Database for design-compatible waveforms

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ETH
Eidgenössische Technische Hochschule Zürich
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Authors
Francesco Panzera, Paolo Bergamo, Donat Fäh

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Deliverable:
Database of waveforms with related meta-data and selection of ground motions for microzonation

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Abstract on selection of ground motions for microzonation

We have analyzed and compared the stations metadata of three strong motion databases: KiK-net (Japan), ESM (Europe and Middle East), and NGA-West2 (USA). For each database, we propose a subset of stations suitable for the purposes of the project. These subsets of stations comprise 772 sites classified in terms of SIA261 (2020) soil categories (A-E), inspecting the provided V_S profiles. For these sites, the metadata of the stations were checked. To increase the number of recordings from earthquakes with large magnitude and short source-site distance, we added 870 three-component recordings, 28 related to the Chi-chi earthquake sequence recorded by 11 Taiwanese seismic stations and 842 from 69 seismic stations in ESM classified by using geologic criteria. This further selection was made to enlarge the dataset of waveforms mostly related to soil class A. The resulting subset of waveforms comprise 51,144 three-component recordings, that we subdivided in terms of SIA261 (2020) soil categories (A-E), inspecting their distribution in terms of magnitude and Joyner-Boore distance. From this database, we extract 15,303 three-component recordings based on the relevant scenarios from the disaggregation of the seismic hazard for Switzerland. This collection of recordings was then supplemented with synthetic strong-motion waveforms from the BB-SPEED set to fill gaps in the magnitude-distance distribution.

Once the disaggregation and the waveforms database are ready, we set a strategy for the selection of 11 waveforms, compatible with the elastic response spectrum defined in SIA261 for each seismic zone. Among the existing algorithms used to select compatible waveforms to a target, the most adaptable to our waveforms database is the one proposed by Baker and Lee (2018). The key steps of the algorithm are: the screening of the ground motion database for suitable motions, statistically simulating response spectra from a target distribution, finding scaled motions whose spectra match each statistically simulated response spectrum, and then performing an optimization to further improve the consistency of the selected motions with the target distribution (more details in Baker and Lee, 2018). For the selection of the 11 design-compatible waveforms, we further implement the Eurocode 8 (2022) criteria. Our selection in this report is made for microzonation purpose. We fit the target elastic response spectrum for a return period of 475 years, in the waveforms' period range 0.02-2.0 s. The selection is initially attempted using unscaled waveforms, but if necessary, a scaling factor between 0.5-2 is then allowed.

For each seismic zone, we selected all possible combinations of 11 scaled waveforms. Among these, we choose the set of waveforms with the lowest RMSE if most of the waveforms are nearby or better inside the disaggregation borders, otherwise we check for another set of waveforms. Finally, we provide recommendations for the use of the selected and scaled waveforms in microzonation studies in Switzerland.

Introduction

Waveform selection is a key step of many applications in engineering seismology, such as seismic microzonation, which aims at identifying and characterizing the seismic response within risk-relevant areas (Marascandola et al., 2020). Moreover, structural engineering studies for performance-based design or for the vulnerability assessment of structures need ground motion recordings (e.g. Silva et al. 2019). The earthquake recordings must be consistent with the seismic hazard of the target region, and able to capture the variability of the expected ground motions, depending on the contributions of both local and distant earthquake sources representing the seismic hazard. Therefore, the probabilistic seismic hazard disaggregation is the base of the selection of the recorded ground motions.

In this report, we first inspect available databases of waveforms and related metadata in order to define standards linked to the quality of three-component (3C) waveforms (compatibility to GMPE, adequate frequency content, absence of non-physical drift in velocity and displacement) and quality of metadata (reliability of magnitude, distance, site condition information, free-field recording, etc.). The purpose of the analysis is to assess which site metadata are given, collate them between different databases, and verify the feasibility of a sub-selection of stations fulfilling the ideal criteria serving the purposes of the project (i.e. free-field stations with a reliable soil classification according to SIA 261 (2020)).

Among the available strong motion databases, we selected the Engineering Strong Motion (ESM) database (Luzi et al., 2016), the Japanese database of KiK-net network recordings (https://www.kyoshin.bosai.go.jp/, Aoi et al., 2004) and recordings from NGA-West2 (Ancheta et al., 2014) for the Western United States. Moreover, to fill gaps in magnitude and distance we inspected the synthetic waveforms obtained by Paolucci et al. (2021) and reported in the BB-SPEED set (http://speed.mox.polimi.it/bb-speedset/).

Therefore, considering the results of the disaggregation of the Swiss seismic hazard, we subselect ground motions sufficiently covering the most significant magnitude-distance pairs for return periods of 475 and 975 years (Bergamo et al., 2022).

The selection of suitable earthquake records from the database can be performed using as target spectrum a design code spectrum or a spectrum determined from a ground motion prediction equation for a specific seismic scenario. The approach is generally based on the selection of ground motions that individually deviate as little as possible from the target (e.g., Youngs et al. 2007); alternatively, one can select a set of ground motions whose mean spectrum is as close as possible to the target. This second approach involves a more complicated optimization problem, and such optimization has been carried out using genetic algorithms (Naeim et al. 2004). In literature, different algorithms have been proposed to select sets of compatible ground motions (e.g. Iervolino et al., 2009; Jayaram et al., 2011; Cimellaro et al., 2015; Baker and Lee, 2018). Among those algorithms, the most adaptable to our purpose is the one proposed by Baker and Lee (2018), which represents an improvement of the Jayaram et al. (2011) code. The major steps of the proposed ground-motion selection process are:

- The definition of a target response spectrum for the selection of ground motions;

- Collection and verification of relevant metadata from the candidate ground motion databases, including spectral acceleration values and parameters describing the station site and earthquake source for each ground motion;
- A set of synthetic response spectra is generated by modifying the target spectrum with random perturbations;
- For each randomly generated response spectrum, the best matching ground motion spectrum from the database is searched. The agreement between synthetic spectrum and candidate ground motion is evaluated by computing the sums of squared errors (SSEs);
- Finally, an optimization procedure is applied to modify the first selected sets of ground motions by replacing individual ground motions from the set with yet available motions from the screened database and seeing whether the average of the set is improved in its match to the target response spectrum. A weighted sum over all periods of interest of the squared errors between the spectra's mean and the target spectrum is used to evaluate the goodness of fit;
- The final set of ground motions is determined.

For the selection, we use an unconditional range of periods both for structural and microzonation analysis. Two-component ground motions (performing the geometric mean of the two horizontal components response spectra) are generally used for structural analysis, whereas one component selection is required for microzonation. The SIA261 elastic response spectrum for soil class A (SIA 2020) is used for microzonation, based on a 475 years return period. For structural analysis, elastic response spectra for all soil classes are used by multiplying the spectral values of the elastic response spectrum by a factor of 1.5, consistent with the prescriptions for 975 years return period. Several period ranges are tested for the selection. In particular, minimum and maximum periods are chosen i) considering the fundamental period of buildings generally observed in Switzerland, and ii) covering site-specific seismic soil amplification as suggested by Eurocode 8 (2022). Sets of 11 one or two-component waveforms are then selected from the database. The number 11 of waveforms was chosen, based on the conclusions in Perron et al. (2022). The selection is initially attempted using unscaled waveforms, but if necessary a scaling factor between 0.5-2 is then allowed. After the first run, the waveforms belonging to the first selected set are removed from the database.

1. Station metadata

The databases provide seismic station metadata, which we used to select those sites having characteristics fitting the purpose of our search for a comprehensive database of design-compatible waveforms. First, we inspected the installation characteristics (e.g. housing, free field or urban free-field) and the site characterization metadata, paying attention to the method used for the definition of the V_S profile. We selected only the stations having a clear description of the installation characteristics and velocity profile measured with an in-situ

geophysical survey; we removed all the stations having V_{S30} extrapolated from geologic setting.

1.1 KiK-net stations

The Japanese KiK-net network is composed of about 690 stations, spread across the whole territory of Japan (Fig. 1.1). The network started recording in 1997, with most of the stations becoming operational in 1997 or in the next years. Each station is composed of two three-component sensors, one placed at the soil surface and the other at the bottom of a borehole (≥ 100 m deep), drilled with the intention of reaching the bedrock formation (Aoi et al, 2004). No specific information about the housing or installation is given for each station, but from the general description provided by Aoi et al. (2011) all stations are assumed to be free-field or urban free-field.

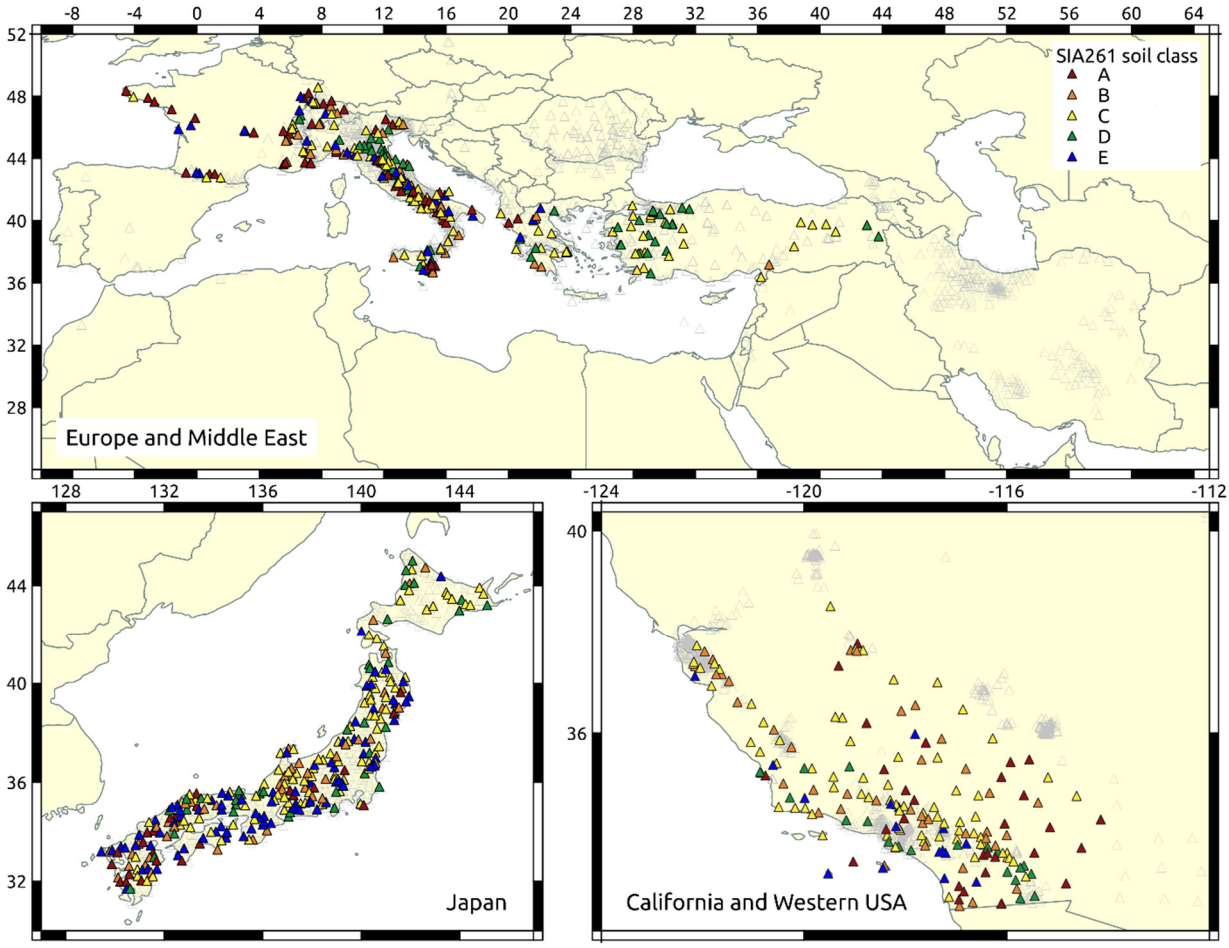

Figure 1.1 – Geographical distribution of the stations belonging to the used databases. In grey, all stations; in colors, the sub-selection of sites with velocity profiles subdivided in SIA261 (2020) soil classes.

At each station, the V_P and V_S profiles of the depth range between the borehole top and bottom were determined with invasive downhole technique (https://www.kyoshin.bosai.go.jp/kyoshin/db/index_en.html?all). The reliability of such velocity profiles has been debated (e.g. Holt et al. 2017); we have chosen to consider the sub-selection of 276 stations whose geophysical profiles were deemed as reliable by Poggi et al.

(2013). Besides the velocity model, for each station a geological profile (in Japanese) is provided, sometimes translated to English. Thanks to the complete geophysical information, it is possible to classify the KiK-net sites according to SIA261 (2020) soil categories (Figs. 1.1 and 1.2).

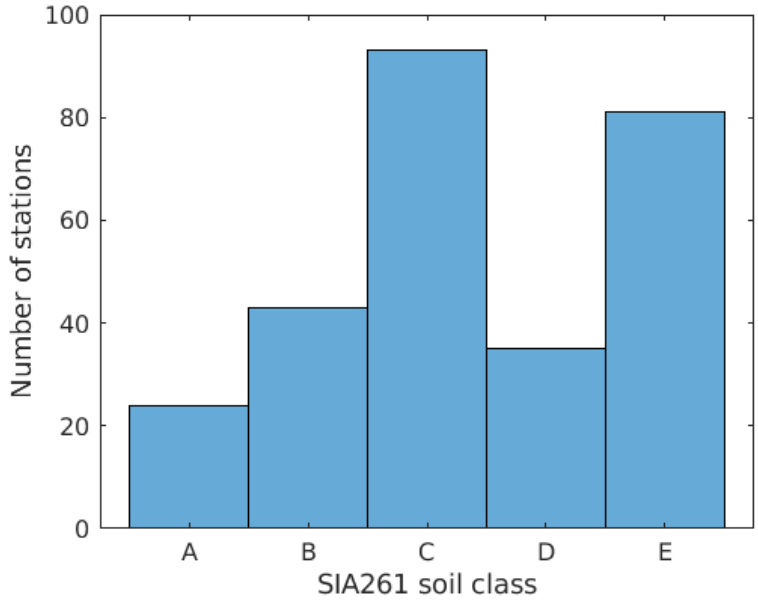

Figure 1.2 – Classification into SIA261 (2020) soil classes of the 276 selected KiK-net stations.

1.2 ESM stations

The Engineering Strong Motion (ESM) database collects earthquake recordings from southern and southeastern Europe, as well as from the Middle East. For our analysis, we used only 2,080 stations appearing in the ESM flatfile compiled by Lanzano et al. (2019), because the station metadata are here verified. The stations belong to different national networks, resulting in quite a varied gamut of information provided for the soil condition, housing and location (Fig. 1.1).

The database contains various fields pertaining to the housing and location of the recording station: proximity code, housing type, installation code and sensor depth, which are defined as following:

- proximity code: feature of the station indicating proximity to structures which could influence the seismic response of the soil (https://esm-db.eu/#/about/glossary)
- housing type: denotes the place where the recording instrument is located (ibid.)
- installation code: feature of the station indicating the type of basement of the recording instrument (ibid.)
- sensor depth: is not formally defined, but it is likely to indicate the depth of the sensor with respect to the soil surface

The proximity code has 5 possible categories: free-field (420 stations), close to structure (211 stations), no information (72 stations), inside structure (103 stations), structure-related free-field (175 stations). For the remaining 1,099 stations, the proximity code is left blank. As far as the housing is concerned, the 17 possible housing categories are reported in Table

1.1. The installation code types are instead: building floor, pillar, building basement directly on the ground or not available (NA).

Table 1.1 – Housing types of ESM database

Label	Description
BOX	Box
BUB	Building basement
BUI	Building
CAB	Enel box
CAV	Cave
DAM	Dam
EMB	Embankment
ERR	Unknown
FIB	Fiberglass box
GAL	Tunnel
HIS	Historical building
HOU	Small masonry building
POW	Power plant
VAU	Vault
WEL	Borehole
BRI	Bridge
<undefined>	"housing type" left blank

Considering the joint distributions of the various fields pertaining to the station location, we can propose the following sequential criteria for the selection of the stations of interest for the project. The first three have already been adopted by Bindi et al. (2019) to define a set of sites for a consistency check of ESM via residual analysis. The additional criteria represent our attempt to further refine this selection and make it consistent with the purpose of the project.

- Exclusion of all stations with sensor depth > 3 m or < 0 m, or undefined (471 stations out of 2,080);
- Exclusion of all stations with "location code" other than 00 (7 stations out of 1,609 left). This code is used to define the main sensor in installation site;
- Exclusion of all stations with installation code equal to BF (building floor; 10 stations out of 1,602 left);
- Exclusion of all stations with housing code equal to BRI, CAV, WEL or GAL (12 stations out of 1,592 remaining stations);
- Exclusion of stations with proximity code equal to "no information", "inside structure" or blank from the groups having housing code equal to BOX, BUB, CAB, DAM, EMB, ERR, FIB, POW, VAU, or undefined (753 out of 1,580 stations);
- Exclusion of stations with undefined installation code from the groups having housing code BUI, DAM, HIS, HOU (13 stations out of 827 stations left).

After the successive application of these criteria, the number of stations left is 814.

The ESM database provides also information about the soil condition of the sites hosting the stations in terms of V_{S30} and EC8 soil class (Eurocode 8, 2004). The technique employed for the geophysical measurement is defined (field "vs30_meas_type"), referring to single or mul-

tiple techniques. In the case of a performed in-situ measurement (355 stations), if the maximum investigation depth of the survey exceeds 30 m (322 stations) the V_{S30} is directly computed from the profile, otherwise it is estimated using Boore (2004) correlations (26 stations) or estimated extending the deepest layer to 30 m (7 stations). For 64 stations the V_{S30} value is attributed from literature, but for the majority of sites (1,660 stations), the V_{S30} calculation method (field "vs30_calc_method") is left unspecified. It should be noted that the field "vs30_calc_method" does not necessarily agree with "vs30_meas_type"; in fact

- 52 stations (all from Switzerland) have unspecified "vs30_calc_method" but a defined "vs30_meas_type" ("A", "A-P-SW", "A-SW");
- other 51 stations (mainly from Greece, but also Italy and Iran) have "vs30_calc_method" = "from literature", but have a "vs30_meas_type" implying a geophysical survey ("A-P-SW", "CH", "DC", "DH", "SASW" or "SCPT"). Stations with "vs30_meas_type" = "PEA_db" are excluded from this count.

For the purposes of the project, we therefore consider as sufficiently characterized the 355 sites with in-situ measurement, adding others 103 stations with V_{S30} from literature but with an in situ-measurement.

The stations passing both the criteria for the installation/housing and for the reliability of the soil condition are 308. They are located in Italy, Switzerland, France, Turkey and Greece (Fig. 1.1). Their distribution in terms of SIA261 (2020) soil class (Fig. 1.3) was determined by inspecting the velocity profiles available in the ESM website for the Italian stations (https://esm-db.eu/#/home); in the European Geotechnical Database (http://egdepos.civil.auth.gr/) for Greek stations; in the AFAD website (https://tadas.afad.gov.tr/login) for Turkish stations and inspecting the velocity profiles for French stations (Hollender at al., 2018; Hollender, 2020 personal communication).

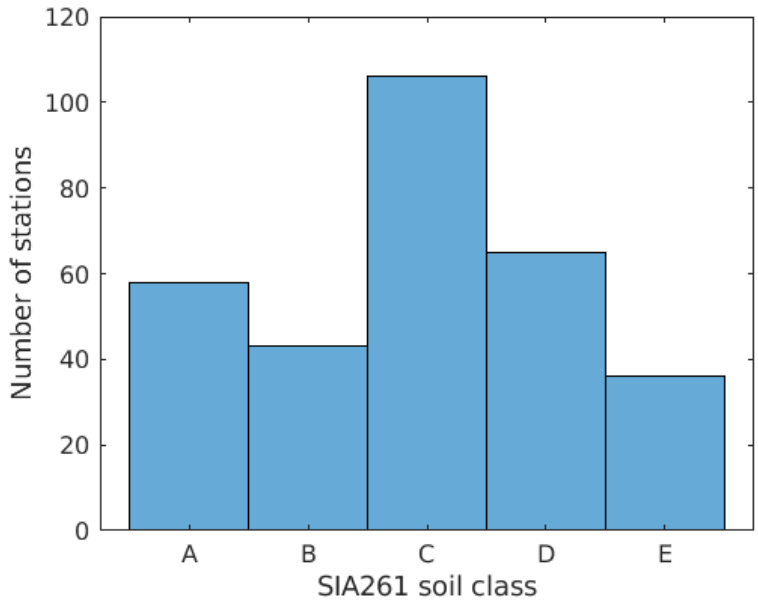

Figure 1.3 – Classification into SIA261 (2020) soil classes of the 259 selected ESM stations.

1.3 California and Western USA stations

For the American seismic stations, we examined the McPhillips et al. (2020) database, which comprises 4,390 stations, distributed across North America and U.S. territories. Among this dataset, we have received a personal communication from an USGS research geophysicist (Alan Yong) indicating a sub-selection of 191 sites (Fig. 1.1) with reliable site characterization (Yong et al., 2019). No detailed information about housing or installation are available for the 191 seismic stations. Some information about housing and sensor depth are reported in the USGS report appendix A by Yong et al. (2013). Most of the stations can be considered free-field or urban free-field except 3 installed on bridges or in caves.

The site condition information for the provided station flatfile comprises measured and adjusted V_{S30}, NEHRP soil class type (Building Seismic Safety Council, 2001), type of geophysical method used for the measurement, maximum depth of investigation and distance station-measurement.

The adjusted V_{S30} is equal or higher than the measured one (median increase = +7.25%). The adjustment was possibly made to account for the insufficient depth of investigation of some of the geophysical surveys, or for the presumed lateral variations of subsoil properties occurring between the station and the measurement site (the mean distance station-measurement is 108 m, with a standard deviation interval of ±71 m). Unfortunately, the provided NEHRP soil classification does not bring any additional information useful for the translation to SIA261 (2020) categories; in fact, NEHRP classes are solely based on V_{S30} intervals. Their distribution in terms of SIA261 (2020) soil class (Fig. 1.4) was performed by inspecting the velocity profiles available in the USGS report appendix A Yong et al. (2013).

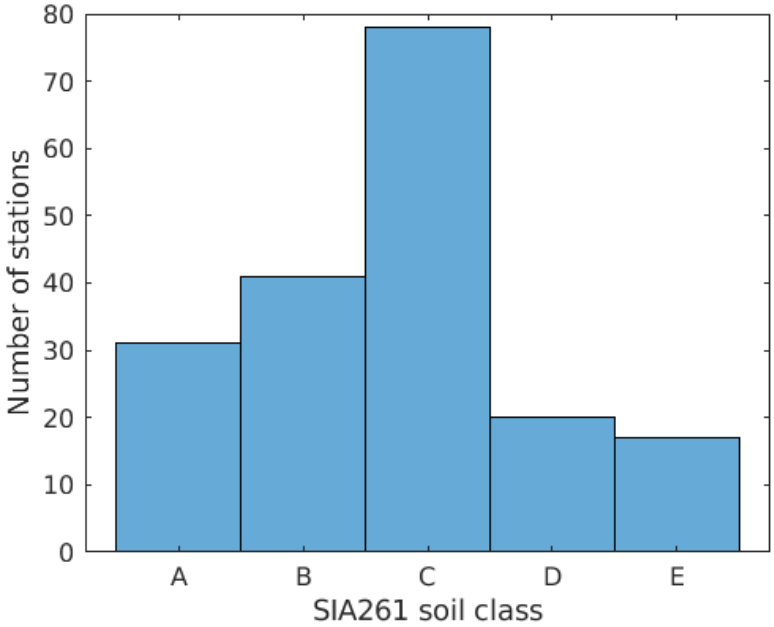

Figure 1.4 – Classification into SIA261 (2020) soil classes of the 188 selected California and Western USA stations.

1.4 Conclusions on stations dataset

We have analyzed and compared the stations metadata of three strong motion databases: KiK-net (Japan), ESM (Europe and Middle East), and USA. For each database, we propose a

subset of stations suitable for the purposes of the project: the selection is based on criteria of reliability of the site condition information and, for ESM, also on criteria of housing and proximity to structures. These subsets of stations comprise 276 sites (out of 689) from KiK-net network, 308 sites (out of 2,080) from ESM, and 188 sites (out of 4,390) from the USA database. We have also classified these stations in terms of SIA261 (2020) soil categories (A-E) inspecting the entire V_S profile in the 0–30 m depth range (Fig. 1.5).

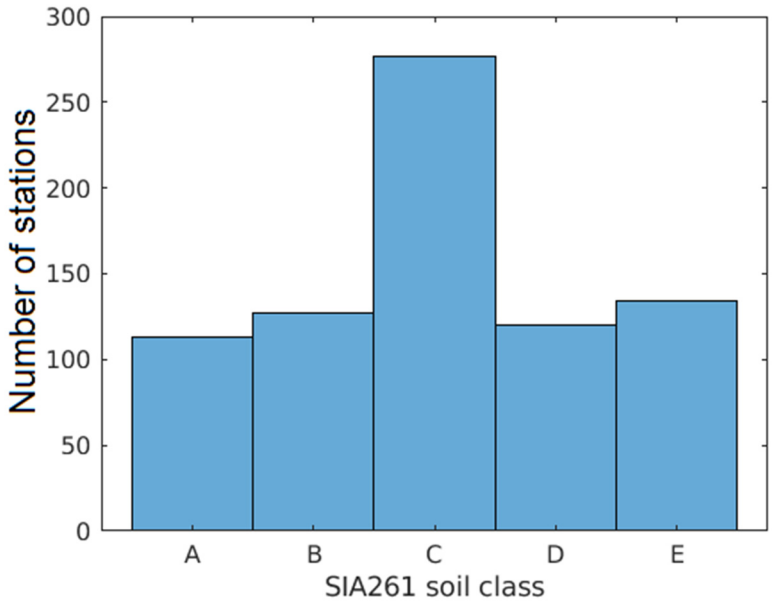

Figure 1.5 – Classification into SIA261 (2020) soil classes of the 771 selected seismic stations.

2. Waveform metadata

For the selected 772 stations we searched in the corresponding databases the available waveforms. Before the final selection of the earthquake recordings, a general check on the metadata (magnitude and depth) was carried out in order to homogenize information coming from different databases.

Generally, the databases contain un-processed and processed waveforms, then we used the available and updated flatfiles for Japan (Dawood et al., 2016), ESM (Lanzano et al., 2019), and USA (Ancheta et al., 2014) that list the processed and verified waveforms related to recorded earthquakes (Fig. 2.1). For our purposes, considering the results of seismic hazard computation for Switzerland (Wiemer et al., 2016), we selected earthquake recordings with moment magnitude in the range 4.0-7.4 and Joyner-Boore (R_{JB}) distance lower than 150 km. Moreover, we chose a depth limit consistent with the area of study (not more than 35 km).

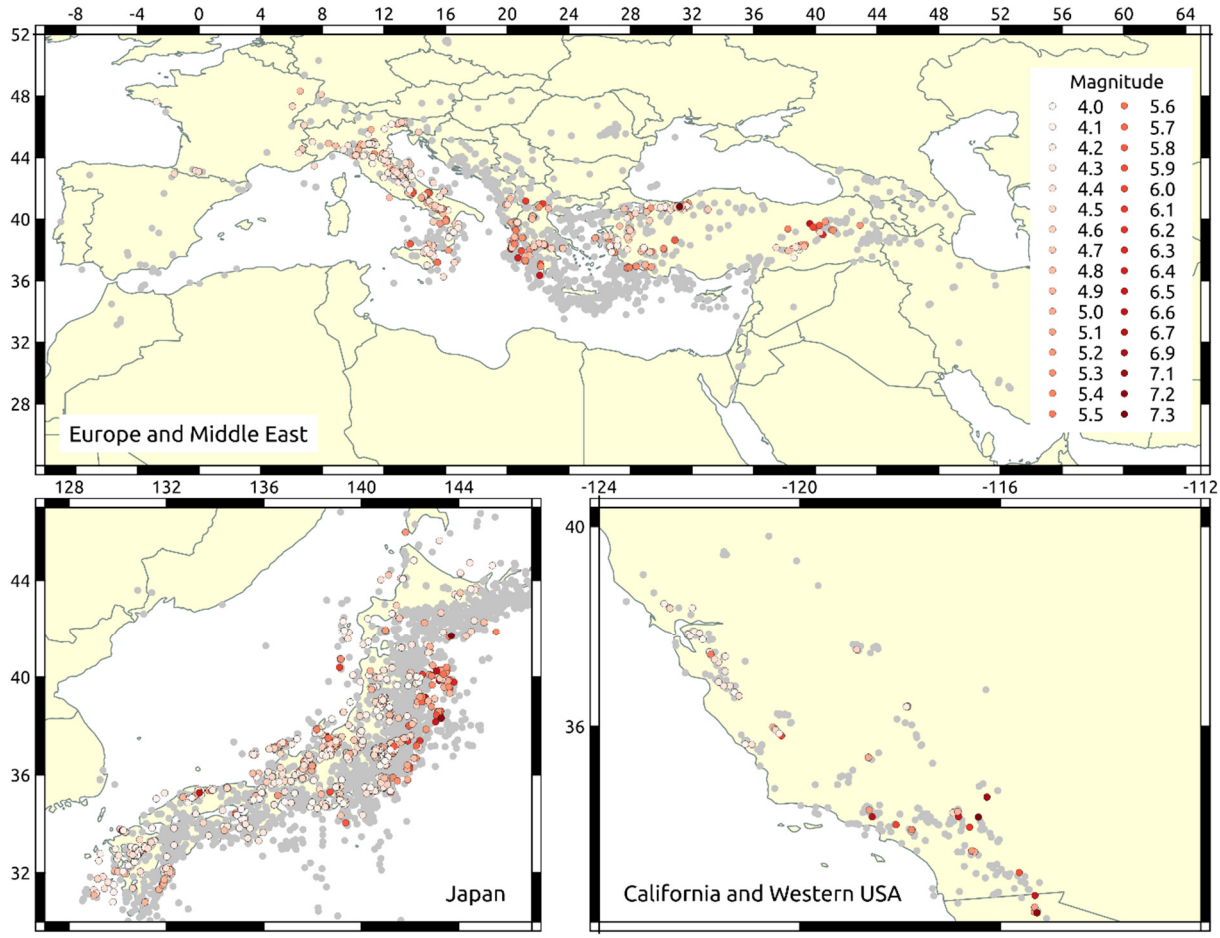

Figure 2.1 – Geographical distribution of the earthquakes belonging to the used databases. In grey, all the events; in colors, the sub-selection of earthquakes with $M_W \geq 4.0$, Depth lower than 25 km (for Japan and USA) and 35 km for Europe and Joyner-Boore distance lower than 150 km.

The R_{JB} is generally computed from finite source rupture models that are not always available for all the earthquakes. In the used KiK-net flatfile only 5,734 recordings have R_{JB} coming from finite source rupture model. For the remaining earthquakes, Dawood et al. (2016) computed R_{JB} from finite fault model using the earthquake magnitude, focal mechanism and location. The authors did not know the exact geometry of the fault planes and then computed two set of R_{JB} distances for the two possible combinations of dip and strike. We used for the KiK-net recordings without R_{JB} the geometric mean of the two values computed by Dawood et al. (2016). In the ESM flatfile only 2,466 recordings have R_{JB} and for this reason we used a simplified method normally applied to compute distance to a fault with random strike (Harmsen, 2008). The distance is obtained using epicentral distance (R_{epi}), magnitude and fault mechanism. In particular, the magnitude and fault mechanism are used to obtain fault length (L) from Wells and Coppersmith (1994) relationship. Therefore, using trigonometry:

$$R_{JB} = \frac{2R_{epi}}{\pi} \qquad if\ L \geq R_{epi}$$

$$R_{JB} = \frac{2}{\pi}\left[\int_0^{\theta} \sqrt{R_{epi}^2 + L^2 - 2R_{epi}Lcos(\theta)}\right] + R_{epi}cos(\theta) \qquad if\ L < R_{epi}$$

Finally, for the USA earthquakes the Ancheta et al. (2014) flatfile provide R_{JB} from finite fault models.

2.1 KiK-net waveforms

The KiK-net network has recorded a large number of strong motion data and has been used by researchers worldwide for several purpose (e.g., Chiou et al. 2008; Akkar et al. 2014; to Edwards and Fäh, 2017). A comprehensive overview of the Japanese recordings is reported in the flatfiles prepared by Dawood et al. (2016) and Bahrampouri et al. (2020). Dawood et al. (2016) analysed and listed a total number of 147,282 earthquake records from 25,212 earthquakes and 692 stations for the period 1997–2011. The flatfile contains earthquake information (e.g. magnitude, earthquake location, date and time), earthquake classification (e.g. active crustal, subduction zone and stable continental region), distance measurements (e.g epicentral distance, hypocentral distance, azimuth, and finite-source distance measures), recording stations (e.g. latitude, longitude, V_{S30}, soil class NEHRP) and strong motion intensity measures. Bahrampouri et al. (2020) extended the analysis up to 2017 adding information on 204,377 further recordings.

First, we analysed the earthquake depth distribution of the flatfile records (Fig. 2.2). Therefore, we filter out all the earthquake recordings linked to events with depth larger than 25 km. This general criterion, according to Edwards and Fäh (2017), allows selecting mainly Japanese crustal events, removing the subduction ones.

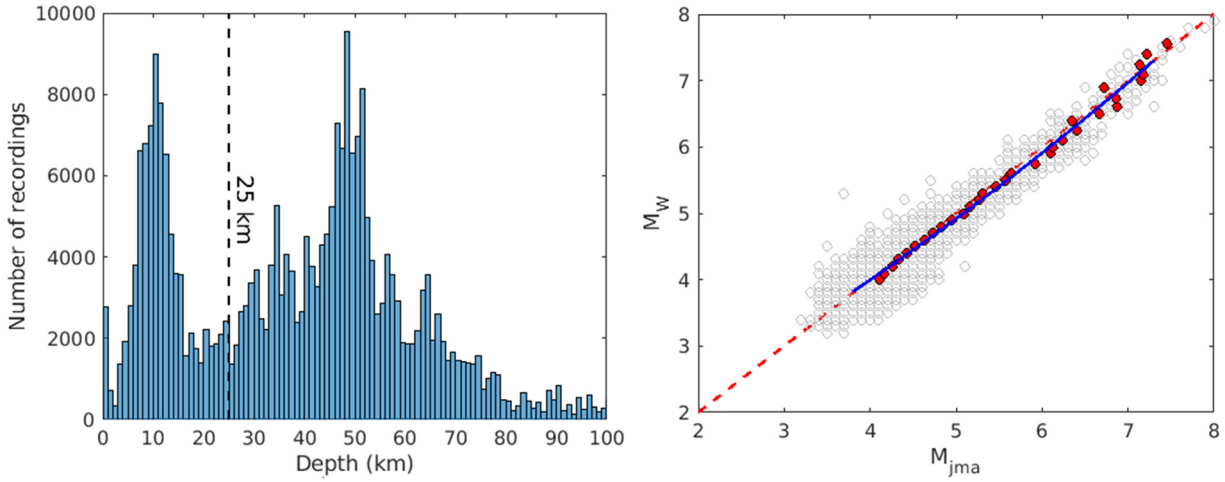

Figure 2.2 – Left panel: plots of hypocentral depth versus number of recordings reported in Dawood et al. (2016). The dashed black line indicates the depth limit chosen for Japan according to Edwards and Fäh (2017). Right panel: M_{JMA} versus M_W scatterplot (grey dots). Red dots are the average M_W values for bins of M_{JMA}, whereas the red dashed line is the 1:1 diagonal showing how closely the values match.

As far as magnitude is concerned, the Dawood et al. (2016) and Bahrampouri et al. (2020) flatfile lists M_{JMA} (Japan Meteorological Agency magnitude) and M_W (moment magnitude). These two types of magnitude are computed for all the recordings and although they are virtually equivalent (Fig. 2.2) we have been working with M_W. The M_W estimate is derived following the Full Range Seismograph Network of Japan (F-net), which computes source parameters from a full-wave inversion code using about 70 different broadband waveforms (Fukuyama et al. 1998, Fukuyama and Dreger 2000).

Therefore, taking into account the seismic stations selected in the paragraph 1.1, all the recordings related to earthquakes with magnitude in the range 4.0-7.4 were selected. Finally,

we filtered out all the earthquakes with Joyner-Boore distance higher than 150 km. The final selection comprises 13,525 earthquake recordings, whose distribution as a function of Joyner and Boore distance, magnitude and SIA soil classes are shown in Figure 2.3.

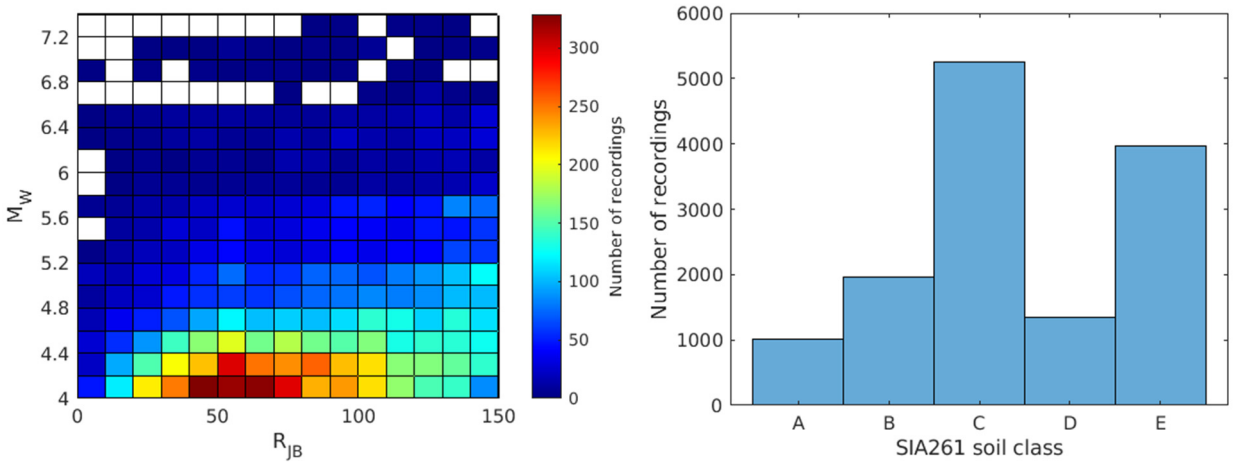

Figure 2.3 – Left panel: selected KiK-net number of recordings for bin of Joyner-Boore distances (10 km width) and M_W (0.2 unit). Right panel: selected KiK-net number of recordings for each SIA261 soil class.

2.2 ESM waveforms

The ESM database represents an important source of accelerometric data engineering seismology applications in Europe (e.g. Kotha et al., 2020; Gomez-Capera et al., 2020). Lanzano et al. (2019) give a comprehensive overview of the recording metadata in ESM. The authors organized the waveform metadata in a flatfile covering the period 1969-2016 with a total number of 23,014 earthquake records from 2,179 earthquakes and 2,080 stations. The flatfile contains event-related metadata such as source-related metadata, station-related metadata, metrics of source-to-site distances, waveform-related metadata and intensity measures.

Similarly, to KiK-net, we analysed the earthquake depth distribution of the flatfile records (Fig. 2.4), filtering out all the earthquake recordings linked to events with depth higher than 35 km. In fact, crustal seismicity in Europe is concentrated above 40 km, according to Woessner et al. (2015).

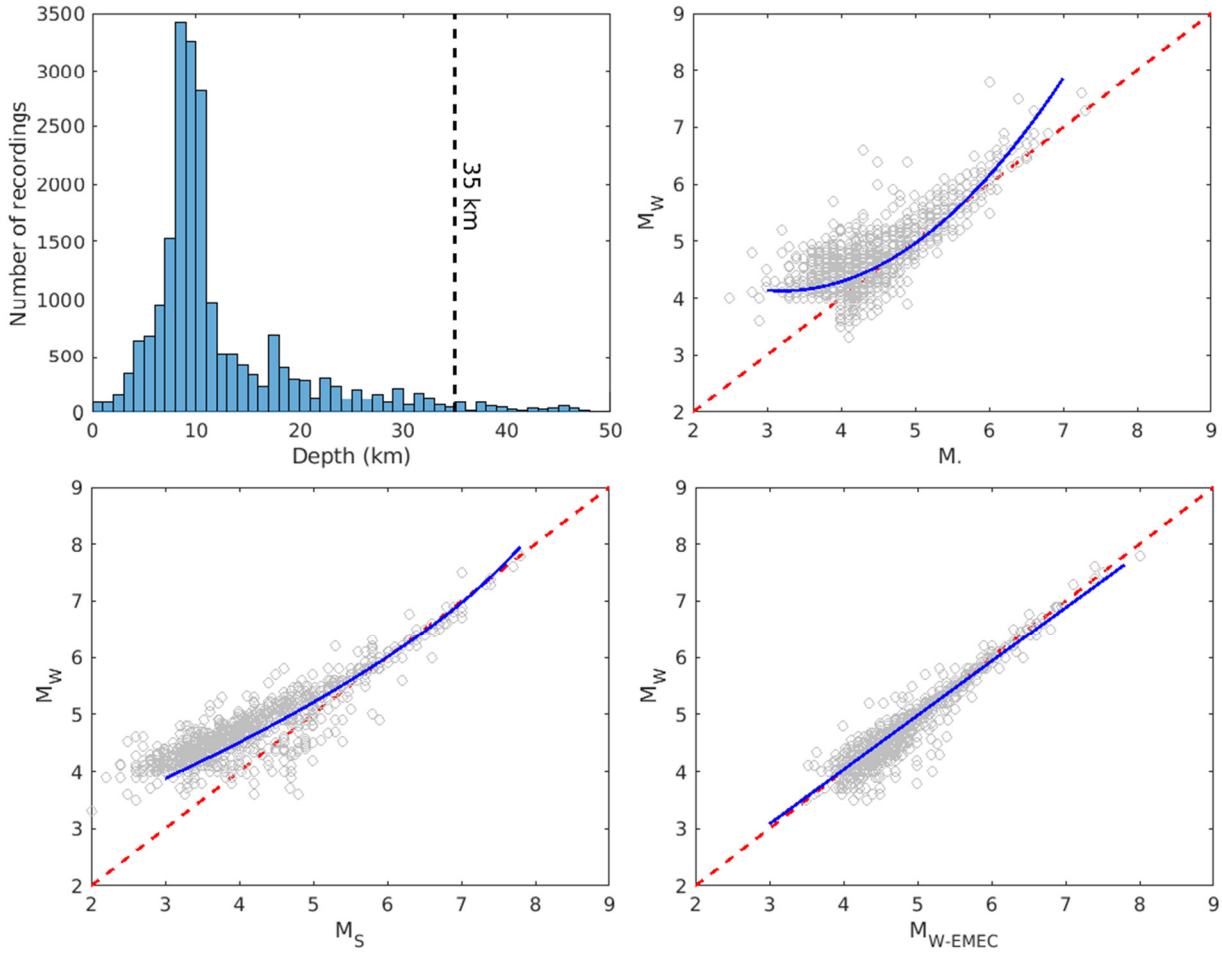

Figure 2.4 – Upper left panel: plots of hypocentral depth versus number of recordings reported in Lanzano et al. (2019). The dashed black line indicates the depth limit chosen for ESM according to Woessner et al. (2015). Upper right panel: M_L versus M_W scatterplot (grey dots). Blue line is the regression estimated by Bindi et al. (2019) using ESM data to convert M_L to M_W, whereas the red dashed line is the 1:1 line showing how closely the values match. Lower left panel: M_S versus M_W scatterplot (grey dots). Blue line is the regression estimated by Utsu (2002) to convert M_S in M_W. Lower right panel: $M_{W\text{-}EMEC}$ versus M_W scatterplot (grey dots). Blue line is the regression estimated by using ESM data.

In terms of magnitude information, the ESM flatfile is more inhomogeneous than the Japanese dataset. In fact, different magnitude estimates are present: local magnitude (M_L), surface magnitude (M_S), moment magnitude (M_W), moment magnitude from EMEC catalogue ($M_{W\text{-}EMEC}$; Grünthal and Wahlström, 2012). The different magnitude values were plotted against the corresponding M_W values to check magnitude scale relationships among these. As expected, M_L underestimates the earthquake size at high and low magnitude (Fig. 2.4). Considering the regional pattern proper of M_L and the fact that a conversion to M_W would add uncertainty on magnitude, it was decided to eliminate the recordings for which only the M_L is available. The same is observed for M_S, it underestimates the magnitude below 5.0, whereas it is close to M_W at higher magnitude (Fig. 2.4). In the ESM flatfile, the earthquakes for which only M_S is available are quite few, and therefore it was decided not to consider these recordings. Finally, the considered recordings are those for which M_W or $M_{W\text{-}EMEC}$ are available, because the two magnitude estimates are almost equivalent, as shown in Figure 2.4.

The final ESM selection, considering the selected seismic stations in paragraph 1.2, includes 2,210 earthquake recordings with M_W in the range 4.0-7.4 and Joyner-Boore distance lower than 150 km, whose distribution as a function of Joyner-Boore distance, magnitude and SIA soil classes is shown in Figure 2.5.

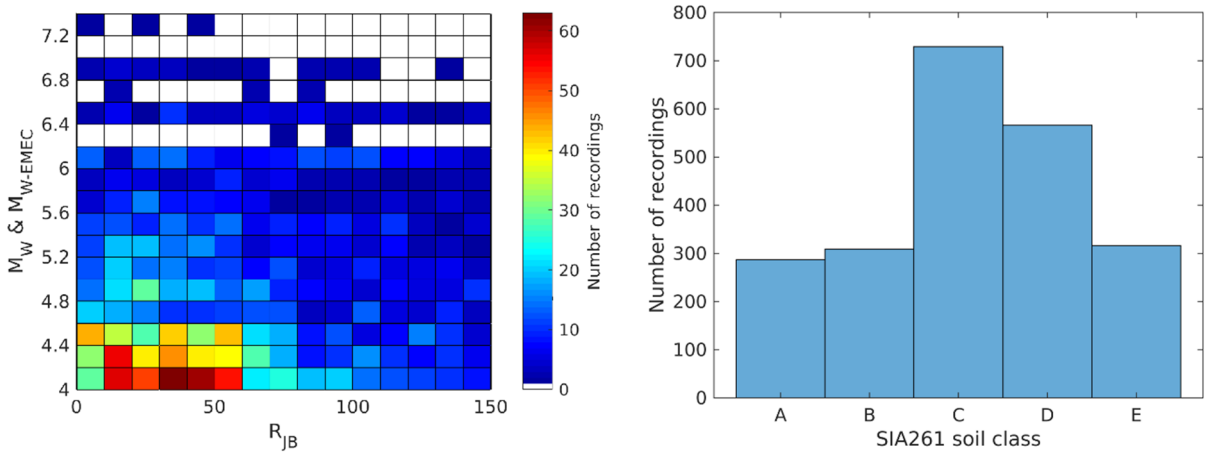

Figure 2.5 – Left panel: selected ESM number of recordings for bin of Joyner-Boore distances (10 km width) and M_W (0.2 unit). Right panel: selected ESM number of recordings for each SIA261 soil class.

2.3 Waveforms from California and Western USA

For the Western North-America earthquakes, the most recent collection of metadata is contained in the flatfile NGA-West2 (Ancheta et al., 2014), which covers the time interval 1935–2011. The flatfile contains earthquake information from a number of agencies managing strong-motion networks worldwide; among the relevant recordings, 12,818 are related to the Western North-America (WNA) and in particular California. Metadata in the flatfile complements each recording containing information on source, path, and site parameters.

The earthquake depth distribution of the California records (Fig. 2.6) was inspected, but no filtering was necessary. All the recorded events from California are with depth lower than 25-35 km, and then they can be considered linked to crustal seismicity.

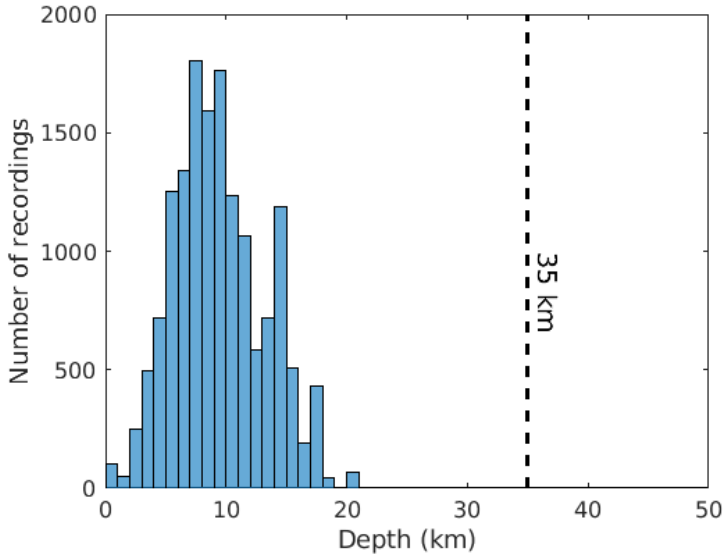

Figure 2.6 – Plots of hypocentral depth versus number of California recordings reported in Ancheta et al. (2014).

