra included in ESM that comply with the specified parameters. The selected spectra are ranked on the basis of a score index, which is a measure (namely the root-mean-squared-error) of the distance between the target and the spectrum of an individual record. This list of ordered spectra allows the program to speed up the spectral matching routine, including up to one thousand candidate records per single request. The program generates a plot of the preliminarily selected spectra along with the mean spectrum compared with the target spectrum (Figure 2). These plots are always returned both in terms of unscaled spectra (i.e. as-originally-recorded) and scaled spectra (i.e. computed from records linearly scaled to a common PGA).
3. Spectrum matching: this step allows to set the tolerances and period bounds within which the average spectrum of a combination found has to be compatible with the target spectrum. In this step, it is possible to allow scaling of the records, which means searching among waveforms linearly scaled to the target spectrum's PGA and assign a maximum admissible scale factor of the mean spectrum. It also allows choosing the size of the record suite among 1, 7, or 30 and the desired number of required spectrum-compatible suites of records. At the end of the analysis, a Summary Tab reporting the set of user options and a table with the list of the compatible waveforms and corresponding metadata are returned. An important feature in this step is that the records in the table are directly linked to the ESM contents and can be clicked by the users to access information on the event, station and waveform details of the ESM web pages. Finally, the user can choose to exclude specific records, or the related stations and/or events, by selecting the corresponding spectrum from the waveforms table or from the figure and excluding it from the combination.

The final results can be downloaded in two types of file formats (ASCII and HDF5) along with a table (JSON format) collecting all the metadata associated with the combination. REXELweb will be maintained and improved with new features to better meet user requirements and design provisions.

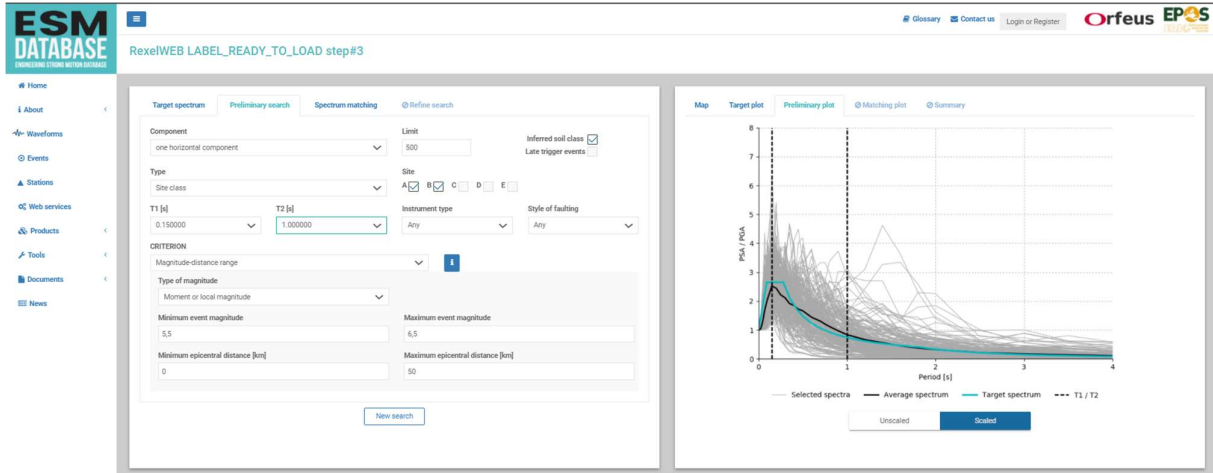


Figure 2. Tab of preliminary search for scaled spectra: the mean spectrum is plotted as black continuous line, the target spectrum is in cyan along with lower and upper periods shown as dashed lines

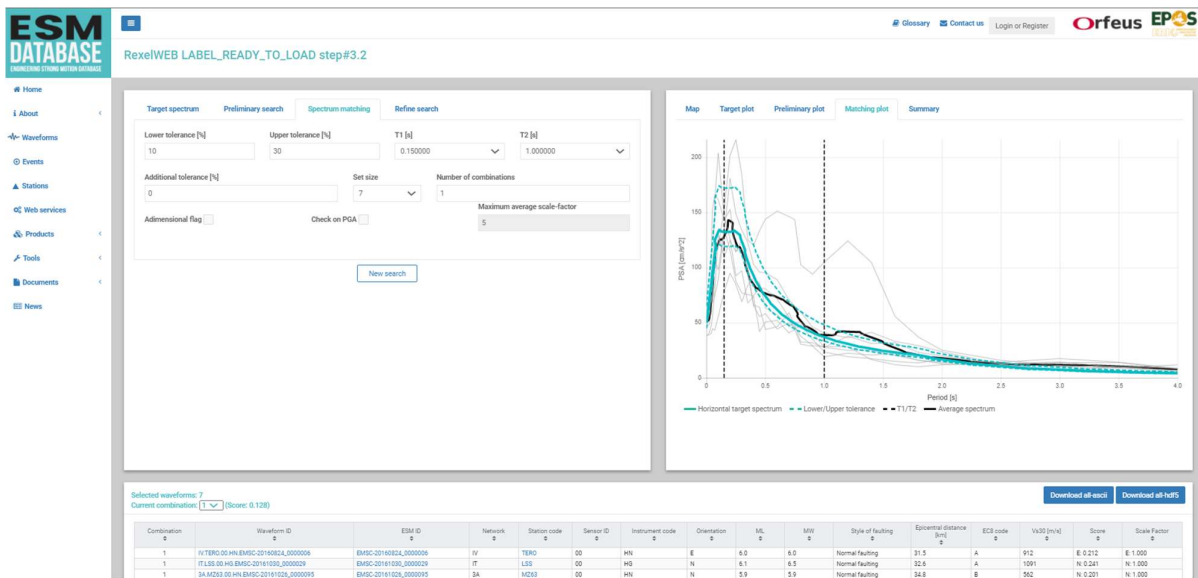


Figure 3. Tab of spectrum matching: plot of one combination of 7 spectra

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