As far as magnitude is concerned, the flatfile reports, for each recording, only one value of magnitude, either local magnitude (M_L) or surface magnitude (M_S) or moment magnitude (M_W). We did not consider records with unspecified magnitude type. As already made for ESM, we consider only M_W to avoid conversion among magnitude scales.
Therefore, 443 earthquake recordings, from the seismic stations selected in paragraph 1.3, with M_W in the range 4.0-7.4 and R_{JB} lower than 150 km were taken into account (Fig. 2.7).

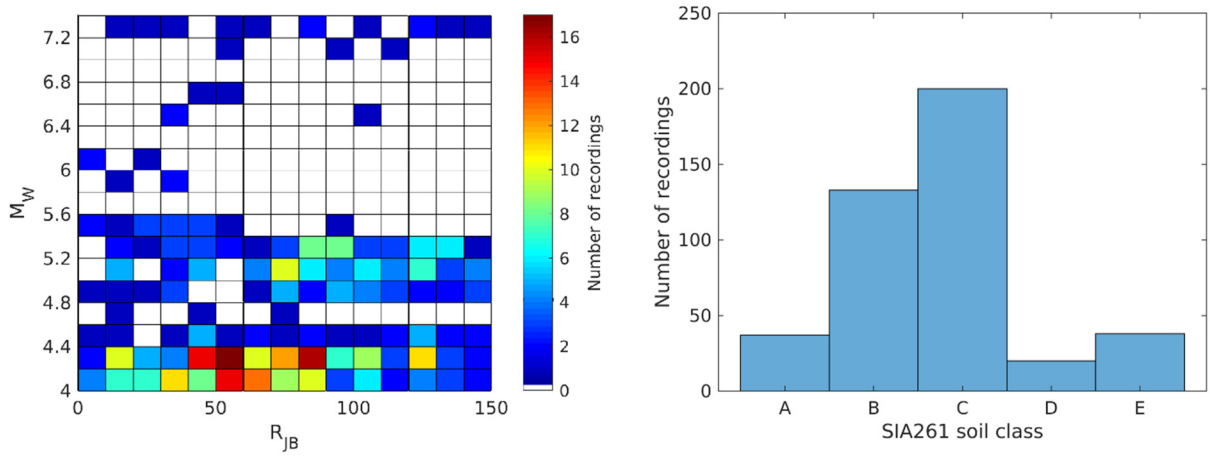

Figure 2.7 – Left panel: selected California number of recordings for bin of Joyner-Boore distances (10 km width) and M_W (0.2 unit). Right panel: selected California number of recordings for each SIA261 soil class.

3. Waveform dataset from observations

We have analyzed and compared the waveform metadata of three strong motion databases: KiK-net (Japan), ESM (Europe and Middle East), and NGA-West2 (USA). For each database, we propose a subset of waveform suitable for the purposes of the project: the selection is based on the analysis of stations metadata as illustrated in paragraph 1, hypocentral depth lower than 25-35 km (depending to the analyzed area), M_W as magnitude type, magnitude range 4.0-7.4 and Joyner-Boore distance lower than 150 km. This final selection of waveforms comprises 13,525 recordings (out of a total of 285,310) from KiK-net network, 2,210 recordings (out of 23,014) from ESM, and 455 recordings (out of 15,393) for the USA area. We have also subdivided these recordings in terms of SIA261 (2020) soil categories (A-E) and inspected their distribution in terms of magnitude and Joyner-Boore distance.
Additionally, due to a lack of recordings in soil class A, we added 28 recordings related to the Chi-chi seismic sequence recorded by Taiwanese strong motion stations classified as soil class A and reported in NGA-West2 database (Ancheta et al., 2014). All the Taiwanese stations are free-field and characterized through a suspension P-S logging technique to retrieve P- and S-wave velocity profile (Kuo et al., 2012). Moreover, 842 recordings from the ESM and NGA-west2 database were added to the final selection related to stations having well defined installation/housing, and soil class A defined using geology (Fig. 3.1).

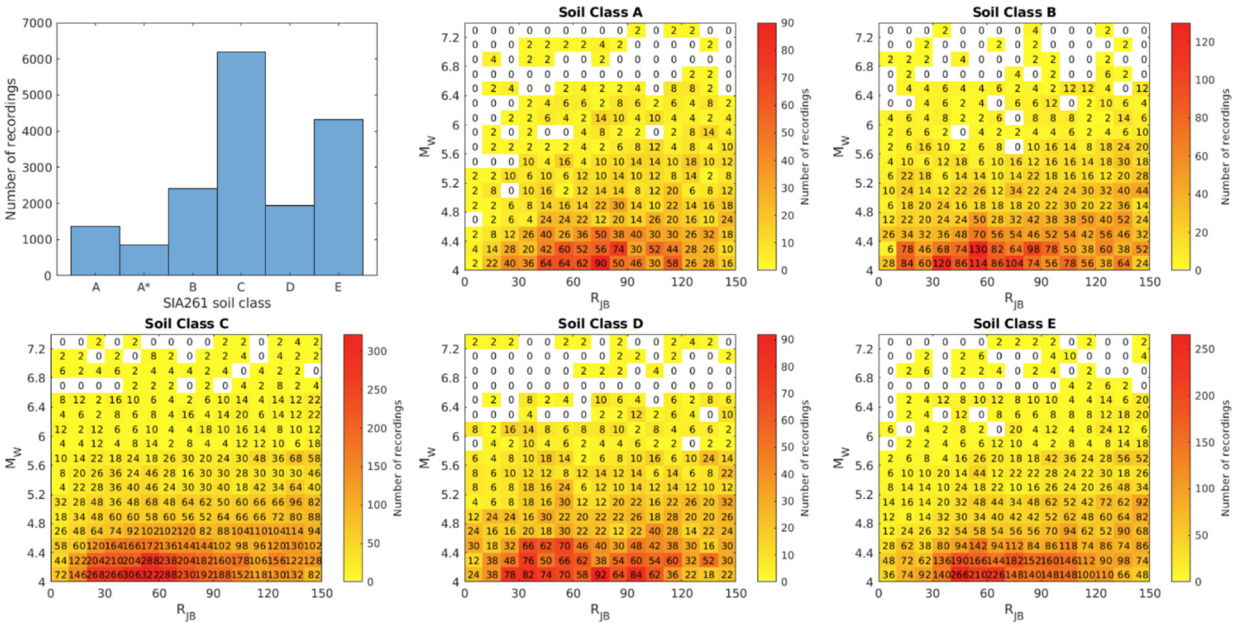

Figure 3.1 – Left upper panel: selected number of recordings for each SIA261 soil class. The remaining plots show number of horizontal component waveforms for bin of Joyner-Boore distances (10 km width) and M_W (0.2 unit) for each SIA261 soil class.

All the waveforms from ESM and NGA-West2 in the dataset are processed with the commonly used methods adopted in engineering seismology. Conversely, the Japanese waveforms are raw data and for this reason the methodology as described in Puglia et al. (2018) was applied. As first step, a baseline correction to the signal was applied and the waveform was cut removing late coda and aftershocks. Moreover, the duration D(5-75%) was computed to verify that there is enough earthquake signal for engineering purpose (Fig. 3.2). In a second step the FAS (Fourier Amplitude Spectrum) of the pre-event window and of the signal plus noise were computed and compared. This comparison allowed us to define the frequency band of the filter to apply on the recording. In particular cases, if the high-pass frequency is not recognized it was set to 0.08 Hz, whereas low-pass filter - if not recognized - was set to 80% of the Nyquist frequency.

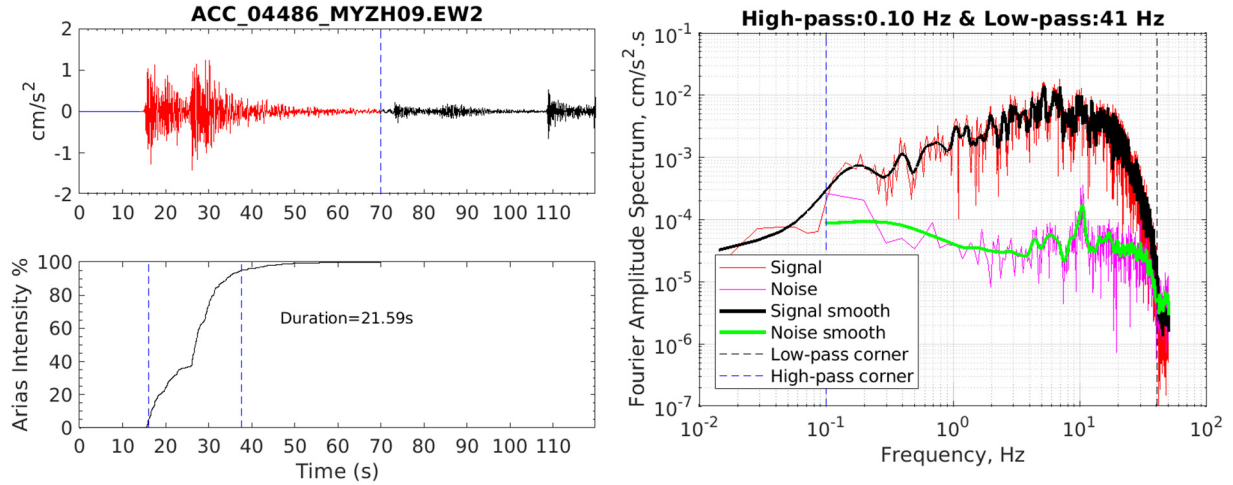

Figure 3.2 – Left panel example of signal to which a baseline correction was applied. The signal was cut to remove late coda and tested for duration. Right panel example of comparison between FAS of the pre-event window and of the signal plus noise with the derived high-pass and high-pass frequencies.

A cosine taper 5% of the signal length was applied and zero-pad were added at the beginning and at the end of the time series (half at the beginning and half at the end). The length in time of the zero-pad is set to:

$$T_{pad} = 1.5 * \frac{N}{Hp}$$

where *N* is the filter order and *Hp* the high pass frequency value. A band pass a-causal Butterworth filter of order 2 was then applied and afterwards the zero-pad were removed. Therefore, velocity and displacement were derived from acceleration in order to check that the signal has not unphysical shape or unusual long period fluctuations (Fig. 3.3).

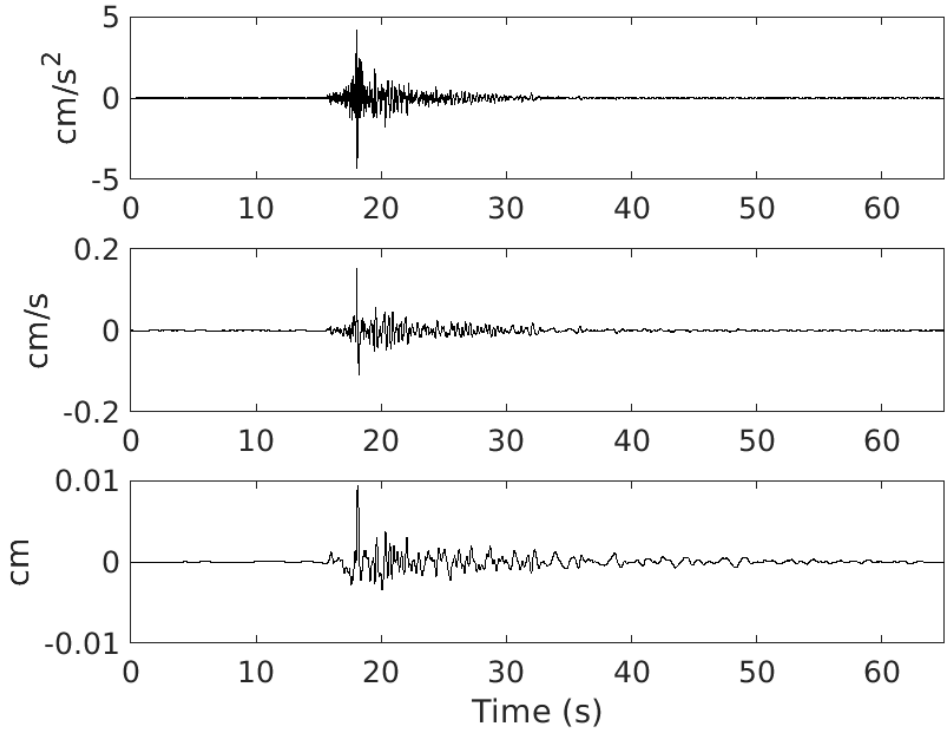

Figure 3.3 – Example of acceleration, velocity and displacement waveforms.

Moreover, after the dataset screening, some waveforms were excluded because the recording is either too noisy, late triggered after the P-wave arrival, the duration is too short, or the signal to noise ratio is insufficient.

Once all the waveforms were processed, the stochastic ground motion model for Switzerland on rock site (Edwards and Fäh, 2013; Cauzzi et al., 2015) was used to check the reliability of the soil class classification of the sites classified using geology, by plotting PGA, PGV, spectral acceleration at 0.15s and 1.0s.

The plots in Figure 3.4 show an example for recordings of magnitude 5.9±0.2 and sites classified as soil class A. The ground motions from sites classified from geology well highlight that they follow the stochastic ground motion model for Switzerland (grey empty dots in Fig. 3.4). In the same plots, we also report the spectral values recorded at seismic stations classified as soil class A derived from V_{S30} computed using shear wave velocity profiles (red empty dots in Fig. 3.4).

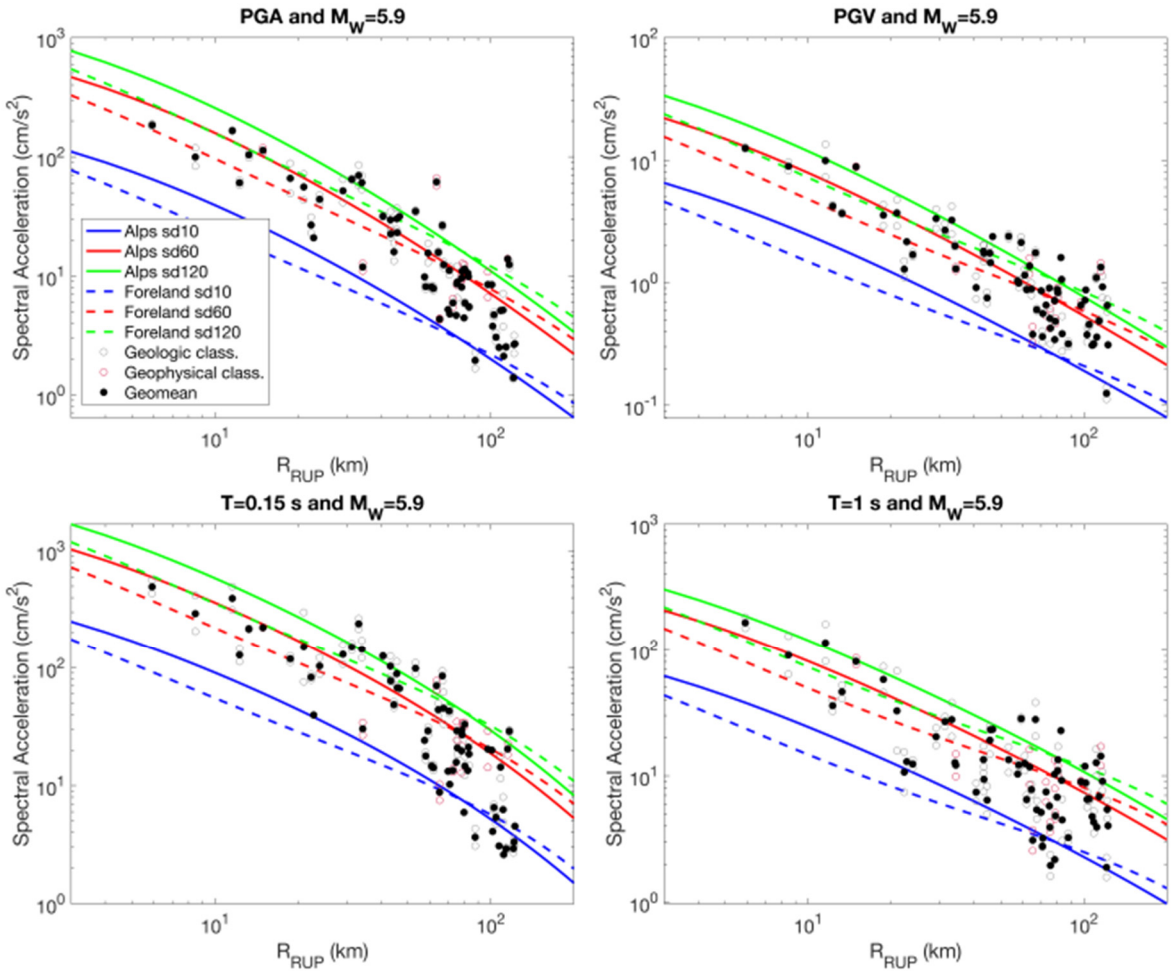

Figure 3.4 – Ground motion obtained for a magnitude 5.9 from the stochastic ground motion model for Switzerland on rock site for PGA, PGV, spectral acceleration at 0.15s and 1.0s considering stress drop (sd) of 10, 60 and 120 in Swiss Alps region and Swiss foreland region. The dots represent the observed values in our dataset, at stations for which the soil class A was inferred from geology (grey dots) and from geophysical measurements (red dots). Black dots are instead the geometric mean of the two horizontal components.

4. Subset of waveforms from observations

From our database, we prepared a subset of waveforms according to the outcomes of the disaggregation (Bergamo et al., 2022). The final dataset used for the selection includes only 5,108 recordings corresponding to 10,216 horizontal component waveforms (Fig. 4.1).

The main outcome from the disaggregation are 5 matrices, one for each SIA261 seismic zones, showing the magnitude versus distance contribution to the seismic hazard for 975 years return period. The disaggregation using the hazard model SuiHAZ15 (Wiemer et al., 2016), mean return period = 975 yrs, was performed at ~800 nodes over a regular grid with 0.1 degree space across Switzerland and considering as intensity measure types PGA, SA(0.15s) and SA(1.0s). At each grid-node, a matrix was derived displaying the relative contributions in term of M_W magnitudes and R_{JB} distances combinations. All such matrices of contribution to exceedance of all nodes belonging to each of the five SIA 261 seismic zones (Z1a, Z1b, Z2, Z3a, Z3b) were combined to obtain one matrix displaying the mean or median contribution to exceedance over the population of nodes of the considered SIA zone. The matrices for each intensity measure types PGA, SA(0.15s) and SA(1.0s) were also stacked

(summed) to obtain a summary representation for the full UHS. Bergamo et al. (2022) demonstrated that magnitude-distance bins having contribution to exceedance > 2% for individual IMTs and sum of contributions (over all IMTs) > 3.15% are significant (i.e. all dominant scenarios from all nodes are included in the defined area). Therefore, we decided to take into account all the waveforms in the magnitude-distance bins inside the contours defining the areas on the M_W-R_{JB} plane of significance for the various SIA zones and IMTs drawn by Bergamo et al. (2022) (Fig. 4.1).

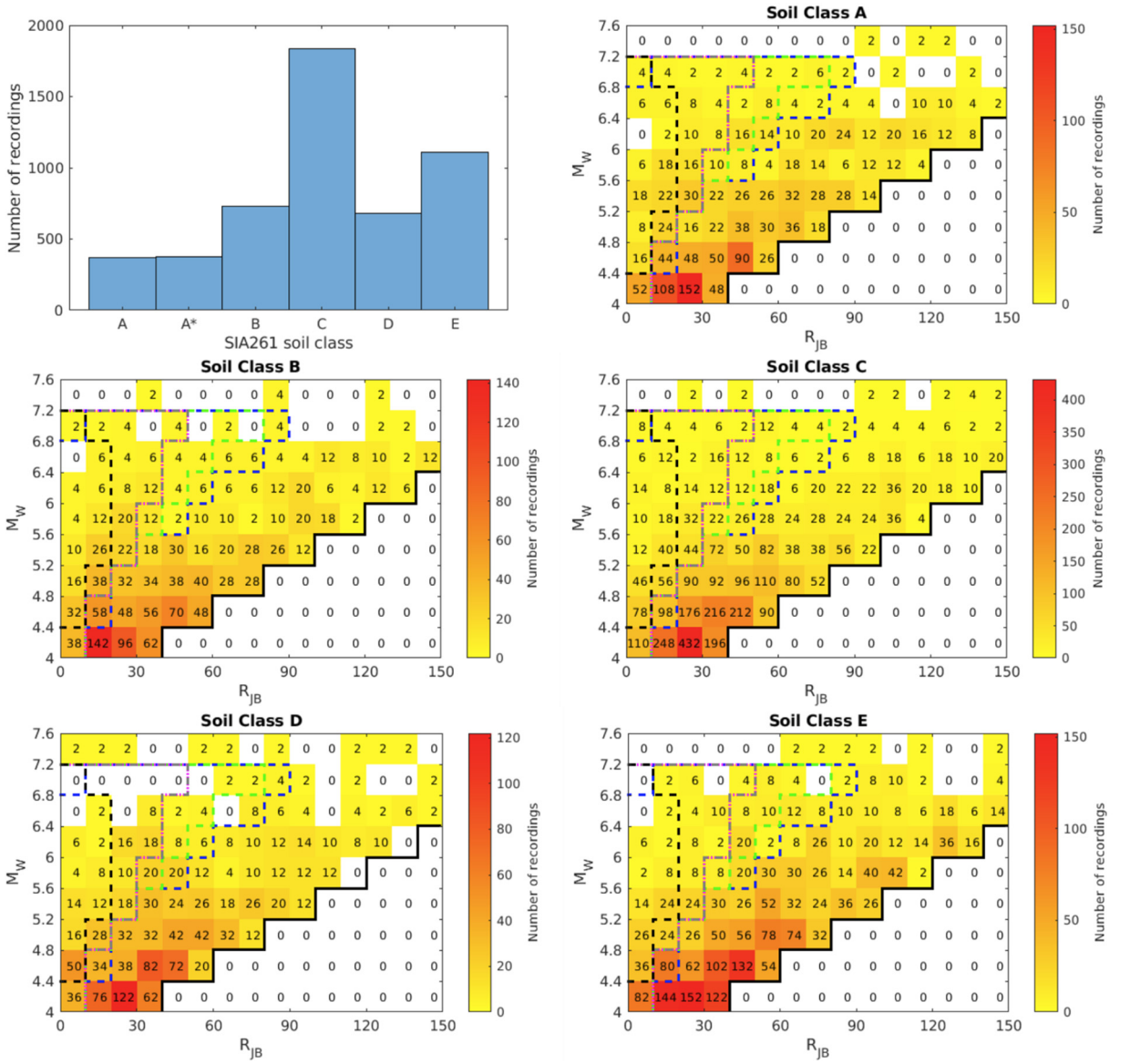

Figure 4.1 - Left upper panel: selected number of recordings for each SIA261 soil class. The remaining plots show number of horizontal component waveforms for bins of Joyner-Boore distances (10 km width) and M_W (0.4 unit) for each SIA261 soil class. The dashed lines indicate the areas where probability of exceedance (over all IMTs) is above 3.15% for the five SIA261 seismic zones (blue=Z1a; green=Z1b; magenta=Z2; grey=Z3a; black=Z3b). The black continuous lines indicate our limit for the first selection of waveforms.

5. Synthetic waveforms

The observed waveforms we selected so far do not fill homogenously the M_W-R_{JB} plane of significance for the hazard and the various SIA zones and IMTs documented in Bergamo et

al. (2022), especially at high magnitudes (> 5.6) and short distances (< 20 km) (Fig. 4.1). For this reason, we explored further available resources. Most promising are hybrid simulations of earthquake ground motions combining deterministic simulations for the low-frequency part of the ground motion (generally at frequencies lower than 0.5-1.0Hz) with stochastic simulations in the high-frequency part. There are different strategies proposed to simulate hybrid synthetics (e.g. Mai et al., 2010; Maechling et al, 2015; van Ede et al., 2020; Paolucci et al., 2021) including different levels of detail related to source, path and site properties in the deterministic part, and sometimes typically observed waveform features in the stochastic part. One problem in such hybrid synthetics is the matching of the low and high frequency synthetics at the so-called matching frequency, which can lead to unrealistic jumps in the Fourier spectra. Moreover, a specific high-frequency site response is generally not included in the stochastic part. Deterministic modelling of ground motion is demanding, because it requires a detailed three-dimensional geophysical model of the region of interest, based on geology and geophysical measurements and sufficient computational resources for the numerical simulations. The reliability of 3D models needs to be tested as well, by comparing observed ground motions from earthquakes or ambient vibration with simulations.

Among such applications, we consider the strong-motion dataset of near-source broadband earthquake ground motions from 3D physics-based numerical simulations called BB-SPEED-set produced by Politecnico di Milano (Italy) (Paolucci et al., 2021). The BB-SPEED set consists of a total number of 12,058 three-component waveforms from worldwide earthquake scenarios with M_W from 5.5 to 7.4 and R_{JB} up to 80 km. The dataset contains waveforms mainly for soil class A, but also for B, C and D classes. However, the waveforms are retrieved from a rather limited number of earthquake scenario simulations (22 earthquake scenarios) that are based on a restricted number of three-dimensional models (16 three-dimensional models). From the dataset, it was not possible to extract sites related to soil class E, because no information on the velocity profiles is available. This additional data help to partly fill the gaps in terms of magnitude and source-to-site distance (Fig. 5.1).

In Figure 5.2 the stochastic ground motion model for Switzerland on rock site (Edwards and Fäh, 2013; Cauzzi et al., 2015) was used to check the synthetic ground motions. The selected synthetics are in a magnitude range 5.9±0.2. It is well highlight that they follow the stochastic ground motion model for Switzerland. However, because the number of synthetics is so large, the waveforms cannot be verified one by one. This needs to be done at a later stage when a limited number of waveforms are selected for each seismic zone and soil class.

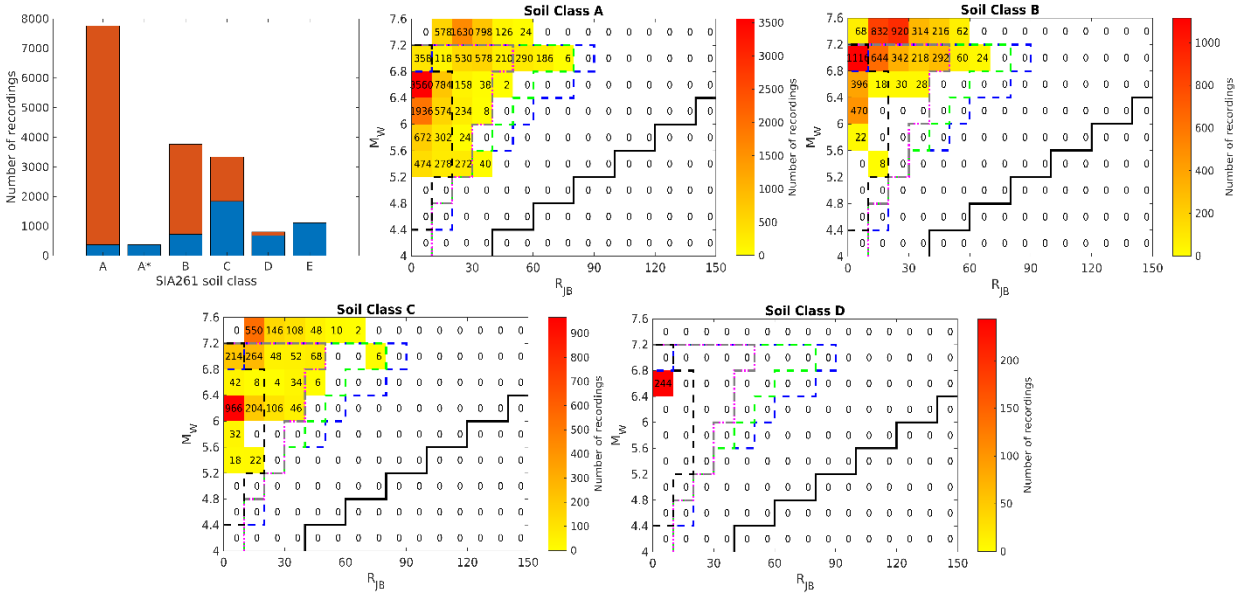

Figure 5.1 - Left upper panel: selected number of recordings for each SIA261 soil class (red synthetic and blue real waveforms). The remaining plots show the number of horizontal component waveforms for bin of Joyner and Boore distances (10 km width) and M_W (0.4 unit) for each SIA261 soil class. The coloured dashed lines indicate the areas where probability of exceedance (over all IMTs) is above 3.15% for the five SIA261 zones (blue=Z1a; green=Z1b; magenta=Z2; grey=Z3a; black=Z3b). The black lines indicate our limit for the first selection of waveforms.

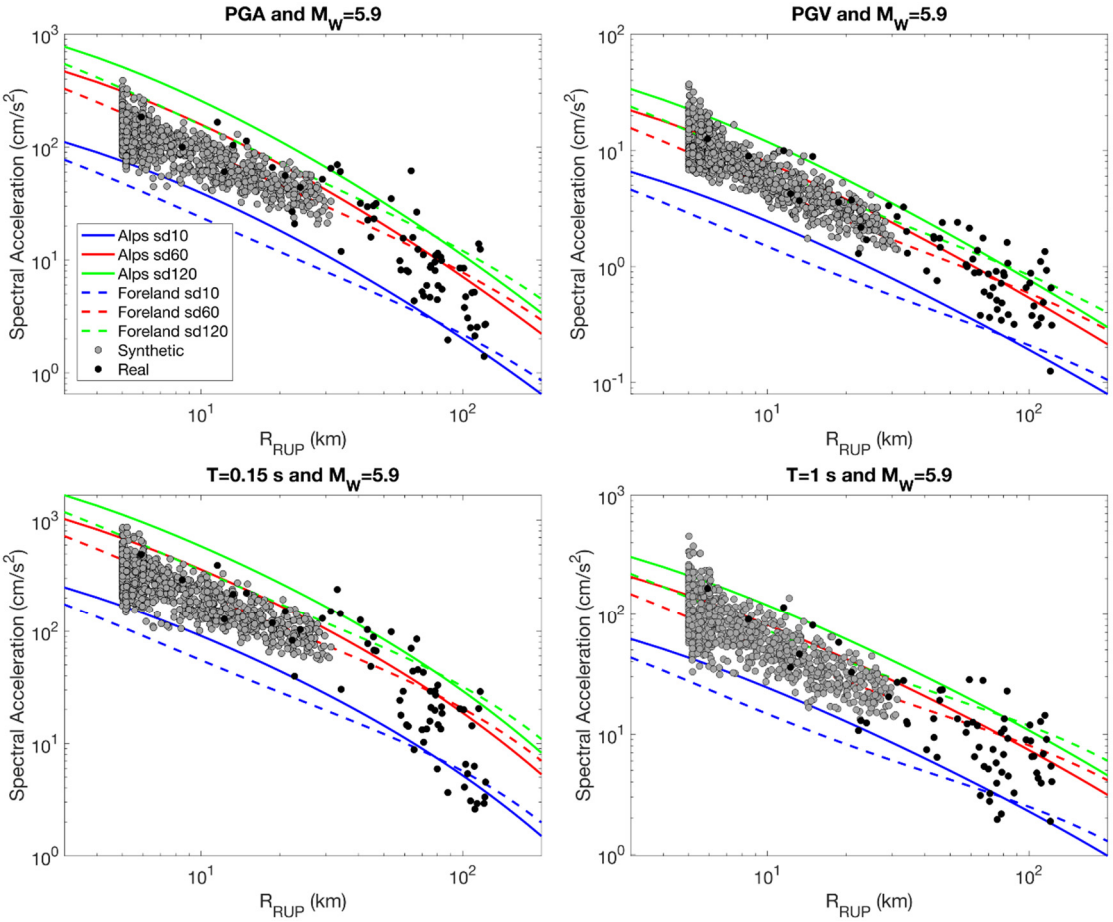

Figure 5.2 – Ground motion expected on rock for magnitude Mw 5.9 using the stochastic ground motion model for Switzerland, for PGA, PGV, spectral acceleration at 0.15s and 1.0s and considering stress drop (sd) of 10, 60 and 120 in Swiss Alps region and Swiss foreland region. The black dots represent the geometric mean from observed ground motion at the soil class A stations in our dataset. The values obtained from synthetic waveforms are given as grey dots.

6. Criteria for selection and scaling of ground motions

According to Eurocode 8 (2022), the waveforms selection must respect the following conditions:

A. The range of periods used for the ground motion selection in case of structural analysis must be from $0.2T_1$ to $1.5T_1$, where T_1 is the fundamental period of the structure in the direction where the accelerogram is applied. For site-specific seismic soil amplification analyses and for geotechnical analyses from T_A to T_0, where $T_0 = 1/f_0$ is the fundamental period of vibration of the soil deposit. If T_0 is unknown, the period range should be from T_A to 2 s;
B. The recorded accelerograms may be scaled to improve their compatibility to the target spectrum. The scaling factor should not be larger than 2 nor smaller than 0.5 and the scaled accelerogram should not present a non-physical drift when integrated to velocity and displacement;
C. In the defined period range, at each period the ratio between the mean over the 5%-damped response spectra of the set and the target spectrum must be comprised between 0.75 and 1.3; furthermore, the average of such ratios over the considered period range must be larger than 0.95. In the same range of periods, the 5%-damped response spectrum of each accelerogram of the suite does not fall below 50% of the target spectrum;
D. The suite of selected accelerograms should not simultaneously contain two components of the same record, and no more than two records of the same earthquake;
E. In case of two-component selection, compatibility to the target spectrum should be verified based on the geometric mean of the horizontal spectral accelerations of records.

We implemented these Eurocode 8 (2022) criteria for the selection of norm-compatible response spectra in the selection algorithm of Baker and Lee (2018). The Eurocode 8 (2022) criteria were enforced and verified – for the selection of waveforms for microzonation (paragraph 8) and the waveforms for structural analysis (paragraph 9) – adopting a period vector with 30 samples logarithmically spaced between the maximum and minimum considered period. The only exception is constituted by the selection of waveforms for structural analysis for the period range 0.25-4.0 s (paragraph 9), for which a period vector with 16 logarithmically-spaced samples was adopted.

7. Code implementation for ground motion selection

As anticipated in the introduction, the key steps for the selection in the Baker and Lee (2018) algorithm are: 1) screening of the ground motion database for suitable motions, 2) statistically simulating response spectra from a target distribution, 3) finding motions whose spectra match each simulated response spectrum, and 4) finally performing an optimization to further improve the consistency of the selected motions with the target distribution. We incorporated the Eurocode 8 (2022) criteria in this process (Paragraph 6).

Condition A (in Paragraph 6) is already implemented in the Baker and Lee (2018) algorithm because it is possible to define the minimum and maximum spectral period for the selection. For structural analysis, the period range is defined as a function of the building fundamental period in the direction where the accelerogram is applied. As far as microzonation is concerned, we fit instead the target response spectrum in the period range 0.02-2.0 s. The selection for microzonation is made without scaling and with scaling, considering condition B of Eurocode 8 (2022).

The Baker and Lee (2018) code allows to indicate the maximum scaling factor (in our case 2); we further added the minimum scaling factor of 0.5.

Finally, in the defined period range, the condition C was implemented in Baker and Lee (2018) code. For this purpose, we focused on the properties of the distribution of the synthetic spectra. The idea is producing a set of *n* synthetic spectra already fulfilling Eurocode 8 criteria, so that the corresponding selected ground-motion spectra too are compatible with Eurocode 8 (2022) requirements. In its original implementation, the Baker and Lee (2018) code works with a target spectrum derived from a ground-motion prediction equation, which provides - for a specific magnitude-distance couple - the lognormal distribution values $\mu_{logSa}(T)$ and $\sigma_{logSa}(T)$ for a set of periods (*T*) abscissae within a defined *T* range. The notation μ_{logSa} indicates the mean spectral acceleration (*Sa*) and σ_{logSa} the *Sa* standard deviation, both in lognormal scale. In the case of our application, the target is prescribed by the SIA 261 (2020) elastic response spectrum Sa_t; hence we identify $\mu_{logSa}(T)$ from Baker and Lee's (2018) formulation as equal to *log(Sa_t(T)),* which is the base 10 logarithm spectral acceleration of the design code spectrum . The design code spectrum does not define $\sigma_{logSa}(T)$; we then determine $\sigma_{logSa}(T)$ from the constraints of condition C from Eurocode 8 (2022) (see above). The first constraint we take into account is that at each period *T'* the mean of the spectral acceleration of the selected ground motions must be comprised between 0.75 and 1.3 times the value of the target spectrum. With these assumptions, at each period *T'* the confidence interval for the true mean (i.e. the target spectrum) is:

$$\log\left(Sa_t(T')\right) \epsilon \left(\overline{\log(Sa_s(T'))} - t^* \frac{\sigma_{logSa}}{\sqrt{n}}, \overline{\log(Sa_s(T'))} + t^* \frac{\sigma_{log}Sa}{\sqrt{n}}\right) \qquad (1)$$

where $\overline{\log(Sa_s(T'))}$ is the sample mean of the *SA*s of the *n* synthetic spectra at period T', σ_{logSa} is the true lognormal standard deviation of the synthetic *SA*s at period *T'*, and *t** is the bilateral critical value of Student's distribution with *n-1* degrees of freedom and chosen confidence level (*cl)*. We can assume a confidence level of 99% or 99.9%.

From equation 1, we obtain that the absolute difference between true and sample mean is bounded by:

$$\left|\log\left(Sa_t(T')\right) - \overline{\log(Sa_s(T'))}\right| < t^*(n-1, cl)\, {}^{\sigma_{logSa}}\!/_{\sqrt{n}} \qquad (2)$$

In cl % of case, hence by imposing that the maximum absolute difference is *log*(1.3) we derive the maximum acceptable value for σ_{logSa}:

$$\sigma_{logSa} = log(1.3)\frac{\sqrt{n}}{t^*(n-1,cl)} \qquad (3)$$

We report in the following table examples of values of σ_{logSa} for n = 10, 15, 20, 30 and *cl* =99, 99.9%:

n	cl=99%	cl=99.9%
10	0.1109	0.0754
15	0.1482	0.1066
20	0.1781	0.1312
30	0.2264	0.1705

In linear scale (multiplicative term), these values become:

n	cl=99%	cl=99.9%
10	1.2908	1.1895
15	1.4068	1.2782
20	1.5070	1.3527
30	1.6843	1.4810

Note that σ_{logSa} increases with the number of spectra (n) and decreases with the required confidence level. We assume that σ_{logSa} is the same for all considered periods.

The second constraint imposed by Eurocode 8 (2022) is that at each period T' the 5%-damped response spectrum of each accelerogram of the selected suite must not fall below 50% of the target spectrum. This constraint can be expressed imposing that *cl* (confidence level) of the individual realizations of the synthetic SA variable respect the condition:

$$\left(\log\left(Sa_t(T')\right) - {}^{log(2)}/_{z^*}, \log\left(Sa_t(T')\right) + {}^{log(2)}/_{z^*}\right) \quad (4)$$

$$\log\left(Sa_s(t')\right) - \log\left(Sa_t(t')\right) > \sigma_{logSa} z^* = \log(0.5)$$

where z^* is the critical value of Gaussian distribution with confidence level *cl*.

Note that the constraint expressed by eq. (4) is symmetric, i.e. it also implies that the simulated spectrum is no more than twice the value of the target spectrum.

Therefore, the standard deviation in equation (4) must be:

$$\sigma_{logSA} = \log(2)/z^*(cl) \quad (5)$$

With confidence level of 99 or 99.9%, the values for σ_{logSa} are:

	cl=99%	*cl*=99.9%
σ_{logSa}	0.1294	0.0974

independently of n; in linear scale (σ as multiplicative term):

	cl=99%	*cl*=99.9%
σ_{Sa}	1.3471	1.2514

Therefore, to comply with both constraints of criterion C of Eurocode 8 (2022), the standard deviation σ_{logSa} of the lognormal distribution whence the perturbation of the target spectrum are to be extracted, is the minimum between the one shown in equation (5) and the one shown in equation (3):

$$\sigma_{logSa} = min\left(log(1.3)\frac{\sqrt{n}}{t^*(n-1,cl_3)}, \frac{log(2)}{z^*(cl_5)}\right) \quad (6)$$

After a number of tests (see later in the text), we adopted a confidence level of 99% for the constraint related to the range 0.75-1.3 (*cl* in equation 3 cl_3 = 99%), and a confidence level of 99.9% for the constraint that each accelerogram of the suite does not fall below 50% of the target spectrum (*cl* in equation (5) cl_5 = 99.9%). In fact, for the generation of n synthetic spectra, each having *Sa* values at m periods, the condition expressed in equation (4) must be fulfilled m x n times. The condition in equation 1 must be fulfilled only m times. With said values of confidence level for cl_3 and cl_5, σ_{logSa} = 0.0974 for $n \geq 9$. Note that σ_{logSa} = 0.0974 corresponds approximately to a variability of +/- 25% around the target spectrum.

So far, we have defined the standard deviation of the lognormal distributions whence synthetic spectra should be drawn, so to respect Eurocode 8 (2022) criteria. Additionally, Baker's code includes the possibility to consider the Sa values of synthetic spectra at various periods not as independent variables, but as variables correlated by non-null covariances (as they realistically are). Literature offers studies on covariances of deviations of empirical response spectra (Baker and Cornell, 2006; Cimellaro, 2013). However, in our case the target spectrum is the SIA 261 elastic response spectrum, so these works cannot be directly employed. To derive realistic values

for the covariances among periods, we resorted to the work of Bergamo and Fäh (2017). In this study, a dataset of site-specific UHSs (inclusive of site response) was derived for 10 Swiss cities (Fig. 7.1).

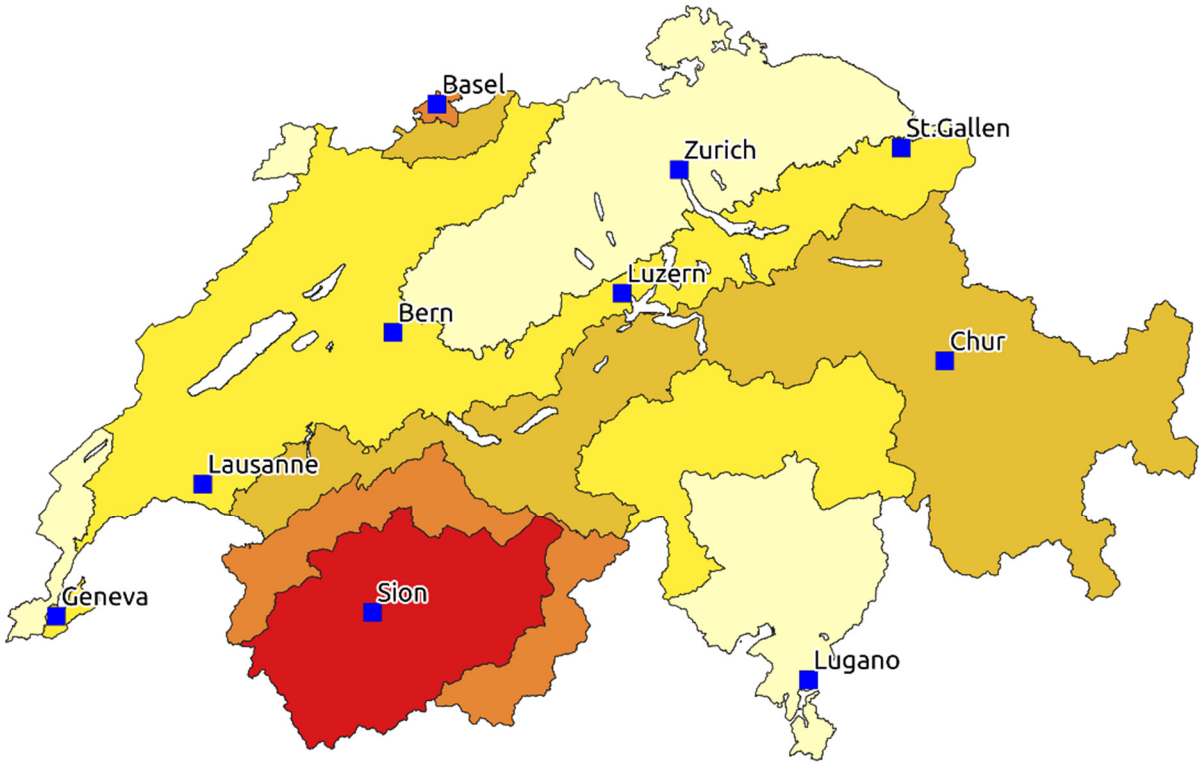

Figure 7.1 – Map of Switzerland showing the five SIA261 seismic zones (z1a=light yellow; z1b=yellow; z2=dark yellow; z3a=orange; z3b=red) and the 10 Swiss cities used to compute the covariance matrix among periods.

In Bergamo and Fäh (2017), the site responses are drawn from local amplifications observed at KiK-net stations, then referred to the Swiss standard rock condition (Poggi et al., 2011). Here, to this initial dataset we added amplification functions computed routinely by SED system using empirical spectral modelling (Edwards et al. 2013) at 121 seismic stations of the strong motion network of Switzerland, for which V_S profiles are measured using geophysical methods (Michel et al., 2014; Hobiger et al., 2021). These Fourier amplification functions (directly referred to the Swiss reference rock model) are then converted through random vibration theory (SMSIM code - Boore, 2003) to Pseudo Spectral Acceleration (PSA) amplification functions (Fig. 7.2).
We collated each of these 10 sets of site-specific UHSs, subdivided by SIA261 soil class, with the corresponding SIA261 elastic response spectra of the corresponding seismic zone and soil type (see example in Figure 7.3 for Sion, zone 3b).

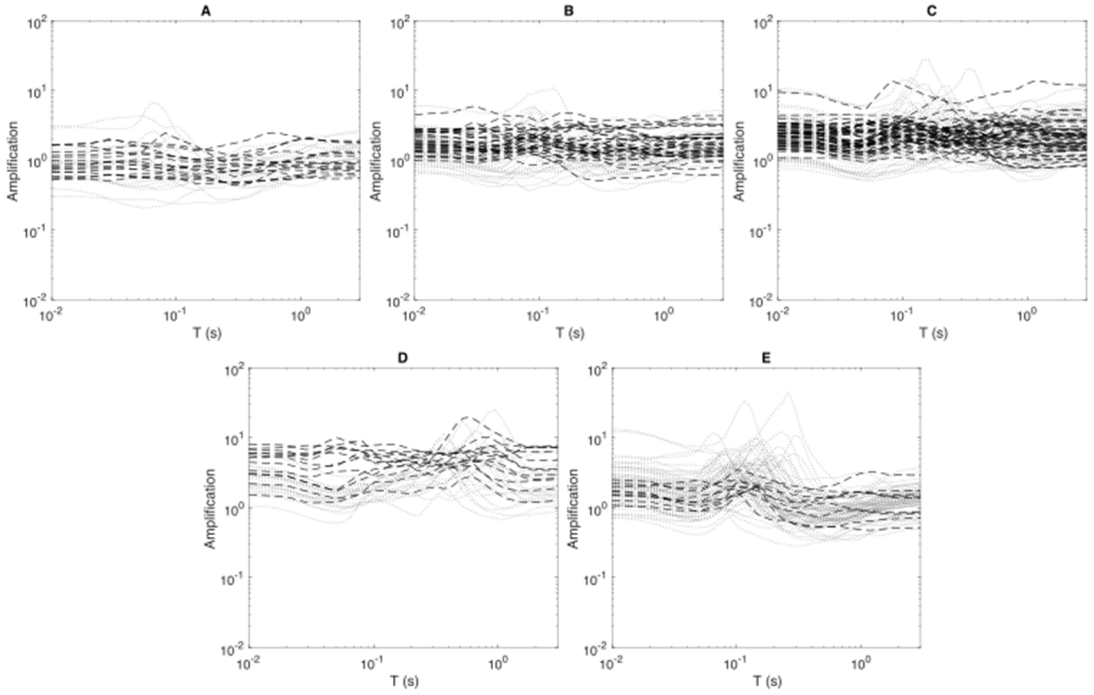

Figure 7.2 – PSA amplification functions subdivided in SIA261 soil classes used to correct the uniform hazard spectrum on rock (V_{S30}=1100 m/s) at 10 Swiss cities. Dotted grey lines are amplification functions from KiK-net stations (Bergamo and Fäh, 2017), whereas dashed black lines are amplification functions for sites in Switzerland.

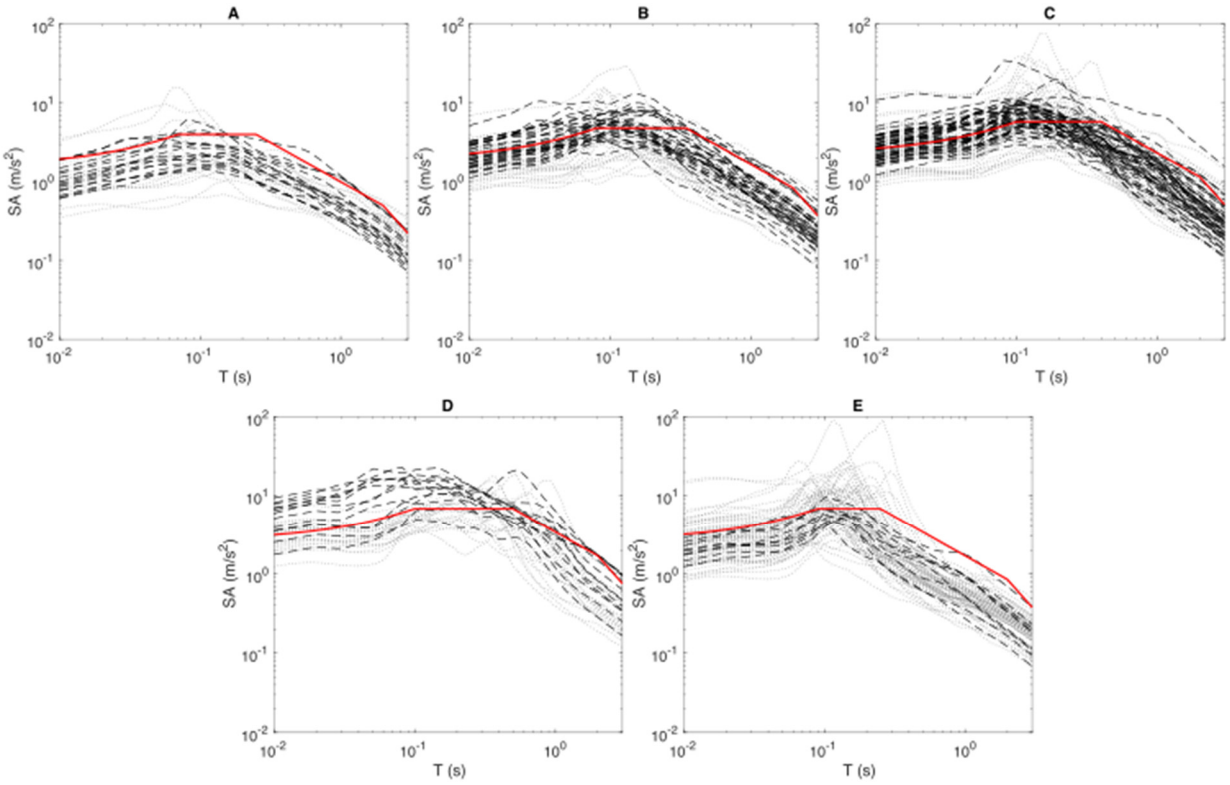

Figure 7.3 – Collation between site-specific UHSs for Sion (black lines) and the corresponding elastic response spectra in SIA 261 (red lines). Each plot refers to a different soil class. Dotted grey lines are UHSs for Sion corrected using amplification functions as in Bergamo and Fäh (2017), whereas dashed black lines are UHSs for Sion corrected using PSA amplification functions for sites in Switzerland.

We then computed the residuals of the site specific UHSs with respect to the elastic response spectra, and finally estimated the correlation coefficients between such residuals for period pairs in the range 0.01 – 3 s (see results in Fig. 7.4). On the one hand, we observe minor discrepancies

across the various SIA261 zones and among cities belonging to the same zone. On the other hand, significant differences are present switching from one soil class to another, with a narrower band of high *r* in the frequency range where observed soil resonance peaks are mostly located. Therefore, correlation coefficient matrices were computed for the 5 SIA261 classes for all Switzerland (displayed in Fig. 7.4). It is worth noting that the correlation coefficient matrices we retrieved empirically show consistency with values obtained by other authors (Ambraseys et al., 2005; Cimellaro, 2013; Baker and Cornell, 2006; Chiou and Youngs, 2008).

We use the empirical correlation coefficients r_{emp} we derived to define the covariance matrix for the random perturbations of the target spectrum to extract the synthetic spectra envisaged by Baker's code:

$$cov(T_1, T_2) = r_{emp}(T_1, T_2, zone, soilclass)\sigma_{log}(T_1)\sigma_{log}(T_2) \qquad (7)$$

where $\sigma_{log}(T_1)$, $\sigma_{log}(T_2)$ are the standard deviations at periods T_1, T_2 defined by equation (6).

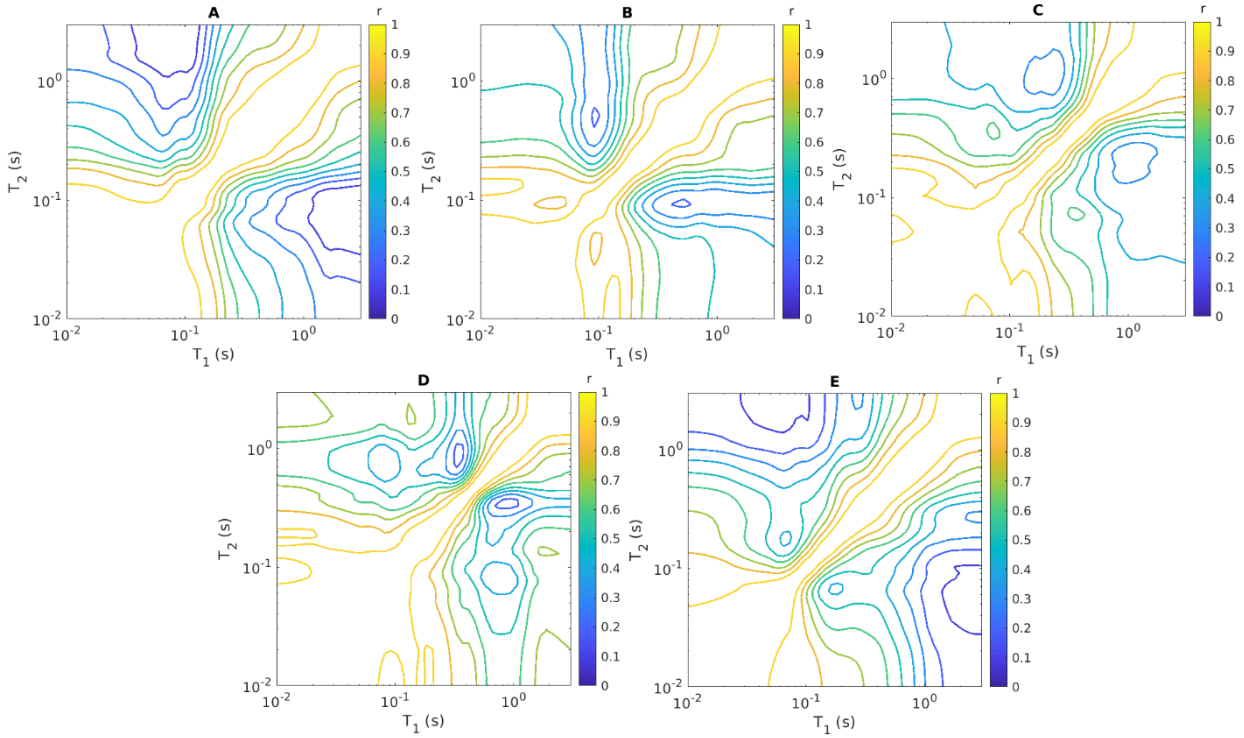

Figure 7.4 – Correlation coefficients r between residuals of site-specific UHSs for all Switzerland with respect to the elastic response spectrum, at pairs of periods in the range 0.01 – 3 s. Each plot refers to a different SIA 261 soil class.

Criterion C of Eurocode 8 (2022) prescribes also that in the defined period range, the ratio to the target spectrum of the average 5%-damped response spectrum of the set has an average value larger than 0.95. Given the constraints expressed in equations 1 and 4, this condition is more likely to be automatically fulfilled as the number of considered periods increases.

To prove that all the conditions imposed by Eurocode 8 (2022) are actually fulfilled when imposing a covariance matrix stemming from equations (6) and (7), we performed a series of Monte Carlo tests. We tested the generation of n = 10, 15, 20 synthetic spectra derived from the perturbation of the SIA261 elastic response spectrum multiplied by a factor of 1.5 (corresponding to a return period = 975 years) for classes A, B, C, D and E considering the seismic zone Z2. The fulfillment of Eurocode8 criteria was verified for the case of a building with T_1 = 0.3s and for a site-specific seismic soil amplification with unknown T_0 (period range 0.01-2s). We imposed the covariance matrix stemming from equation (7), as well as a matrix with null out-of-diagonal elements (no

correlation among periods). For each case we simulated 50,000 realizations for which the main outcomes are summarized in Table7.1 and displayed Figures 7.5 and 7.6. In particular, Figures 7.5 and 7.6 represent the % sets of 15 synthetic spectra (out of the 50,000 Monte Carlo population) satisfying each of the Eurocode 8 (2022) criteria of point C, paragraph 6 (first three bars from the left in each panel) and all the criteria simultaneously (bar on the right of each panel). Figure 7.5 represents the rates of a successful extraction of Eurocode 8 (2022)-compatible sets of synthetic spectra while implementing the inter-period covariance matrices of Fig. 7.4; in Figure 7.6, the success rates of extractions with null inter-period covariance are displayed.

Table 7.1 – Percentage of realizations where all Eurocode 8 (2022) criteria hold true.

	Non-null off-diagonal covariance mat.		Null off-diagonal covariance mat.	
	Structural analysis T1 = 0.3s	site-specific soil amplification analysis T_0 unknown	Structural analysis T1 = 0.3s	site-specific soil amplification analysis T_0 unknown
n = 10	86.6%	86.9%	90.9%	89.1%
n = 15	88.5%	87.9%	87.4%	84.7%
n = 20	88.3%	86.5%	83.3%	80.1%

The implementation of the statistical constraints illustrated in this chapter is then suitable for the extraction of synthetic spectra satisfying the Eurocode 8 (2022) criteria (the rate of success is comprised between 80-90%). Note that, in the 10 – 20% of cases when a non Eurocode 8 (2022) compatible set of synthetic spectra is extracted, the random generation is repeated. The number of spectra to be randomly extracted, the number of periods to be constrained, and the adoption of the class-dependent covariance among periods do not affect significantly the success rate (see Figs. 7.5 and 7.6, Table 7.1).

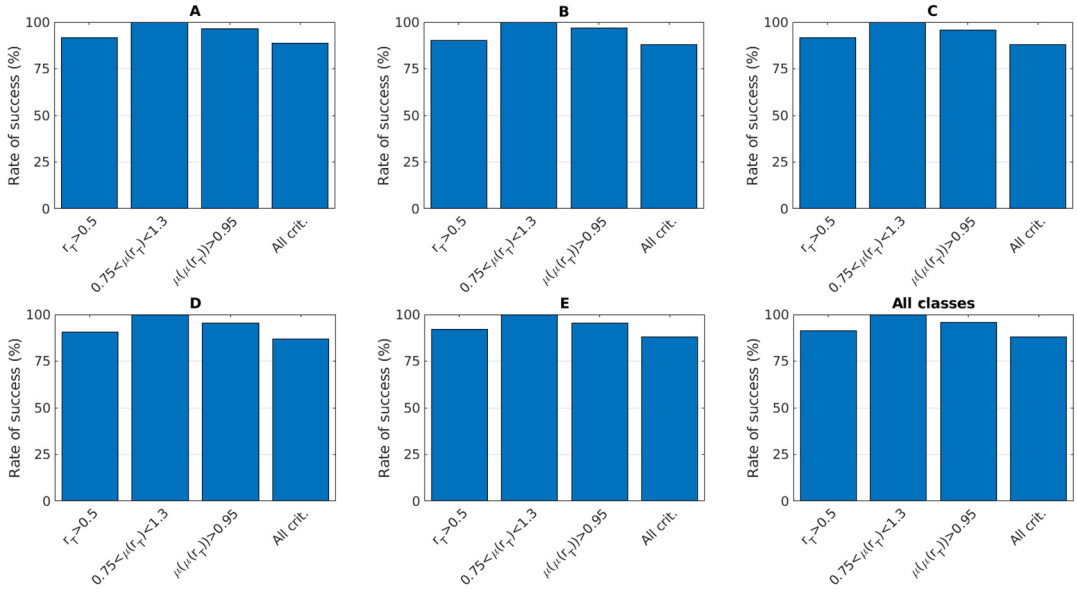

Figure 7.5 – Rate of success in case of **non-null covariance** between periods for the extraction of 15 synthetic spectra, centered around the SIA 261 elastic response spectra for classes A, B, C D and E, zone z2, return period 975 years. The fulfillment of Eurocode 8 (2022) criteria is evaluated in the period range 0.01–2s. 1st bar: all ratios r_T synthetic/target spectra are > 0.5; 2nd bar: the mean of the synthetic spectra at each period is comprised within 0.75–1.3; 3rd bar: the mean of the average ratios across all periods is > 0.95; 4th bar: all above criteria are fulfilled.

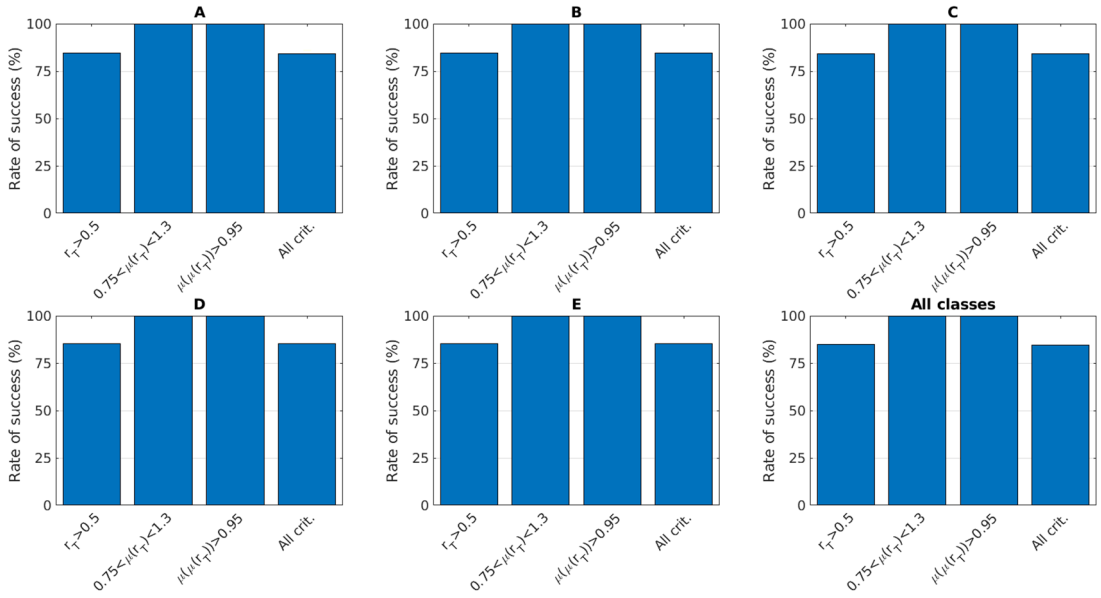

Figure 7.6 – Rate of success in case of **null covariance** between periods for the extraction of 15 synthetic spectra, centered around the SIA 261 elastic response spectra for classes A, B, C D and E, zone z2, return period 975 years. The fulfillment of Eurocode 8 (2022) criteria is evaluated in the period range 0.01–2s. 1st bar: all ratios r_T synthetic/target spectra are > 0.5; 2nd bar: the mean of the synthetic spectra at each period is comprised within 0.75–1.3; 3rd bar: the mean of the average ratios across all periods is > 0.95; 4th bar: all above criteria are fulfilled.

It should be remarked that the adoption of covariances among periods makes the appearance of the synthetic spectra realistic; setting to 0 all off-diagonal entries of the covariance matrix result in synthetic spectra with unrealistic peaks and troughs at neighboring periods (compare Figs. 7.7 and 7.8). To conclude, we recommend the implementation of non-null covariances between periods to simulate feasible synthetic spectra.

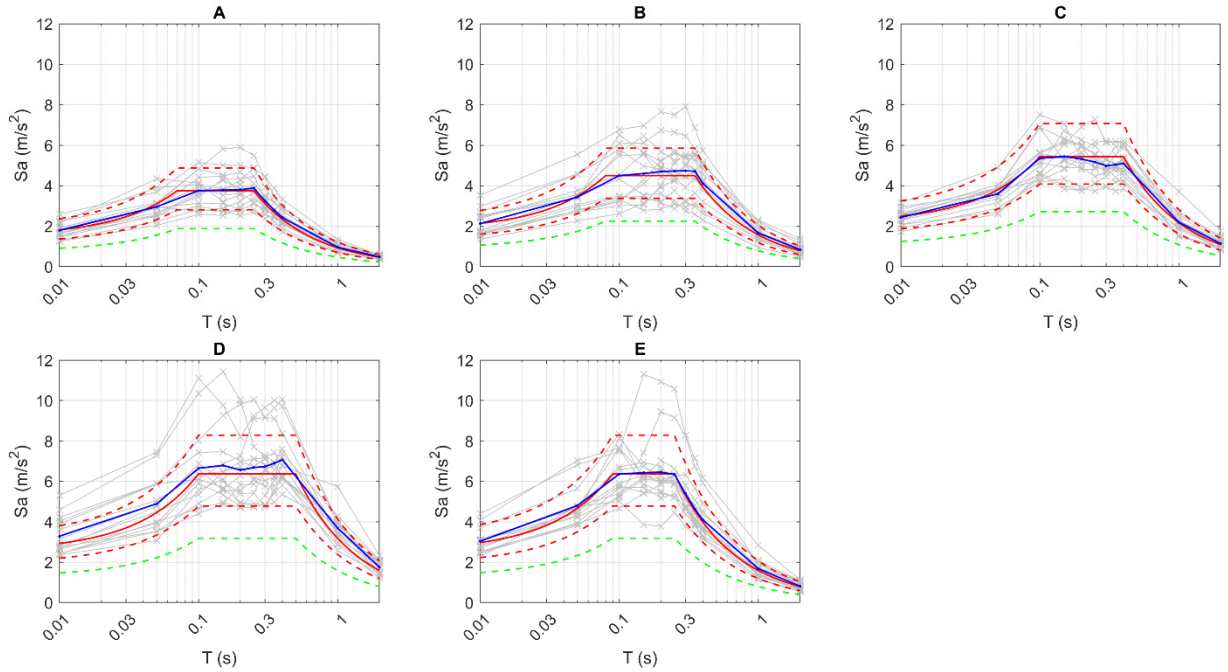

Figure 7.7 – Example of extraction of a set of n=15 synthetic response spectra (gray lines) in case of **non-null covariance** between periods centered around the SIA 261 elastic response spectra for classes A, B, C, D, E, seismic zone z2, return period 975 years. The blue line is the mean of the synthetic spectra. All the Eurocode 8 (2022) criteria in C are satisfied. Red dashed lines indicate the 1.3 and 0.75 ratio threshold; the green dashed line indicates the 0.5 ratio threshold.

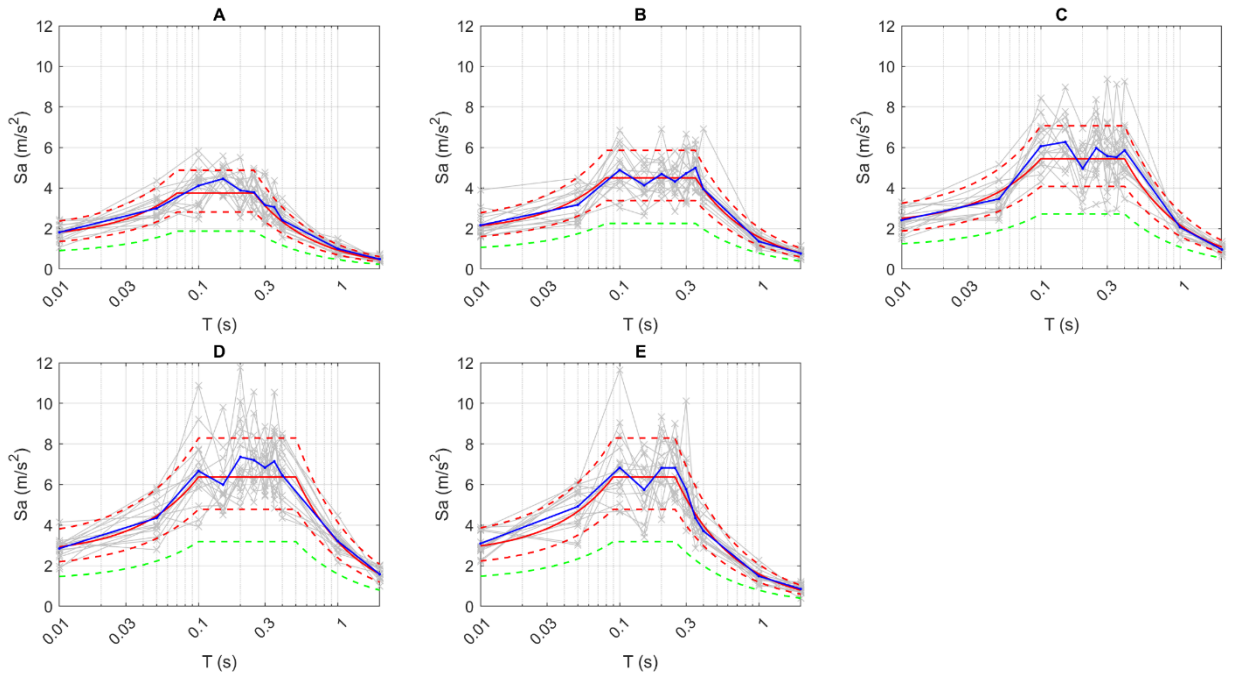

Figure 7.8 – Example of extraction of a set of n=15 synthetic response spectra (gray lines) in case of **null covariance** between periods centered around the SIA 261 elastic response spectra for classes A, B, C, D, E, seismic zone z2, return period 975 years. The blue line is the mean of the synthetic spectra. All the Eurocode 8 (2022) criteria C are satisfied. Red dashed lines indicate the 1.3 and 0.75 ratio threshold; the green dashed line indicates the 0.5 ratio threshold.

8. Ground motion selection for microzonation

Using the Baker and Lee (2018) algorithm, supplemented with all Eurocode 8 (2022) criteria, we selected 11 scaled waveforms, whose response spectrum is compatible with the design one (Fig. 8.1 and 8.2). The selection is performed for each SIA261 zone using as target the SIA 261 elastic response spectra for soil class A (475 years return period) in the period range 0.02-2.0 s. The short period limit 0.02 s is chosen in agreement with the maximum sample frequency of some old waveforms, whereas 2.0 s limit is a compromise between the minimum resonance frequency observed in Switzerland (except deep alluvial valleys) and the low frequency content of the accelerograms that are part of our database (the number of waveforms decreases at high magnitudes and large distances). Although some sites in Switzerland have fundamental frequency lower than 0.5 Hz, it was not possible to find compatible waveforms up to 3.0s (i.e. respecting all Eurocode 8 (2022) criteria up to 3.0s). We tried also to select only unscaled waveforms, but after several tests, we decided to introduce amplitude scaling to improve the final fit with the target, especially at short periods. During our tests we also observed a lack of soil class A waveforms (especially at short distances ≤ 20 km and magnitudes ≥ 5.0), that we solved extending the selection to sites with V_{S30}≥700 m/s, according to Poggi et al. (2012) who observed no resonance in such sites.

For each seismic zone, we provide a folder containing scaled acceleration waveforms, picture of response spectra set and pictures for each scaled waveform in acceleration, velocity and displacement. In the following paragraph, a short description of the results for each zone is reported. It is important to highlight that sometime velocity and displacement time series could show the effect of the acausal filter.

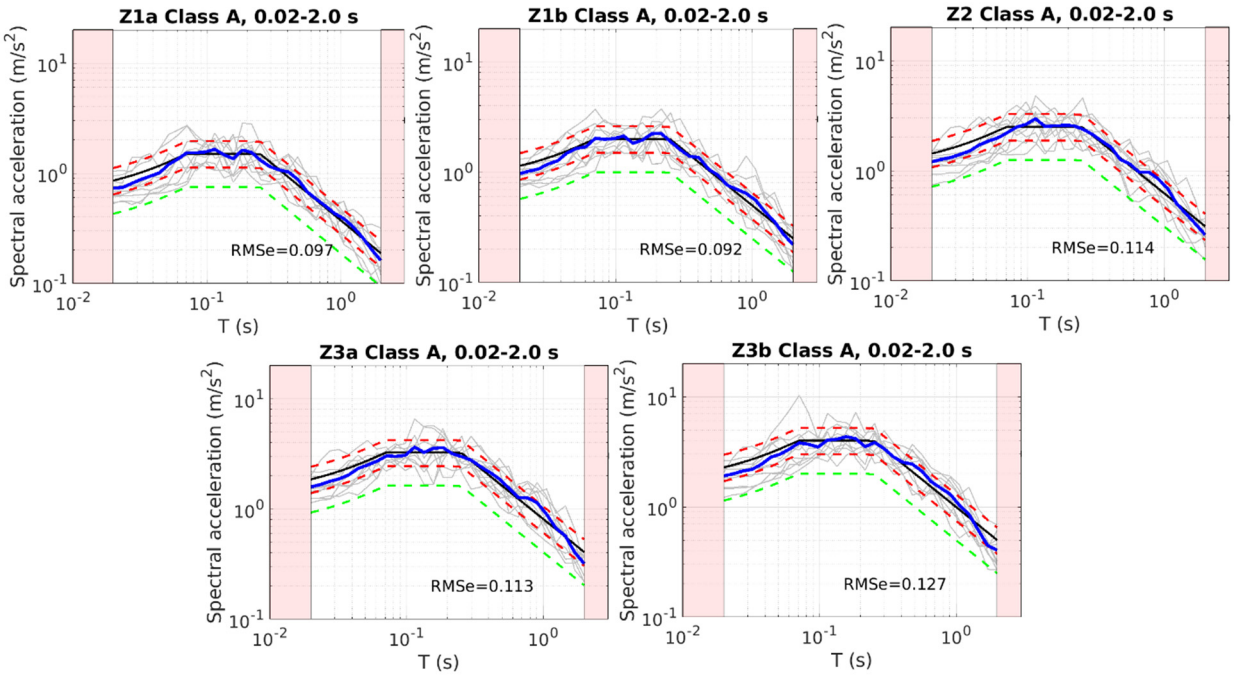

Figure 8.1 – Extracted sets of n=11 scaled response spectra (gray lines) for each SIA261 zone using as target the SIA261 elastic response spectra (black line). The blue line is the mean of the spectra. All the Eurocode 8 (2022) criteria of this document are satisfied. Red dashed lines indicate the 1.3 and 0.75 ratio threshold; the green dashed line indicates the 0.5 ratio threshold.

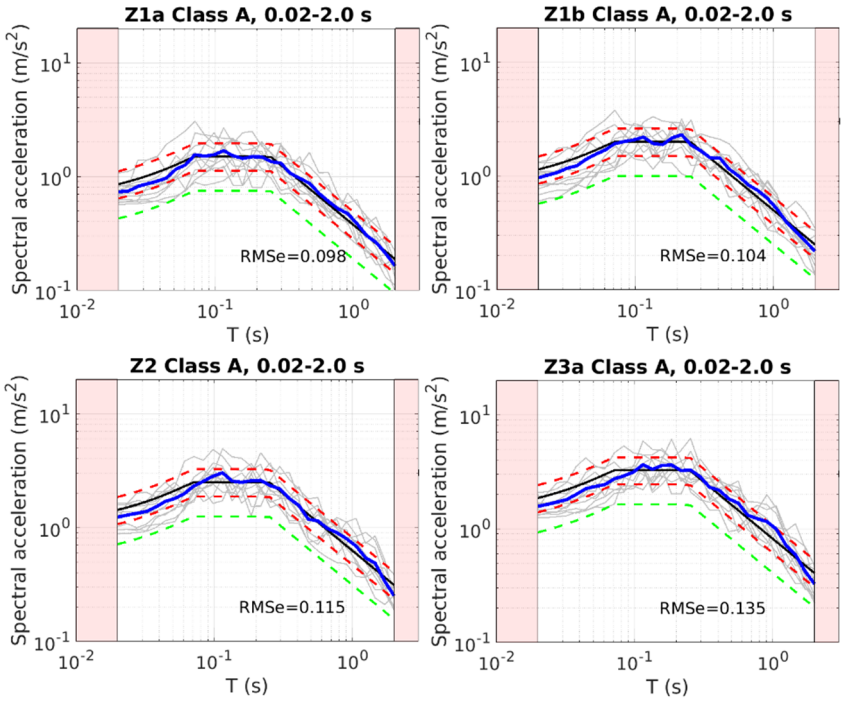

Figure 8.2 – Extracted sets of n=11 scaled response spectra (gray lines) for each SIA261 zone using as target the SIA261 elastic response spectra (black line) after post-processing analysis of metadata for zones: Z1a, Z1b, Z2 and Z3a. The blue line is the mean of the spectra. All the Eurocode 8 (2022) criteria of this document are satisfied. Red dashed lines indicate the 1.3 and 0.75 ratio threshold; the green dashed line indicates the 0.5 ratio threshold.

8.1 Seismic zone Z1a

The seismic zone Z1a covers the area of Central and Eastern Mittelland, Canton Ticino, North of Canton Jura, West of Cantons Geneva and Vaud (see Fig. 7.1). The Baker and Lee (2018) code found 53 possible compatible combinations with RMSE ranging between 0.097 and 0.154. Among these, we choose the one with the lowest RMSE (Fig. 8.1). In Table 8.1 the selected waveforms metadata are reported.

Table 8.1 – Metadata of the selected waveforms for seismic zone Z1a. Filename is related to our database (ACC acronym for acceleration is followed by a 5 digits number, then the name of the station followed by component (xa is North-South or Longitudinal; ya is East-West or Transversal). SF=scaling factor; V_{S30}=average velocity in the upper 30 m; SC=soil class; M_W=moment magnitude; R_{JB}= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database; KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_00208_IWTH17.ya	1.41	1270	A	6.9	72.6	14.06.08	08:43:00	KiK-net
ACC_04076_TER.xa	0.65	-	A	6.5	32.9	30.10.16	06:40:18	ESM
ACC_00861_KMMH07.ya	1.54	765	B	6.6	119.7	20.03.05	10:53:00	KiK-net
ACC_04393_OITH05.xa	1.63	1269	A	7.1	75.0	16.04.16	01:25:00	KiK-net
ACC_04038_TER.xa	1.45	-	A	6.0	28.7	24.08.16	01:36:32	ESM
ACC_03159_AQP.ya	0.96	836	E	5.4	10.4	09.04.09	00:52:59	ESM
ACC_04064_SLO.ya	0.87	-	A	5.9	11.2	26.10.16	19:18:06	ESM
ACC_04035_MNF.xa	1.66	-	A	6.0	20.4	24.08.16	01:36:32	ESM
ACC_00041_MRM.xa	0.54	1906	A	5.2	1.6	25.10.12	23:05:24	ESM
ACC_00017_LSS.ya	1.49	1091	A	6.5	25.1	30.10.16	06:40:18	ESM
ACC_04066_TER.ya	1.96	-	A	5.9	45.3	26.10.16	19:18:06	ESM

This first selection shows 3 waveforms from the same site (seismic station TER). Therefore, to ensure the maximum variability in terms of site conditions, we search in the 53 possible compatible selections another set with maximum 2 waveforms per site (Table 8.2). This selection has a RMSE equal to 0.098 (rank as second in term of RMSE) and it is plotted in Figure 8.2.

Table 8.2 – Metadata of the second waveforms set for seismic zone Z1a. Filename is related to our database (ACC acronym for acceleration is followed by a 5 digits number, then the name of the station followed by component (xa is North-South or Longitudinal; ya is East-West or Transversal). SF=scaling factor; V_{S30}=average velocity in the upper 30 m; SC=soil class; M_W=moment magnitude; R_{JB}= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database; KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_05089_KMMH07.xa	0.50	765	B	6.1	23.1	14.04.16	21:26:00	KiK-net
ACC_04393_OITH05.xa	0.97	1269	A	7.1	75.0	16.04.16	01:25:00	KiK-net
ACC_04057_ACC.xa	1.16	-	A	5.9	18.1	26.10.16	19:18:06	ESM
ACC_04071_GNU.xa	1.59	-	A	6.5	40.8	30.10.16	06:40:18	ESM
ACC_00041_MRM.xa	0.54	1906	A	5.2	1.6	25.10.12	23:05:24	ESM
ACC_00208_IWTH17.ya	1.61	1270	A	6.9	72.6	14.06.08	08:43:00	KiK-net
ACC_00017_LSS.ya	1.72	1091	A	6.5	25.1	30.10.16	06:40:18	ESM
ACC_04064_SLO.xa	1.13	-	A	5.9	11.2	26.10.16	19:18:06	ESM
ACC_04422_KMMH11.xa	1.67	1292	A	6.0	46.4	15.04.16	00:03:00	KiK-net
ACC_04088_NOT.ya	0.74	-	A	5.6	49.4	13.12.90	00:24:26	ESM
ACC_04853_CHY102.xa	1.26	804	A	6.2	39.3	20.09.99	21:46:00	NGA

8.2 Seismic zone Z1b

The Z1b covers the NW of Switzerland, N of Canton Ticino area and a belt spanning central Switzerland from St. Gallen to Lausanne (see Fig. 7.1). The Baker and Lee (2018) code found 61 possible compatible combinations with RMSE ranging between 0.092 and 0.138. Among these, we choose the one with the lowest RMSE (Fig. 8.1). In Table 8.3 the selected waveforms metadata are reported.

Table 8.3 – Metadata of the selected waveforms for seismic zone Z1b. Filename is related to our database (ACC acronym for acceleration is followed by a 5 digits number, then the name of the station followed by component (xa is North-South or Longitudinal; ya is East-West or Transversal). SF=scaling factor; V_{S30}=average velocity in the upper 30 m; SC=soil class; M_W=moment magnitude; R_{JB}= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database; KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_04062_MNF.xa	0.98	-	A	5.9	6.8	26.10.16	19:18:06	ESM
ACC_04064_SLO.ya	1.21	-	A	5.9	11.2	26.10.16	19:18:06	ESM
ACC_04088_NOT.ya	1.10	-	A	5.6	49.4	13.12.90	00:24:26	ESM
ACC_04073_MNF.ya	0.84	-	A	6.5	12.6	30.10.16	06:40:18	ESM
ACC_04072_MMO.ya	0.57	-	A	6.5	9.8	30.10.16	06:40:18	ESM
ACC_04393_OITH05.xa	1.66	1269	A	7.1	75.0	16.04.16	01:25:00	KiK-net
ACC_03159_AQP.ya	1.18	836	E	5.4	10.4	09.04.09	00:52:59	ESM
ACC_00208_IWTH17.ya	1.96	1270	A	6.9	72.6	14.06.08	08:43:00	KiK-net
ACC_04035_MNF.xa	1.74	-	A	6.0	20.4	24.08.16	01:36:32	ESM
ACC_00041_MRM.ya	0.51	1906	A	5.2	1.6	25.10.12	23:05:24	ESM
ACC_04038_TER.xa	1.81	-	A	6.0	28.7	24.08.16	01:36:32	ESM

This first selection shows 3 waveforms from the same site (seismic station MNF). Therefore, to ensure the maximum variability in terms of site conditions, we search in the 61 possible compatible selections another set with maximum 2 waveforms per site (Table 8.4). This selection has a RMSE equal to 0.104 (rank as third in term of RMSE) and it is plotted in Figure 8.2.

Table 8.4 – Metadata of the second waveforms set for seismic zone for seismic zone Z1b. Filename is related to our database (ACC acronym for acceleration is followed by a 5 digits number, then the name of the station followed by component (xa is North-South or Longitudinal; ya is East-West or Transversal). SF=scaling factor; V_{S30}=average velocity in the upper 30 m; SC=soil class; M_W=moment magnitude; R_{JB}= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database; KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_04393_OITH05.xa	1.70	1269	A	7.1	75.0	16.04.16	01:25:00	KiK-net
ACC_03159_AQP.ya	1.51	836	E	5.4	10.4	09.04.09	00:52:59	ESM
ACC_04062_MNF.xa	0.64	-	A	5.9	6.8	26.10.16	19:18:06	ESM
ACC_05089_KMMH07.xa	0.78	765	B	6.1	23.1	14.04.16	21:26:00	KiK-net
ACC_00208_IWTH17.ya	1.99	1270	A	6.9	72.6	14.06.08	08:43:00	KiK-net
ACC_00017_LSS.xa	1.47	1091	A	6.5	25.1	30.10.16	06:40:18	ESM
ACC_04064_SLO.xa	1.01	-	A	5.9	11.2	26.10.16	19:18:06	ESM
ACC_04072_MMO.ya	0.51	-	A	6.5	9.8	30.10.16	06:40:18	ESM
ACC_04104_VGG.ya	1.20	-	A	5.6	1.6	09.09.98	11:28:00	ESM
ACC_00041_MRM.ya	0.56	1906	A	5.2	1.6	25.10.12	23:05:24	ESM
ACC_04035_MNF.xa	1.86	-	A	6.0	20.4	24.08.16	01:36:32	ESM

8.3 Seismic zone Z2

The Z2 covers part of Canton Basel-Landschaft, Canton Graubünden and a belt crossing central Switzerland south of Luzern and Lausanne (see Fig. 7.1). The Baker and Lee (2018) code found 29 possible compatible combinations with RMSE ranging between 0.114 and 0.140. Among these, we choose the one with the lowest RMSE (Fig. 8.1). In Table 8.5 the selected waveforms metadata are reported.

Table 8.5 – Metadata of the selected waveforms for seismic zone Z2. Filename is related to our database (ACC acronym for acceleration is followed by a 5 digits number, then the name of the station followed by component (xa is North-South or Longitudinal; ya is East-West or Transversal). SF=scaling factor; V_{S30}=average velocity in the upper 30 m; SC=soil class; M_W=moment magnitude; R_{JB}= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database; KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_04088_NOT.ya	1.45	-	A	5.6	49.35	13.12.90	00:24:26	ESM
ACC_04393_OITH05.xa	1.75	1269	A	7.1	75.0	16.04.16	01:25:00	KiK-net
ACC_03159_AQP.ya	1.75	836	E	5.4	10.4	09.04.09	00:52:59	ESM
ACC_04072_MMO.ya	0.75	-	A	6.5	9.8	30.10.16	06:40:18	ESM
ACC_04076_TER.xa	1.42	-	A	6.5	32.9	30.10.16	06:40:18	ESM
ACC_04062_MNF.xa	0.79	-	A	5.9	6.8	26.10.16	19:18:06	ESM
ACC_04061_MMO.ya	0.55	-	A	5.9	10.4	26.10.16	19:18:06	ESM
ACC_05089_KMMH07.xa	0.66	765	B	6.1	23.1	14.04.16	21:26:00	KiK-net
ACC_00041_MRM.ya	0.79	1906	A	5.2	1.6	25.10.12	23:05:24	ESM
ACC_05101_KMMH07.xa	1.26	765	B	6.0	16.8	15.04.16	00:03:00	KiK-net
ACC_04104_VGG.ya	1.72	-	A	5.6	1.6	09.09.98	11:28:00	ESM

This first selection shows 1 waveform (ACC_04088_NOT.ya) at large distance, outside the disaggregation borders. Therefore, we first search in the 29 possible compatible selections another set, but there is not an acceptable set. To improve the solution, we run again the code extracting others 32 sets imposing a maximum R_{JB} of 60 km. In this case, the RMSE range between 0.115 and 0.156. Among these, we choose the one with the lowest RMSE (Fig. 8.2). In Table 8.6 the selected waveforms metadata are reported.

Table 8.6 – Metadata of the second waveforms set for seismic zone for seismic zone Z2. Filename is related to our database (ACC acronym for acceleration is followed by a 5 digits number, then the name of the station followed by component (xa is North-South or Longitudinal; ya is East-West or Transversal). SF=scaling factor; V_{S30}=average velocity in the upper 30 m; SC=soil class; M_W=moment magnitude; R_{JB}= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database; KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_04104_VGG.ya	1.34	-	A	5.6	1.6	09.09.98	11:28:00	ESM
ACC_04072_MMO.ya	0.61	-	A	6.5	9.8	30.10.16	06:40:18	ESM
ACC_04088_NOT.ya	1.42	-	A	5.6	49.4	13.12.90	00:24:26	ESM
ACC_00041_MRM.ya	0.64	1906	A	5.2	1.6	25.10.12	23:05:24	ESM
ACC_04057_ACC.ya	1.73	-	A	5.9	18.1	26.10.16	19:18:06	ESM
ACC_04076_TER.xa	1.14	-	A	6.5	32.9	30.10.16	06:40:18	ESM
ACC_04064_SLO.ya	1.67	-	A	5.9	11.2	26.10.16	19:18:06	ESM
ACC_04130_VGG.ya	1.37	-	A	5.2	9.6	25.10.12	23:05:24	ESM
ACC_03159_AQP.ya	1.92	836	E	5.4	10.4	09.04.09	00:52:59	ESM
ACC_04390_KMMH11.ya	1.66	1292	A	7.1	44.1	16.04.16	01:25:00	KiK-net
ACC_04138_SPT1.xa	1.85	-	A	5.0	7.6	29.12.13	17:08:43	ESM

8.4 Seismic zone Z3a

The Z3a covers Canton Basel-Stadt and surrounds Canton Valais (see Fig. 7.1). The Baker and Lee (2018) code found 26 possible compatible combinations with RMSE ranging between 0.113 and 0.160. Among these we choose the one with the lowest RMSE (Fig. 8.1). In Table 8.7 the selected waveforms metadata are reported.

Table 8.7 – Metadata of the selected waveforms for seismic zone Z3a. Filename is related to our database (ACC acronym for acceleration is followed by a 5 digits number, then the name of the station followed by component (xa is North-South or Longitudinal; ya is East-West or Transversal). SF=scaling factor; V_{S30}=average velocity in the upper 30 m; SC= soil class; M_W=moment magnitude; R_{JB}= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database; KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_04062_MNF.xa	1.21	-	A	5.9	6.8	26.10.16	19:18:06	ESM
ACC_04072_MMO.ya	0.75	-	A	6.5	9.8	30.10.16	06:40:18	ESM
ACC_00041_MRM.ya	1.08	1906	A	5.2	1.6	25.10.12	23:05:24	ESM
ACC_04130_VGG.ya	1.82	-	A	5.2	9.6	25.10.12	23:05:24	ESM
ACC_04075_SPM.ya	1.48	-	A	6.5	31.3	30.10.16	06:40:18	ESM
ACC_04393_OITH05.xa	1.94	1269	A	7.1	75.0	16.04.16	01:25:00	KiK-net
ACC_04061_MMO.ya	1.17	-	A	5.9	10.4	26.10.16	19:18:06	ESM
ACC_04088_NOT.ya	1.79	-	A	5.6	49.4	13.12.90	00:24:26	ESM
ACC_05089_KMMH07.xa	0.96	765	B	6.1	23.1	14.04.16	21:26:00	KiK-net
ACC_00207_FKOH06.xa	1.71	1002	A	6.6	78.2	20.03.05	10:53:00	KiK-net
ACC_04388_FKOH06.xa	1.60	1002	A	7.1	87.1	16.04.16	01:25:00	KiK-net

This first selection shows 3 waveforms (ACC_04393_OITH05.xa, ACC_00207_FKOH06.xa and ACC_04388_FKOH06.xa) at large distance, outside the disaggregation borders. Therefore, we first search in the 26 possible compatible selections another set, but there is not an acceptable set. To improve the solution, we run again the code extracting others 20 sets imposing a maximum R_{JB} of 60 km. In this case the RMSE range between 0.135 and 0.173. Among these, we choose the one with the lowest RMSE (Fig. 8.2). In Table 8.8 the selected waveforms metadata are reported.

Table 8.8 – Metadata of the second waveforms set for seismic zone for seismic zone Z3a. Filename is related to our database (ACC acronym for acceleration is followed by a 5 digits number, then the name of the station followed by component (xa is North-South or Longitudinal; ya is East-West or Transversal). SF=scaling factor; V_{S30}=average velocity in the upper 30 m; SC=soil class; M_W=moment magnitude; R_{JB}= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database; KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_04062_MNF.xa	1.39	-	A	5.9	6.8	26.10.16	19:18:06	ESM
ACC_00041_MRM.ya	0.81	1906	A	5.2	1.6	25.10.12	23:05:24	ESM
ACC_04072_MMO.ya	1.02	-	A	6.5	9.8	30.10.16	06:40:18	ESM
ACC_04075_SPM.ya	1.69	-	A	6.5	31.3	30.10.16	06:40:18	ESM
ACC_04088_NOT.ya	1.86	-	A	5.6	49.4	13.12.90	00:24:26	ESM
ACC_05089_KMMH07.xa	0.98	765	B	6.1	23.1	14.04.16	21:26:00	KiK-net
ACC_04061_MMO.ya	0.87	-	A	5.9	10.4	26.10.16	19:18:06	ESM
ACC_03159_AQP.ya	1.87	836	E	5.4	10.4	09.04.09	00:52:59	ESM
ACC_04511_90017.ya	0.80	1222	A	6.7	15.1	17.01.94	12:31:00	NGA
ACC_04130_VGG.ya	1.63	-	A	5.2	9.6	25.10.12	23:05:24	ESM
ACC_00173_SAGH05.xa	1.75	1000	A	6.6	58.1	20.03.05	10:53:00	KiK-net

8.5 Seismic zone Z3b

The Z3b is entirely covering Canton Valais (see Fig. 7.1). The Baker and Lee (2018) code found 16 possible compatible combinations with RMSE ranging between 0.127 and 0.179. Among these,

we choose the one with the lowest RMSE (Fig. 8.1). In Table 8.9 the selected waveforms metadata are reported.

Table 8.9 – Metadata of the selected waveforms for seismic zone Z3b. Filename is related to our database (ACC acronym for acceleration is followed by a 5 digits number, then the name of the station followed by component (xa is North-South or Longitudinal; ya is East-West or Transversal). SF=scaling factor; V_{S30}=average velocity in the upper 30 m; SC=soil class; M_W=moment magnitude; R_{JB}= Joyner and Boore distance; DD.MM.YY.=day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database; KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB}	DD.MM.YY	HH.MM.SS.	Ref.
ACC_04511_90017.ya	0.94	1223	A	6.7	15.1	17.01.94	12:31:00	NGA
ACC_04072_MMO.ya	0.94	-	A	6.5	9.8	30.10.16	06:40:18	ESM
ACC_04130_VGG.ya	1.96	-	A	5.2	9.6	25.10.12	23:05:24	ESM
ACC_00041_MRM.ya	1.11	1906	A	5.2	1.6	25.10.12	23:05:24	ESM
ACC_05089_KMMH07.xa	1.32	765	B	6.1	23.1	14.04.16	21:26:00	KiK-net
ACC_04062_MNF.xa	1.30	-	A	5.9	6.8	26.10.16	19:18:06	ESM
ACC_04061_MMO.ya	1.09	-	A	5.9	10.4	26.10.16	19:18:06	ESM
ACC_04075_SPM.ya	2.00	-	A	6.5	31.3	30.10.16	06:40:18	ESM
ACC_00022_ATH4.ya	1.74	970	A	5.9	14.0	07.09.99	11:56:49	ESM
ACC_00062_OKYH07.xa	1.41	929	A	6.6	17.2	06.10.00	13:30:00	KiK-net
ACC_04104_VGG.xa	1.91	-	A	5.6	1.6	09.09.98	11:28:00	ESM

Conclusions on selection of ground motions for microzonation

We inspected the stations metadata of three strong motion databases: KiK-net (Japan), ESM (Europe and Middle East), and NGA-West2 (USA) and selected from each database a subset of stations having reliable metadata information. We paid attention to the installation characteristics and the site characterization metadata (V_S profile). The final subsets of stations comprise 772 sites classified in terms of SIA261 (2020) soil categories (A-E). Due to the limited number of recordings in soil class A, we added waveforms from the Taiwanese network and from ESM classified using geologic criteria (80 seismic stations).

For the selected stations were then extracted 51,147 three-component recordings inspecting their distribution in terms of hypocenter depth, magnitude and Joyner-Boore distance. A further selection according to the outcomes of the disaggregation of the seismic hazard comprise only 5,108 recordings corresponding to 10,216 horizontal component waveforms. To fill the gaps in the magnitude-distance distribution, this dataset of observed waveforms was complemented with 24,118 horizontal component waveforms from synthetic strong motion simulations of the BB-SPEEDset dataset. This dataset of synthetic waveforms so far is based on only 22 earthquake scenarios using 16 structural models. However, in the future, there might be other synthetic datasets of hybrid synthetics available, or the number of simulations in the BB-SPEEDset will increase with time.

Observed strong ground motion remains the preferred option in engineering applications as long as the quality of recordings is high and the information about the site and installation is available. The further increase in number of waveforms of our dataset in the high magnitude-short distance range could be based on requests to operators of non-public strong motion databases (e.g. Taiwan, China) or by investigating KikNet station sites labelled as having unreliable V_S profiles. This assessment of these KikNet stations would require an assessment

of geological information, H/V spectral ratios or a reassessment of the existing velocity profiles. The same might be addressed for stations in Japanese K-Net with recordings of interest. K-Net stations generally have only shallow Vs-profiles and this would also require additional work for site-characterization. Finally, the sites from the recordings collected in the NEar-Source Strong-motion dataset NESS (v.2.0) (Sgobba et al. 2021; updated after Pacor et al. (2018) not yet included in our dataset might be investigated to improve the site characterization and installation information.

Using the database of waveforms obtained inspecting the metadata for each seismic zone in SIA261, a set of eleven scaled waveforms was selected for an application in microzonation. At the time of the start of the project (early 2022) we followed the selection criteria as listed in the Eurocode 8 draft prEN 1998-1-1:2022. At the time of writing of this report (September 2023) a new draft version of Eurocode 8 is being distributed (FprEN 1998-1-1:2024). We verified that the selection criteria we used are still valid and we can confirm that our selected sets are extracted in agreement with the Eurocode 8 criteria.

In general, most of the waveforms belong to the soil class A (mainly classified from geology), only few waveforms from class B and E. Despite the lower V_{S30} limit was set to 700 m/s, all the station sites have V_{S30} higher than 765 m/s. The average spectra of the combinations fit well the target, with a slight deviation towards lower values at short periods. Further, we inspected the metadata and we extract for Z1a, Z1b, Z2 and Z3a another set of waveforms to avoid more than 2 recordings from the same station and to be sure that most of the waveforms are nearby or better inside the disaggregation borders (Fig. 8.3).

In general, after the adjustments the selected waveforms for Z1a, Z1b, Z2 and Z3a fall inside the areas where probability of exceedance (over all IMTs) is significant for the five seismic zones and a return period of 475 years (Fig. 8.4) and no more of 2 records from the same station are present.

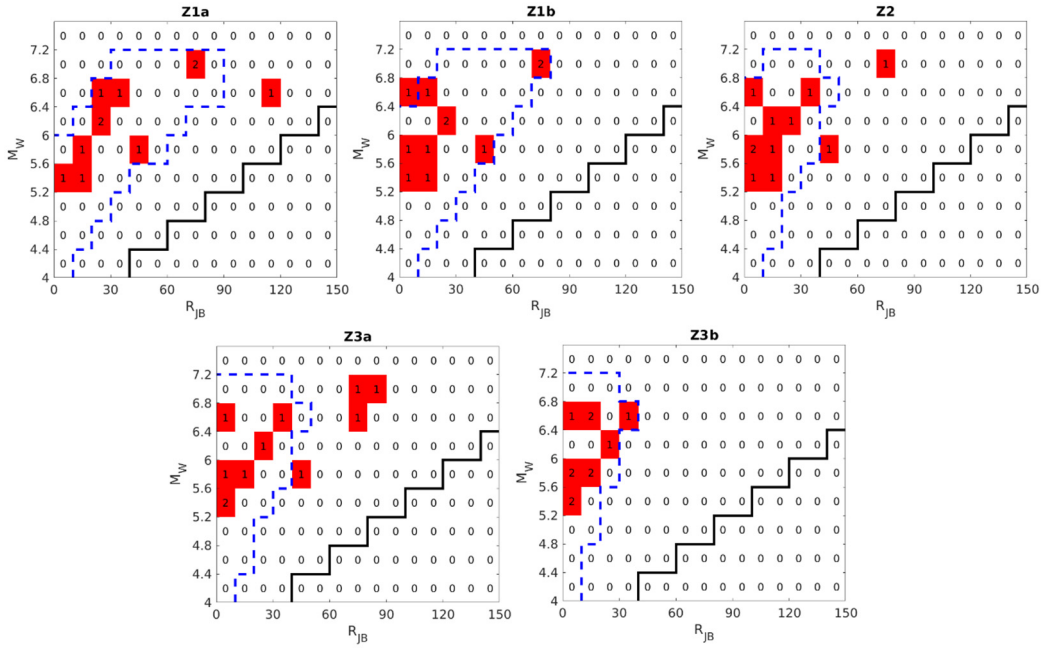

Figure 8.3 – Selected number of recordings by bin of Joyner-Boore distances (10 km width) and M_W (0.2 unit) for the first selected set of waveforms for each zone. The dashed blue lines indicate the areas where probability of exceedance (over all IMTs) is significant for the five

SIA261 zones for return period 475 years following Bergamo et al. (2022) approach. The black continuous lines indicate our limit for the first selection of waveforms.

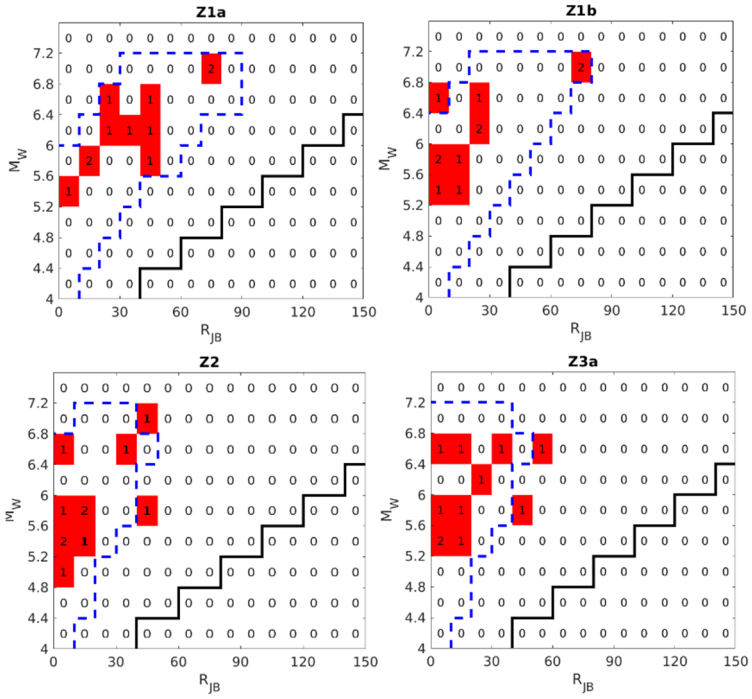

Figure 8.4 – Selected number of recordings by bin of Joyner-Boore distances (10 km width) and M_W (0.2 unit) for the second selected set of waveforms for zones Z1a, Z1b, Z2 and Z3a. The dashed blue lines indicate the areas where probability of exceedance (over all IMTs) is significant for the five SIA261 zones for return period 475 years following Bergamo et al. (2022) approach. The black continuous lines indicate our limit for the first selection of waveforms.

As concerns the scenarios average and median values of magnitude and distance for the first and adjusted waveforms sets are reported in Table 8.10, together with the values from disaggregation.

Table 8.10 – Magnitude and distance average and median values for the sets of selected waveforms.

Zone	First selection				Adjusted selection				Disaggregation			
	Average		Median		Average		Median		Average		Median	
	M_W	R_{JB} (km)	M_W	R_{JB} (km)	M_W	R_{JB} (km)	M_W	RJB (km)	M_W	R_{JB} (km)	M_W	R_{JB} (km)
Z1a	6.2	40.2	6.0	28.7	6.2	36.6	6.1	39.3	6.0	38.7	6.2	35
Z1b	6.1	27.1	6.0	12.6	6.1	23.4	6.0	11.2	6.0	31.1	6.2	25
Z2	6.0	21.6	5.9	10.4	5.8	17.8	5.6	10.4	5.8	22.3	5.8	15
Z3a	6.2	34.7	6.1	23.1	6.0	20.5	5.9	10.4	5.9	20.3	5.8	15
Z3b	6.0	12.8	5.9	10.4	-	-	-	-	5.9	14.5	5.8	15

9. Recommendation for waveforms application

The waveforms were scaled to the elastic response spectrum of soil class A. This response spectrum refers to a rock subsoil, but the shear-wave velocity profile is not defined and the geotechnical description in SIA 261 also includes weathered rock. To account for this fact, the SIA Working Group on Earthquakes introduced a factor of 1.6 (Duvernay et al., 2019) to determine the elastic response spectrum of ground class A in SIA 261 from the values of the

Uniform Hazard Spectra of the National Seismic Hazard Model (Wiemer et al., 2016). For this reason, it is recommended to reduce the amplitudes of the waveforms by this factor 1.6. The waveforms then refer to a well-defined reference rock condition (Vs30=1105 m/s; Poggi et al., 2011), which is the same for the national seismic hazard model. For the definition of the shear-wave reference profile, see also:
http://www.seismo.ethz.ch/en/knowledge/seismic-hazard-switzerland/for-professionals/.
It is important to note that the waveforms represent the earthquake ground-motion at a site on the soil surface, i.e. the outcropping reference rock when the amplitudes are reduced by applying the factor 1/1.6. In order to define the incident wave field at depth, it is recommended to perform a deconvolution to a depth where the reference velocity profile displays the same V_S of the bedrock used in the site response analysis.

Schweizerischer Erdbebendienst
Service Sismologique Suisse
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Swiss Seismological Service

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Database for design-compatible waveforms

Deliverable:
Selection of three-component ground motions for structural analysis

Schweizerischer Erdbebendienst, ETH Zürich
22.09.2023

Authors
Francesco Panzera, Paolo Bergamo, Donat Fäh

Abstract on selection of ground motions for structural analysis

We set a strategy for the selection of 11 two-component waveforms, compatible with the elastic response spectrum defined in SIA261 for buildings of importance class III and for each seismic zone and soil class. Our selection in this report is made for structural analysis purpose. We fit the target elastic response spectrum in SIA 261 multiplied with a factor 1.5, corresponding to about 975 years return period in the seismic hazard. Three period ranges were chosen to cover the fundamental periods of most of the Swiss building stock, in agreement with the definition of period range in the EC8 rules (0.2T0-1.5T0). In particular, the covered building periods are 0.10-0.66 s, 0.50-1.33 s and 1.25-2.66 s respectively. The selection is initially attempted using real waveforms scaled up to a factor of 2, but if necessary we add to the database synthetic waveforms and we scale the waveforms up to a factor of 3.

For each seismic zone, we selected all suitable combinations of 11 two-components scaled wave-forms. The search is made using the geometric mean of the two horizontal components. For the vertical components, the same scaling is applied, although we do not expect that we match the vertical ground motion design spectrum defined in SIA261. Among the possible suitable combinations, we choose the set of waveforms with the lowest RMSE if most of its time histories are nearby or better inside the disaggregation magnitude-distance boundaries; otherwise we select another set of waveforms satisfying the latter criterion. In particular cases, some search constrains had to be waived (e.g. selection for spectral period range 0.1-2.0 s zone Z2 soil class E we allow a scale factor up to 3).

10. Ground motion selection for structural analysis

The Baker and Lee (2018) algorithm, supplemented with all Eurocode 8 (2022) criteria according to prEN 1998-1-1:2022, is used to select 11 two-components horizontal scaled waveforms, whose response spectrum is compatible with the design one. The selection is performed for each seismic zone using as target the SIA261 elastic response spectra for all soil classes and buildings of importance class III (elastic response spectra in SIA 261 are multiplied with a factor 1.5, thus corresponding to about 975 years return period in the seismic hazard). We consider three period ranges for the selection: 0.02-1.0 s, 0.1-2.0 s, and 0.25-4.0 s. These three period ranges were chosen to cover the fundamental periods of most of the Swiss building stock, in agreement with the definition of period range in the EC8 rules ($0.2T_0$-$1.5T_0$). In particular, the covered building periods are 0.10-0.66 s, 0.50-1.33 s and 1.25-2.66 s respectively. The search is made using the geometric mean of the two horizontal components, and scaling in amplitude the waveforms to improve the final fit with the target (minimum scaling factor = 0.5, maximum scaling factor = 2.0 if possible). For the vertical components, the same scaling is applied, although we do not expect to match the vertical ground motion design spectrum defined in SIA261.

During our tests, we observed a lack of recorded waveforms when searching for ground motions for specific soil classes. We solved this issue extending the soil class limits based on the following considerations:

- As already used for microzonation, the selection for soil class A is made considering all the sites with $V_{S30} \geq 700$ m/s, following Poggi et al. (2012) who observed no resonance at such sites.
- The selection for soil class B fails if only stations strictly assigned to this class are used. From the V_S30 measured at strong motion station sites in Switzerland - SSMNet sites (Michel et al. 2014, Hobiger et al. 2021), we observed that the associated uncertainty may reach values up to 90-200 m/s, in the V_S30 range of soil class B (500 – 800 m/s; Fig. 10.1, left panel). We therefore extended the soil class B borders of about ±100 m/s, i.e. we considered a V_{S30} range 400 ≤ V_{S30} ≤ 900 m/s, therefore adding some class A and C sites.

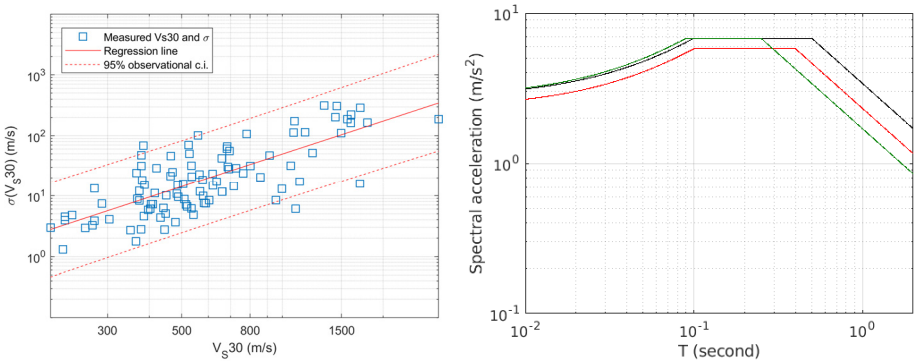

Figure 10.1 – Left panel: V_{S30} versus corresponding standard deviation for the SSMNet sites for which a site characterization measurement is available. It is possible to observe that between 500 and 800 m/s (V_S30 range for B class) the standard deviation can reach values up to 90 - 200 m/s. Right panel: response spectra for SIA261 zone 3b class C (red line), D (black line) and E (green line), considering the elastic response spectra in SIA261 which corresponds a return period of 475 years in the seismic hazard.

- Vice versa, for soil class C only stations assigned to this class are used, since in our dataset there is a sufficient number of such waveforms.
- For soil class D, the selection fails if only stations strictly belonging to this class are used. Comparing the SIA261 elastic response spectra for class D and E (Fig. 10.1, right panel) we observe that they are similar at short periods (< 0.25 s), whereas the class C response spectrum lies between D and E at large periods (> 0.3 s). We therefore used waveforms related to soil classes C, D and E to find sets of compatible waveforms.
- The lowest number of waveforms available in our database is related to soil class E; therefore, we defined a strategy to increase the number of waveforms that can be considered during the selection process. Following the approach proposed by Zhao *et al*. (2006) and Fukushima *et al*. (2007), we determine the predominant period range for soil class E through the average H/V spectral ratio of the 5%-damped response spectra (Fig. 10.2). We observed that almost all the soil class E sites have a predominant period in the range 0.1-0.25 s (Fig. 10.2, upper-left panel). Considering that soil class E and D elastic response spectra are similar at short periods (< 0.25 s), and are similar to short periods to soil class C, we searched in our database soil class C and D waveforms having a similar H/V behavior as sites in soil class E. Following this strategy, for the selection of waveforms in soil class E, we considered also 57 seismic stations from soil class C and 10 seismic stations from soil class D.

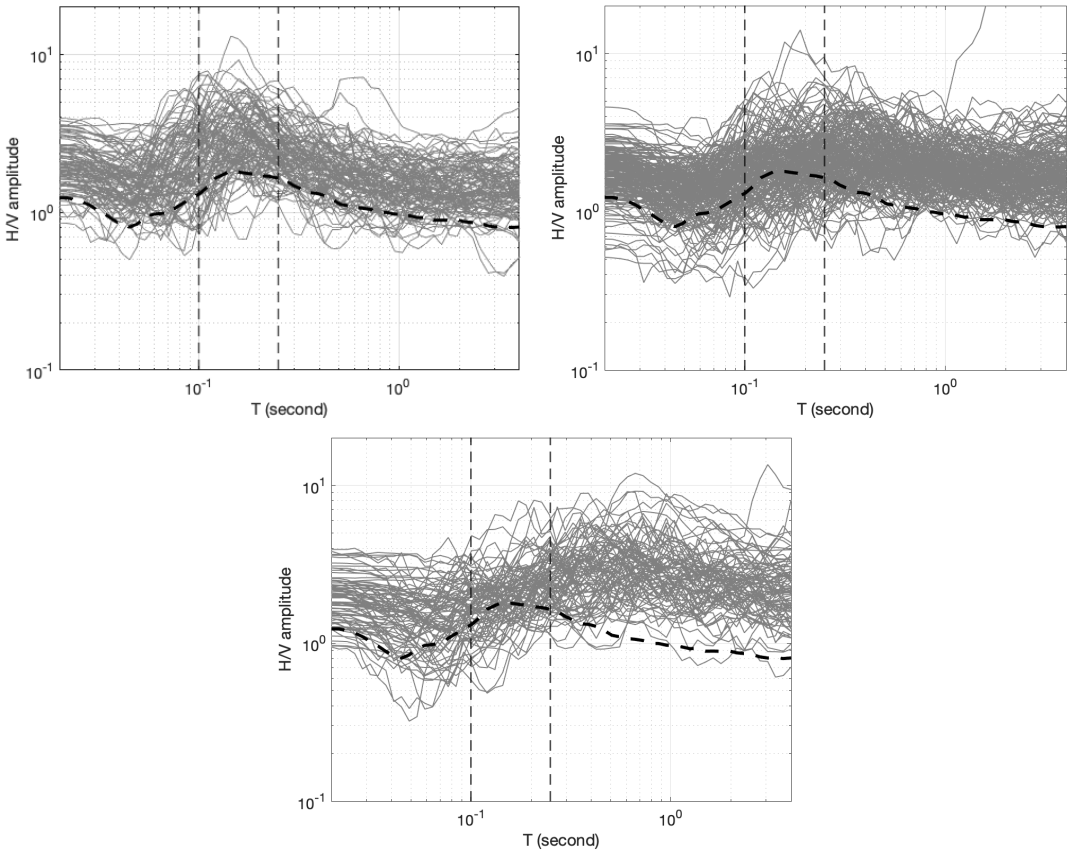

Figure 10.2 – Upper left panel: average H/V ratio for 107 seismic stations classified as soil class E (grey lines). Upper right panel: average H/V ratio for 197 seismic stations classified as soil class C (grey lines). Lower panel: average H/V ratio for 87 seismic stations classified as soil class D (grey lines). In all plots, the dashed black line indicates the 16th percentile of the class E H/V distribution, used as lower limit for the peak amplitude in the period range 0.1-0.25 s (which is indicated by the dashed vertical black lines).

Furthermore, limitedly to soil class E, if no valid sets of observed accelerograms are found for a SIA261 zone and a particular spectral period, we define additional strategies for the selection. First, we added to the input dataset the synthetic waveforms from BB-SPEED set (Paolucci et al., 2021). In particular, 48 synthetic waveforms of soil classes C and D with H/V behavior similar to the one from stations in soil class E are added. During the selection process, the maximum number of synthetics is fixed to 4, as needed. For long period selections (0.25-4.0 s), if no solutions are obtained, we remove also the constraint on the magnitude-distance. Finally, in case the previous strategies are not sufficient, we increase the scaling factor up to 3 following Du et al. (2019), who demonstrated that the scaling factor can be increased up to 3 to 5 (Fig. 10.3).

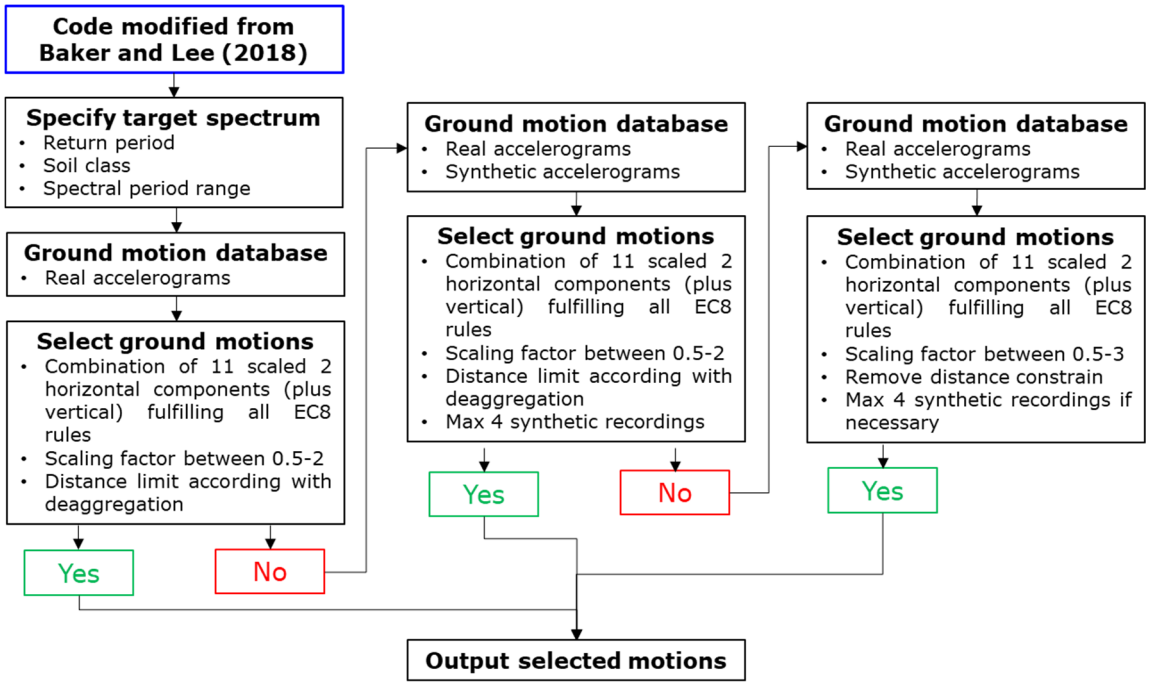

Figure 10.3 – Diagram summarizing selection strategies followed during structural analysis selection.

As final result of the selection process, for each spectral period range, 25 folders are eventually provided (for each combination of 5 soil classes and 5 seismic zones); each folder contains metadata of the scaled acceleration waveforms, pictures of their response spectra and pictures of each scaled waveform in acceleration, velocity and displacement. In the following paragraphs, short descriptions of the results obtained for each zone are reported. It is important to highlight that sometime velocity and displacement time series could show the effect of the acausal filter.

10.1 Seismic zone Z1a

The seismic zone Z1a covers the central and eastern Foreland, Canton Ticino, North of Canton Jura, West of Cantons Geneva and Vaud (see Fig. 7.1). We selected waveforms for all the 5 soil classes and for the 3 defined spectral period ranges.

The Baker and Lee (2018) selection code found 55 possible compatible combinations with RMSE ranging between 0.055 and 0.104 (in units) for soil class A and period range 0.1-2.0

s. Among these we choose the one with the lowest RMSE (Fig. 10.4, left panel). In Table 10.1 the selected waveforms metadata are reported. For the period range 0.02-1.0 s, the code found 100 possible compatible combinations with RMSE ranging between 0.062 and 0.116 (ln units) for soil class A. Among these, we choose the one with the lowest RMSE (Fig. 10.4, center panel). In Table 10.2 the selected waveforms metadata are reported. The selection for period range 0.25-4.0 s extracted 49 compatible combinations with RMSE in the range 0.069-0.122 (ln units), from which the one having lowest RMSE 0.069 is taken (Fig. 10.4). In Table 10.3 the selected waveforms metadata are reported.

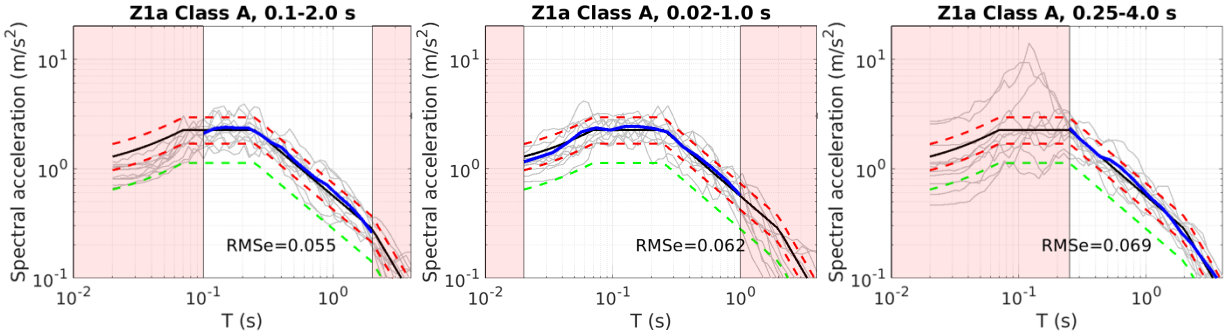

Figure 10.4 – Extracted sets of n=11 geometric mean of two-components scaled response spectra (gray lines) for Z1a zone using as target the SIA261 elastic response spectrum (black line) for soil class A. The blue line is the mean of the retrieved spectra. All the Eurocode 8 (2022) criteria of this document (section 9) are satisfied. Red dashed lines indicate the 1.3 and 0.75 ratio threshold; the green dashed line indicates the 0.5 ratio threshold. Shadowed red areas highlight the period range not considered in the selection.

The selected waveforms for Z1a soil class A fall inside the areas where the probability of exceedance (over all IMTs) is significant for the corresponding seismic zone considering a return period of 975 years (Fig. 10.5; see the disaggregation report of this project, Bergamo et al. 2022); no more than 2 records of the same earthquake are present in each set.

Table 10.1 – Metadata of the waveforms selected for seismic zone Z1a, soil class A, period range 0.1-2.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; V_{S30}=average velocity of the station in the upper 30 m; SC=soil class; M_W=moment magnitude; R_{JB}= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_04035_MNF	1.70	-	A	6.0	20.4	24.08.16	01:36:32	ESM
ACC_05089_KMMH07	0.66	765	B	6.1	23.1	14.04.16	21:26:00	KiK-net
ACC_04388_FKOH06	1.45	1002	A	7.1	87.1	16.04.16	01:25:00	KiK-net
ACC_00173_SAGH05	0.97	1000	A	6.6	58.1	20.03.05	10:53:00	KiK-net
ACC_04062_MNF	1.06	-	A	5.9	6.8	26.10.16	19:18:06	ESM
ACC_00017_LSS	1.33	1091	A	6.5	25.1	30.10.16	06:40:18	ESM
ACC_00291_ATH2	0.81	706	B	5.9	16.0	07.09.99	11:56:49	ESM
ACC_04071_GNU	1.85	-	A	6.5	40.8	30.10.16	06:40:18	ESM
ACC_04511_90017	0.63	1223	A	6.7	15.1	17.01.94	12:31:00	NGA-West2
ACC_04064_SLO	1.28	-	A	5.9	11.2	26.10.16	19:18:06	ESM
ACC_00496_YMNH13	1.36	788	B	5.9	23.4	15.03.11	22:31:00	KiK-net

Table 10.2 – Metadata of the selected waveforms for seismic zone Z1a soil class A period range 0.02-1.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; V_{S30}=average velocity of the station in the upper 30 m; SC=soil class; M_W=moment magnitude; R_{JB}= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_04053_SLO	1.68	-	A	5.4	13.0	26.10.16	17:10:36	ESM
ACC_04393_OITH05	1.66	1269	A	7.1	75.0	16.04.16	01:25:00	KiK-net
ACC_00041_MRM	0.81	1906	A	5.2	1.6	25.10.12	23:05:24	ESM
ACC_04072_MMO	0.65	-	A	6.5	9.8	30.10.16	06:40:18	ESM
ACC_00207_FKOH06	1.50	1002	A	6.6	79.2	20.03.05	10:53:00	KiK-net
ACC_04130_VGG	0.96	-	A	5.2	9.6	25.10.12	23:05:24	ESM
ACC_00386_ISKH02	1.37	721	B	5.2	16.6	25.03.07	18:11:00	KiK-net
ACC_04064_SLO	1.64	-	A	5.9	11.2	26.10.16	19:18:06	ESM
ACC_04164_CLO	1.32	-	A	4.2	2.0	28.08.16	15:55:35	ESM
ACC_04035_MNF	1.71	-	A	6	20.4	24.08.16	01:36:32	ESM
ACC_04088_NOT	1.00	-	A	5.6	49.4	13.12.90	00:24:26	ESM

Table 10.3 – Metadata of the selected waveforms for seismic zone Z1a soil class A period range 0.25-4.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; V_{S30}=average velocity of the station in the upper 30 m; SC=soil class; M_W=moment magnitude; R_{JB}= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_00496_YMNH13	1.94	788	B	5.9	23.4	15.03.11	22:31:00	KiK-net
ACC_04035_MNF	1.64	-	A	6.0	20.4	24.08.16	01:36:32	ESM
ACC_03711_MYGH11	1.69	859	E	6.9	57.0	14.06.08	08:43:00	KiK-net
ACC_04388_FKOH06	0.82	1002	A	7.1	87.1	16.04.16	01:25:00	KiK-net
ACC_04390_KMMH11	1.68	1292	A	7.1	44.1	16.04.16	01:25:00	KiK-net
ACC_00600_OKYH14	0.78	710	B	6.6	33.4	06.10.00	13:30:00	KiK-net
ACC_03535_SAGH04	1.08	724	E	6.6	36.3	20.03.05	10:53:00	KiK-net
ACC_00173_SAGH05	0.72	1000	A	6.6	58.1	20.03.05	10:53:00	KiK-net
ACC_00722_YMNH13	1.60	788	B	6.2	57.6	11.08.09	05:07:00	KiK-net
ACC_04062_MNF	0.96	-	A	5.9	6.8	26.10.16	19:18:06	ESM
ACC_04057_ACC	1.26	-	A	5.9	18.1	26.10.16	19:18:06	ESM

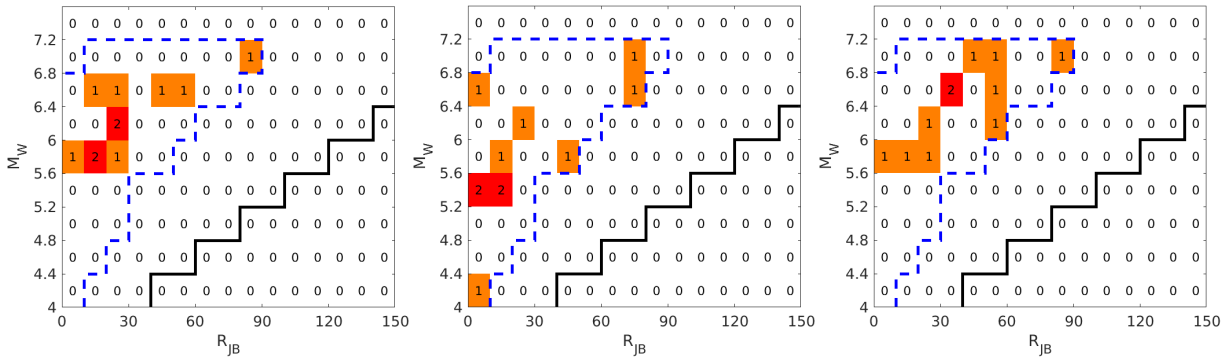

Figure 10.5 – Selected number of recordings by bin of Joyner-Boore distances (10 km width) and M_W (0.4 unit) for the period ranges 0.1-2.0s (left panel), 0.02-1.0 s (central panel) and 0.25-4.0 s (right panel), soil class A. The dashed blue lines indicate the areas where the probability of exceedance (over all IMTs) is significant for the relevant SIA261 zone for return period 975 years, following the approach illustrated in Bergamo et al. (2022). The black continuous lines indicate our limit for the first selection of waveforms.

The search was repeated for soil class B, resulting in 45 compatible selections for the period range 0.1-2.0 s and RMSE ranging between 0.050 and 0.109. Among these, we choose the one with the lowest RMSE (Fig. 10.6, left panel). In Table 10.4 the selected waveforms metadata are reported. For the period range 0.02-1.0 s, the code found 75 possible compatible combinations with RMSE ranging between 0.081 and 0.125 ln units for soil class B. Among these, we choose the one with the lowest RMSE (Fig. 10.6, central panel). In Table 10.5 the selected waveforms metadata are reported. The selection for the period range 0.25-4.0 s extracted 50 compatible combinations, with RMSE in the range 0.065-0.128, from which the one having RMSE 0.065 is taken (Fig. 10.6, right panel). In Table 10.6 the selected waveforms metadata are reported.

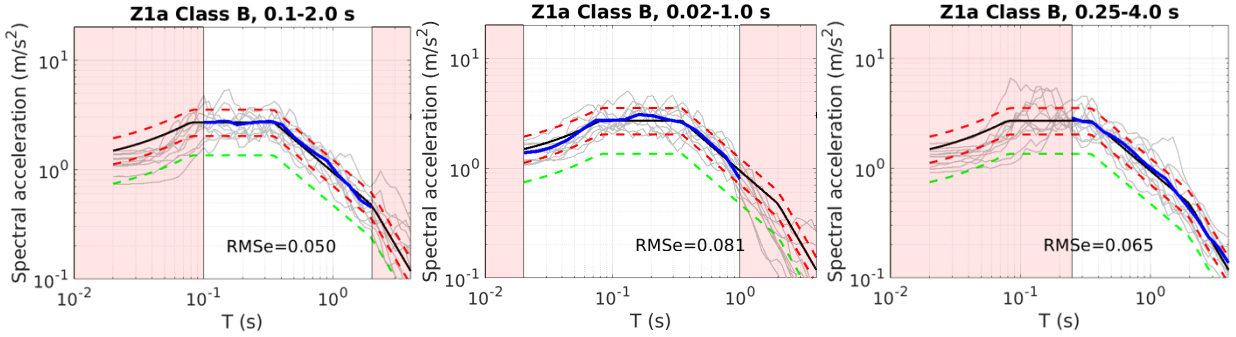

Figure 10.6 – Extracted sets of n=11 geometric mean of two-components, scaled response spectra (gray lines) for Z1a zone using as target the SIA261 elastic response spectra (black line) for soil class B. The blue line is the mean of the spectra. All the Eurocode 8 (2022) criteria of this document (section 9) are satisfied. Red dashed lines indicate the 1.3 and 0.75 ratio threshold; the green dashed line indicates the 0.5 ratio threshold. Shadowed red areas highlight the period range not considered for the selection.

In general, the selected waveforms for Z1a soil class B fall inside the areas where probability of exceedance (over all IMTs) is significant for the seismic zone considering the return period of 975 years (Fig. 10.7) and no more than 2 records from the same earthquake are present in each set.

Table 10.4 – Metadata of the selected waveforms for seismic zone Z1a soil class B period range 0.1-2.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; V_{S30}=average velocity of the station in the upper 30 m; SC=soil class; M_W=moment magnitude; R_{JB}= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_01836_AKTH18	1.22	431	C	6.9	47.5	14.06.08	08:43:00	KiK-net
ACC_03995_SWS	1.77	587	B	7.2	31.8	04.04.10	22:40:00	NGA-West2
ACC_05514_KMMH13	1.53	403	C	7.1	34.9	16.04.16	01:25:00	KiK-net
ACC_00781_TYMH06	1.62	570	B	6.7	78.5	25.03.07	09:42:00	KiK-net
ACC_00815_FKSH16	1.92	532	B	6.6	80.5	11.04.11	17:16:00	KiK-net
ACC_01565_AQV	1.60	474	C	6.5	38.0	30.10.16	06:40:18	ESM
ACC_00324_BZZ	1.84	679	B	5.5	0.8	07.04.09	17:47:37	ESM
ACC_00308_CSC	1.50	698	B	5.6	17.0	14.10.97	15:23:09	ESM
ACC_00496_YMNH13	1.91	788	B	5.9	23.4	15.03.11	22:31:00	KiK-net
ACC_00924_NOR	0.68	423	C	5.9	6.1	26.10.16	19:18:06	ESM
ACC_05576_NGNH29	1.99	465	C	6.3	46.0	22.11.14	22:08:00	KiK-net

Table 10.5 – Metadata of the selected waveforms for seismic zone Z1a soil class B period range 0.02-1.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; V_{S30}=average velocity of the station in the upper 30 m; SC=soil class; M_W=moment magnitude; R_{JB}= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_03995_SWS	1.66	587	B	7.2	31.8	04.04.10	22:40:00	NGA-West2
ACC_00496_YMNH13	1.99	788	B	5.9	23.4	15.03.11	22:31:00	KiK-net
ACC_00026_SRT	1.71	871	A	5.6	24.6	13.12.90	00:24:26	ESM
ACC_00923_NRC	0.59	498	C	5.4	8.7	26.10.16	17:10:36	ESM
ACC_01836_AKTH18	1.21	431	C	6.9	47.5	14.06.08	08:43:00	KiK-net
ACC_00427_NIGH10	0.68	653	B	6.6	25.3	23.10.04	17:56:00	KiK-net
ACC_03158_AQA	1.89	549	E	5.4	11.2	09.04.09	00:52:59	ESM
ACC_00823_KYP1	1.68	550	B	6.4	98.5	18.11.97	13:07:38	ESM
ACC_00325_AQG	1.84	696	B	4.5	2.5	07.04.09	21:34:29	ESM
ACC_00276_CSC	0.66	698	B	6.5	12.8	30.10.16	06:40:18	ESM
ACC_01419_NGNH29	1.19	465	C	5.4	16.5	12.04.11	07:26:00	KiK-net

Table 10.6 – Metadata of the selected waveforms for seismic zone Z1a soil class B period range 0.25-4.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; V_{S30}=average velocity of the station in the upper 30 m; SC=soil class; M_W=moment magnitude; R_{JB}= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_00622_MTL	1.92	579	B	6.0	44.5	24.08.16	01:36:32	ESM
ACC_00924_NOR	0.80	423	C	5.9	6.1	26.10.16	19:18:06	ESM
ACC_00547_AQG	1.55	696	B	6.5	38.2	30.10.16	06:40:18	ESM
ACC_01882_NGNH29	1.45	465	C	6.6	47.0	16.07.07	10:13:00	KiK-net
ACC_03097_AMT	1.92	670	E	5.9	25.9	26.10.16	19:18:06	ESM
ACC_01565_AQV	1.96	474	C	6.5	38.0	30.10.16	06:40:18	ESM
ACC_05387_NGNH27	0.86	478	C	6.3	13.9	22.11.14	22:08:00	KiK-net
ACC_00815_FKSH16	1.53	532	B	6.6	80.5	11.04.11	17:16:00	KiK-net
ACC_04742_FKOH08	1.69	536	E	7.1	60.0	16.04.16	01:25:00	KiK-net
ACC_00781_TYMH06	1.41	570	B	6.7	78.5	25.03.07	09:42:00	KiK-net
ACC_00253_AQG	1.66	696	B	6.0	29.5	24.08.16	01:36:32	ESM

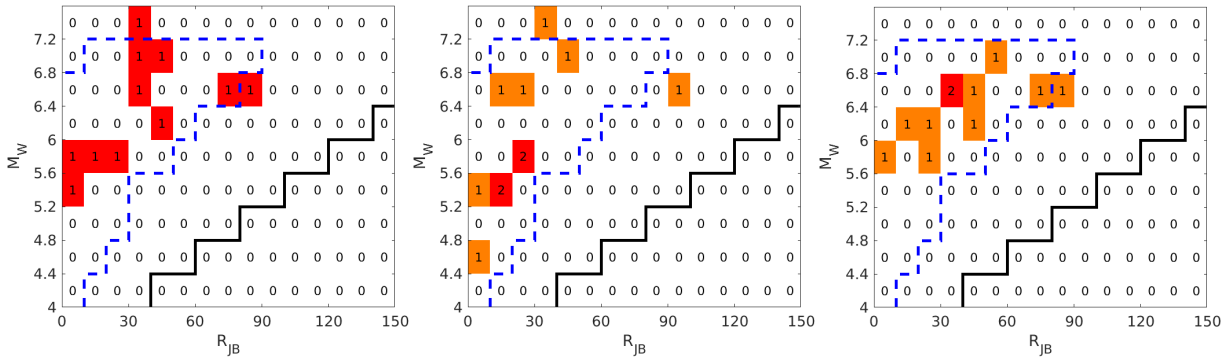

Figure 10.7 – Selected number of recordings by bin of Joyner-Boore distances (10 km width) and M_W (0.4 unit) for the period ranges 0.1-2.0s (left panel), 0.02-1.0 s (central panel) and 0.25-4.0 s (right panel), soil class B. The dashed blue lines indicate the areas where probability of exceedance (over all IMTs) is significant for the five SIA261 zones for return period 975 years, following the approach illustrated in Bergamo et al. (2022). The black continuous lines indicate our limit for the first selection of waveforms.

For soil class C, 47 compatible selections for the period range 0.1-2.0 s and RMSE ranging between 0.063 and 0.118 ln units are found. Among these, we choose the one with the lowest RMSE (Fig. 10.8, left). In Table 10.7 the selected waveforms metadata are reported. In the period range 0.02-1.0 s the code found 50 possible compatible combinations with RMSE ranging between 0.060 and 0.109 ln units. Among these, we choose the one with RMSE 0.067 to limit the records recorded by the same station to the maximum number of 3 (Fig. 10.8, central panel). In Table 10.8 the selected waveforms metadata are reported. The selection for the period range 0.25-4.0 s extracted 43 compatible combinations with RMSE in the range 0.051-0.129 ln units, from which the one having RMSE 0.051 is taken (Fig. 10.8). In Table 10.9 the selected waveforms metadata are reported.

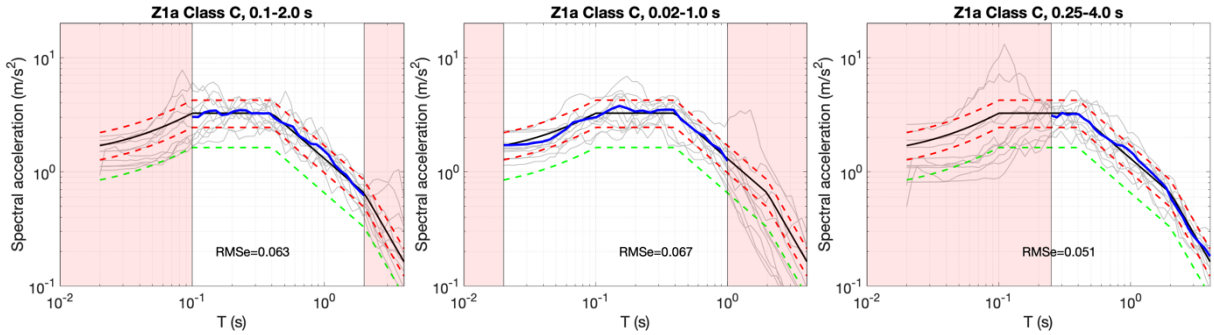

Figure 10.8 – Extracted sets of n=11 geometric mean of two-components scaled response spectra (gray lines) for Z1a zone using as target the SIA261 elastic response spectra (black line) for soil class C. The blue line is the mean of the spectra. All the Eurocode 8 (2022) criteria of this document (section 9) are satisfied. Red dashed lines indicate the 1.3 and 0.75 ratio threshold; the green dashed line indicates the 0.5 ratio threshold. Shadowed red areas highlight the period range not considered for the selection.

In general, the selected waveforms for Z1a soil class C fall inside the areas where the probability of exceedance (over all IMTs) is significant for the seismic zone considering the return period of 975 years (Fig. 10.9) and no more than 2 records from the same earthquake are present in each set.

Table 10.7 – Metadata of the selected waveforms for seismic zone Z1a soil class C period range 0.1-2.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_01836_AKTH18	1.53	431	C	6.9	47.5	14.06.08	08:43:00	KiK-net
ACC_03997_12149	1.52	385	C	7.1	56.4	16.10.99	--:--:--	NGA-West2
ACC_00924_NOR	0.65	423	C	5.9	6.1	26.10.16	19:18:06	ESM
ACC_01893_NIGH08	1.49	327	C	6.6	40.6	23.10.04	17:56:00	KiK-net
ACC_02015_AKTH03	1.84	320	C	6.9	60.0	14.06.08	08:43:00	KiK-net
ACC_05445_TTRH07	1.03	389	C	6.2	8.6	21.10.16	14:07:00	KiK-net
ACC_01342_NIGH11	0.77	375	C	6.2	17.2	12.03.11	03:59:00	KiK-net
ACC_03996_12149	0.84	385	C	7.3	21.8	28.06.92	11:58:00	NGA-West2
ACC_01346_NIGH18	1.11	311	C	6.2	23.5	12.03.11	03:59:00	KiK-net
ACC_01527_PHOB	0.66	404	C	6.0	4.5	28.09.04	17:15:00	NGA-West2
ACC_01567_TRL	1.45	380	C	6.5	34.9	30.10.16	06:40:18	ESM

Table 10.8 – Metadata of the selected waveforms for seismic zone Z1a soil class C period range 0.02-1.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; V_{S30}=average velocity of the station in the upper 30 m; SC=soil class; M_W=moment magnitude; R_{JB}= Joyner and Boore distance; DD.MM.YY. = day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_00923_NRC	0.80	498	C	5.4	8.7	26.10.16	17:10:36	ESM
ACC_01529_CHR	1.00	471	C	5.5	4.3	31.10.07	03:04:00	NGA-West2
ACC_01342_NIGH11	0.82	375	C	6.2	17.2	12.03.11	03:59:00	KiK-net
ACC_01237_NIGH11	0.90	375	C	5.2	21.0	04.01.01	13:18:00	KiK-net
ACC_00918_NOR	2.00	423	C	4.2	3.7	03.09.16	01:34:12	ESM
ACC_00924_NOR	0.82	423	C	5.9	6.1	26.10.16	19:18:06	ESM
ACC_01836_AKTH18	1.39	431	C	6.9	47.5	14.06.08	08:43:00	KiK-net
ACC_01419_NGNH29	0.93	465	C	5.4	16.5	12.04.11	07:26:00	KiK-net
ACC_05387_NGNH27	1.57	478	C	6.3	13.9	22.11.14	22:08:00	KiK-net
ACC_01252_NIGH11	1.50	375	C	5.8	24.0	27.10.04	10:40:00	KiK-net
ACC_05351_HYGH01	0.90	348	C	5.8	10.3	13.04.13	05:33:00	KiK-net

Table 10.9 – Metadata of the selected waveforms for seismic zone Z1a soil class C period range 0.25-4.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; V_{S30}=average velocity of the station in the upper 30 m; SC=soil class; M_W=moment magnitude; R_{JB}= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_03996_12149	0.69	385	C	7.3	21.8	28.06.92	11:58:00	NGA-West2
ACC_00924_NOR	1.19	423	C	5.9	6.1	26.10.16	19:18:06	ESM
ACC_03997_12149	1.53	385	C	7.1	56.4	16.10.99	--:--:--	NGA-West2
ACC_05445_TTRH07	1.23	389	C	6.2	8.6	21.10.16	14:07:00	KiK-net
ACC_01346_NIGH18	1.00	311	C	6.2	23.5	12.03.11	03:59:00	KiK-net
ACC_01986_24644	1.16	421	C	6.7	41.3	17.01.94	12:31:00	NGA-West2
ACC_05506_NIGH18	1.24	311	C	6.3	34.2	22.11.14	22:08:00	KiK-net
ACC_02146_14560	1.82	322	C	6.7	53.9	17.01.94	12:31:00	NGA-West2
ACC_01342_NIGH11	0.83	375	C	6.2	17.2	12.03.11	03:59:00	KiK-net
ACC_01901_NIGH18	1.37	311	C	6.6	47.9	16.07.07	10:13:00	KiK-net
ACC_05736_MYGH07	1.72	366	C	7.0	108.6	22.11.16	05:59:00	KiK-net

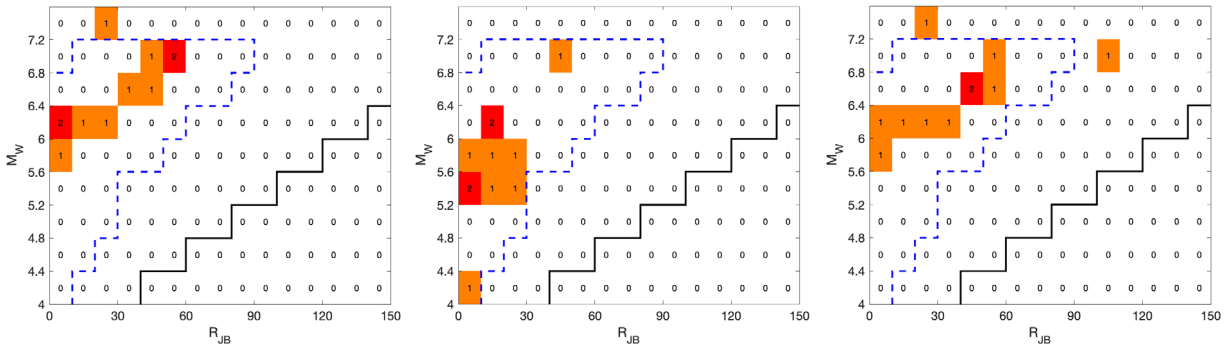

Figure 10.9 – Selected number of recordings by bin of Joyner-Boore distances (10 km width) and M_W (0.4 unit) for the period ranges 0.1-2.0s (left panel), 0.02-1.0 s (central panel) and 0.25-4.0 s (right panel) soil class C. The dashed blue lines indicate the areas where probability of exceedance (over all IMTs) is significant for the five SIA261 zones for return period 975 years following the approach illustrated in Bergamo et al. (2022). The black continuous lines indicate our limit for the first selection of waveforms.

For the period range 0.1-2.0 s, soil class D, we find 42 compatible selections with RMSE ranging between 0.057 and 0.119 ln units. Among these, we choose the one with the lowest RMSE (Fig. 10.10, left panel). In Table 10.10 the selected waveforms metadata are reported. In the period range 0.02-1.0 s the code found 49 possible compatible combinations with RMSE ranging between 0.050 and 0.092 ln units. Among these, we choose the one with the lowest RMSE (Fig. 10.10). In Table 10.11 the selected waveforms metadata are reported. The selection for the period range 0.25-4.0 s extracted 37 compatible combinations with RMSE in the range 0.058-0.139 ln units, from which the one having RMSE 0.058 is taken (Fig. 10.10, right panel). In Table 10.12 the selected waveforms metadata are reported.

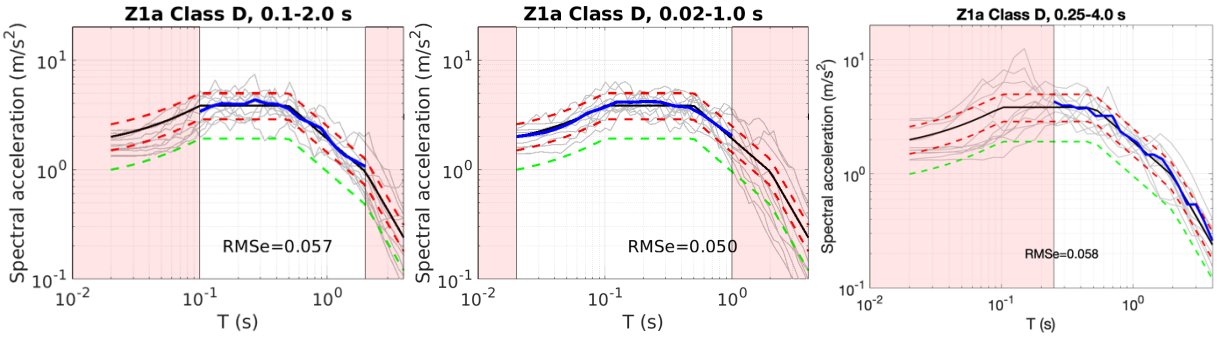

Figure 10.10 – Extracted sets of n=11 geometric mean of two components scaled response spectra (gray lines) for Z1a zone using as target the SIA261 elastic response spectra (black line) for soil class D. The blue line is the mean of the spectra. All the Eurocode 8 (2022) criteria of this document (section 9) are satisfied. Red dashed lines indicate the 1.3 and 0.75 ratio threshold; the green dashed line indicates the 0.5 ratio threshold. Shadowed red areas highlight the period range not considered for the selection.

In general, the selected waveforms for Z1a, soil class D, fall inside the areas where the probability of exceedance (over all IMTs) is significant for the seismic zone considering the return period of 975 years (Fig. 10.11), and no more than 2 records from the same earthquake are present in each set.

Table 10.10 – Metadata of the selected waveforms for seismic zone Z1a soil class D period range 0.1-2.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; V_{S30}=average velocity of the station in the upper 30 m; SC=soil class; M_W=moment magnitude; R_{JB}= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_00924_NOR	1.06	423	C	5.9	6.1	26.10.16	19:18:06	ESM
ACC_03997_12149	1.80	385	C	7.1	56.4	16.10.99	--:--:--	NGA-West2
ACC_02537_MRN	0.57	208	D	6.1	4.3	20.05.12	02:03:50	ESM
ACC_04007_WES	0.50	269	D	7.2	10.3	04.04.10	22:40:00	NGA-West2
ACC_02543_MRN	0.73	208	D	6.0	0.0	29.05.12	07:00:02	ESM
ACC_04006_ERR	1.35	253	D	7.2	50.9	04.04.10	22:40:00	NGA-West2
ACC_05764_IBRH20	1.67	244	D	5.8	15.4	14.03.12	21:05:00	KiK-net
ACC_05445_TTRH07	0.89	389	C	6.2	8.6	21.10.16	14:07:00	KiK-net
ACC_01527_PHOB	0.81	404	C	6.0	4.5	28.09.04	17:15:00	NGA-West2
ACC_01346_NIGH18	1.32	311	C	6.2	23.5	12.03.11	03:59:00	KiK-net
ACC_01572_PAT2	1.82	369	C	6.5	37.0	15.06.95	00:15:47	ESM

Table 10.11 – Metadata of the selected waveforms for seismic zone Z1a soil class D period range 0.02-1.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; V_{S30}=average velocity of the station in the upper 30 m; SC=soil class; M_W=moment magnitude; R_{JB}= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_05445_TTRH07	1.07	389	C	6.2	8.6	21.10.16	14:07:00	KiK-net
ACC_02485_NVL	1.35	190	D	5.4	6.5	15.10.96	09:56:00	ESM
ACC_05764_IBRH20	1.84	244	D	5.8	15.4	14.03.12	21:05:00	KiK-net
ACC_00924_NOR	1.25	423	C	5.9	6.1	26.10.16	19:18:06	ESM
ACC_01237_NIGH11	1.37	375	C	5.2	21.0	04.01.01	13:18:00	KiK-net
ACC_01572_PAT2	1.88	369	C	6.5	37.0	15.06.95	00:15:47	ESM
ACC_01529_CHR	0.78	471	C	5.5	4.3	31.10.07	03:04:00	NGA-West2
ACC_01527_PHOB	0.60	404	C	6.0	4.5	28.09.04	17:15:00	NGA-West2
ACC_02490_CLF	1.04	145	D	6.0	1.6	26.09.97	09:40:24	ESM
ACC_02543_MRN	0.66	208	D	6.0	0.0	29.05.12	07:00:02	ESM
ACC_04635_NGNH28	1.36	1172	E	6.3	12.1	22.11.14	22:08:00	KiK-net

Table 10.12 – Metadata of the selected waveforms for seismic zone Z1a soil class D period range 0.25-4.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; V_{S30}=average velocity of the station in the upper 30 m; SC=soil class; M_W=moment magnitude; R_{JB}= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_02537_MRN	0.51	208	D	6.1	4.3	20.05.0012	02:03:50	ESM
ACC_01346_NIGH18	1.34	311	C	6.2	23.5	12.03.0011	03:59:00	KiK-net
ACC_04635_NGNH28	0.84	1172	E	6.3	12.1	22.11.0014	22:08:00	KiK-net
ACC_01901_NIGH18	1.77	311	C	6.6	47.9	16.07.0007	10:13:00	KiK-net
ACC_01238_NIGH11	0.56	375	C	6.6	0.0	23.10.0004	17:56:00	KiK-net
ACC_01266_NIGH11	1.08	375	C	6.6	27.8	16.07.0007	10:13:00	KiK-net
ACC_02791_FKSH11	0.98	240	D	6.6	31.4	11.04.0011	17:16:00	KiK-net
ACC_05387_NGNH27	1.04	478	C	6.3	13.9	22.11.0014	22:08:00	KiK-net
ACC_02543_MRN	0.75	208	D	6.0	0.0	29.05.0012	07:00:02	ESM
ACC_01986_24644	1.41	421	C	6.7	41.3	17.01.0094	12:31:00	NGA-West2
ACC_05445_TTRH07	1.37	389	C	6.2	8.6	21.10.0016	14:07:00	KiK-net

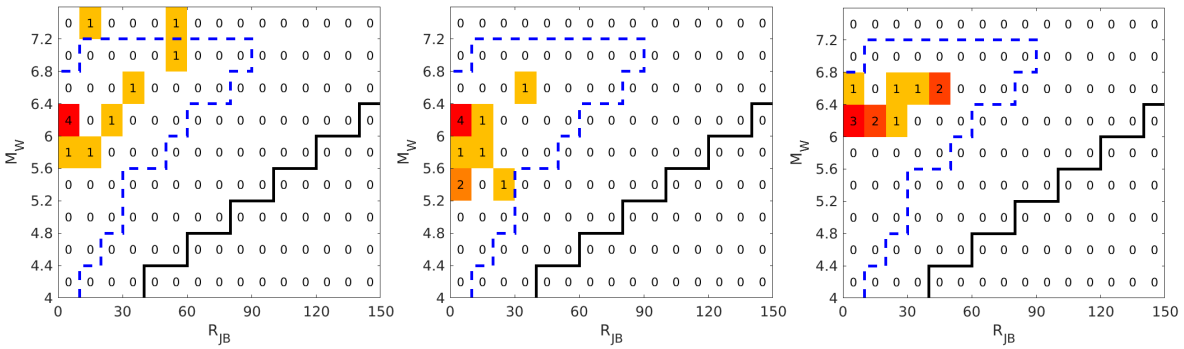

Figure 10.11 – Selected number of recordings by bin of Joyner-Boore distances (10 km width) and M_W (0.2 unit) for the period ranges 0.1-2.0s (left panel), 0.02-1.0 s (central panel) and 0.25-4.0 s (right panel) soil class D. The dashed blue lines indicate the areas where probability of exceedance (over all IMTs) is significant for the five SIA261 zones for return period 975 years following the approach illustrated in Bergamo et al. (2022). The black continuous lines indicate our limit for the first selection of waveforms.

For the period range 0.1-2.0 s, soil class E, we find 8 compatible selections with RMSE ranging between 0.084 and 0.134 ln units. Among these, we choose the one with the lowest RMSE (Fig. 10.12, left panel). In Table 10.13 the selected waveforms metadata are reported. In the period range 0.02-1.0 s, the code found 25 possible compatible combinations with RMSE ranging between 0.117 and 0.156 ln units for soil class E. Among these we choose the one with the lowest RMSE (Fig. 10.12, center panel). In Table 10.14 the selected waveforms metadata are reported. The selection for period range 0.25-4.0 s extracted 15 compatible combinations with RMSE in the range 0.091-0.135 ln units, from which the one having RMSE 0.091 is chosen (Fig. 10.12, right panel). In Table 10.15 the selected waveforms metadata are reported.

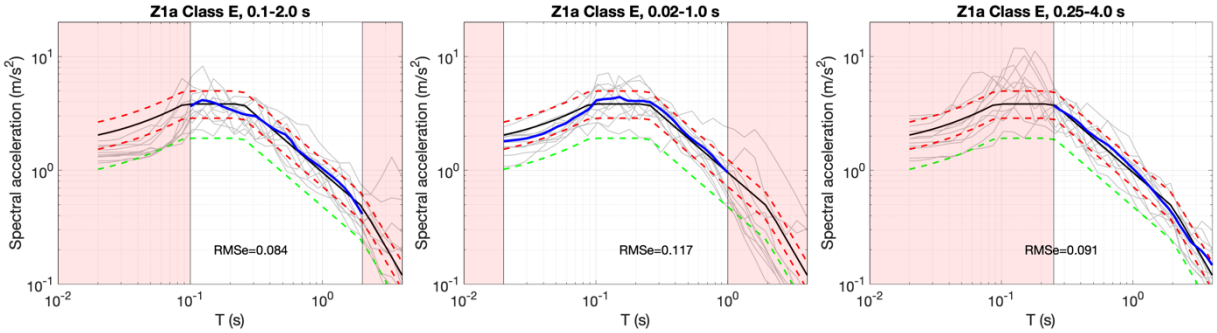

Figure 10.12 – Extracted sets of n=11 geometric mean of two components scaled response spectra (gray lines) for Z1a zone using as target the SIA261 elastic response spectra (black line) for soil class E. The blue line is the mean of the spectra. All the Eurocode 8 (2022) criteria of this document (section 9) are satisfied. Red dashed lines indicate the 1.3 and 0.75 ratio threshold; the green dashed line indicates the 0.5 ratio threshold. Shadowed red areas highlight the period range not considered for the selection.

In general, the selected waveforms for Z1a, soil class E, fall inside the areas where probability of exceedance (over all IMTs) is significant for the seismic zone considering the return period of 975 years (Fig. 10.13), and no more than 2 records from the same earthquake are present in each set.

Table 10.13 – Metadata of the selected waveforms for seismic zone Z1a, soil class E, period range 0.1-2.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; V_{S30}=average velocity of the station in the upper 30 m; SC=soil class; M_W=moment magnitude; R_{JB}= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_01836_AKTH18	1.32	431	C	6.9	47.5	14.06.08	08:43:00	KiK-net
ACC_04742_FKOH08	1.67	536	E	7.1	60.0	16.04.16	01:25:00	KiK-net
ACC_01882_NGNH29	1.32	465	C	6.6	47.0	16.07.07	10:13:00	KiK-net
ACC_05835_FKSH11	1.22	240	D	7.0	84.4	22.11.16	05:59:00	KiK-net
ACC_05628_MYZH08	1.00	374	C	7.1	53.9	16.04.16	01:25:00	KiK-net
ACC_01658_NGNH29	1.27	465	C	6.6	39.3	23.10.04	17:56:00	KiK-net
ACC_02165_AKTH16	1.67	375	C	6.9	61.4	14.06.08	08:43:00	KiK-net
ACC_04002_11023	1.53	212	D	7.2	66.7	04.04.10	22:40:00	NGA-West2
ACC_03159_AQP	1.77	836	E	5.4	10.4	09.04.09	00:52:59	ESM
ACC_01565_AQV	1.71	474	C	6.5	38.0	30.10.16	06:40:18	ESM
ACC_03097_AMT	1.80	670	E	5.9	25.9	26.10.16	19:18:06	ESM

Table 10.14 – Metadata of the selected waveforms for seismic zone Z1a, soil class E, period range 0.02-1.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the event , then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_00957_KOZ1	1.18	482	C	6.6	10.7	13.05.95	08:47:13	ESM
ACC_01419_NGNH29	1.14	465	C	5.4	16.5	12.04.11	07:26:00	KiK-net
ACC_01009_AQV	1.53	474	C	5.4	11.0	09.04.09	00:52:59	ESM
ACC_03153_AQP	1.88	836	E	5.5	9.6	07.04.09	17:47:37	ESM
ACC_03158_AQA	1.92	549	E	5.4	11.2	09.04.09	00:52:59	ESM
ACC_01836_AKTH18	1.39	431	C	6.9	47.5	14.06.08	08:43:00	KiK-net
ACC_03084_AMT	1.93	670	E	5.3	19.6	24.08.16	02:33:29	ESM
ACC_04635_NGNH28	1.05	1172	E	6.3	12.1	22.11.14	22:08:00	KiK-net
ACC_03203_FVZ	1.28	509	E	5.1	10.9	21.06.13	10:33:56	ESM
ACC_05628_MYZH08	1.46	374	C	7.1	53.9	16.04.16	01:25:00	KiK-net
ACC_04551_NIGH19	1.74	625	E	6.6	63.2	16.07.07	10:13:00	KiK-net

Table 10.15 – Metadata of the selected waveforms for seismic zone Z1a, soil class E, period range 0.25-4.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the event , then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_03739_SAGH02	1.36	558	E	6.6	59.3	20.03.05	10:53:00	KiK-net
ACC_03097_AMT	1.73	670	E	5.9	25.9	26.10.16	19:18:06	ESM
ACC_03084_AMT	1.88	670	E	5.3	19.6	24.08.16	02:33:29	ESM
ACC_03150_AQA	0.58	549	E	6.1	0.0	06.04.09	01:32:40	ESM
ACC_03301_AKTH06	1.48	455	E	6.9	19.2	14.06.08	08:43:00	KiK-net
ACC_01836_AKTH18	1.37	431	C	6.9	47.5	14.06.08	08:43:00	KiK-net
ACC_03535_SAGH04	1.46	724	E	6.6	36.3	20.03.05	10:53:00	KiK-net
ACC_01565_AQV	1.78	474	C	6.5	38.0	30.10.16	06:40:18	ESM
ACC_02670_FKSH11	1.54	240	D	5.9	28.2	12.04.11	14:07:00	KiK-net
ACC_04742_FKOH08	1.64	536	E	7.1	60.0	16.04.16	01:25:00	KiK-net
ACC_01882_NGNH29	1.68	465	C	6.6	47.0	16.07.07	10:13:00	KiK-net

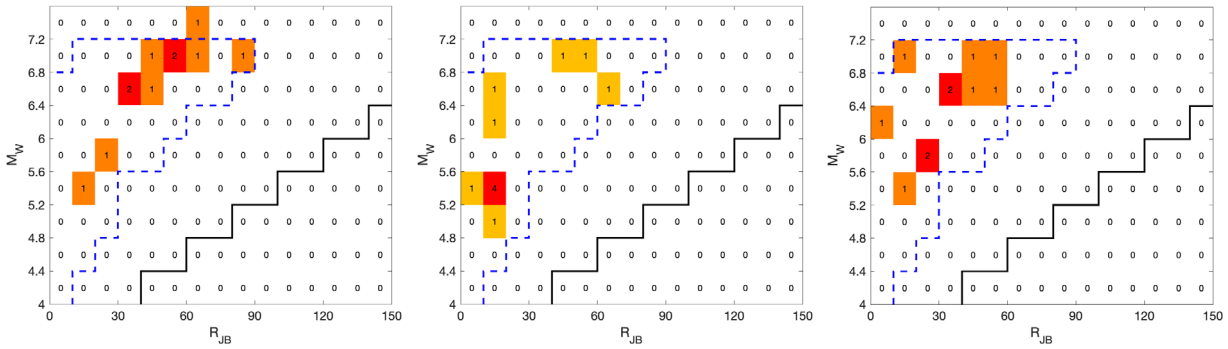

Figure 10.13 – Selected number of recordings by bin of Joyner-Boore distances (10 km width) and M_W (0.4 unit) for the period ranges 0.1-2.0s (left panel), 0.02-1.0 s (central panel) and 0.25-4.0 s (right panel) soil class E. The dashed blue lines indicate the areas where the probability of exceedance (over all IMTs) is significant for the five SIA261 zones for return period 975 years following the approach illustrated in Bergamo et al. (2022). The black continuous lines indicate our limit for the first selection of waveforms.

10.2 Seismic zone Z1b

The zone Z1b covers the NW of Switzerland, an area N of Canton Ticino and a belt spanning central Switzerland from St. Gallen to Lausanne (see Fig. 7.1). The Baker and Lee (2018) code found 89 possible compatible combinations, with RMSE ranging between 0.040 and 0.130 ln units for soil class A and spectral period range 0.1-2.0 s. Among these, we choose the one with the lowest RMSE (Fig. 10.14). In Table 10.16 the selected waveforms metadata are reported. For the period range 0.02-1.0 s the code found 99 possible compatible combinations with RMSE ranging between 0.079 and 0.121 ln units (soil class A). Among these, we choose the one with the lowest RMSE (Fig. 10.14). In Table 10.17 the selected waveforms metadata are reported. The selection for period range 0.25-4.0 s extracted 50 compatible combinations with RMSE in the range 0.068-0.120 ln units, from which the one having RMSE 0.068 is chosen (Fig. 10.14). In Table 10.18 the selected waveforms metadata are reported.

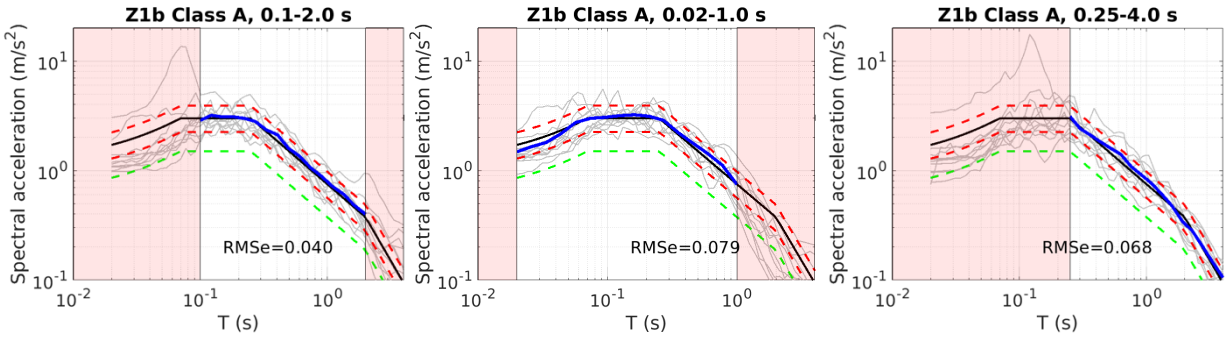

Figure 10.14 – Extracted sets of n=11 geometric mean of two components scaled response spectra (gray lines) for Z1b zone using as target the SIA261 elastic response spectra (black line) for soil class A. The blue line is the mean of the spectra. All the Eurocode 8 (2022) criteria of this document (section 9) are satisfied. Red dashed lines indicate the 1.3 and 0.75 ratio threshold; the green dashed line indicates the 0.5 ratio threshold. Shadowed red areas highlight the period range not considered for the selection.

The selected waveforms for Z1b soil class A largely fall inside the area where the probability of exceedance (over all IMTs) is significant for the seismic zone considering the return period of 975 years (Fig. 10.15), and no more than 2 records of the same earthquake are present in each set.

Table 10.16 – Metadata of the selected waveforms for seismic zone Z1b, soil class A, period range 0.1-2.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording , then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_04064_SLO	1.78	-	A	5.9	11.2	26.10.16	19:18:06	ESM
ACC_04062_MNF	1.21	-	A	5.9	6.8	26.10.16	19:18:06	ESM
ACC_05089_KMMH07	0.68	765	B	6.1	23.1	14.04.16	21:26:00	KiK-net
ACC_04035_MNF	1.92	-	A	6.0	20.4	24.08.16	01:36:32	ESM
ACC_04076_TER	1.49	-	A	6.5	32.9	30.10.16	06:40:18	ESM
ACC_03159_AQP	1.78	836	E	5.4	10.4	09.04.09	00:52:59	ESM
ACC_00173_SAGH05	0.97	1000	A	6.6	58.1	20.03.05	10:53:00	KiK-net
ACC_00041_MRM	1.12	1906	A	5.2	1.6	25.10.12	23:05:24	ESM
ACC_00017_LSS	1.99	1091	A	6.5	25.1	30.10.16	06:40:18	ESM
ACC_00062_OKYH07	1.90	929	A	6.6	17.2	06.10.00	13:30:00	KiK-net
ACC_00065_SMNH10	0.73	967	A	6.6	20.8	06.10.00	13:30:00	KiK-net

Table 10.17 – Metadata of the selected waveforms for seismic zone Z1b, soil class A, period range 0.02-1.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording , then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_04072_MMO	0.66	-	A	6.5	9.8	30.10.16	06:40:18	ESM
ACC_04053_SLO	1.84	-	A	5.4	13.0	26.10.16	17:10:36	ESM
ACC_04130_VGG	1.21	-	A	5.2	9.6	25.10.12	23:05:24	ESM
ACC_00041_MRM	1.36	1906	A	5.2	1.6	25.10.12	23:05:24	ESM
ACC_04061_MMO	0.82	-	A	5.9	10.4	26.10.16	19:18:06	ESM
ACC_04164_CLO	1.87	-	A	4.2	2.0	28.08.16	15:55:35	ESM
ACC_00207_FKOH06	1.96	1002	A	6.6	78.2	20.03.05	10:53:00	KiK-net
ACC_04104_VGG	1.64	-	A	5.6	1.6	09.09.98	11:28:00	ESM
ACC_00386_ISKH02	1.71	721	B	5.2	16.6	25.03.07	18:11:00	KiK-net
ACC_04076_TER	1.61	-	A	6.5	32.9	30.10.16	06:40:18	ESM
ACC_04062_MNF	1.14	-	A	5.9	6.8	26.10.16	19:18:06	ESM

Table 10.18 – Metadata of the selected waveforms for seismic zone Z1b, soil class A, period range 0.25-4.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording , then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_04388_FKOH06	1.11	1002	A	7.1	87.1	16.04.16	01:25:00	KiK-net
ACC_00600_OKYH14	0.98	710	B	6.6	33.4	06.10.00	13:30:00	KiK-net
ACC_04062_MNF	1.28	-	A	5.9	6.8	26.10.16	19:18:06	ESM
ACC_04511_90017	0.75	1223	A	6.7	15.1	17.01.94	12:31:00	NGA-West2
ACC_04390_KMMH11	1.92	1292	A	7.1	44.1	16.04.16	01:25:00	KiK-net
ACC_04057_ACC	1.78	-	A	5.9	18.1	26.10.16	19:18:06	ESM
ACC_00291_ATH2	1.19	706	B	5.9	16.0	07.09.99	11:56:49	ESM
ACC_04035_MNF	1.71	-	A	6.0	20.4	24.08.16	01:36:32	ESM
ACC_04512_24047	0.74	996	A	6.7	23.1	17.01.94	12:31:00	NGA-West2
ACC_00173_SAGH05	1.28	1000	A	6.6	58.1	20.03.05	10:53:00	KiK-net
ACC_00496_YMNH13	1.96	788	B	5.9	23.4	15.03.11	22:31:00	KiK-net

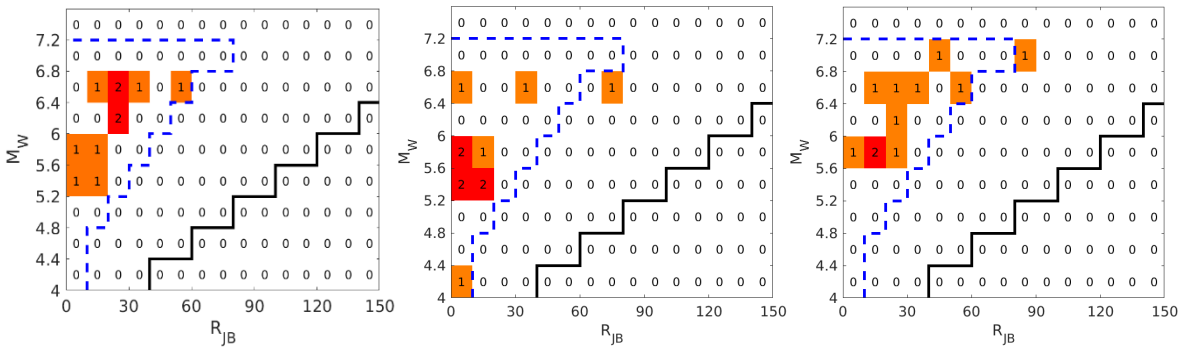

Figure 10.15 – Selected number of recordings by bin of Joyner-Boore distances (10 km width) and M_W (0.4 unit) for the period ranges 0.1-2.0s (left panel), 0.02-1.0 s (central panel) and 0.25-4.0 s (right panel) soil class A. The dashed blue lines indicate the areas where probability of exceedance (over all IMTs) is significant for the five SIA261 zones for return period 975 years following the approach illustrated in Bergamo et al. (2022). The black continuous lines indicate our limit for the first selection of waveforms.

The search was repeated for soil class B, resulting in 30 compatible selections for the period range 0.1-2.0 s, with RMSE ranging between 0.074 and 0.122. Among these, we choose the one with the lowest RMSE (Fig. 10.16, left panel). In Table 10.19 the selected waveforms metadata are reported. For the period range 0.02-1.0 s the code found 34 possible compatible combinations with RMSE ranging between 0.085 and 0.134 ln units (soil class B). Among these we choose the one with the lowest RMSE (Fig. 10.16, center panel). In Table 10.20 the selected waveforms metadata are reported. The selection for period range 0.25-4.0 s extracted 34 compatible combinations with RMSE in the range 0.090-0.134, from which the one having RMSE 0.090 is taken (Fig. 10.16, right panel). In Table 10.21 the selected waveforms metadata are reported.

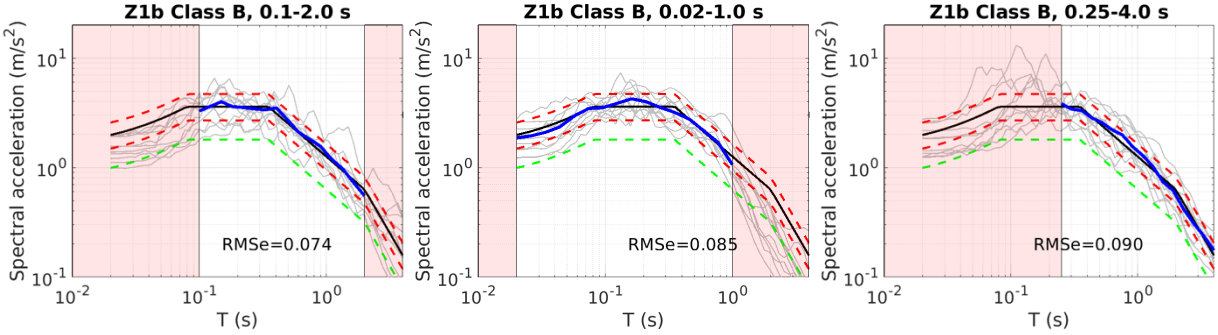

Figure 10.16 – Extracted sets of n=11 geometric mean of two components scaled response spectra (gray lines) for Z1b zone using as target the SIA261 elastic response spectra (black line) for soil class B. The blue line is the mean of the spectra. All the Eurocode 8 (2022) criteria of this document (section 9) are satisfied. Red dashed lines indicate the 1.3 and 0.75 ratio threshold; the green dashed line indicates the 0.5 ratio threshold. Shadowed red areas highlight the period range not considered for the selection.

The selected waveforms for Z1b soil class B fall inside the areas where probability of exceedance (over all IMTs) is significant for the seismic zone considering the return period of 975 years (Fig. 10.17), and no more of 2 records of the same earthquake are present in each set.

Table 10.19 – Metadata of the selected waveforms for seismic zone Z1b, soil class B, period range 0.1-2.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_00924_NOR	0.70	423	C	5.9	6.1	26.10.16	19:18:06	ESM
ACC_00276_CSC	1.17	698	B	6.5	12.8	30.10.16	06:40:18	ESM
ACC_00308_CSC	1.71	698	B	5.6	17.0	14.10.97	15:23:09	ESM
ACC_03995_SWS	1.60	587	B	7.2	31.8	04.04.10	22:40:00	NGA-West2
ACC_00781_TYMH06	1.98	570	B	6.7	78.5	25.03.07	09:42:00	KiK-net
ACC_05387_NGNH27	1.06	478	C	6.3	13.9	22.11.14	22:08:00	KiK-net
ACC_01527_PHOB	0.73	404	C	6.0	4.5	28.09.04	17:15:00	NGA-West2
ACC_01836_AKTH18	1.67	431	C	6.9	47.5	14.06.08	08:43:00	KiK-net
ACC_05514_KMMH13	1.55	403	C	7.1	34.9	16.04.16	01:25:00	KiK-net
ACC_01565_AQV	1.78	474	C	6.5	38.0	30.10.16	06:40:18	ESM
ACC_05089_KMMH07	1.26	765	B	6.1	23.1	14.04.16	21:26:00	KiK-net

Table 10.20 – Metadata of the selected waveforms for seismic zone Z1b, soil class B, period range 0.02-1.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording , then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_00923_NRC	0.94	498	C	5.4	8.7	26.10.16	17:10:36	ESM
ACC_00276_CSC	0.89	698	B	6.5	12.8	30.10.16	06:40:18	ESM
ACC_00254_CSC	1.28	698	B	6.0	11.6	24.08.16	01:36:32	ESM
ACC_00781_TYMH06	1.59	570	B	6.7	78.5	25.03.07	09:42:00	KiK-net
ACC_01529_CHR	1.02	471	C	5.5	4.3	31.10.07	03:04:00	NGA-West2
ACC_00427_NIGH10	1.11	653	B	6.6	25.3	23.10.04	17:56:00	KiK-net
ACC_00325_AQG	1.97	696	B	4.5	2.5	07.04.09	21:34:29	ESM
ACC_01419_NGNH29	1.17	465	C	5.4	16.5	12.04.11	07:26:00	KiK-net
ACC_00270_CSC	1.99	698	B	5.4	18.7	26.10.16	17:10:36	ESM
ACC_00319_AQG	0.52	696	B	6.1	0.0	06.04.09	01:32:40	ESM
ACC_05089_KMMH07	1.41	765	B	6.1	23.1	14.04.16	21:26:00	KiK-net

Table 10.21 – Metadata of the selected waveforms for seismic zone Z1b, soil class B, period range 0.25-4.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording , then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_00894_NOR	0.65	423	C	6.0	2.3	24.08.16	01:36:32	ESM
ACC_00924_NOR	1.15	423	C	5.9	6.1	26.10.16	19:18:06	ESM
ACC_00547_AQG	1.93	696	B	6.5	38.2	30.10.16	06:40:18	ESM
ACC_03739_SAGH02	1.87	558	E	6.6	59.3	20.03.05	10:53:00	KiK-net
ACC_00306_MTL	1.96	579	B	6.0	19.0	26.09.97	09:40:24	ESM
ACC_01565_AQV	1.82	474	C	6.5	38.0	30.10.16	06:40:18	ESM
ACC_03301_AKTH06	1.34	455	E	6.9	19.2	14.06.08	08:43:00	KiK-net
ACC_00781_TYMH06	1.82	570	B	6.7	78.5	25.03.07	09:42:00	KiK-net
ACC_03995_SWS	1.61	587	B	7.2	31.8	04.04.10	22:40:00	NGA-West2
ACC_03150_AQA	0.65	549	E	6.1	0.0	06.04.09	01:32:40	ESM
ACC_01882_NGNH29	1.79	465	C	6.6	47.0	16.07.07	10:13:00	KiK-net

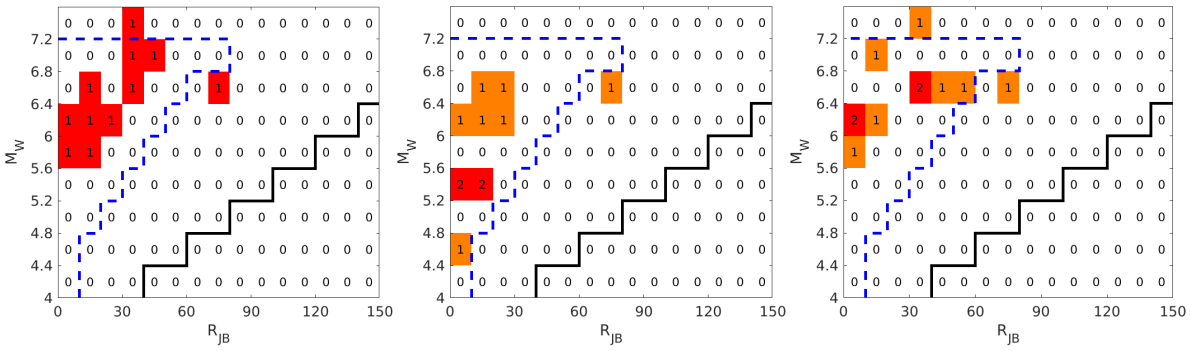

Figure 10.17 – Selected number of recordings by bin of Joyner-Boore distances (10 km width) and M_W (0.2 unit) for the period ranges 0.1-2.0s (left panel), 0.02-1.0 s (central panel) and 0.25-4.0 s (right panel), soil class B. The dashed blue lines indicate the areas where probability of exceedance (over all IMTs) is significant for the five SIA261 zones for return period 975 years following the approach illustrated in Bergamo et al. (2022). The black continuous lines indicate our limit for the first selection of waveforms.

For soil class C, 42 compatible selections for the period range 0.1-2.0 s are found, with RMSE ranging between 0.067 and 0.115 ln units. Among these, we choose the one with the lowest RMSE (Fig. 10.18, left panel). In Table 10.22 the selected waveforms metadata are reported. In the period range 0.02-1.0 s, the code found 45 possible compatible combinations with RMSE ranging between 0.063 and 0.107 ln units. Among these, we choose the one with RMSE = 0.067 to limit the records from the same station to the maximum number of 3 (Fig. 10.18, central panel). In Table 10.23 the selected waveforms metadata are reported. The selection for period range 0.25-4.0 s extracted 49 compatible combinations with RMSE in the range 0.056-0.119 ln units, whence the one having RMSE 0.056 is chosen (Fig. 10.18, right panel). In Table 10.24 the selected waveforms metadata are reported.

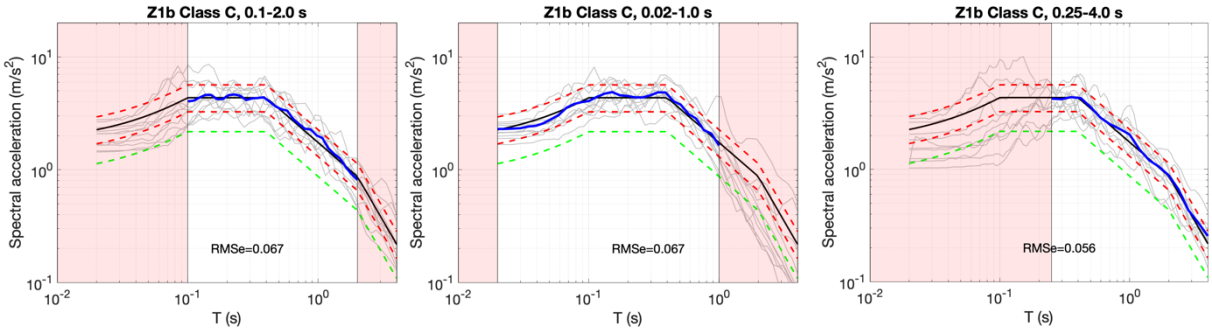

Figure 10.18 – Extracted sets of n=11 geometric mean of two components scaled response spectra (gray lines) for Z1b zone using as target the SIA261 elastic response spectra (black line) for soil class C. The blue line is the mean of the spectra. All the Eurocode 8 (2022) criteria of this document (section 9) are satisfied. Red dashed lines indicate the 1.3 and 0.75 ratio threshold; the green dashed line indicates the 0.5 ratio threshold. Shadowed red areas highlight the period range not considered for the selection.

The selected waveforms for Z1b, soil class C, largely fall inside the area where the probability of exceedance (over all IMTs) is significant for the relevant seismic zone, considering the return period of 975 years (Fig. 10.19), and no more than 2 records from the same earthquake are present in each set.

Table 10.22 – Metadata of the selected waveforms for seismic zone Z1b, soil class C, period range 0.1-2.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_00924_NOR	1.49	423	C	5.9	6.1	26.10.16	19:18:06	ESM
ACC_01527_PHOB	0.63	404	C	6.0	4.5	28.09.04	17:15:00	NGA-West2
ACC_05387_NGNH27	1.00	478	C	6.3	13.9	22.11.14	22:08:00	KiK-net
ACC_01238_NIGH11	0.53	375	C	6.6	0.0	23.10.04	17:56:00	KiK-net
ACC_01346_NIGH18	1.46	311	C	6.2	23.5	12.03.11	03:59:00	KiK-net
ACC_01266_NIGH11	1.16	375	C	6.6	27.8	16.07.07	10:13:00	KiK-net
ACC_01893_NIGH08	1.59	327	C	6.6	40.6	23.10.04	17:56:00	KiK-net
ACC_01342_NIGH11	1.06	375	C	6.2	17.2	12.03.11	03:59:00	KiK-net
ACC_01567_TRL	1.86	380	C	6.5	34.9	30.10.16	06:40:18	ESM
ACC_01836_AKTH18	1.82	431	C	6.9	47.5	14.06.08	08:43:00	KiK-net
ACC_05445_TTRH07	1.45	389	C	6.2	8.6	21.10.16	14:07:00	KiK-net

Table 10.23 – Metadata of the selected waveforms for seismic zone Z1b, soil class C, period range 0.02-1.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_00925_NRC	0.70	498	C	5.9	5.9	26.10.16	19:18:06	ESM
ACC_01419_NGNH29	1.52	465	C	5.4	16.5	12.04.11	07:26:00	KiK-net
ACC_01266_NIGH11	1.71	375	C	6.6	27.8	16.07.07	10:13:00	KiK-net
ACC_00923_NRC	0.89	498	C	5.4	8.7	26.10.16	17:10:36	ESM
ACC_01342_NIGH11	0.96	375	C	6.2	17.2	12.03.11	03:59:00	KiK-net
ACC_05351_HYGH01	1.54	348	C	5.8	10.3	13.04.13	05:33:00	KiK-net
ACC_01836_AKTH18	1.99	431	C	6.9	47.5	14.06.08	08:43:00	KiK-net
ACC_00993_AQV	0.51	474	C	6.1	0.0	06.04.09	01:32:40	ESM
ACC_01529_CHR	1.19	471	C	5.5	4.3	31.10.07	03:04:00	NGA-West2
ACC_01237_NIGH11	1.19	375	C	5.2	21.0	04.01.01	13:18:00	KiK-net
ACC_00924_NOR	1.05	423	C	5.9	6.1	26.10.16	19:18:06	ESM

Table 10.24 – Metadata of the selected waveforms for seismic zone Z1b, soil class C, period range 0.25-4.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_01238_NIGH11	0.54	375	C	6.6	0.0	23.10.04	17:56:00	KiK-net
ACC_00924_NOR	1.15	423	C	5.9	6.1	26.10.16	19:18:06	ESM
ACC_01266_NIGH11	1.38	375	C	6.6	27.8	16.07.07	10:13:00	KiK-net
ACC_03996_12149	0.98	385	C	7.3	21.8	28.06.92	11:58:00	NGA-West2
ACC_03997_12149	1.61	385	C	7.1	56.4	16.10.99	--:--:--	NGA-West2
ACC_05445_TTRH07	1.66	389	C	6.2	8.6	21.10.16	14:07:00	KiK-net
ACC_01346_NIGH18	1.32	311	C	6.2	23.5	12.03.11	03:59:00	KiK-net
ACC_05506_NIGH18	1.57	311	C	6.3	34.2	22.11.14	22:08:00	KiK-net
ACC_01342_NIGH11	1.33	375	C	6.2	17.2	12.03.11	03:59:00	KiK-net
ACC_01986_24644	1.33	421	C	6.7	41.3	17.01.94	12:31:00	NGA-West2
ACC_01901_NIGH18	1.61	311	C	6.6	47.9	16.07.07	10:13:00	KiK-net

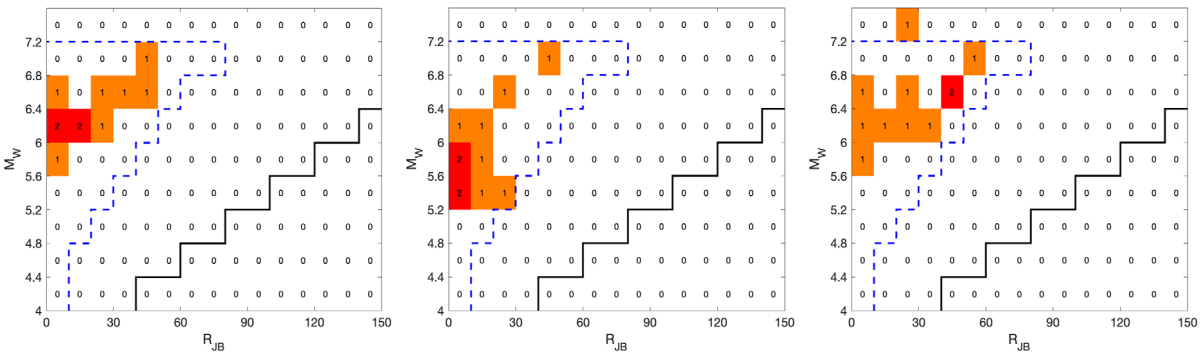

Figure 10.19 – Selected number of recordings by bin of Joyner-Boore distances (10 km width) and M_W (0.4 unit) for the period ranges 0.1-2.0s (left panel), 0.02-1.0 s (central panel) and 0.25-4.0 s (right panel) soil class C. The dashed blue lines indicate the areas where probability of exceedance (over all IMTs) is significant for the five SIA261 zones for return period 975 years following the approach illustrated in Bergamo et al. (2022). The black continuous lines indicate our limit for the first selection of waveforms.

For the period range 0.1-2.0 s, soil class D, we find 45 compatible selections with RMSE ranging between 0.067 and 0.128. Among these, we choose the one with the lowest RMSE (Fig. 10.20, left panel). In Table 10.25 the selected waveforms metadata are reported. In the period range 0.02-1.0 s the code found 50 possible compatible combinations with RMSE ranging between 0.048 and 0.084 (soil class D). Among these we choose the one with the lowest RMSE (Fig. 10.20, center panel). In Table 10.26 the selected waveforms metadata are reported. The selection for period range 0.25-4.0 s extracted 43 compatible combinations with RMSE in the range 0.059-0.160, from which the one having RMSE 0.059 is taken (Fig. 10.20, right panel). In Table 10.27 the selected waveforms metadata are reported.

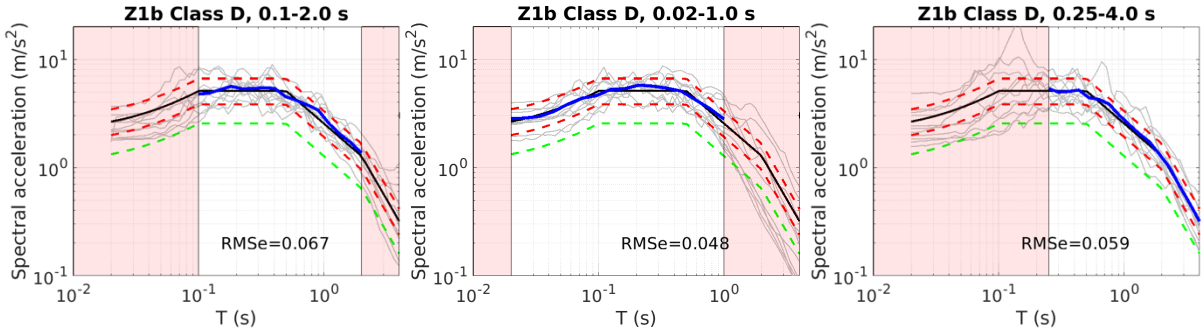

Figure 10.20 – Extracted sets of n=11 geometric mean of two-components, scaled response spectra (gray lines) for Z1b zone using as target the SIA261 elastic response spectra (black line) for soil class D. The blue line is the mean of the spectra. All the Eurocode 8 (2022) criteria of this document (section 9) are satisfied. Red dashed lines indicate the 1.3 and 0.75 ratio threshold; the green dashed line indicates the 0.5 ratio threshold. Shadowed red areas highlight the period range not considered for the selection.

The selected waveforms for Z1b soil, class D, largely fall inside the area where the probability of exceedance (over all IMTs) is significant for the relevant seismic zone, considering a return period of 975 years (Fig. 10.21), and no more than 2 records from the same earthquake are present in each set.

Table 10.25 – Metadata of the selected waveforms for seismic zone Z1b, soil class D, period range 0.1-2.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_01238_NIGH11	0.70	375	C	6.6	0.0	23.10.04	17:56:00	KiK-net
ACC_04007_WES	0.69	269	D	7.2	10.3	04.04.10	22:40:00	NGA-West2
ACC_05764_IBRH20	1.91	244	D	5.8	15.4	14.03.12	21:05:00	KiK-net
ACC_05419_KMMH03	0.60	421	C	7.1	18.2	16.04.16	01:25:00	KiK-net
ACC_02543_MRN	0.86	208	D	6.0	0.0	29.05.12	07:00:02	ESM
ACC_05445_TTRH07	1.45	389	C	6.2	8.6	21.10.16	14:07:00	KiK-net
ACC_00924_NOR	1.93	423	C	5.9	6.1	26.10.16	19:18:06	ESM
ACC_02537_MRN	0.71	208	D	6.1	4.3	20.05.12	02:03:50	ESM
ACC_03996_12149	1.55	385	C	7.3	21.8	28.06.92	11:58:00	NGA-West2
ACC_01266_NIGH11	1.47	375	C	6.6	27.8	16.07.07	10:13:00	KiK-net
ACC_04002_11023	1.92	212	D	7.2	66.7	04.04.10	22:40:00	NGA-West2

Table 10.26 – Metadata of the selected waveforms for seismic zone Z1b, soil class D, period range 0.02-1.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2)

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_01527_PHOB	0.67	404	C	6.0	4.5	28.09.04	17:15:00	NGA-West2
ACC_04635_NGNH28	1.81	1172	E	6.3	12.1	22.11.14	22:08:00	KiK-net
ACC_03991_1401	0.51	294	D	7.3	24.9	11.12.99	16:57:19	ESM
ACC_01529_CHR	1.09	471	C	5.5	4.3	31.10.07	03:04:00	NGA-West2
ACC_00924_NOR	1.69	423	C	5.9	6.1	26.10.16	19:18:06	ESM
ACC_05419_KMMH03	0.60	421	C	7.1	18.2	16.04.16	01:25:00	KiK-net
ACC_02543_MRN	0.95	208	D	6.0	0.0	29.05.12	07:00:02	ESM
ACC_01238_NIGH11	0.53	375	C	6.6	0.0	23.10.04	17:56:00	KiK-net
ACC_02485_NVL	1.59	190	D	5.4	6.5	15.10.96	09:56:00	ESM
ACC_00993_AQV	0.53	474	C	6.1	0.0	06.04.09	01:32:40	ESM
ACC_00923_NRC	1.02	498	C	5.4	8.7	26.10.16	17:10:36	ESM

Table 10.27 – Metadata of the selected waveforms for seismic zone Z1b, soil class D, period range 0.25-4.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2)

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_02537_MRN	0.66	208	D	6.1	4.3	20.05.12	02:03:50	ESM
ACC_00934_NOR	0.52	423	C	6.5	3.1	30.10.16	06:40:18	ESM
ACC_01238_NIGH11	0.65	375	C	6.6	0.0	23.10.04	17:56:00	KiK-net
ACC_02543_MRN	0.80	208	D	6.0	0.0	29.05.12	07:00:02	ESM
ACC_05387_NGNH27	1.65	478	C	6.3	13.9	22.11.14	22:08:00	KiK-net
ACC_05445_TTRH07	1.77	389	C	6.2	8.6	21.10.16	14:07:00	KiK-net
ACC_02791_FKSH11	1.57	240	D	6.6	31.4	11.04.11	17:16:00	KiK-net
ACC_00924_NOR	1.44	423	C	5.9	6.1	26.10.16	19:18:06	ESM
ACC_01342_NIGH11	1.53	375	C	6.2	17.2	12.03.11	03:59:00	KiK-net
ACC_01266_NIGH11	1.32	375	C	6.6	27.8	16.07.07	10:13:00	KiK-net
ACC_01986_24644	1.97	421	C	6.7	41.3	17.01.94	12:31:00	NGA-West2

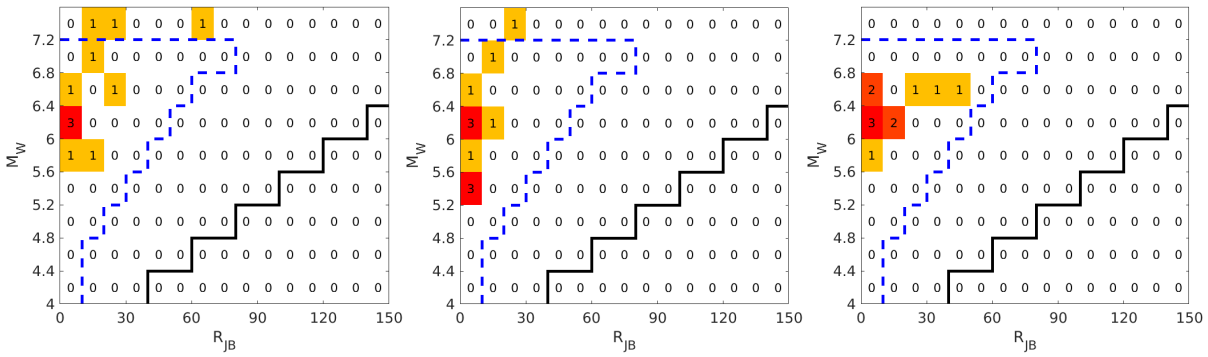

Figure 10.21 – Selected number of recordings by bin of Joyner-Boore distances (10 km width) and M_W (0.4 unit) for the period ranges 0.1-2.0s (left panel), 0.02-1.0 s (central panel) and 0.25-4.0 s (right panel) soil class D. The dashed blue lines indicate the areas where probability of exceedance (over all IMTs) is significant for the five SIA261 zones for return period 975 years following the approach illustrated in Bergamo et al. (2022). The black continuous lines indicate our limit for the first selection of waveforms.

For the period range 0.1-2.0 s, soil class E, we find only one compatible selection with RMSE = 0.149 ln units and too many records from the same station. Therefore, we repeat the selection adding synthetic waveforms, thus retrieving 7 compatible sets with RMSE ranging between 0.083 and 0.149. Among these, we choose the one with the lowest RMSE (Fig. 10.22, left panel). In Table 10.28 the selected waveforms metadata are reported. In the period range 0.02-1.0 s the code found 14 possible compatible combinations with RMSE ranging between 0.127 and 0.161 (soil class E). Among these we choose the one with the lowest RMSE (Fig. 10.22, central panel). In Table 10.29 the selected waveforms metadata are reported. The selection for period range 0.25-4.0 s extracted 4 compatible combinations with RMSE in the range 0.111-0.129, from which the one having lowest RMSE of 0.111 is taken (Fig. 10.22, right panel). In Table 10.30 the selected waveforms metadata are reported.

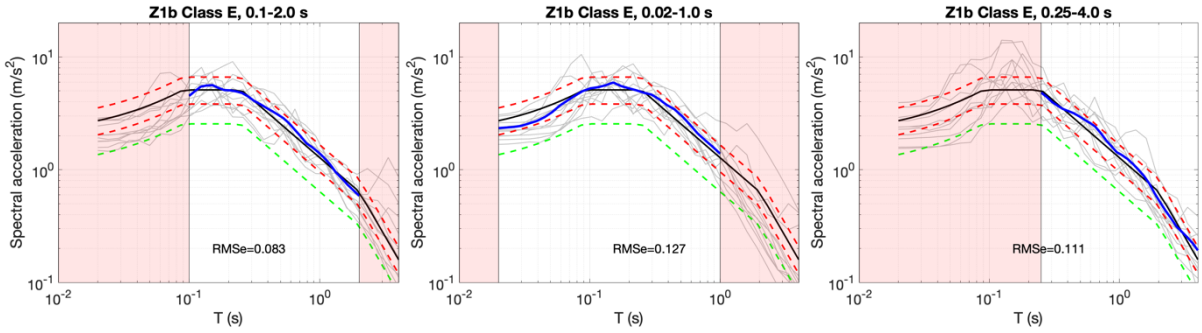

Figure 10.22 – Extracted sets of n=11 geometric mean of two components scaled response spectra (gray lines) for Z1b zone using as target the SIA261 elastic response spectra (black line) for soil class E. The blue line is the mean of the spectra. All the Eurocode 8 (2022) criteria of this document (section 9) are satisfied. Red dashed lines indicate the 1.3 and 0.75 ratio threshold; the green dashed line indicates the 0.5 ratio threshold. Shadow red areas highlight not used period range for the selection.

The selected waveforms for Z1b soil class E fall inside the areas where probability of exceedance (over all IMTs) is significant for the relevant seismic zone, considering a return period of 975 years (Fig. 10.23), and no more than 2 records from the same earthquake are present in each set.

Table 10.28 – Metadata of the selected waveforms for seismic zone Z1b, soil class E, period range 0.1-2.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_06022_17100	1.87	300	C	6.0	6.5	29.05.12	09:00:00	BB-SPEED
ACC_06271_17019	1.83	300	C	6.0	11.8	29.05.12	09:00:00	BB-SPEED
ACC_06885_3322	1.11	405	C	6.2	4.3	06.04.09	03:32:00	BB-SPEED
ACC_06860_3382	0.59	405	C	6.2	1.8	06.04.09	03:32:00	BB-SPEED
ACC_03150_AQA	0.58	549	E	6.1	0.0	06.04.09	01:32:40	ESM
ACC_03081_AMT	0.50	670	E	6.0	1.4	24.08.16	01:36:32	ESM
ACC_01836_AKTH18	1.77	431	C	6.9	47.5	14.06.08	08:43:00	KiK-net
ACC_01882_NGNH29	1.96	465	C	6.6	47.0	16.07.07	10:13:00	KiK-net
ACC_00957_KOZ1	1.57	482	C	6.6	10.7	13.05.95	08:47:13	ESM
ACC_02791_FKSH11	0.58	240	D	6.6	31.4	11.04.11	17:16:00	KiK-net
ACC_02165_AKTH16	1.64	375	C	6.9	61.4	14.06.08	08:43:00	KiK-net

Table 10.29 – Metadata of the selected waveforms for seismic zone Z1b, soil class E, period range 0.02-1.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2)

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_01836_AKTH18	1.92	431	C	6.9	47.5	14.06.08	08:43:00	KiK-net
ACC_01419_NGNH29	1.42	465	C	5.4	16.5	12.04.11	07:26:00	KiK-net
ACC_01658_NGNH29	1.32	465	C	6.6	39.3	23.10.04	17:56:00	KiK-net
ACC_00957_KOZ1	1.50	482	C	6.6	10.7	13.05.95	08:47:13	ESM
ACC_05628_MYZH08	1.53	374	C	7.1	53.9	16.04.16	01:25:00	KiK-net
ACC_01068_5401	1.16	412	C	5.7	10.2	11.11.99	14:41:23	ESM
ACC_01009_AQV	1.75	474	C	5.4	11.0	09.04.09	00:52:59	ESM
ACC_03081_AMT	0.52	670	E	6.0	1.4	24.08.16	01:36:32	ESM
ACC_01882_NGNH29	1.92	465	C	6.6	47.0	16.07.07	10:13:00	KiK-net
ACC_03150_AQA	0.54	549	E	6.1	0.0	06.04.09	01:32:40	ESM
ACC_04635_NGNH28	1.18	1172	E	6.3	12.1	22.11.14	22:08:00	KiK-net

Table 10.30 – Metadata of the selected waveforms for seismic zone Z1b, soil class E, period range 0.25-4.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording , then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_03301_AKTH06	1.42	455	E	6.9	19.2	14.06.08	08:43:00	ESM
ACC_02791_FKSH11	0.74	240	D	6.6	31.4	11.04.11	17:16:00	KiK-net
ACC_05387_NGNH27	1.08	478	C	6.3	13.9	22.11.14	22:08:00	KiK-net
ACC_03150_AQA	0.69	549	E	6.1	0.0	06.04.09	01:32:40	ESM
ACC_01882_NGNH29	1.82	465	C	6.6	47.0	16.07.07	10:13:00	KiK-net
ACC_03551_SAGH03	1.83	434	E	6.6	30.5	20.03.05	10:53:00	KiK-net
ACC_05628_MYZH08	1.28	374	C	7.1	53.9	16.04.16	01:25:00	KiK-net
ACC_01836_AKTH18	1.78	431	C	6.9	47.5	14.06.08	08:43:00	KiK-net
ACC_01658_NGNH29	1.88	465	C	6.6	39.3	23.10.04	17:56:00	KiK-net
ACC_02670_FKSH11	1.83	240	D	5.9	28.2	12.04.11	14:07:00	KiK-net
ACC_03100_AMT	0.52	670	E	6.5	10.1	30.10.16	06:40:18	ESM

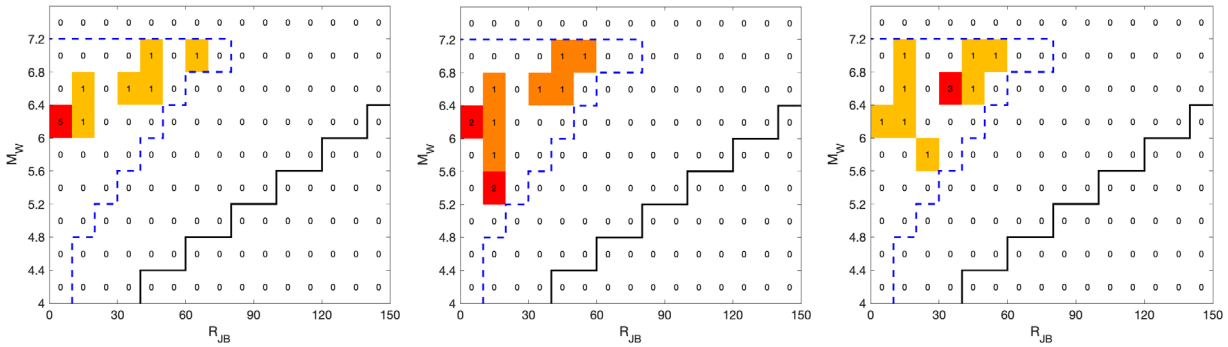

Figure 10.23 – Selected number of recordings by bin of Joyner-Boore distances (10 km width) and M_W (0.4 unit) for the period ranges 0.1-2.0s (left panel), 0.02-1.0 s (central panel) and 0.25-4.0 s (right panel) soil class E. The dashed blue lines indicate the areas where probability of exceedance (over all IMTs) is significant for the five SIA261 zones for return period 975 years the approach illustrated in Bergamo et al. (2022). The black continuous lines indicate our limit for the first selection of waveforms.

10.3 Seismic zone Z2

The Z2 covers part of the Canton Basel-Landschaft, Canton Graubünden, and a pre-alpine belt crossing central Switzerland south of Luzern and Lausanne (Fig. 7.1). The Baker and Lee (2018) code found 99 possible compatible combinations with RMSE in the range 0.055-0.129 ln units for soil class A and spectral period range 0.1-2.0 s. Among these, we choose the one with the lowest RMSE (Fig. 10.24, left panel and Table 10.31 for the waveforms metadata). For the period range 0.02-1.0 s, the code found 97 possible compatible combinations with RMSE in the range 0.099-0.145 (soil class A). Among these, we choose the one with the lowest RMSE (Fig. 10.24, center panel and Table 10.32 for the waveforms metadata). The selection for period range 0.25-4.0 s extracted 47 compatible combinations with RMSE in the range 0.090-0.127 s, from which the one having lowest RMSE = 0.090 is chosen (Fig. 10.24, right panel and Table 10.33 for the waveforms metadata).

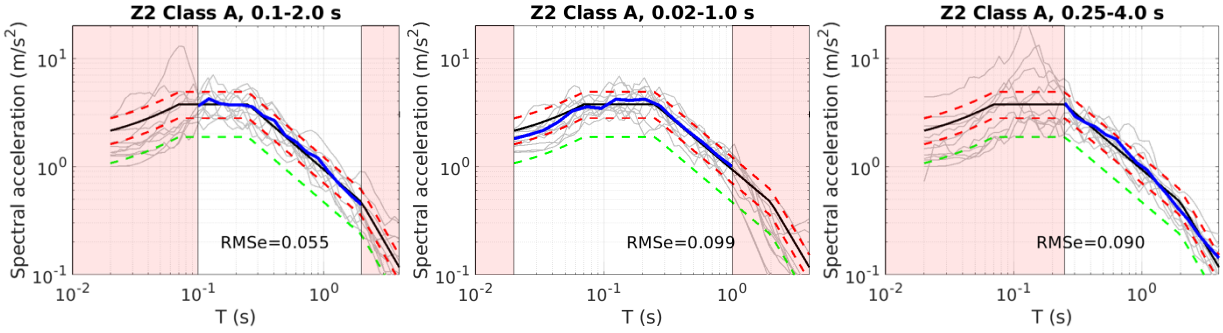

Figure 10.24 – Extracted sets of n=11 geometric mean of two components scaled response spectra (gray lines) for Z2 zone using as target the SIA261 elastic response spectra (black line) for soil class A. The blue line is the mean of the spectra. All the Eurocode 8 (2022) criteria of this document (section 9) are satisfied. Red dashed lines indicate the 1.3 and 0.75 ratio threshold; the green dashed line indicates the 0.5 ratio threshold. Shadowed red areas highlight the period range not considered for the selection.

The selected waveforms for Z2, soil class A, largely fall inside the area where the probability of exceedance (over all IMTs) is significant for the relevant seismic zone considering the return period of 975 years (Fig. 10.25), and no more than 2 records from the same earthquake are present in each set.

Table 10.31 – Metadata of the selected waveforms for seismic zone Z2, soil class A, period range 0.1-2.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_00173_SAGH05	1.24	1000	A	6.6	58.1	20.03.05	10:53:00	KiK-net
ACC_04062_MNF	1.24	-	A	5.9	6.8	26.10.16	19:18:06	ESM
ACC_05089_KMMH07	1.36	765	B	6.1	23.1	14.04.16	21:26:00	KiK-net
ACC_04059_CLO	0.80	-	A	5.9	3.2	26.10.16	19:18:06	ESM
ACC_00041_MRM	1.68	1906	A	5.2	1.6	25.10.12	23:05:24	ESM
ACC_04072_MMO	0.82	-	A	6.5	9.8	30.10.16	06:40:18	ESM
ACC_04076_TER	1.69	-	A	6.5	32.9	30.10.16	06:40:18	ESM
ACC_04511_90017	0.78	1223	A	6.7	15.1	17.01.94	12:31:00	NGA-West2
ACC_00065_SMNH10	0.86	967	A	6.6	20.8	06.10.00	13:30:00	KiK-net
ACC_03159_AQP	1.73	836	E	5.4	10.4	09.04.09	00:52:59	ESM
ACC_00062_OKYH07	1.81	929	A	6.6	17.2	06.10.00	13:30:00	KiK-net

Table 10.32 – Metadata of the selected waveforms for seismic zone Z2, soil class A, period range 0.02-1.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_00041_MRM	1.31	1906	A	5.2	1.6	25.10.12	23:05:24	ESM
ACC_04072_MMO	0.94	-	A	6.5	9.8	30.10.16	06:40:18	ESM
ACC_04061_MMO	0.82	-	A	5.9	10.4	26.10.16	19:18:06	ESM
ACC_04062_MNF	1.46	-	A	5.9	6.8	26.10.16	19:18:06	ESM
ACC_04130_VGG	1.54	-	A	5.2	9.6	25.10.12	23:05:24	ESM
ACC_04088_NOT	1.78	-	A	5.6	49.4	13.12.90	00:24:26	ESM
ACC_05089_KMMH07	1.32	765	B	6.1	23.1	14.04.16	21:26:00	KiK-net
ACC_00386_ISKH02	1.85	721	B	5.2	16.6	25.03.07	18:11:00	KiK-net
ACC_04075_SPM	1.92	-	A	6.5	31.3	30.10.16	06:40:18	ESM
ACC_04031_GVD	0.76	-	A	5.3	1.7	12.09.12	03:27:45	ESM
ACC_04049_CLO	1.64	-	A	5.4	7.1	26.10.16	17:10:36	ESM

Table 10.33 – Metadata of the selected waveforms for seismic zone Z2, soil class A, period range 0.25-4.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_00600_OKYH14	1.27	710	B	6.6	33.4	06.10.00	13:30:00	KiK-net
ACC_04512_24047	0.72	996	A	6.7	23.1	17.01.94	12:31:00	NGA-West2
ACC_04511_90017	1.34	1223	A	6.7	15.1	17.01.94	12:31:00	NGA-West2
ACC_04062_MNF	1.72	-	A	5.9	6.8	26.10.16	19:18:06	ESM
ACC_03535_SAGH04	1.90	724	E	6.6	36.3	20.03.05	10:53:00	KiK-net
ACC_04390_KMMH11	1.52	1292	A	7.1	44.1	16.04.16	01:25:00	KiK-net
ACC_04064_SLO	1.84	-	A	5.9	11.2	26.10.16	19:18:06	ESM
ACC_00173_SAGH05	1.14	1000	A	6.6	58.1	20.03.05	10:53:00	KiK-net
ACC_00022_ATH4	1.12	970	A	5.9	14.0	07.09.99	11:56:49	ESM
ACC_04076_TER	1.83	-	A	6.5	32.9	30.10.16	06:40:18	ESM
ACC_00291_ATH2	1.77	706	B	5.9	16.0	07.09.99	11:56:49	ESM

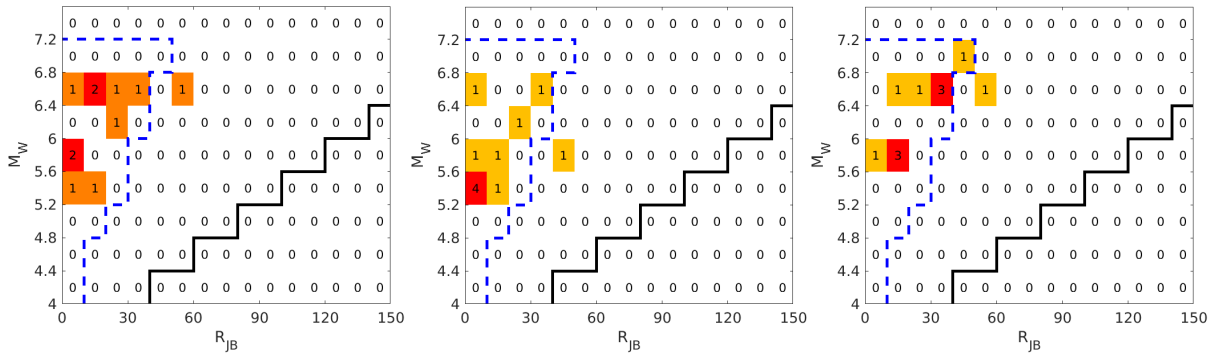

Figure 10.25 – Selected number of recordings by bin of Joyner-Boore distances (10 km width) and M_W (0.4 unit) for the period ranges 0.1-2.0s (left panel), 0.02-1.0 s (central panel) and 0.25-4.0 s (right panel) soil class A. The dashed blue lines indicate the areas where probability of exceedance (over all IMTs) is significant for the five SIA261 zones for return period 975 years following the approach illustrated in Bergamo et al. (2022). The black continuous lines indicate our limit for the first selection of waveforms.

The search was repeated for soil class B, resulting in 9 compatible selections for the period range 0.1-2.0 s, having RMSE ranging between 0.112 and 0.125 ln units. Among these, we choose the one with the lowest RMSE (Fig. 10.26, left panel). In Table 10.34 the selected waveforms metadata are reported. For the period range 0.02-1.0 s the code found 44 possible compatible combinations with RMSE ranging between 0.082 and 0.125 ln units. Among these, we choose the one with the lowest RMSE (Fig. 10.26, center panel). In Table 10.35 the selected waveforms metadata are reported. The selection for period range 0.25-4.0 s extracted 13 compatible combinations with RMSE in the range 0.103-0.145, from which the one having RMSE 0.090 is taken (Fig. 10.26, right panel). In Table 10.36 the selected waveforms metadata are reported.

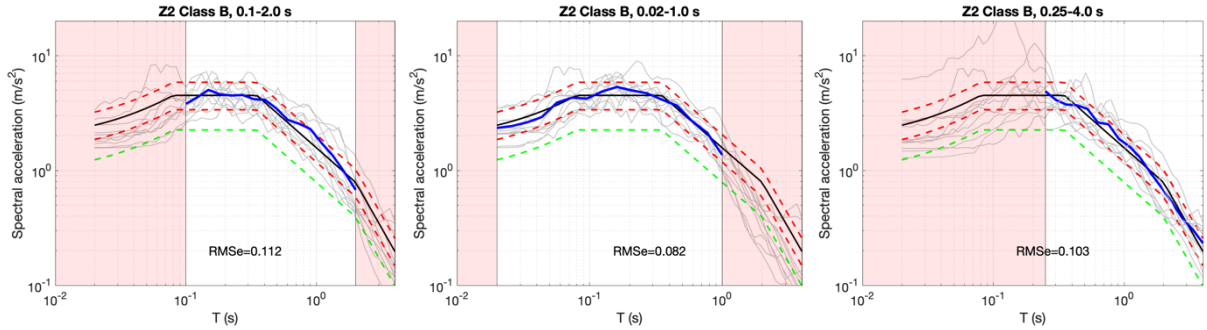

Figure 10.26 – Extracted sets of n=11 geometric mean of two components scaled response spectra (gray lines) for Z2 zone using as target the SIA261 elastic response spectra (black line) for soil class B. The blue line is the mean of the spectra. All the Eurocode 8 (2022) criteria of this document (section 9) are satisfied. Red dashed lines indicate the 1.3 and 0.75 ratio threshold; the green dashed line indicates the 0.5 ratio threshold. Shadowed red areas highlight the period range not considered for the selection.

The selected waveforms for Z2 soil class B largely fall inside the area where the probability of exceedance (over all IMTs) is significant for the relevant seismic zone considering the return period of 975 years (Fig. 10.27), and no more than 2 records from the same earthquake are present in each set.

Table 10.34 – Metadata of the selected waveforms for seismic zone Z2, soil class B, period range 0.1-2.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_01836_AKTH18	1.65	431	C	6.9	47.5	14.06.08	08:43:00	KiK-net
ACC_00924_NOR	1.00	423	C	5.9	6.1	26.10.16	19:18:06	ESM
ACC_00276_CSC	1.16	698	B	6.5	12.8	30.10.16	06:40:18	ESM
ACC_05089_KMMH07	1.34	765	B	6.1	23.1	14.04.16	21:26:00	KiK-net
ACC_01527_PHOB	0.68	404	C	6.0	4.5	28.09.04	17:15:00	NGA-West2
ACC_00319_AQG	0.63	696	B	6.1	0.0	06.04.09	01:32:40	ESM
ACC_01882_NGNH29	1.97	465	C	6.6	47.0	16.07.07	10:13:00	KiK-net
ACC_03150_AQA	0.66	549	E	6.1	0.0	06.04.09	01:32:40	ESM
ACC_00922_NOR	1.54	423	C	5.4	8.8	26.10.16	17:10:36	ESM
ACC_05387_NGNH27	1.07	478	C	6.3	13.9	22.11.14	22:08:00	KiK-net
ACC_00894_NOR	0.89	423	C	6.0	2.3	24.08.16	01:36:32	ESM

Table 10.35 – Metadata of the selected waveforms for seismic zone Z2, soil class B, period range 0.02-1.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_00276_CSC	1.25	698	B	6.5	12.8	30.10.16	06:40:18	ESM
ACC_00923_NRC	0.84	498	C	5.4	8.7	26.10.16	17:10:36	ESM
ACC_03150_AQA	0.63	549	E	6.1	0.0	06.04.09	01:32:40	ESM
ACC_01529_CHR	1.17	471	C	5.5	4.3	31.10.07	03:04:00	NGA-West2
ACC_01419_NGNH29	1.12	465	C	5.4	16.5	12.04.11	07:26:00	KiK-net
ACC_01836_AKTH18	1.81	431	C	6.9	47.5	14.06.08	08:43:00	KiK-net
ACC_00254_CSC	1.69	698	B	6.0	11.6	24.08.16	01:36:32	KiK-net
ACC_03081_AMT	0.61	670	E	6.0	1.4	24.08.16	01:36:32	ESM
ACC_00319_AQG	0.59	696	B	6.1	0.0	06.04.09	01:32:40	ESM
ACC_05089_KMMH07	1.33	765	B	6.1	23.1	14.04.16	21:26:00	KiK-net
ACC_00427_NIGH10	1.26	653	B	6.6	25.3	23.10.04	17:56:00	KiK-net

Table 10.36 – Metadata of the selected waveforms for seismic zone Z2, soil class B, period range 0.25-4.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_05387_NGNH27	0.88	478	C	6.3	13.9	22.11.14	22:08:00	KiK-net
ACC_00924_NOR	1.12	423	C	5.9	6.1	26.10.16	19:18:06	ESM
ACC_00276_CSC	1.09	698	B	6.5	12.8	30.10.16	06:40:18	ESM
ACC_00894_NOR	0.90	423	C	6.0	2.3	24.08.16	01:36:32	ESM
ACC_00600_OKYH14	1.80	710	B	6.6	33.4	06.10.00	13:30:00	KiK-net
ACC_01836_AKTH18	1.62	431	C	6.9	47.5	14.06.08	08:43:00	KiK-net
ACC_00895_NRC	0.75	498	C	6.0	2.0	24.08.16	01:36:32	ESM
ACC_01527_PHOB	0.91	404	C	6.0	4.5	28.09.04	17:15:00	NGA-West2
ACC_03995_SWS	1.76	587	B	7.2	31.8	04.04.10	22:40:00	NGA-West2
ACC_03150_AQA	0.61	549	E	6.1	0.0	06.04.09	01:32:40	ESM
ACC_01986_24644	1.66	421	C	6.7	41.3	17.01.94	12:31:00	NGA-West2

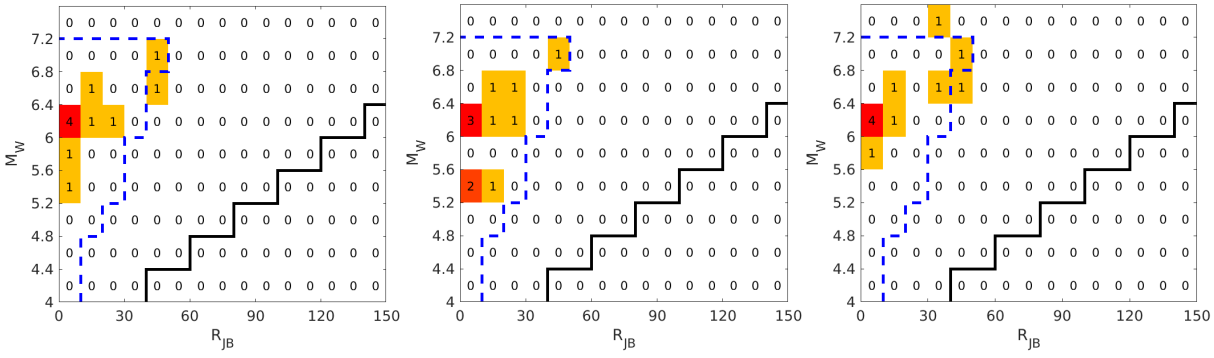

Figure 10.27 – Selected number of recordings by bin of Joyner-Boore distances (10 km width) and M_W (0.4 unit) for the period ranges 0.1-2.0s (left panel), 0.02-1.0 s (central panel) and 0.25-4.0 s (right panel) soil class B. The dashed blue lines indicate the areas where probability of exceedance (over all IMTs) is significant for the five SIA261 zones for return period 975 years following the approach illustrated in Bergamo et al. (2022). The black continuous lines indicate our limit for the first selection of waveforms.

For soil class C, 24 compatible selections for the period range 0.1-2.0 s, having RMSE ranging between 0.075 and 0.118 ln units are found. Among these we choose the one with RMSE = 0.085 to limit the records acquired by the same station to the maximum number of 3 (Fig. 10.28, left panel). In Table 10.37 the selected waveforms metadata are reported. In the period range 0.02-1.0 s, the code found 50 possible compatible combinations with RMSE ranging between 0.049 and 0.082 ln units. Among these, we choose the one with the lowest RMSE (Fig. 10.28, center panel). In Table 10.38 the selected waveforms metadata are reported. The selection for period range 0.25-4.0 s extracted 34 compatible combinations with RMSE in the range 0.069-0.125, from which the one having RMSE 0.069 is taken (Fig. 10.28, right panel). In Table 10.39 the selected waveforms metadata are reported.

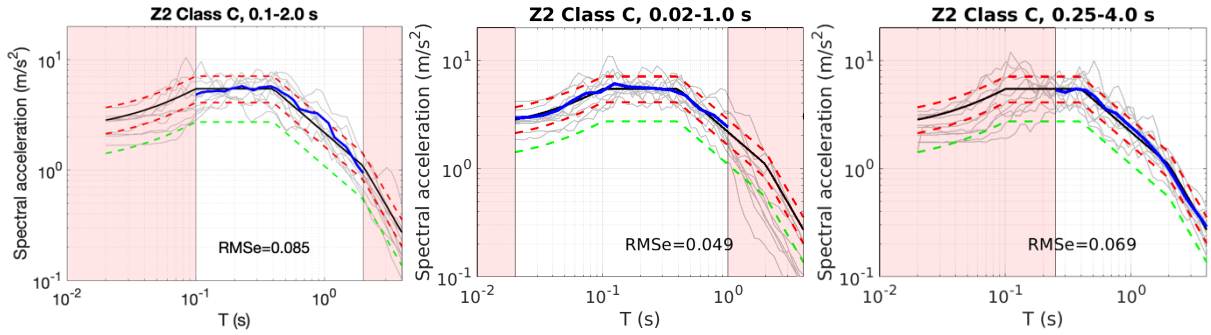

Figure 10.28 – Extracted sets of n=11 geometric mean of two-components, scaled response spectra (gray lines) for Z2 zone using as target the SIA261 elastic response spectra (black line) for soil class C. The blue line is the mean of the spectra. All the Eurocode 8 (2022) criteria of this document (section 9) are satisfied. Red dashed lines indicate the 1.3 and 0.75 ratio threshold; the green dashed line indicates the 0.5 ratio threshold. Shadowed red areas highlight the period range not considered for the selection.

The selected waveforms for Z2, soil class C, largely fall inside the areas where the probability of exceedance (over all IMTs) is significant for the relevant seismic zone considering the return period of 975 years (Fig. 10.29), and no more than 2 records from the same earthquake are present in each set.

Table 10.37– Metadata of the selected waveforms for seismic zone Z2, soil class C, period range 0.1-2.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_00924_NOR	1.28	423	C	5.9	6.1	26.10.16	19:18:06	ESM
ACC_01238_NIGH11	0.55	375	C	6.6	0.0	23.10.04	17:56:00	KiK-net
ACC_01893_NIGH08	2.00	327	C	6.6	40.6	23.10.04	17:56:00	KiK-net
ACC_05387_NGNH27	1.14	478	C	6.3	13.9	22.11.14	22:08:00	KiK-net
ACC_01342_NIGH11	1.46	375	C	6.2	17.2	12.03.11	03:59:00	KiK-net
ACC_00922_NOR	1.75	423	C	5.4	8.8	26.10.16	17:10:36	ESM
ACC_05419_KMMH03	0.66	421	C	7.1	18.2	16.04.16	01:25:00	KiK-net
ACC_01346_NIGH18	1.86	311	C	6.2	23.5	12.03.11	03:59:00	KiK-net
ACC_01527_PHOB	0.83	404	C	6.0	4.5	28.09.04	17:15:00	NGA-West2
ACC_00993_AQV	0.60	474	C	6.1	0.0	06.04.09	01:32:40	ESM
ACC_00958_AIGA	0.61	410	C	6.5	13.6	15.06.95	00:15:47	ESM

Table 10.38 – Metadata of the selected waveforms for seismic zone Z2, soil class C, period range 0.02-1.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording , then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_01529_CHR	1.20	471	C	5.5	4.3	31.10.07	03:04:00	NGA-West2
ACC_00954_PAT2	1.34	369	C	5.6	4.3	14.07.93	12:31:48	ESM
ACC_01342_NIGH11	1.36	375	C	6.2	17.2	12.03.11	03:59:00	KiK-net
ACC_01238_NIGH11	0.52	375	C	6.6	0.0	23.10.04	17:56:00	KiK-net
ACC_05419_KMMH03	0.67	421	C	7.1	18.2	16.04.16	01:25:00	KiK-net
ACC_00993_AQV	0.50	474	C	6.1	0.0	06.04.09	01:32:40	ESM
ACC_00924_NOR	1.75	423	C	5.9	6.1	26.10.16	19:18:06	ESM
ACC_01527_PHOB	0.70	404	C	6.0	4.5	28.09.04	17:15:00	NGA-West2
ACC_00923_NRC	0.97	498	C	5.4	8.7	26.10.16	17:10:36	ESM
ACC_01242_NIGH11	0.64	375	C	6.3	15.0	23.10.04	18:34:00	KiK-net
ACC_01419_NGNH29	1.84	465	C	5.4	16.5	12.04.11	07:26:00	KiK-net

Table 10.39 – Metadata of the selected waveforms for seismic zone Z2, soil class C, period range 0.25-4.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2)

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_03996_12149	1.28	385	C	7.3	21.8	28.06.92	11:58:00	NGA-West2
ACC_01238_NIGH11	0.60	375	C	6.6	0.0	23.10.04	17:56:00	KiK-net
ACC_01342_NIGH11	1.49	375	C	6.2	17.2	12.03.11	03:59:00	KiK-net
ACC_05387_NGNH27	1.39	478	C	6.3	13.9	22.11.14	22:08:00	KiK-net
ACC_05628_MYZH08	1.98	374	C	7.1	53.9	16.04.16	01:25:00	KiK-net
ACC_01346_NIGH18	1.55	311	C	6.2	23.5	12.03.11	03:59:00	KiK-net
ACC_01266_NIGH11	1.41	375	C	6.6	27.8	16.07.07	10:13:00	KiK-net
ACC_00924_NOR	1.58	423	C	5.9	6.1	26.10.16	19:18:06	ESM
ACC_01527_PHOB	1.28	404	C	6.0	4.5	28.09.04	17:15:00	NGA-West2
ACC_05445_TTRH07	1.66	389	C	6.2	8.6	21.10.16	14:07:00	KiK-net
ACC_01986_24644	1.86	421	C	6.7	41.3	17.01.94	12:31:00	NGA-West2

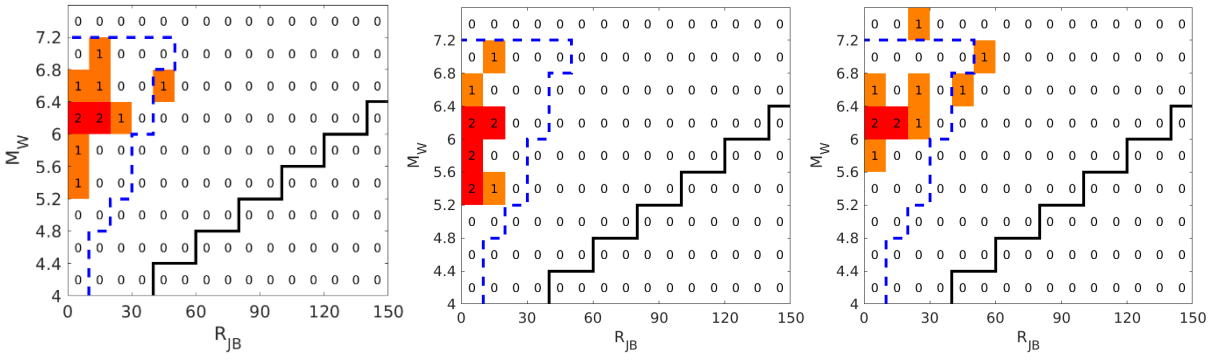

Figure 10.29 – Selected number of recordings by bin of Joyner-Boore distances (10 km width) and M_W (0.4 unit) for the period ranges 0.1-2.0s (left panel), 0.02-1.0 s (central panel) and 0.25-4.0 s (right panel) soil class C. The dashed blue lines indicate the areas where probability of exceedance (over all IMTs) is significant for the five SIA261 zones for return period 975 years following the approach illustrated in Bergamo et al. (2022). The black continuous lines indicate our limit for the first selection of waveforms.

For the period range 0.1-2.0 s, soil class D, we find 41 compatible selections having RMSE ranging between 0.059 and 0.127 ln units. Among these, we choose the one with the lowest RMSE (Fig. 10.30, left panel). In Table 10.40 the selected waveforms metadata are reported. In the period range 0.02-1.0 s, the code found 50 possible compatible combinations with RMSE ranging between 0.046 and 0.073. Among these, we choose the one with the lowest RMSE (Fig. 10.30, center panel). In Table 10.41 the selected waveforms metadata are reported. The selection for period range 0.25-4.0 s extracted 44 compatible combinations with RMSE in the range 0.070-0.150, from which the one having lowest RMSE = 0.070 is taken (Fig. 10.30, right panel). In Table 10.42 the selected waveforms metadata are reported.

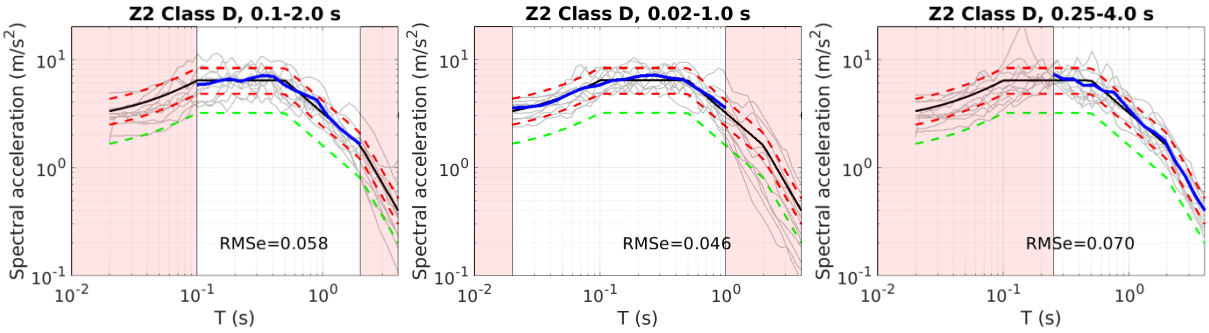

Figure 10.30 – Extracted sets of n=11 geometric mean of two-components, scaled response spectra (gray lines) for Z2 zone using as target the SIA261 elastic response spectra (black line) for soil class D. The blue line is the mean of the spectra. All the Eurocode 8 (2022) criteria of this document (section 9) are satisfied. Red dashed lines indicate the 1.3 and 0.75 ratio threshold; the green dashed line indicates the 0.5 ratio threshold. Shadowed red areas highlight the period range not considered for the selection.

The selected waveforms for Z2, soil class D, largely fall inside the area where probability of exceedance (over all IMTs) is significant for the relevant seismic zone considering the return period of 975 years (Fig. 10.31), and no more than 2 records from the same earthquake are present in each set.

Table 10.40 – Metadata of the selected waveforms for seismic zone Z2, soil class D, period range 0.1-2.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_00924_NOR	1.98	423	C	5.9	6.1	26.10.16	19:18:06	ESM
ACC_01238_NIGH11	0.56	375	C	6.6	0.0	23.10.04	17:56:00	KiK-net
ACC_02537_MRN	1.10	208	D	6.1	4.3	20.05.12	02:03:50	ESM
ACC_02543_MRN	1.30	208	D	6.0	0.0	29.05.12	07:00:02	ESM
ACC_05445_TTRH07	1.92	389	C	6.2	8.6	21.10.16	14:07:00	KiK-net
ACC_04007_WES	0.73	269	D	7.2	10.3	04.04.10	22:40:00	NGA-West2
ACC_03996_12149	1.55	385	C	7.3	21.8	28.06.92	11:58:00	NGA-West2
ACC_03991_1401	0.63	294	D	7.3	24.9	11.12.99	16:57:19	ESM
ACC_02488_CLF	1.05	145	D	5.7	0.3	26.09.97	00:33:11	ESM
ACC_01527_PHOB	1.18	404	C	6.0	4.5	28.09.04	17:15:00	NGA-West2
ACC_01266_NIGH11	1.70	375	C	6.6	27.8	16.07.07	10:13:00	KiK-net

Table 10.41 – Metadata of the selected waveforms for seismic zone Z2, soil class D, period range 0.02-1.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY. = day, month and year; HH.MM.YY. = hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_01238_NIGH11	0.73	375	C	6.6	0.0	23.10.04	17:56:00	KiK-net
ACC_00993_AQV	0.52	474	C	6.1	0.0	06.04.09	01:32:40	ESM
ACC_01527_PHOB	0.90	404	C	6.0	4.5	28.09.04	17:15:00	NGA-West2
ACC_02543_MRN	1.06	208	D	6.0	0.0	29.05.12	07:00:02	ESM
ACC_03991_1401	0.52	294	D	7.3	24.9	11.12.99	16:57:19	ESM
ACC_00923_NRC	1.60	498	C	5.4	8.7	26.10.16	17:10:36	ESM
ACC_00958_AIGA	0.75	410	C	6.5	13.6	15.06.95	00:15:47	ESM
ACC_00924_NOR	1.78	423	C	5.9	6.1	26.10.16	19:18:06	ESM
ACC_01419_NGNH29	2.00	465	C	5.4	16.5	12.04.11	07:26:00	KiK-net
ACC_04635_NGNH28	1.89	1172	E	6.3	12.1	22.11.14	22:08:00	KiK-net
ACC_05419_KMMH03	1.01	421	C	7.1	18.2	16.04.16	01:25:00	KiK-net

Table 10.42 – Metadata of the selected waveforms for seismic zone Z2, soil class D, period range 0.25-4.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the event , then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_03996_12149	1.71	385	C	7.3	21.8	28.06.92	11:58:00	NGA-West2
ACC_03991_1401	0.52	294	D	7.3	24.9	11.12.99	16:57:19	ESM
ACC_04635_NGNH28	1.50	1172	E	6.3	12.1	22.11.14	22:08:00	KiK-net
ACC_01238_NIGH11	0.65	375	C	6.6	0.0	23.10.04	17:56:00	KiK-net
ACC_02537_MRN	0.81	208	D	6.1	4.3	20.05.12	02:03:50	ESM
ACC_04006_ERR	1.80	253	D	7.2	50.9	04.04.10	22:40:00	NGA-West2
ACC_02543_MRN	0.86	208	D	6.0	0.0	29.05.12	07:00:02	ESM
ACC_00894_NOR	1.49	423	C	6.0	2.3	24.08.16	01:36:32	ESM
ACC_01527_PHOB	1.54	404	C	6.0	4.5	28.09.04	17:15:00	NGA-West2
ACC_02791_FKSH11	1.51	240	D	6.6	31.4	11.04.11	17:16:00	KiK-net
ACC_00924_NOR	1.89	423	C	5.9	6.1	26.10.16	19:18:06	ESM

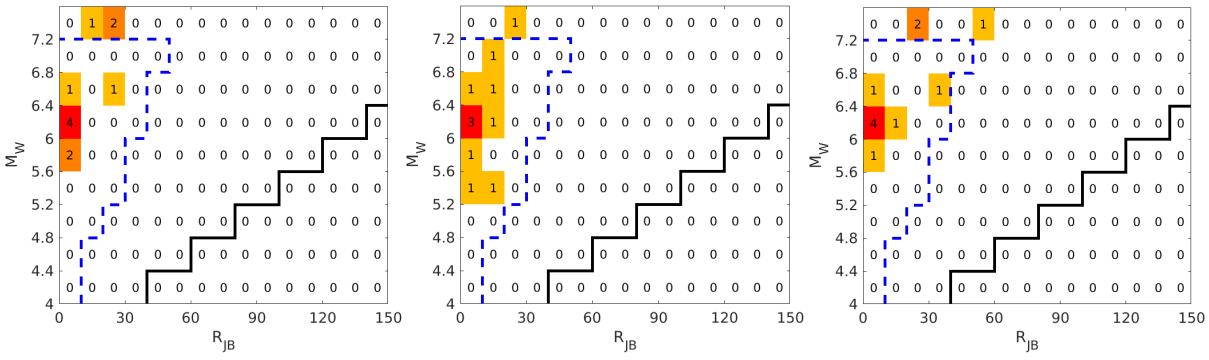

Figure 10.31 – Selected number of recordings by bin of Joyner-Boore distances (10 km width) and M_W (0.4 unit) for the period ranges 0.1-2.0s (left panel), 0.02-1.0 s (central panel) and 0.25-4.0 s (right panel) soil class D. The dashed blue lines indicate the areas where probability of exceedance (over all IMTs) is significant for the five SIA261 zones for return period 975 years following the approach illustrated in Bergamo et al. (2022). The black continuous lines indicate our limit for the first selection of waveforms.

For the period range 0.1-2.0 s, soil class E, no spectrum compatible selection is found searching exclusively among real accelerograms. The selection is repeated allowing a maximum of 4 synthetic recordings, but also in this case no compatible selections are found. Therefore, we increase the scaling factor up to 3 (Du et al., 2019). We find 2 compatible selections with RMSE in the range 0.085-0.124 ln units. Among these, we choose the one with the lowest RMSE (Fig. 10.32, left panel). In Table 10.43 the selected waveforms metadata are reported. In the period range 0.02-1.0 s, the code found 16 possible compatible combinations of real accelerograms with RMSE ranging between 0.121 and 0.159. Among these, we choose the one with the lowest RMSE (Fig. 10.32, center panel). In Table 10.44 the selected waveforms metadata are reported. The selection for period range 0.25-4.0 s does not return compatible combinations using real accelerograms, synthetics and releasing distance limitations. Therefore, we increase the scaling factor up to 3 (Du et al., 2018), finding 18 compatible combinations with RMSE in the range 0.099-0.140, from which the one having lowest RMSE = 0.099 is taken (Fig. 10.32, right panel). In Table 10.45 the selected waveforms metadata are reported.

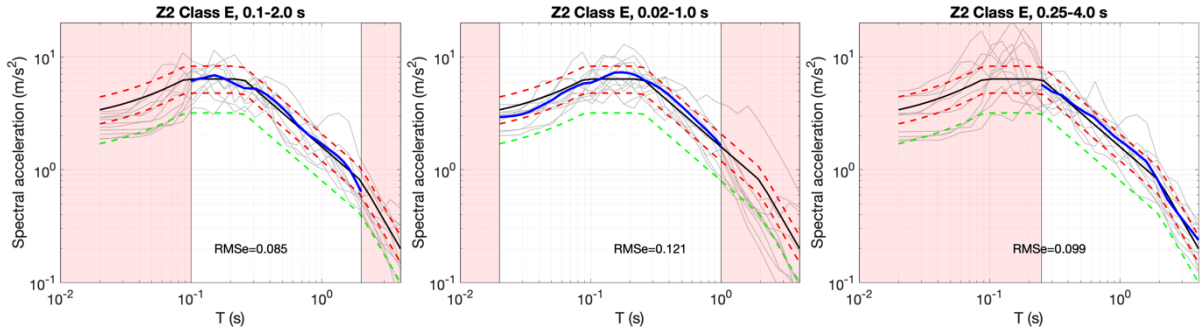

Figure 10.32 – Extracted sets of n=11 geometric mean of two-components, scaled response spectra (gray lines) for Z2 zone using as target the SIA261 elastic response spectra (black line) for soil class E. The blue line is the mean of the spectra. All the Eurocode 8 (2022) criteria of this document (section 9) are satisfied. Red dashed lines indicate the 1.3 and 0.75 ratio threshold; the green dashed line indicates the 0.5 ratio threshold. Shadowed red areas highlight the period range not considered for the selection.

Table 10.43 – Metadata of the selected waveforms for seismic zone Z2, soil class E, period range 0.1-2.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_01882_NGNH29	2.46	465	C	6.6	47.0	16.07.07	10:13:00	KiK-net
ACC_00957_KOZ1	1.81	482	C	6.6	10.7	13.05.95	08:47:13	ESM
ACC_01836_AKTH18	2.09	431	C	6.9	47.5	14.06.08	08:43:00	KiK-net
ACC_03150_AQA	0.69	549	E	6.1	0.0	06.04.09	01:32:40	ESM
ACC_05628_MYZH08	1.57	374	C	7.1	53.9	16.04.16	01:25:00	KiK-net
ACC_00993_AQV	0.54	474	C	6.1	0.0	06.04.09	01:32:40	ESM
ACC_01658_NGNH29	2.28	465	C	6.6	39.3	23.10.04	17:56:00	KiK-net
ACC_04742_FKOH08	2.81	536	E	7.1	60.0	16.04.16	01:25:00	KiK-net
ACC_05387_NGNH27	1.53	478	C	6.3	13.9	22.11.14	22:08:00	KiK-net
ACC_03097_AMT	2.79	670	E	5.9	25.9	26.10.16	19:18:06	ESM
ACC_01565_AQV	2.77	474	C	6.5	38.0	30.10.16	06:40:18	ESM

Table 10.44 – Metadata of the selected waveforms for seismic zone Z2, soil class E, period range 0.02-1.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_03118_NCR	0.55	555	C	6.0	0.0	26.09.97	09:40:24	ESM
ACC_03081_AMT	0.53	670	E	6.0	1.4	24.08.16	01:36:32	ESM
ACC_03579_SZOH36	1.79	677	E	5.8	35.2	01.08.11	23:58:00	KiK-net
ACC_01419_NGNH29	1.43	465	C	5.4	16.5	12.04.11	07:26:00	KiK-net
ACC_01068_5401	1.22	412	C	5.7	10.2	11.11.99	14:41:23	ESM
ACC_03150_AQA	0.51	549	E	6.1	0.0	06.04.09	01:32:40	ESM
ACC_00957_KOZ1	1.78	482	C	6.6	10.7	13.05.95	08:47:13	ESM
ACC_01836_AKTH18	1.95	431	C	6.9	47.5	14.06.08	08:43:00	KiK-net
ACC_02110_TCGH10	1.46	371	C	6.6	57.3	11.04.11	17:16:00	KiK-net
ACC_04635_NGNH28	1.69	1172	E	6.3	12.1	22.11.14	22:08:00	KiK-net
ACC_00993_AQV	0.53	474	C	6.1	0.0	06.04.09	01:32:40	ESM

Table 10.45 – Metadata of the selected waveforms for seismic zone Z2, soil class E, period range 0.25-4.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_03301_AKTH06	2.34	455	E	6.9	19.2	14.06.08	08:43:00	KiK-net
ACC_05628_MYZH08	1.62	374	C	7.1	53.9	16.04.16	01:25:00	KiK-net
ACC_02791_FKSH11	1.02	240	D	6.6	31.4	11.04.11	17:16:00	KiK-net
ACC_03097_AMT	2.43	670	E	5.9	25.9	26.10.16	19:18:06	ESM
ACC_03739_SAGH02	2.24	558	E	6.6	59.3	20.03.05	10:53:00	KiK-net
ACC_05387_NGNH27	1.48	478	C	6.3	13.9	22.11.14	22:08:00	KiK-net
ACC_03535_SAGH04	2.99	724	E	6.6	36.3	20.03.05	10:53:00	KiK-net
ACC_03150_AQA	0.73	549	E	6.1	0.0	06.04.09	01:32:40	ESM
ACC_01882_NGNH29	2.96	465	C	6.6	47.0	16.07.07	10:13:00	KiK-net
ACC_01565_AQV	2.71	474	C	6.5	38.0	30.10.16	06:40:18	ESM
ACC_01068_5401	1.87	412	C	5.7	10.2	11.11.99	14:41:23	ESM

In general, the selected waveforms for Z2 soil, class E, mostly fall inside the area where the probability of exceedance (over all IMTs) is significant for the relevant seismic zone for the return period of 975 years (Fig. 10.33), and no more than 2 records from the same earthquake are present in each set.

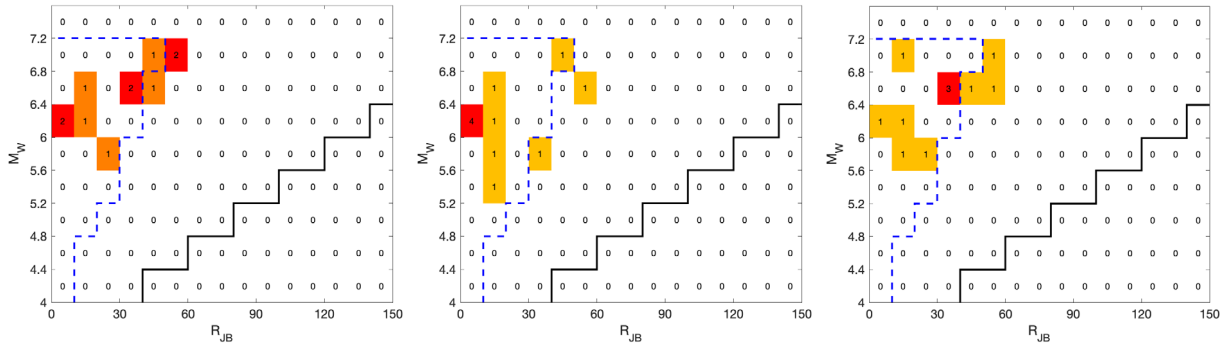

Figure 10.33 – Selected number of recordings by bin of Joyner-Boore distances (10 km width) and M_W (0.4 unit) for the period ranges 0.1-2.0s (left panel), 0.02-1.0 s (central panel) and 0.25-4.0 s (right panel) soil class E. The dashed blue lines indicate the area where the probability of exceedance (over all IMTs) is significant for the five SIA261 zones for return period 975 years, following the approach illustrated in Bergamo et al. (2022). The black continuous lines indicate our limit for the first selection of waveforms.

10.4 Seismic zone Z3a

The Z3a covers Canton Basel-Stadt and a belt surrounding the central and upper Swiss Rhône valley (see Fig. 7.1). The Baker and Lee (2018) code found 42 possible compatible combinations with RMSE ranging between 0.079 and 0.142 ln units for soil class A and spectral period range 0.1-2.0 s. Among these, we choose the one with the lowest RMSE (Fig. 10.34, left panel). In Table 10.46 the selected waveforms metadata are reported. For the period range 0.02-1.0 s, the code found 61 possible compatible combinations with RMSE ranging between 0.129 and 0.167. Among these, we choose the one with the lowest RMSE (Fig. 10.34, center panel). In Table 10.47 the selected waveforms metadata are reported. The selection for period range 0.25-4.0 s extracted 34 compatible combinations with RMSE in the range 0.077-0.124, from which the one having RMSE 0.077 is taken (Fig. 10.34). In Table 10.48 the selected waveforms metadata are reported.

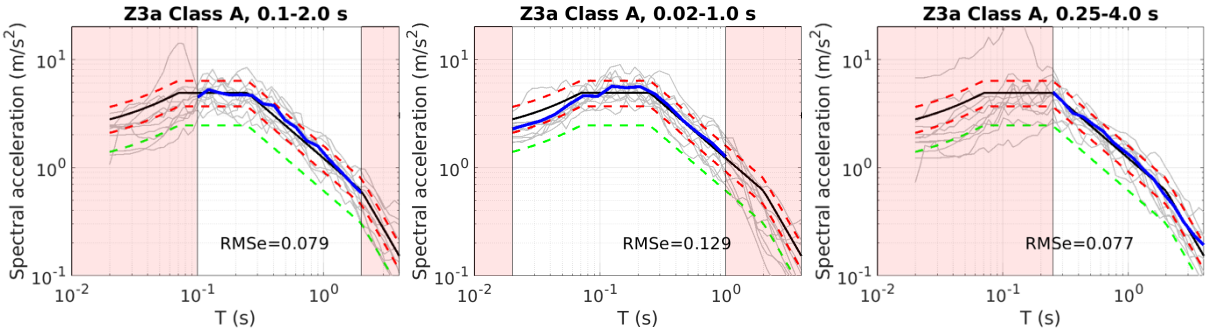

Figure 10.34 – Extracted sets of n=11 geometric means of two-components, scaled response spectra (gray lines) for Z3a zone using as target the SIA261 elastic response spectra (black line) for soil class A. The blue line is the mean of the spectra. All the Eurocode 8 (2022) criteria of this document (section 9) are satisfied. Red dashed lines indicate the 1.3 and 0.75 ratio threshold; the green dashed line indicates the 0.5 ratio threshold. Shadowed red areas highlight the period range not considered for the selection.

The selected waveforms for Z3a, soil class A, largely fall inside the area where the probability of exceedance (over all IMTs) is significant for the relevant seismic zone considering the return period of 975 years (Fig. 10.35), and no more than 2 records from the same earthquake are present in each set.

Table 10.46– Metadata of the selected waveforms for seismic zone Z3a, soil class A, period range 0.1-2.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_05089_KMMH07	1.56	765	B	6.1	23.1	14.04.16	21:26:00	KiK-net
ACC_00041_MRM	1.38	1906	A	5.2	1.6	25.10.12	23:05:24	ESM
ACC_00173_SAGH05	1.41	1000	A	6.6	58.1	20.03.05	10:53:00	KiK-net
ACC_04059_CLO	1.26	-	A	5.9	3.2	26.10.16	19:18:06	ESM
ACC_04062_MNF	1.98	-	A	5.9	6.8	26.10.16	19:18:06	ESM
ACC_00065_SMNH10	1.24	967	A	6.6	20.8	06.10.00	13:30:00	KiK-net
ACC_04511_90017	1.02	1223	A	6.7	15.1	17.01.94	12:31:00	NGA-West2
ACC_00022_ATH4	1.73	970	A	5.9	14.0	07.09.99	11:56:49	ESM
ACC_00062_OKYH07	1.97	929	A	6.6	17.2	06.10.00	13:30:00	KiK-net
ACC_04512_24047	1.06	996	A	6.7	23.1	17.01.94	12:31:00	NGA-West2
ACC_04072_MMO	1.14	-	A	6.5	9.8	30.10.16	06:40:18	ESM

Table 10.47 – Metadata of the selected waveforms for seismic zone Z3a, soil class A, period range 0.02-1.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_00041_MRM	1.93	1906	A	5.2	1.6	25.10.12	23:05:24	ESM
ACC_04061_MMO	1.44	-	A	5.9	10.4	26.10.16	19:18:06	ESM
ACC_04072_MMO	0.84	-	A	6.5	9.8	30.10.16	06:40:18	ESM
ACC_04130_VGG	1.57	-	A	5.2	9.6	25.10.12	23:05:24	ESM
ACC_05089_KMMH07	1.52	765	B	6.1	23.1	14.04.16	21:26:00	KiK-net
ACC_04062_MNF	1.98	-	A	5.9	6.8	26.10.16	19:18:06	ESM
ACC_00291_ATH2	1.94	706	B	5.9	16.0	07.09.99	11:56:49	ESM
ACC_04511_90017	1.46	1223	A	6.7	15.1	17.01.94	12:31:00	NGA-West2
ACC_04049_CLO	1.91	-	A	5.4	7.1	26.10.16	17:10:36	ESM
ACC_04031_GVD	1.25	-	A	5.3	1.7	12.09.12	03:27:45	ESM
ACC_04075_SPM	1.93	-	A	6.5	31.3	30.10.16	06:40:18	ESM

Table 10.48 – Metadata of the selected waveforms for seismic zone Z3a, soil class A, period range 0.25-4.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_00600_OKYH14	1.95	710	B	6.6	33.4	06.10.00	13:30:00	KiK-net
ACC_04512_24047	0.72	996	A	6.7	23.1	17.01.94	12:31:00	NGA-West2
ACC_04062_MNF	1.74	-	A	5.9	6.8	26.10.16	19:18:06	ESM
ACC_04511_90017	1.09	1223	A	6.7	15.1	17.01.94	12:31:00	NGA-West2
ACC_04635_NGNH28	0.64	1172	E	6.3	12.1	22.11.14	22:08:00	KiK-net
ACC_00173_SAGH05	1.69	1000	A	6.6	58.1	20.03.05	10:53:00	KiK-net
ACC_04059_CLO	1.25	-	A	5.9	3.2	26.10.16	19:18:06	ESM
ACC_00022_ATH4	1.51	970	A	5.9	14.0	07.09.99	11:56:49	ESM
ACC_04072_MMO	0.93	-	A	6.5	9.8	30.10.16	06:40:18	ESM
ACC_00041_MRM	1.54	1906	A	5.2	1.6	25.10.12	23:05:24	ESM
ACC_00065_SMNH10	1.06	967	A	6.6	20.8	06.10.00	13:30:00	KiK-net

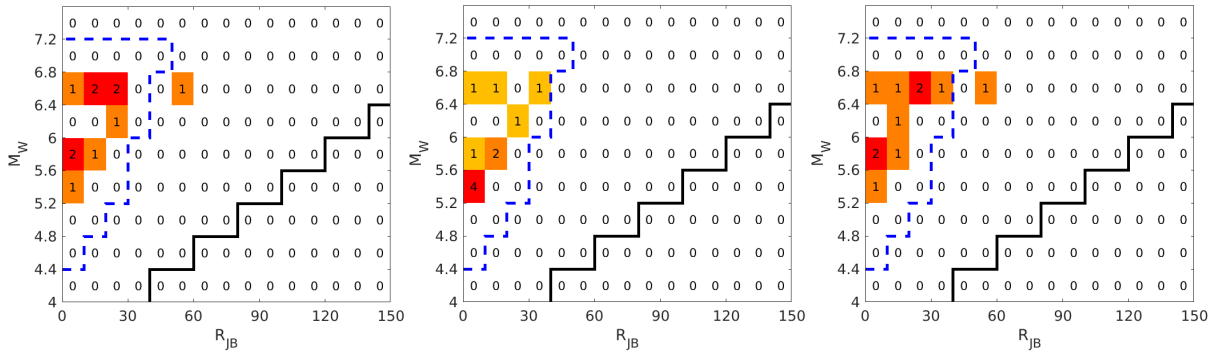

Figure 10.35 – Selected number of recordings by bin of Joyner-Boore distances (10 km width) and M_W (0.4 unit) for the period ranges 0.1-2.0s (left panel), 0.02-1.0 s (central panel) and 0.25-4.0 s (right panel) soil class A. The dashed blue lines indicate the areas where probability of exceedance (over all IMTs) is significant for the five SIA261 zones for return period 975 years following the approach illustrated in Bergamo et al. (2022). The black continuous lines indicate our limit for the first selection of waveforms.

The search was repeated for soil class B, resulting in 2 compatible selections for the period range 0.1-2.0 s with RMSE ranging between 0.128 and 0.137 ln units. Among these, we choose the one with the lowest RMSE (Fig. 10.36, left panel). In Table 10.49 the selected waveforms metadata are reported. For the period range 0.02-1.0 s, the code found 49 possible compatible combinations with RMSE ranging between 0.085 and 0.112. Among these, we choose the one with the lowest RMSE (Fig. 10.36). In Table 10.50 the selected waveforms metadata are reported. Only 1 compatible combination is found for period range 0.25-4.0 s, with RMSE = 0.130 (Fig. 10.36). In Table 10.51 the selected waveforms metadata are reported.

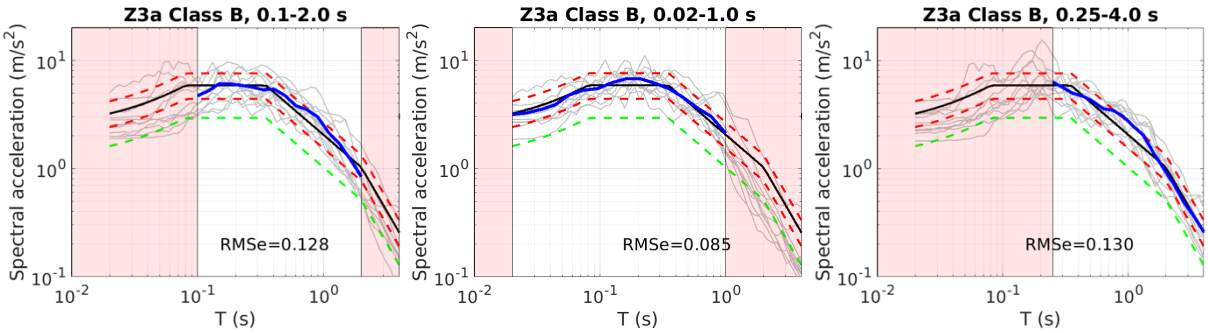

Figure 10.36 – Extracted sets of n=11 geometric mean of two-components, scaled response spectra (gray lines) for Z3a zone using as target the SIA261 elastic response spectra (black line) for soil class B. The blue line is the mean of the spectra. All the Eurocode 8 (2022) criteria of this document (section 9) are satisfied. Red dashed lines indicate the 1.3 and 0.75 ratio threshold; the green dashed line indicates the 0.5 ratio threshold. Shadowed red areas highlight the period range not considered for the selection.

The selected waveforms for Z3a soil class B fall inside the area where the probability of exceedance (over all IMTs) is significant for the relevant seismic zone considering the return period of 975 years (Fig. 10.37); no more than 2 records from the same earthquake are present in each set.

Table 10.49– Metadata of the selected waveforms for seismic zone Z3a, soil class B, period range 0.1-2.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_01527_PHOB	0.75	404	C	6.0	4.5	28.09.04	17:15:00	NGA-West2
ACC_00924_NOR	1.24	423	C	5.9	6.1	26.10.16	19:18:06	ESM
ACC_03150_AQA	0.77	549	E	6.1	0.0	06.04.09	01:32:40	ESM
ACC_00319_AQG	0.94	696	B	6.1	0.0	06.04.09	01:32:40	ESM
ACC_05387_NGNH27	1.29	478	C	6.3	13.9	22.11.14	22:08:00	KiK-net
ACC_00276_CSC	1.45	698	B	6.5	12.8	30.10.16	06:40:18	ESM
ACC_05089_KMMH07	1.84	765	B	6.1	23.1	14.04.16	21:26:00	KiK-net
ACC_00922_NOR	1.57	423	C	5.4	8.8	26.10.16	17:10:36	ESM
ACC_00958_AIGA	0.56	410	C	6.5	13.6	15.06.95	00:15:47	KiK-net
ACC_00923_NRC	1.59	498	C	5.4	8.7	26.10.16	17:10:36	ESM
ACC_00894_NOR	1.11	423	C	6.0	2.3	24.08.16	01:36:32	ESM

Table 10.50 – Metadata of the selected waveforms for seismic zone Z3a, soil class B, period range 0.02-1.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2)

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_00993_AQV	0.63	474	C	6.1	0.0	06.04.09	01:32:40	ESM
ACC_00319_AQG	0.85	696	B	6.1	0.0	06.04.09	01:32:40	ESM
ACC_05419_KMMH03	0.62	421	C	7.1	18.2	16.04.16	01:25:00	KiK-net
ACC_00276_CSC	1.48	698	B	6.5	12.8	30.10.16	06:40:18	ESM
ACC_03081_AMT	0.59	670	E	6.0	1.4	24.08.16	01:36:32	ESM
ACC_00923_NRC	1.02	498	C	5.4	8.7	26.10.16	17:10:36	ESM
ACC_00292_ATH3	1.12	512	B	5.9	14.5	07.09.99	11:56:49	ESM
ACC_01419_NGNH29	1.89	465	C	5.4	16.5	12.04.11	07:26:00	KiK-net
ACC_00427_NIGH10	1.75	653	B	6.6	25.3	23.10.04	17:56:00	KiK-net
ACC_00254_CSC	1.94	698	B	6.0	11.6	24.08.16	01:36:32	ESM
ACC_03100_AMT	0.71	670	E	6.5	10.1	30.10.16	06:40:18	ESM

Table 10.51 – Metadata of the selected waveforms for seismic zone Z3a, soil class B, period range 0.25-4.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording , then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2)

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_03150_AQA	0.74	549	E	6.1	0.0	06.04.09	01:32:40	ESM
ACC_00276_CSC	1.79	698	B	6.5	12.8	30.10.16	06:40:18	ESM
ACC_00895_NRC	0.90	498	C	6.0	2.0	24.08.16	01:36:32	ESM
ACC_01836_AKTH18	1.97	431	C	6.9	47.5	14.06.08	08:43:00	KiK-net
ACC_00924_NOR	1.57	423	C	5.9	6.1	26.10.16	19:18:06	ESM
ACC_05387_NGNH27	1.22	478	C	6.3	13.9	22.11.14	22:08:00	KiK-net
ACC_00935_NRC	0.53	498	C	6.5	2.8	30.10.16	06:40:18	ESM
ACC_05419_KMMH03	0.53	421	C	7.1	18.2	16.04.16	01:25:00	KiK-net
ACC_00894_NOR	1.10	423	C	6.0	2.3	24.08.16	01:36:32	ESM
ACC_00922_NOR	1.63	423	C	5.4	8.8	26.10.16	17:10:36	ESM
ACC_00925_NRC	1.39	498	C	5.9	5.9	26.10.16	19:18:06	ESM

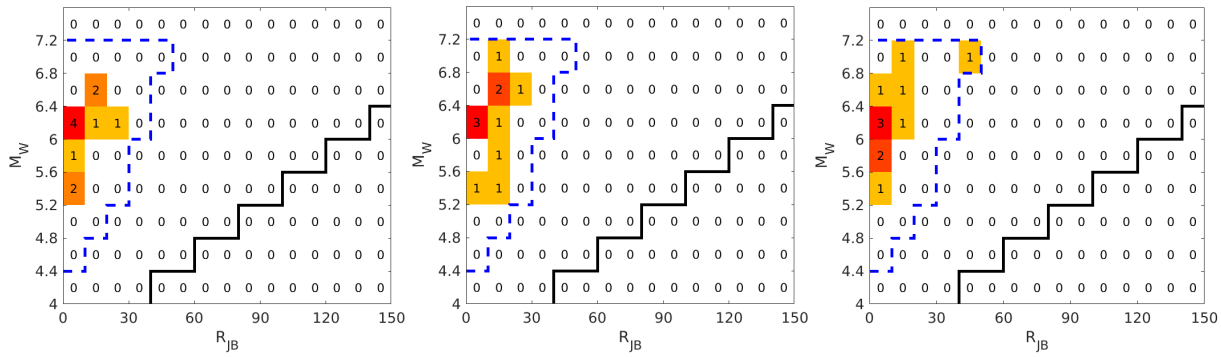

Figure 10.37 – Selected number of recordings by bin of Joyner-Boore distances (10 km width) and M_W (0.4 unit) for the period ranges 0.1-2.0s (left panel), 0.02-1.0 s (central panel) and 0.25-4.0 s (right panel), soil class B. The dashed blue lines indicate the areas where the probability of exceedance (over all IMTs) is significant for the five SIA261 zones for return period 975 years, following the approach illustrated in Bergamo et al. (2022). The black continuous lines indicate our limit for the first selection of waveforms.

For soil class C, 14 compatible selections for the period range 0.1-2.0 s and RMSE ranging between 0.099 and 0.119 ln units are found. Among these, we choose the one with RMSE = 0.101 to limit the records acquired by the same station to the maximum number of 3 (Fig. 10.38, left panel). In Table 10.52, the selected waveforms metadata are reported. In the period range 0.02-1.0 s, the code found 50 possible compatible combinations with RMSE ranging between 0.052 and 0.098 ln units. Among these, we choose the one with the lowest RMSE (Fig. 10.38, central panel). In Table 10.53, the selected waveforms metadata are reported. The selection for period range 0.25-4.0 s extracted 23 compatible combinations with RMSE in the range 0.096-0.138, from which the one having lowest RMSE = 0.096 is taken (Fig. 10.38). In Table 10.54 the selected waveforms metadata are reported.

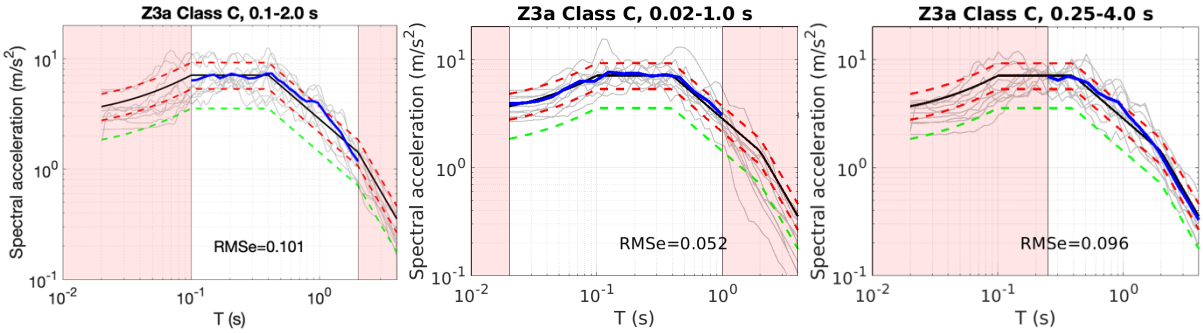

Figure 10.38– Extracted sets of n=11 geometric means of two-components, scaled response spectra (gray lines) for Z3a zone using as target the SIA261 elastic response spectra (black line) for soil class C. The blue line is the mean of the spectra. All the Eurocode 8 (2022) criteria of this document (section 9) are satisfied. Red dashed lines indicate the 1.3 and 0.75 ratio threshold; the green dashed line indicates the 0.5 ratio threshold. Shadowed red areas highlight the period range not considered for the selection.

The selected waveforms for Z3a soil class C largely fall inside the area where the probability of exceedance (over all IMTs) is significant for the relevant seismic zone considering the return period of 975 years (Fig. 10.39); no more than 2 records from the same earthquake are present in each set.

Table 10.52– Metadata of the selected waveforms for seismic zone Z3a, soil class C, period range 0.1-2.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the event , then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_01238_NIGH11	0.96	375	C	6.6	0.0	23.10.04	17:56:00	KiK-net
ACC_01342_NIGH11	1.72	375	C	6.2	17.2	12.03.11	03:59:00	KiK-net
ACC_00924_NOR	1.75	423	C	5.9	6.1	26.10.16	19:18:06	ESM
ACC_01527_PHOB	1.03	404	C	6.0	4.5	28.09.04	17:15:00	NGA-West2
ACC_01242_NIGH11	0.80	375	C	6.3	15.0	23.10.04	18:34:00	KiK-net
ACC_05387_NGNH27	1.56	478	C	6.3	13.9	22.11.14	22:08:00	KiK-net
ACC_03996_12149	1.59	385	C	7.3	21.8	28.06.92	11:58:00	NGA-West2
ACC_01787_12149	1.65	385	C	6.5	39.5	28.06.92	15:06:00	NGA-West2
ACC_05445_TTRH07	1.84	389	C	6.2	8.6	21.10.16	14:07:00	KiK-net
ACC_05419_KMMH03	0.69	421	C	7.1	18.2	16.04.16	01:25:00	KiK-net
ACC_00958_AIGA	0.71	410	C	6.5	13.6	15.06.95	00:15:47	ESM

Table 10.53 – Metadata of the selected waveforms for seismic zone Z3a, soil class C, period range 0.02-1.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the event , then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_01242_NIGH11	0.67	375	C	6.3	15.0	23.10.04	18:34:00	KiK-net
ACC_00993_AQV	0.63	474	C	6.1	0.0	06.04.09	01:32:40	ESM
ACC_05419_KMMH03	0.76	421	C	7.1	18.2	16.04.16	01:25:00	KiK-net
ACC_01238_NIGH11	0.61	375	C	6.6	0.0	23.10.04	17:56:00	KiK-net
ACC_01527_PHOB	1.11	404	C	6.0	4.5	28.09.04	17:15:00	NGA-West2
ACC_01342_NIGH11	1.85	375	C	6.2	17.2	12.03.11	03:59:00	KiK-net
ACC_00923_NRC	1.63	498	C	5.4	8.7	26.10.16	17:10:36	ESM
ACC_00954_PAT2	1.89	369	C	5.6	4.3	14.07.93	12:31:48	ESM
ACC_01529_CHR	1.61	471	C	5.5	4.3	31.10.07	03:04:00	NGA-West2
ACC_00958_AIGA	1.03	410	C	6.5	13.6	15.06.95	00:15:47	ESM
ACC_00924_NOR	1.68	423	C	5.9	6.1	26.10.16	19:18:06	ESM

Table 10. 54 – Metadata of the selected waveforms for seismic zone Z3a, soil class C, period range 0.25-4.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_01238_NIGH11	0.79	375	C	6.6	0.0	23.10.04	17:56:00	KiK-net
ACC_00924_NOR	1.61	423	C	5.9	6.1	26.10.16	19:18:06	ESM
ACC_03996_12149	1.94	385	C	7.3	21.8	28.06.92	11:58:00	NGA-West2
ACC_05419_KMMH03	0.81	421	C	7.1	18.2	16.04.16	01:25:00	KiK-net
ACC_05387_NGNH27	1.77	478	C	6.3	13.9	22.11.14	22:08:00	KiK-net
ACC_01266_NIGH11	1.90	375	C	6.6	27.8	16.07.07	10:13:00	KiK-net
ACC_01346_NIGH18	1.78	311	C	6.2	23.5	12.03.11	03:59:00	KiK-net
ACC_05445_TTRH07	2.00	389	C	6.2	8.6	21.10.16	14:07:00	KiK-net
ACC_01527_PHOB	1.45	404	C	6.0	4.5	28.09.04	17:15:00	NGA-West2
ACC_00958_AIGA	0.79	410	C	6.5	13.6	15.06.95	00:15:47	ESM
ACC_01342_NIGH11	1.62	375	C	6.2	17.2	12.03.11	03:59:00	KiK-net

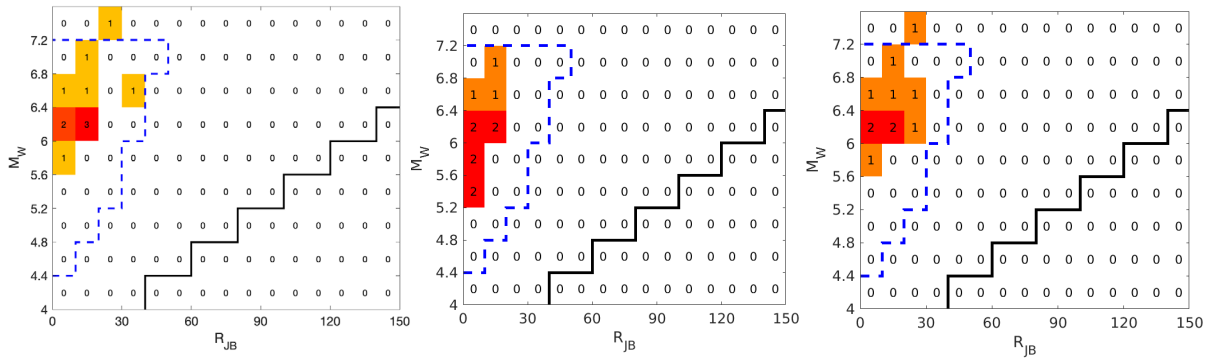

Figure 10.39 – Selected number of recordings by bin of Joyner-Boore distances (10 km width) and M_W (0.4 unit) for the period ranges 0.1-2.0s (left panel), 0.02-1.0 s (central panel) and 0.25-4.0 s (right panel) soil class C. The dashed blue lines indicate the areas where probability of exceedance (over all IMTs) is significant for the five SIA261 zones for return period 975 years, following the approach illustrated in Bergamo et al. (2022). The black continuous lines indicate our limit for the first selection of waveforms.

For the period range 0.1-2.0 s, soil class D, we find 17 compatible selections having RMSE ranging between 0.059 and 0.116 ln units. Among these, we choose the one with the lowest RMSE (Fig. 10.40, left panel). In Table 10.55 the selected waveforms metadata are reported. In the period range 0.02-1.0 s, the code found 50 possible compatible combinations with RMSE ranging between 0.044 and 0.076. Among these, we choose the one with the lowest RMSE (Fig. 10.40, central panel). In Table 10.56 the selected waveforms metadata are reported. The selection for period range 0.25-4.0 s extracted 46 compatible combinations with RMSE in the range 0.081-0.138, from which the one having lowest RMSE = 0.081 is taken (Fig. 10.40, right panel). In Table 10.57 the selected waveforms metadata are reported.

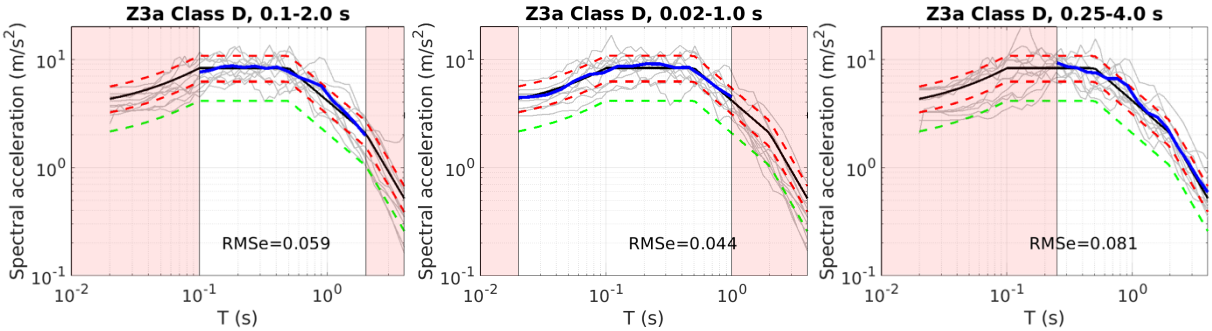

Figure 10.40– Extracted sets of n=11 geometric means of two-component, scaled response spectra (gray lines) for Z3a zone using as target the SIA261 elastic response spectra (black line) for soil class D. The blue line is the mean of the spectra. All the Eurocode 8 (2022) criteria of this document (section 9) are satisfied. Red dashed lines indicate the 1.3 and 0.75 ratio threshold; the green dashed line indicates the 0.5 ratio threshold. Shadowed red areas highlight the period range not considered for the selection.

The selected waveforms for Z3a, soil class D, mostly fall inside the area where the probability of exceedance (over all IMTs) is significant for the relevant seismic zone considering the return period of 975 years (Fig. 10.41); no more than 2 records from the same earthquake are present in each set.

Table 10.55– Metadata of the selected waveforms for seismic zone Z3a, soil class D, period range 0.1-2.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_02537_MRN	1.24	208	D	6.1	4.3	20.05.12	02:03:50	ESM
ACC_04007_WES	1.25	269	D	7.2	10.3	04.04.10	22:40:00	NGA-West2
ACC_01238_NIGH11	0.86	375	C	6.6	0.0	23.10.04	17:56:00	KiK-net
ACC_03991_1401	0.53	294	D	7.3	24.9	11.12.99	16:57:19	ESM
ACC_01527_PHOB	1.72	404	C	6.0	4.5	28.09.04	17:15:00	NGA-West2
ACC_02543_MRN	1.17	208	D	6.0	0.0	29.05.12	07:00:02	ESM
ACC_05419_KMMH03	1.27	421	C	7.1	18.2	16.04.16	01:25:00	KiK-net
ACC_00958_AIGA	0.95	410	C	6.5	13.6	15.06.95	00:15:47	ESM
ACC_01787_12149	1.64	385	C	6.5	39.5	28.06.92	15:06:00	NGA-West2
ACC_05445_TTRH07	1.99	389	C	6.2	8.6	21.10.16	14:07:00	KiK-net
ACC_00894_NOR	1.94	423	C	6.0	2.3	24.08.16	01:36:32	ESM

Table 10.56 – Metadata of the selected waveforms for seismic zone Z3a, soil class D, period range 0.02-1.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_01238_NIGH11	0.84	375	C	6.6	0.0	23.10.04	17:56:00	KiK-net
ACC_03991_1401	0.53	294	D	7.3	24.9	11.12.99	16:57:19	ESM
ACC_02537_MRN	1.34	208	D	6.1	4.3	20.05.12	02:03:50	ESM
ACC_01527_PHOB	1.72	404	C	6.0	4.5	28.09.04	17:15:00	NGA-West2
ACC_02543_MRN	1.34	208	D	6.0	0.0	29.05.12	07:00:02	ESM
ACC_00993_AQV	1.04	474	C	6.1	0.0	06.04.09	01:32:40	ESM
ACC_05419_KMMH03	1.08	421	C	7.1	18.2	16.04.16	01:25:00	KiK-net
ACC_01242_NIGH11	0.80	375	C	6.3	15.0	23.10.04	18:34:00	KiK-net
ACC_05445_TTRH07	1.83	389	C	6.2	8.6	21.10.16	14:07:00	KiK-net
ACC_00924_NOR	1.89	423	C	5.9	6.1	26.10.16	19:18:06	ESM
ACC_00958_AIGA	0.95	410	C	6.5	13.6	15.06.95	00:15:47	ESM

Table 10.57 – Metadata of the selected waveforms for seismic zone Z3a, soil class D, period range 0.25-4.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the event , then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_02537_MRN	1.23	208	D	6.1	4.3	20.05.12	02:03:50	ESM
ACC_02543_MRN	1.60	208	D	6.0	0.0	29.05.12	07:00:02	ESM
ACC_03996_12149	1.85	385	C	7.3	21.8	28.06.92	11:58:00	NGA-West2
ACC_01238_NIGH11	0.85	375	C	6.6	0.0	23.10.04	17:56:00	KiK-net
ACC_03991_1401	0.70	294	D	7.3	24.9	11.12.99	16:57:19	ESM
ACC_04635_NGNH28	1.69	1172	E	6.3	12.1	22.11.14	22:08:00	KiK-net
ACC_02791_FKSH11	1.69	240	D	6.6	31.4	11.04.11	17:16:00	KiK-net
ACC_05419_KMMH03	1.24	421	C	7.1	18.2	16.04.16	01:25:00	KiK-net
ACC_03992_8101	0.59	282	D	7.3	8.6	11.12.99	16:57:19	ESM
ACC_01527_PHOB	2.00	404	C	6.0	4.5	28.09.04	17:15:00	ESM
ACC_04006_ERR	1.91	253	D	7.2	50.9	04.04.10	22:40:00	NGA-West2

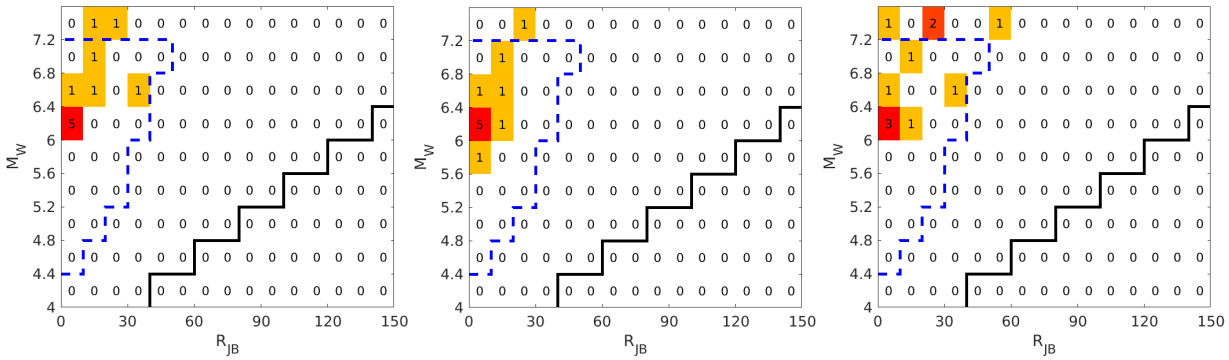

Figure 10.41 – Selected number of recordings by bin of Joyner-Boore distances (10 km width) and M_W (0.4 unit) for the period ranges 0.1-2.0s (left panel), 0.02-1.0 s (central panel) and 0.25-4.0 s (right panel) soil class D. The dashed blue lines indicate the areas where probability of exceedance (over all IMTs) is significant for the five SIA261 zones for return period 975 years, following the approach illustrated in Bergamo et al. (2022). The black continuous lines indicate our limit for the first selection of waveforms.

For the period range 0.1-2.0 s, soil class E, no spectrum compatible selections are found using real accelerograms only. The selection is repeated allowing a maximum of 4 synthetic recordings, but also in this case no compatible selections are found. Therefore, we increase the scaling factor up to 3 (Du et al., 2018). We then find only 1 compatible selection with RMSE 0.113 (Fig. 10.42, left panel). In Table 10.58 the selected waveforms metadata are reported. In the period range 0.02-1.0 s, the code found 10 possible compatible combinations of real accelerograms with RMSE ranging between 0.128 and 0.141. Among these, we choose the one with the lowest RMSE (Fig. 10.42, center panel). In Table 10.59, the selected waveforms metadata are reported. The selection for period range 0.25-4.0 s doesn't return compatible combinations using real accelerograms and synthetics. Therefore, we increase the scaling factor up to 3 (Du et al., 2018) and we release the distance limitations, finding 1 compatible combination with RMSE in the range 0.114 (Fig. 10.42, right panel). In Table 10.60 the selected waveforms metadata are reported.

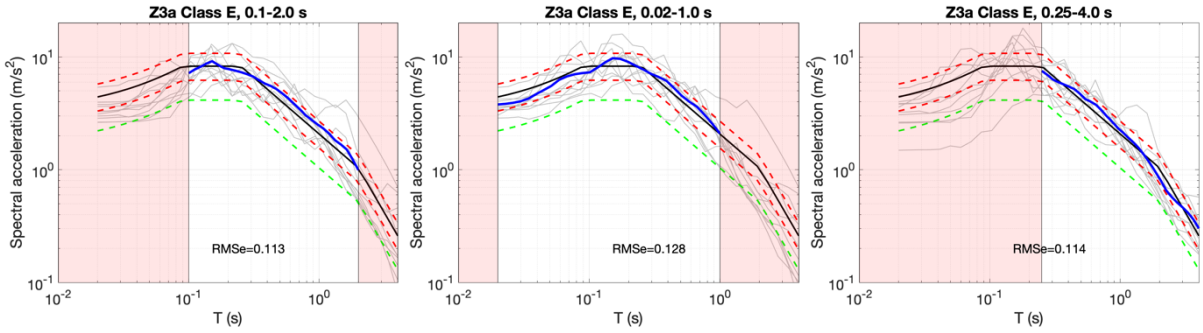

Figure 10.42 – Extracted sets of n=11 geometric mean of two components scaled response spectra (gray lines) for Z3a zone using as target the SIA261 elastic response spectra (black line) for soil class E. The blue line is the mean of the spectra. All the Eurocode 8 (2022) criteria of this document (section 9) are satisfied. Red dashed lines indicate the 1.3 and 0.75 ratio threshold; the green dashed line indicates the 0.5 ratio threshold. Shadowed red areas highlight the period range not considered for the selection.

Table 10.58 – Metadata of the selected waveforms for seismic zone Z3a, soil class E, period range 0.1-2.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_01836_AKTH18	2.89	431	C	6.9	47.5	14.06.08	08:43:00	KiK-net
ACC_03150_AQA	0.74	549	E	6.1	0.0	06.04.09	01:32:40	ESM
ACC_05387_NGNH27	1.80	478	C	6.3	13.9	22.11.14	22:08:00	KiK-net
ACC_00957_KOZ1	2.28	482	C	6.6	10.7	13.05.95	08:47:13	ESM
ACC_00993_AQV	0.62	474	C	6.1	0.0	06.04.09	01:32:40	ESM
ACC_02791_FKSH11	0.97	240	D	6.6	31.4	11.04.11	17:16:00	KiK-net
ACC_05628_MYZH08	2.18	374	C	7.1	53.9	16.04.16	01:25:00	KiK-net
ACC_01658_NGNH29	2.58	465	C	6.6	39.3	23.10.04	17:56:00	KiK-net
ACC_01882_NGNH29	2.77	465	C	6.6	47.0	16.07.07	10:13:00	KiK-net
ACC_03081_AMT	0.94	670	E	6.0	1.4	24.08.16	01:36:32	ESM
ACC_04635_NGNH28	1.91	1172	E	6.3	12.1	22.11.14	22:08:00	KiK-net

Table 10.59 – Metadata of the selected waveforms for seismic zone Z3a, soil class E, period range 0.02-1.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_03081_AMT	0.63	670	E	6.0	1.4	24.08.16	01:36:32	ESM
ACC_00993_AQV	0.56	474	C	6.1	0.0	06.04.09	01:32:40	ESM
ACC_03150_AQA	0.83	549	E	6.1	0.0	06.04.09	01:32:40	ESM
ACC_03118_NCR	0.62	555	C	6.0	0.0	26.09.97	09:40:24	ESM
ACC_01167_IWTH26	0.51	371	C	6.9	6.0	14.06.08	08:43:00	KiK-net
ACC_00957_KOZ1	1.94	482	C	6.6	10.7	13.05.95	08:47:13	ESM
ACC_01068_5401	1.53	412	C	5.7	10.2	11.11.99	14:41:23	ESM
ACC_03100_AMT	0.92	670	E	6.5	10.1	30.10.16	06:40:18	ESM
ACC_02110_TCGH10	1.92	371	C	6.6	57.3	11.04.11	17:16:00	KiK-net
ACC_02791_FKSH11	0.93	240	D	6.6	31.4	11.04.11	17:16:00	KiK-net
ACC_04635_NGNH28	1.90	1172	E	6.3	12.1	22.11.14	22:08:00	KiK-net

Table 10.60 – Metadata of the selected waveforms for seismic zone Z3a, soil class E, period range 0.25-4.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_01167_IWTH26	0.50	371	C	6.9	6.0	14.06.08	08:43:00	KiK-net
ACC_03150_AQA	0.95	549	E	6.1	0.0	06.04.09	01:32:40	ESM
ACC_01658_NGNH29	3.00	465	C	6.6	39.3	23.10.04	17:56:00	KiK-net
ACC_03301_AKTH06	2.39	455	E	6.9	19.2	14.06.08	08:43:00	KiK-net
ACC_01882_NGNH29	2.98	465	C	6.6	47.0	16.07.07	10:13:00	KiK-net
ACC_02791_FKSH11	1.05	240	D	6.6	31.4	11.04.11	17:16:00	KiK-net
ACC_04002_11023	1.59	212	D	7.2	66.7	04.04.10	22:40:00	NGA-West2
ACC_05387_NGNH27	1.80	478	C	6.3	13.9	22.11.14	22:08:00	KiK-net
ACC_05835_FKSH11	2.32	240	D	7.0	84.4	22.11.16	05:59:00	KiK-net
ACC_03100_AMT	0.84	670	E	6.5	10.1	30.10.16	06:40:18	ESM
ACC_03118_NCR	0.73	555	C	6.0	0.0	26.09.97	09:40:24	ESM

The selected waveforms for Z3a, soil class E, largely fall inside the areas where probability of exceedance (over all IMTs) is significant for the relevant seismic zone, considering the return period of 975; a partial exception is represented by the period range 0.25-4.0 s (Fig. 10.43, right panel), where the distance constraint had to be waived. For all period intervals, no more than 2 records from the same earthquake are present in each set.

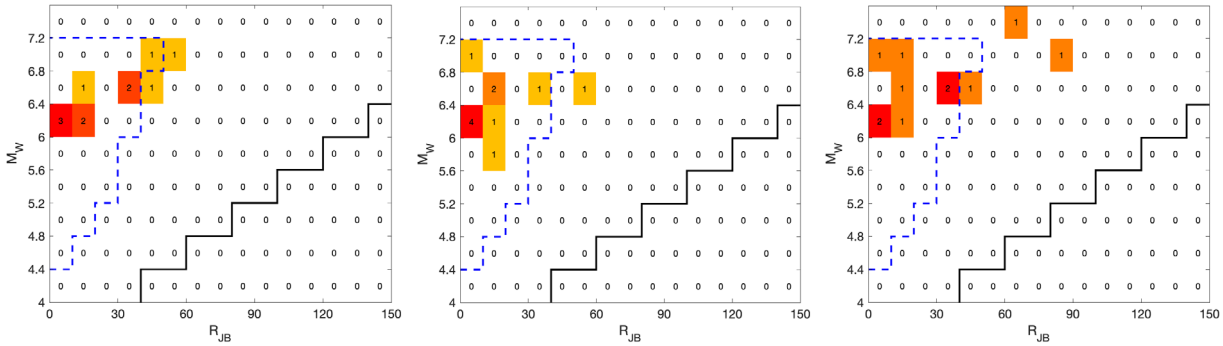

Figure 10.43 – Selected number of recordings by bin of Joyner-Boore distances (10 km width) and M_W (0.4 unit) for the period ranges 0.1-2.0s (left panel), 0.02-1.0 s (central panel) and 0.25-4.0 s (right panel) soil class E. The dashed blue lines indicate the area where probability of exceedance (over all IMTs) is significant for the five SIA261 zones for return period 975 years, following the approach illustrated in Bergamo et al. (2022) approach. The black continuous lines indicate our limit for the first selection of waveforms.

10.5 Seismic zone Z3b

The Z3b covers the upper and central Swiss Rhone valley (see Fig. 7.1). The Baker and Lee (2018) code found 11 possible compatible combinations with RMSE ranging between 0.132 and 0.155 for soil class A and spectral period range 0.1-2.0 s. Among these, we choose the one with the lowest RMSE (Fig. 10.44, left panel). In Table 10.61 the selected waveforms metadata are reported. For the period range 0.02-1.0 s the code found 11 possible compatible combinations with RMSE ranging between 0.173 and 0.196. Among these, we choose the one with the lowest RMSE (Fig. 10.44, central panel). In Table 10.62 the selected waveforms metadata are reported. The selection for period range 0.25-4.0 s extracted 7 compatible combinations with RMSE in the range 0.097-0.108, from which the one having RMSE 0.097 is taken (Fig. 10.44, right panel). In Table 10.63, the selected waveforms metadata are reported.

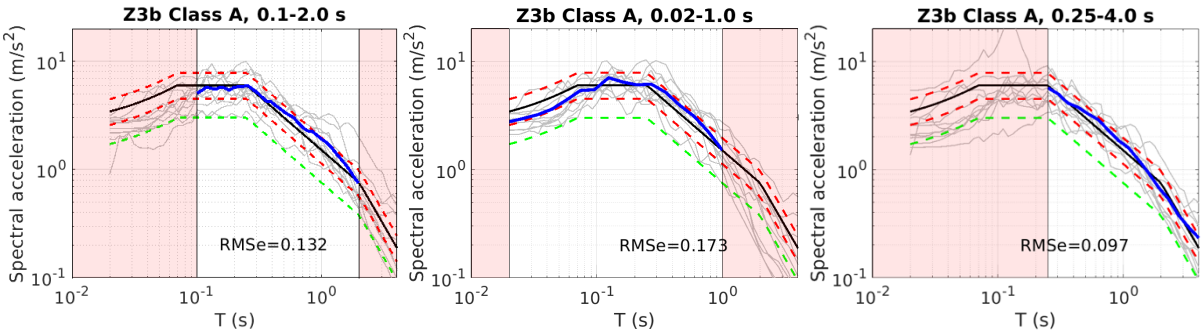

Figure 10.44 – Extracted sets of n=11 geometric means of two-component, scaled response spectra (gray lines) for Z3b zone using as target the SIA261 elastic response spectra (black line) for soil class A. The blue line is the mean of the spectra. All the Eurocode 8 (2022) criteria of this document (section 9) are satisfied. Red dashed lines indicate the 1.3 and 0.75 ratio threshold; the green dashed line indicates the 0.5 ratio threshold. Shadowed red areas highlight the period range not considered for the selection.

The selected waveforms for Z3b, soil class A, mostly fall inside the area where the probability of exceedance (over all IMTs) is significant for the seismic zone considering the return period

of 975 years (Fig. 10.45); no more than 2 records from the same earthquake are present in each set.

Table 10.61– Metadata of the selected waveforms for seismic zone Z3b, soil class A, period range 0.1-2.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_05089_KMMH07	1.84	765	B	6.1	23.1	14.04.16	21:26:00	KiK-net
ACC_04059_CLO	1.43	-	A	5.9	3.2	26.10.16	19:18:06	ESM
ACC_04512_24047	0.89	996	A	6.7	23.1	17.01.94	12:31:00	NGA-West2
ACC_04072_MMO	1.48	-	A	6.5	9.8	30.10.16	06:40:18	ESM
ACC_04062_MNF	1.76	-	A	5.9	6.8	26.10.16	19:18:06	ESM
ACC_04068_ACC	0.64	-	A	6.5	2.2	30.10.16	06:40:18	ESM
ACC_00065_SMNH10	1.47	967	A	6.6	20.8	06.10.00	13:30:00	KiK-net
ACC_00041_MRM	1.84	1906	A	5.2	1.6	25.10.12	23:05:24	ESM
ACC_04511_90017	1.69	1223	A	6.7	15.1	17.01.94	12:31:00	NGA-West2
ACC_00022_ATH4	1.91	970	A	5.9	14.0	07.09.99	11:56:49	ESM
ACC_04635_NGNH28	1.25	1172	E	6.3	12.1	22.11.14	22:08:00	KiK-net

Table 10.62 – Metadata of the selected waveforms for seismic zone Z3b, soil class A, period range 0.02-1.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_00041_MRM	1.95	1906	A	5.2	1.6	25.10.12	23:05:24	ESM
ACC_04072_MMO	1.43	-	A	6.5	9.8	30.10.16	06:40:18	ESM
ACC_05089_KMMH07	1.70	765	B	6.1	23.1	14.04.16	21:26:00	KiK-net
ACC_04059_CLO	1.71	-	A	5.9	3.2	26.10.16	19:18:06	ESM
ACC_04061_MMO	1.68	-	A	5.9	10.4	26.10.16	19:18:06	ESM
ACC_04031_GVD	1.62	-	A	5.3	1.7	12.09.12	03:27:45	ESM
ACC_04049_CLO	2.00	-	A	5.4	7.1	26.10.16	17:10:36	ESM
ACC_00065_SMNH10	1.52	967	A	6.6	20.8	06.10.00	13:30:00	KiK-net
ACC_04511_90017	1.80	1223	A	6.7	15.1	17.01.94	12:31:00	NGA-West2
ACC_04130_VGG	1.71	-	A	5.2	9.6	25.10.12	23:05:24	ESM
ACC_00028_LRS	1.43	1024	A	5.6	16.2	09.09.98	11:28:00	ESM

Table 10.63 – Metadata of the selected waveforms for seismic zone Z3b, soil class A, period range 0.25-4.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_04072_MMO	1.49	-	A	6.5	9.8	30.10.16	06:40:18	ESM
ACC_04512_24047	1.35	996	A	6.7	23.1	17.01.94	12:31:00	NGA-West2
ACC_04511_90017	1.35	1223	A	6.7	15.1	17.01.94	12:31:00	NGA-West2
ACC_04059_CLO	1.08	-	A	5.9	3.2	26.10.16	19:18:06	ESM
ACC_04068_ACC	0.51	-	A	6.5	2.2	30.10.16	06:40:18	ESM
ACC_00065_SMNH10	1.34	967	A	6.6	20.8	06.10.00	13:30:00	KiK-net
ACC_00600_OKYH14	1.56	710	B	6.6	33.4	06.10.00	13:30:00	KiK-net
ACC_00022_ATH4	1.72	970	A	5.9	14.0	07.09.99	11:56:49	ESM
ACC_04061_MMO	1.58	-	A	5.9	10.4	26.10.16	19:18:06	ESM
ACC_00041_MRM	1.85	1906	A	5.2	1.6	25.10.12	23:05:24	ESM
ACC_04635_NGNH28	0.84	1172	E	6.3	12.1	22.11.14	22:08:00	KiK-net

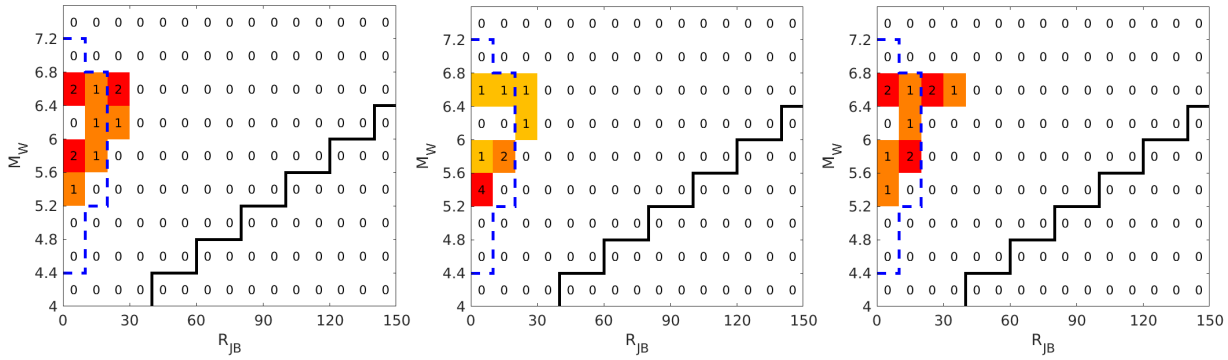

Figure 10.45 – Selected number of recordings by bin of Joyner-Boore distances (10 km width) and M_W (0.4 unit) for the period ranges 0.1-2.0s (left panel), 0.02-1.0 s (central panel) and 0.25-4.0 s (right panel) soil class A. The dashed blue lines indicate the areas where probability of exceedance (over all IMTs) is significant for the five SIA261 zones for return period 975 years following the approach illustrated in Bergamo et al. (2022). The black continuous lines indicate our limit for the first selection of waveforms.

The search was repeated for soil class B, resulting in only 1 compatible selection for the period range 0.1-2.0 s and RMSE 0.140 (Fig. 10.46, left panel). In Table 10.64 the selected waveforms metadata are reported. For the period range 0.02-1.0 s, the code found 99 possible compatible combinations with RMSE ranging between 0.088 and 0.123 B. Among these we choose the one with the lowest RMSE (Fig. 10.46, center panel). In Table 10.65 the selected waveforms metadata are reported. For period range 0.25-4.0 s, 6 compatible combinations - with RMSE between 0.145 and 0.151 – are found (Fig. 10.46, right panel). In Table 10.66 the selected waveforms metadata are reported.

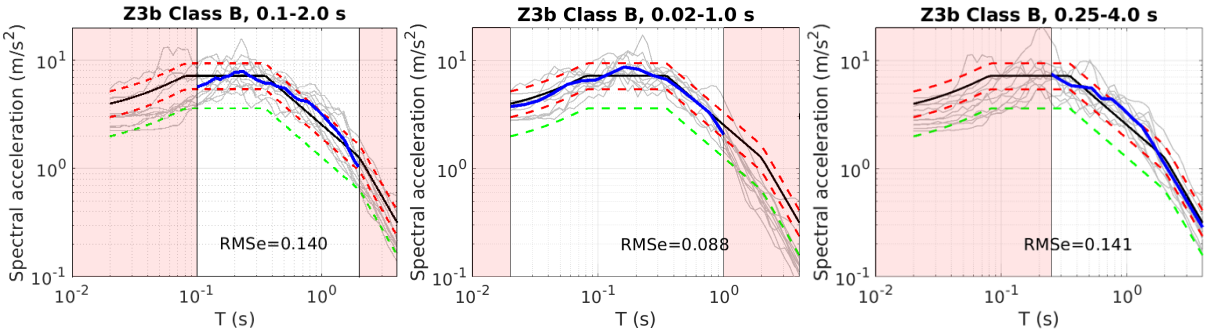

Figure 10.46 – Extracted sets of n=11 geometric means of two-component, scaled response spectra (gray lines) for Z3b zone using as target the SIA261 elastic response spectra (black line) for soil class B. The blue line is the mean of the spectra. All the Eurocode 8 (2022) criteria of this document (section 9) are satisfied. Red dashed lines indicate the 1.3 and 0.75 ratio threshold; the green dashed line indicates the 0.5 ratio threshold. Shadowed red areas highlight the period range not considered for the selection.

The selected waveforms for Z3b, soil class B, largely fall inside the area where probability of exceedance (over all IMTs) is significant for the relevant seismic zone considering the return period of 975 years (Fig. 10.47); no more than 2 records from the same earthquake are present in each set.

Table 10.64 – Metadata of the selected waveforms for seismic zone Z3b, soil class B, period range 0.1-2.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_00924_NOR	1.88	423	C	5.9	6.1	26.10.16	19:18:06	ESM
ACC_00276_CSC	1.85	698	B	6.5	12.8	30.10.16	06:40:18	ESM
ACC_01527_PHOB	0.91	404	C	6.0	4.5	28.09.04	17:15:00	NGA-West2
ACC_03150_AQA	1.04	549	E	6.1	0.0	06.04.09	01:32:40	ESM
ACC_00958_AIGA	0.62	410	C	6.5	13.6	15.06.95	00:15:47	ESM
ACC_00922_NOR	2.00	423	C	5.4	8.8	26.10.16	17:10:36	ESM
ACC_00319_AQG	1.01	696	B	6.1	0.0	06.04.09	01:32:40	ESM
ACC_05387_NGNH27	1.52	478	C	6.3	13.9	22.11.14	22:08:00	KiK-net
ACC_00935_NRC	0.71	498	C	6.5	2.8	30.10.16	06:40:18	ESM
ACC_00292_ATH3	1.60	512	B	5.9	14.5	07.09.99	11:56:49	ESM
ACC_00894_NOR	1.27	423	C	6.0	2.3	24.08.16	01:36:32	ESM

Table 10.65 – Metadata of the selected waveforms for seismic zone Z3b, soil class B, period range 0.02-1.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2)

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_00993_AQV	0.65	474	C	6.1	0.0	06.04.09	01:32:40	ESM
ACC_00923_NRC	1.52	498	C	5.4	8.7	26.10.16	17:10:36	ESM
ACC_03081_AMT	0.69	670	E	6.0	1.4	24.08.16	01:36:32	ESM
ACC_00276_CSC	1.68	698	B	6.5	12.8	30.10.16	06:40:18	ESM
ACC_00319_AQG	0.97	696	B	6.1	0.0	06.04.09	01:32:40	ESM
ACC_00292_ATH3	1.73	512	B	5.9	14.5	07.09.99	11:56:49	ESM
ACC_05089_KMMH07	1.87	765	B	6.1	23.1	14.04.16	21:26:00	KiK-net
ACC_01419_NGNH29	1.98	465	C	5.4	16.5	12.04.11	07:26:00	KiK-net
ACC_03118_NCR	0.70	555	C	6.0	0.0	26.09.97	09:40:24	ESM
ACC_00427_NIGH10	1.98	653	B	6.6	25.3	23.10.04	17:56:00	KiK-net
ACC_01529_CHR	1.58	471	C	5.5	4.3	31.10.07	03:04:00	NGA-West2

Table 10.66 – Metadata of the selected waveforms for seismic zone Z3b, soil class B, period range 0.25-4.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_00924_NOR	1.48	423	C	5.9	6.1	26.10.16	19:18:06	ESM
ACC_00276_CSC	1.88	698	B	6.5	12.8	30.10.16	06:40:18	ESM
ACC_00935_NRC	0.60	498	C	6.5	2.8	30.10.16	06:40:18	ESM
ACC_00894_NOR	1.46	423	C	6.0	2.3	24.08.16	01:36:32	ESM
ACC_03150_AQA	0.89	549	E	6.1	0.0	06.04.09	01:32:40	ESM
ACC_05387_NGNH27	1.51	478	C	6.3	13.9	22.11.14	22:08:00	KiK-net
ACC_00895_NRC	1.23	498	C	6.0	2.0	24.08.16	01:36:32	ESM
ACC_00922_NOR	1.73	423	C	5.4	8.8	26.10.16	17:10:36	ESM
ACC_05419_KMMH03	0.59	421	C	7.1	18.2	16.04.16	01:25:00	KiK-net
ACC_01527_PHOB	1.31	404	C	6.0	4.5	28.09.04	17:15:00	NGA-West2
ACC_00958_AIGA	0.78	410	C	6.5	13.6	15.06.95	00:15:47	ESM

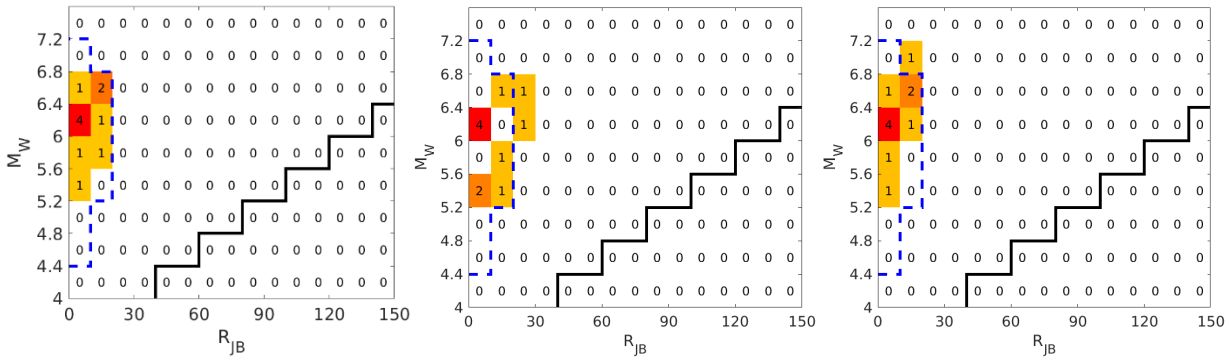

Figure 10.47 – Selected number of recordings by bin of Joyner-Boore distances (10 km width) and M_W (0.4 unit) for the period ranges 0.1-2.0s (left panel), 0.02-1.0 s (central panel) and 0.25-4.0 s (right panel) soil class B. The dashed blue lines indicate the area where the probability of exceedance (over all IMTs) is significant for the five SIA261 zones for return period 975 years, following the approach illustrated in Bergamo et al. (2022). The black continuous lines indicate our limit for the first selection of waveforms.

For soil class C, 5 compatible selections for the period range 0.1-2.0 s are found, with RMSE ranging between 0.094 and 0.133. Among these, we choose the one with lowest RMSE = 0.094 (Fig. 10.48, left panel). In Table 10.67 the selected waveforms metadata are reported. In the period range 0.02-1.0 s, the code found 49 possible compatible combinations with RMSE ranging between 0.065 and 0.124. Among these, we choose the one with the lowest RMSE (Fig. 10.48). In Table 10.68 the selected waveforms metadata are reported. The selection for period range 0.25-4.0 s extracted 4 compatible combinations with RMSE in the range 0.119-0.136, from which the one having lowest RMSE = 0.119 is taken (Fig. 10.48). In Table 10.69 the selected waveforms metadata are reported.

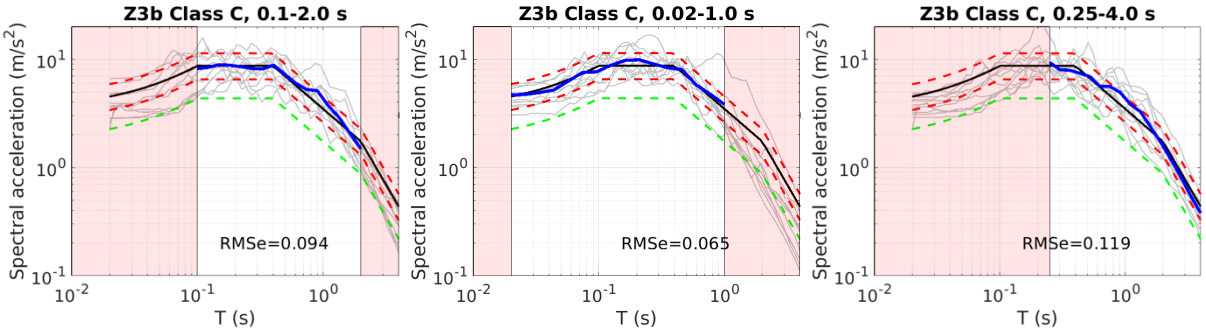

Figure 10.48 – Extracted sets of n=11 geometric means of two-component, scaled response spectra (gray lines) for Z3b zone using as target the SIA261 elastic response spectra (black line) for soil class C. The blue line is the mean of the spectra. All the Eurocode 8 (2022) criteria of this document (section 9) are satisfied. Red dashed lines indicate the 1.3 and 0.75 ratio threshold; the green dashed line indicates the 0.5 ratio threshold. Shadowed red areas highlight the period range not considered for the selection.

The selected waveforms for Z3b, soil class C, mostly fall inside the area where the probability of exceedance (over all IMTs) is significant for the relevant seismic zone considering the return period of 975 years (Fig. 10.49); no more than 2 records from the same earthquake are present in each set.

Table 10.67– Metadata of the selected waveforms for seismic zone Z3b, soil class C, period range 0.1-2.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_01238_NIGH11	0.92	375	C	6.6	0.0	23.10.04	17:56:00	KiK-net
ACC_03996_12149	1.98	385	C	7.3	21.8	28.06.92	11:58:00	NGA-West2
ACC_01527_PHOB	1.41	404	C	6.0	4.5	28.09.04	17:15:00	NGA-West2
ACC_00993_AQV	0.99	474	C	6.1	0.0	06.04.09	01:32:40	ESM
ACC_05445_TTRH07	1.96	389	C	6.2	8.6	21.10.16	14:07:00	KiK-net
ACC_00924_NOR	1.79	423	C	5.9	6.1	26.10.16	19:18:06	ESM
ACC_01342_NIGH11	1.98	375	C	6.2	17.2	12.03.11	03:59:00	KiK-net
ACC_05387_NGNH27	1.95	478	C	6.3	13.9	22.11.14	22:08:00	KiK-net
ACC_01242_NIGH11	1.02	375	C	6.3	15.0	23.10.04	18:34:00	KiK-net
ACC_01787_12149	1.65	385	C	6.5	39.5	28.06.92	15:06:00	NGA-West2
ACC_05419_KMMH03	1.12	421	C	7.1	18.2	16.04.16	01:25:00	KiK-net

Table 10.68 – Metadata of the selected waveforms for seismic zone Z3b, soil class C, period range 0.02-1.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_00923_NRC	1.73	498	C	5.4	8.7	26.10.16	17:10:36	ESM
ACC_00993_AQV	0.74	474	C	6.1	0.0	06.04.09	01:32:40	ESM
ACC_01238_NIGH11	0.80	375	C	6.6	0.0	23.10.04	17:56:00	KiK-net
ACC_00925_NRC	1.62	498	C	5.9	5.9	26.10.16	19:18:06	ESM
ACC_01242_NIGH11	0.87	375	C	6.3	15.0	23.10.04	18:34:00	KiK-net
ACC_01527_PHOB	1.38	404	C	6.0	4.5	28.09.04	17:15:00	NGA-West2
ACC_00961_SPLB	1.58	362	C	5.9	11.7	07.09.99	11:56:49	ESM
ACC_01342_NIGH11	1.91	375	C	6.2	17.2	12.03.11	03:59:00	KiK-net
ACC_00958_AIGA	0.80	410	C	6.5	13.6	15.06.95	00:15:47	ESM
ACC_01529_CHR	1.71	471	C	5.5	4.3	31.10.07	03:04:00	NGA-West2
ACC_05419_KMMH03	1.38	421	C	7.1	18.2	16.04.16	01:25:00	KiK-net

Table 10.69 – Metadata of the selected waveforms for seismic zone Z3b, soil class C, period range 0.25-4.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_03996_12149	2.00	385	C	7.3	21.8	28.06.92	11:58:00	NGA-West2
ACC_05387_NGNH27	1.97	478	C	6.3	13.9	22.11.14	22:08:00	KiK-net
ACC_01238_NIGH11	0.81	375	C	6.6	0.0	23.10.04	17:56:00	KiK-net
ACC_01527_PHOB	1.85	404	C	6.0	4.5	28.09.04	17:15:00	NGA-West2
ACC_01342_NIGH11	1.83	375	C	6.2	17.2	12.03.11	03:59:00	KiK-net
ACC_00935_NRC	0.76	498	C	6.5	2.8	30.10.16	06:40:18	ESM
ACC_00895_NRC	1.30	498	C	6.0	2.0	24.08.16	01:36:32	ESM
ACC_00894_NOR	1.96	423	C	6.0	2.3	24.08.16	01:36:32	ESM
ACC_00924_NOR	1.95	423	C	5.9	6.1	26.10.16	19:18:06	ESM
ACC_05419_KMMH03	1.03	421	C	7.1	18.2	16.04.16	01:25:00	KiK-net
ACC_00958_AIGA	0.82	410	C	6.5	13.6	15.06.95	00:15:47	ESM

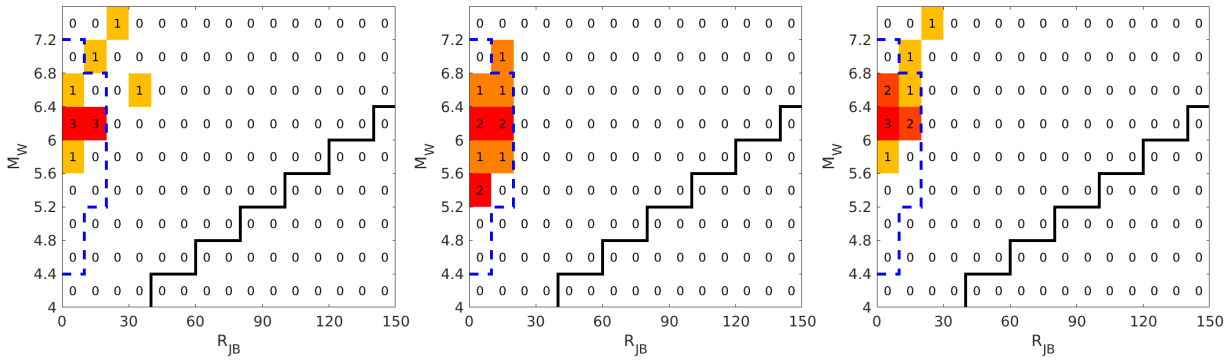

Figure 10.49 – Selected number of recordings by bin of Joyner-Boore distances (10 km width) and M_W (0.4 unit) for the period ranges 0.1-2.0s (left panel), 0.02-1.0 s (central panel) and 0.25-4.0 s (right panel), soil class C. The dashed blue lines indicate the areas where probability of exceedance (over all IMTs) is significant for the five SIA261 zones for return period 975 years following the approach illustrated in Bergamo et al. (2022). The black continuous lines indicate our limit for the first selection of waveforms.

For the period range 0.1-2.0 s, soil class D, we find 5 compatible selections and RMSE ranging between 0.083 and 0.120. Among these, we choose the one with the lowest RMSE (Fig. 10.50, left panel). In Table 10.70 the selected waveforms metadata are reported. In the period range 0.02-1.0 s, the code found 43 possible compatible combinations with RMSE ranging between 0.053 and 0.076. Among these, we choose the one with the lowest RMSE (Fig. 10.50, center panel). In Table 10.71 the selected waveforms metadata are reported. The selection for period range 0.25-4.0 s extracted 17 compatible combinations with RMSE in the range 0.093-0.129, from which the one having lowest RMSE = 0.093 is taken (Fig. 10.50, right panel). In Table 10.72, the selected waveforms metadata are reported.

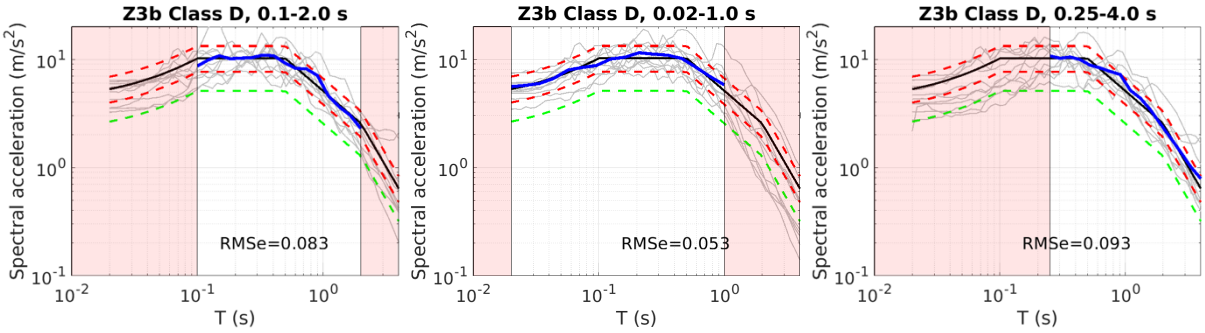

Figure 10.50 – Extracted sets of n=11 geometric means of two-component, scaled response spectra (gray lines) for Z3b zone using as target the SIA261 elastic response spectra (black line) for soil class D. The blue line is the mean of the spectra. All the Eurocode 8 (2022) criteria of this document (section 9) are satisfied. Red dashed lines indicate the 1.3 and 0.75 ratio threshold; the green dashed line indicates the 0.5 ratio threshold. Shadowed red areas highlight the period range not considered for the selection.

The selected waveforms for Z3b, soil class D, mostly fall inside the areas where the probability of exceedance (over all IMTs) is significant for the relevant seismic zone considering the return period of 975 years (Fig. 10.51); no more than 2 records from the same earthquake are present in each set.

Table 10.70– Metadata of the selected waveforms for seismic zone Z3b, soil class D, period range 0.1-2.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the event , then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_04007_WES	1.31	269	D	7.2	10.3	04.04.10	22:40:00	NGA-West2
ACC_01238_NIGH11	1.03	375	C	6.6	0.0	23.10.04	17:56:00	KiK-net
ACC_05419_KMMH03	1.43	421	C	7.1	18.2	16.04.16	01:25:00	KiK-net
ACC_02537_MRN	1.24	208	D	6.1	4.3	20.05.12	02:03:50	ESM
ACC_00958_AIGA	1.27	410	C	6.5	13.6	15.06.95	00:15:47	ESM
ACC_02791_FKSH11	1.92	240	C	6.6	31.4	11.04.11	17:16:00	KiK-net
ACC_03992_8101	0.93	282	D	7.3	8.6	11.12.99	16:57:19	ESM
ACC_02543_MRN	1.36	208	D	6.0	0.0	29.05.12	07:00:02	ESM
ACC_01527_PHOB	1.89	404	C	6.0	4.5	28.09.04	17:15:00	NGA-West2
ACC_03991_1401	0.71	294	D	7.3	24.9	11.12.99	16:57:19	ESM
ACC_02488_CLF	1.98	145	D	5.7	0.3	26.09.97	00:33:11	ESM

Table 10.71 – Metadata of the selected waveforms for seismic zone Z3b, soil class D, period range 0.02-1.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_01527_PHOB	1.31	404	C	6.0	4.5	28.09.04	17:15:00	NGA-West2
ACC_01238_NIGH11	1.16	375	C	6.6	0.0	23.10.04	17:56:00	KiK-net
ACC_00993_AQV	0.82	474	C	6.1	0.0	06.04.09	01:32:40	ESM
ACC_03991_1401	0.77	294	D	7.3	24.9	11.12.99	16:57:19	ESM
ACC_05419_KMMH03	1.11	421	C	7.1	18.2	16.04.16	01:25:00	KiK-net
ACC_00934_NOR	1.42	423	C	6.5	3.1	30.10.16	06:40:18	ESM
ACC_02543_MRN	1.91	208	D	6.0	0.0	29.05.12	07:00:02	ESM
ACC_03081_AMT	1.28	670	E	6.0	1.4	24.08.16	01:36:32	ESM
ACC_00958_AIGA	1.49	410	C	6.5	13.6	15.06.95	00:15:47	ESM
ACC_01242_NIGH11	0.80	375	C	6.3	15.0	23.10.04	18:34:00	KiK-net
ACC_02488_CLF	1.89	145	D	5.7	0.3	26.09.97	00:33:11	ESM

Table 10.72 – Metadata of the selected waveforms for seismic zone Z3b, soil class D, period range 0.25-4.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_02537_MRN	1.48	208	D	6.1	4.3	20.05.12	02:03:50	ESM
ACC_05419_KMMH03	1.48	421	C	7.1	18.2	16.04.16	01:25:00	KiK-net
ACC_03991_1401	0.60	294	D	7.3	24.9	11.12.99	16:57:19	ESM
ACC_00934_NOR	0.91	423	C	6.5	3.1	30.10.16	06:40:18	ESM
ACC_01238_NIGH11	1.07	375	C	6.6	0.0	23.10.04	17:56:00	KiK-net
ACC_02543_MRN	1.99	208	D	6.0	0.0	29.05.12	07:00:02	ESM
ACC_00958_AIGA	1.41	410	C	6.5	13.6	15.06.95	00:15:47	ESM
ACC_03996_12149	1.95	385	C	7.3	21.8	28.06.92	11:58:00	NGA-West2
ACC_00935_NRC	1.02	498	C	6.5	2.8	30.10.16	06:40:18	ESM
ACC_03992_8101	0.84	282	D	7.3	8.6	11.12.99	16:57:19	ESM
ACC_04007_WES	1.22	269	D	7.2	10.3	04.04.10	22:40:00	NGA-West2

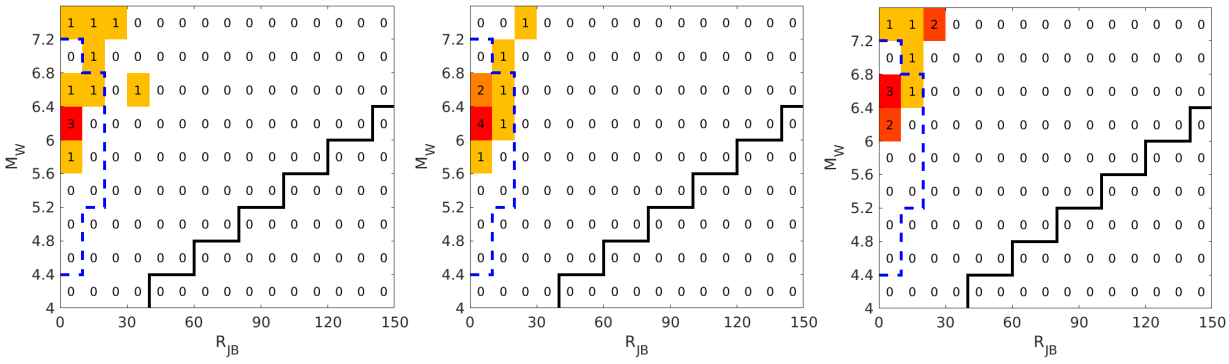

Figure 10.51 – Selected number of recordings by bin of Joyner-Boore distances (10 km width) and M_W (0.4unit) for the period ranges 0.1-2.0s (left panel), 0.02-1.0 s (central panel) and 0.25-4.0 s (right panel) soil class D. The dashed blue lines indicate the areas where probability of exceedance (over all IMTs) is significant for the five SIA261 zones for return period 975 years following the approach illustrated in Bergamo et al. (2022). The black continuous lines indicate our limit for the first selection of waveforms.

For the period range 0.1-2.0 s, soil class E, no spectrum compatible selections are found using real accelerograms only. The selection is repeated allowing a maximum of 4 synthetic recordings. We find only 1 compatible selection with RMSE = 0.136 (Fig. 10.52). In Table 10.73 the selected waveforms metadata are reported. In the period range 0.02-1.0 s, no spectrum compatible selections are found using real accelerograms only. The selection is repeated allowing a maximum of 4 synthetic recordings. We find 18 combinations of accelerograms with RMSE ranging between 0.133 and 0.168 for soil class E. Among these, we choose the one with the lowest RMSE (Fig. 10.52). In Table 10.74 the selected waveforms metadata are reported. The selection for period range 0.25-4.0 s doesn't return compatible combinations using real accelerograms and synthetics. Therefore, we increase the scaling factor up to 3 (Du et al., 2018) and we allow a maximum of 4 synthetics, finding 4 compatible combinations with RMSE in the range 0.107-0.136. The one with the lowest RMSE is chosen (Fig. 10.52). In Table 10.75 the selected waveforms metadata are reported.

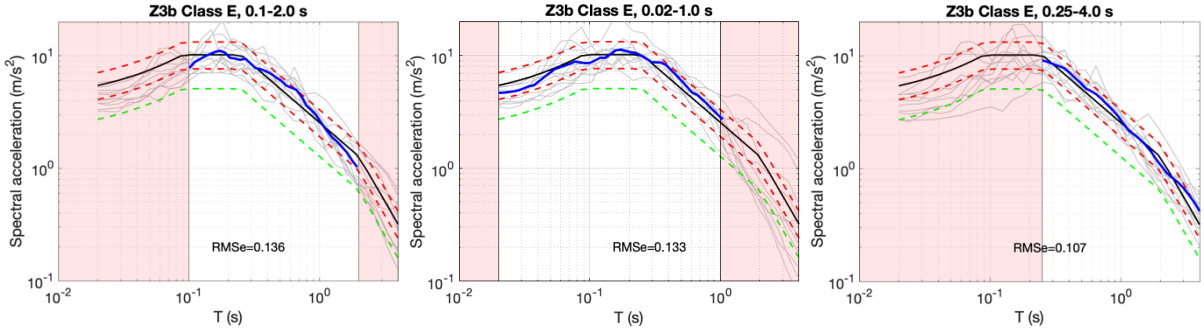

Figure 10.52 – Extracted sets of n=11 geometric means of two-component, scaled response spectra (gray lines) for Z3b zone using as target the SIA261 elastic response spectra (black line) for soil class E. The blue line is the mean of the spectra. All the Eurocode 8 (2022) criteria of this document (section 9) are satisfied. Red dashed lines indicate the 1.3 and 0.75 ratio threshold; the green dashed line indicates the 0.5 ratio threshold. Shadowed red areas highlight the period range not considered for the selection.

Table 10.73– Metadata of the selected waveforms for seismic zone Z3b, soil class E, period range 0.1-2.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_06860_3382	1.16	405.3	C	6.2	1.8	06.04.09	03:32:00	BB-SPEED
ACC_06245_15766	1.05	300.0	C	6.0	1.2	29.05.12	09:00:00	BB-SPEED
ACC_05970_16745	1.30	300.0	C	6.0	1.3	29.05.12	09:00:00	BB-SPEED
ACC_06868_3285	1.07	405.3	C	6.2	1.0	06.04.09	03:32:00	BB-SPEED
ACC_03150_AQA	0.94	549.0	E	6.1	0.0	06.04.09	01:32:40	ESM
ACC_01167_IWTH26	0.50	371.1	C	6.9	6.0	14.06.08	08:43:00	KiK-net
ACC_00993_AQV	0.74	474.0	C	6.1	0.0	06.04.09	01:32:40	ESM
ACC_01338_NGNH29	1.54	464.9	C	6.2	9.6	12.03.11	03:59:00	KiK-net
ACC_02791_FKSH11	1.33	239.8	C	6.6	31.4	11.04.11	17:16:00	KiK-net
ACC_03081_AMT	1.01	670.0	E	6.0	1.4	24.08.16	01:36:32	ESM
ACC_03100_AMT	1.07	670.0	E	6.5	10.1	30.10.16	06:40:18	ESM

Table 10.74 – Metadata of the selected waveforms for seismic zone Z3b, soil class E, period range 0.02-1.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_03081_AMT	0.96	670.0	E	6.0	1.4	24.08.16	01:36:32	ESM
ACC_01167_IWTH26	0.66	371.1	C	6.9	6.0	14.06.08	08:43:00	KiK-net
ACC_06860_3382	1.32	405.3	C	6.2	1.8	06.04.09	03:32:00	BB-SPEED
ACC_03118_NCR	0.73	555.0	C	6.0	0.0	26.09.97	09:40:24	ESM
ACC_01068_5401	1.97	412.0	C	5.7	10.2	11.11.99	14:41:23	ESM
ACC_06008_16984	1.72	300.0	C	6.0	0.0	29.05.12	09:00:00	BB-SPEED
ACC_09415_7675	1.94	492.2	C	5.5	11.6	--.--.--	--:--:--	BB-SPEED
ACC_06245_15766	1.69	300.0	C	6.0	1.2	29.05.12	09:00:00	BB-SPEED
ACC_03150_AQA	1.09	549.0	E	6.1	0.0	06.04.09	01:32:40	ESM
ACC_00993_AQV	0.61	474.0	C	6.1	0.0	06.04.09	01:32:40	ESM
ACC_03100_AMT	0.84	670.0	E	6.5	10.1	30.10.16	06:40:18	ESM

Table 10.75 – Metadata of the selected waveforms for seismic zone Z3b, soil class E, period range 0.25-4.0 s. Filename indicates the recording in our database (ACC - acronym for acceleration - is followed by a 5 digits number labeling the recording, then by the name of the station); SF=scaling factor; VS30=average velocity of the station in the upper 30 m; SC=soil class; MW=moment magnitude; RJB= Joyner and Boore distance; DD.MM.YY.= day, month and year; HH.MM.YY.= hour, minutes and seconds; Reference= original database (ESM= European strong motion database, KiK-net or NGA-West2).

Filename	SF	V_{S30}	SC	M_W	R_{JB} (km)	DD.MM.YY	HH.MM.SS.	Ref.
ACC_06868_3285	1.35	405	C	6.2	1.0	06.04.09	03:32:00	BB-SPEED
ACC_03150_AQA	1.07	549	E	6.1	0.0	06.04.09	01:32:40	ESM
ACC_06860_3382	0.97	405	C	6.2	1.8	06.04.09	03:32:00	BB-SPEED
ACC_06241_15732	2.37	300	C	6.0	10.9	29.05.12	09:00:00	BB-SPEED
ACC_06277_17865	2.72	300	C	6.0	10.0	29.05.12	09:00:00	BB-SPEED
ACC_01836_AKTH18	2.84	431	C	6.9	47.5	14.06.08	08:43:00	KiK-net
ACC_01167_IWTH26	0.61	371	C	6.9	6.0	14.06.08	08:43:00	KiK-net
ACC_03100_AMT	0.99	670	E	6.5	10.1	30.10.16	06:40:18	ESM
ACC_04635_NGNH28	1.41	1172	E	6.3	12.1	22.11.14	22:08:00	KiK-net
ACC_02791_FKSH11	1.37	240	C	6.6	31.4	11.04.11	17:16:00	KiK-net
ACC_03118_NCR	0.93	555	C	6.0	0.0	26.09.97	09:40:24	ESM

The selected waveforms for Z3b, soil class E, in general fall inside the areas where the probability of exceedance (over all IMTs) is significant for the relevant seismic zone considering the return period of 975 years; exceptions are represented by few waveforms for the period range 0.1-2.0 s and 0.25-4.0 s (Fig. 10.53). No more than 2 records from the same earthquake are present in each set.

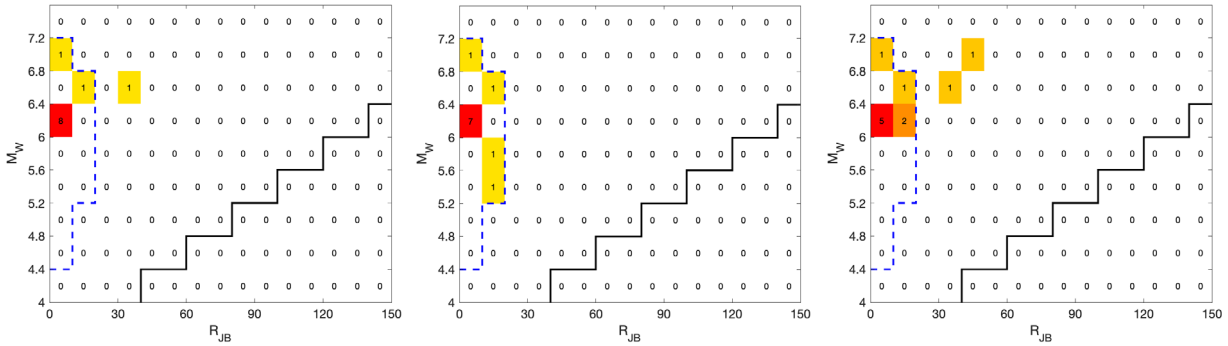

Figure 10.53 – Selected number of recordings by bin of Joyner-Boore distances (10 km width) and M_W (0.4unit) for the period ranges 0.1-2.0s (left panel), 0.02-1.0 s (central panel) and 0.25-4.0 s (right panel) soil class E. The dashed blue lines indicate the area where the probability of exceedance (over all IMTs) is significant for the five SIA261 zones for return period 975 years following the approach illustrated in Bergamo et al. (2022). The black continuous lines indicate our limit for the first selection of waveforms.

Conclusions on selection of ground motions for structural analysis

Using the collected database of waveforms, for each seismic zone and soil class in SIA261 a set of eleven three-component, scaled waveforms was selected for application in structural analysis of buildings of importance class III in SIA261. The target elastic response spectra are defined multiplying the elastic response spectra in SIA261 with a factor of 1.5. This corresponds to a return period in the seismic hazard of about 975 years. The covered building periods are 0.10-066 s, 0.50-1.33 s and 1.25-2.66 s respectively. Therefore, 75 spectrum compatible sets of waveforms are selected. The selection was based on the scaling and match to the target spectrum of the horizontal components. The vertical components are scaled with the same scaling factor. We do not expect to fulfill the definition of the vertical design ground motion defined in SIA261. However, we preserve the consistence between ground motion on the horizontal and vertical components. It is important to note that the waveforms represent the earthquake ground-motion at a site on the surface.

At the time of the start of the project (early 2022) we followed the selection criteria as listed in the Eurocode 8 draft prEN 1998-1-1:2022. At the time of writing of this report (September 2023) a new draft version of Eurocode 8 is being distributed (FprEN 1998-1-1:2024). We verified that the selection criteria we used are still valid and we can confirm that our selected sets are extracted in agreement with the Eurocode 8 criteria.

For soil classes A, B, C and D we selected only real accelerograms applying all EC8 rules in prEN 1998-1-1:2022. For soil class E we release some restrictions and we add synthetics for some spectral periods and zones. Moreover, sometimes we increased also the scaling factor up to 3. We should also mention that no selection code so far implements all proposed EC8 criteria (e.g. neither Rexel by Iervolino et al. (2009) nor Search & Match by Youngs et al. (2007)). The selection criteria in the EC rules are very restrictive causing a number of challenges in the selection procedure.

Related to applications of the waveforms to buildings of importance class I and II in SIA261, we recommend to reduce the amplitudes by a factor 1/1.5 or 1.2/1.5 respectively.

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