swissnuclear
Nuclear Energy Section of swisselectric

Intermediate Seismic Hazard (May 2011)

Evaluation of an intermediate seismic hazard for the existing Swiss nuclear power plants

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FGK-11.039.GS	1	27.06.2011	[redacted]		
		Signature	[redacted]		

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1 INTRODUCTION

1.1 Summary

The cause for evaluating an intermediate seismic hazard for the Swiss nuclear power plants (NPP) was the ENSI letter to the NPPs of April 1, 2011: "*Verfügung - Vorgehensvorgaben zur Überprüfung der Auslegung bezüglich Erdbeben und Überflutung*". As a consequence of this regulatory request, the NPPs charged swissnuclear to perform an intermediate hazard computation. The intermediate hazard evaluation consists of the assessment of the seismic hazard at the rock and soil surface for the four existing Swiss NPP sites. The calculations are based on the best available and quality assured data, expert models and practice available within the PEGASOS Refinement Project (PRP) as of May 31. The final PRP cannot be predicted and will differ from the intermediate hazard. However, every reasonable effort has been taken to ensure that the intermediate hazard reflects all available knowledge and should not underestimate the future PRP results. The final chapters of this report consist of plots of the intermediate rock hazard results for each NPP in terms of hazard curves, uniform hazard spectra (UHS) and deaggregation plots, followed by rock hazard results of relevant dam sites.

Swissnuclear did not compute the intermediate soil hazard because the logic trees from the SP3 experts are not available yet. In order to obtain an intermediate soil hazard at the surface and sub-surface levels, it is necessary to combine the given intermediate rock hazard results with a best-estimate assessment of the NPP specific site response. Therefore, in order to be consistent with the given rock hazard, the site amplification needs to be based on the already available new site specific soil profiles, material properties and PRP amplification functions. Thus, each NPP has to perform a simplified soil hazard evaluation at the surface and necessary depth levels individually, but applying up to date information and data from the PRP.

Due to the limited time frame available for the evaluation of the intermediate hazard, some assumptions and simplifications had to be made in order to be able to deliver the results to the NPPs by May 31, 2011. The models used and their simplifications are described in the following.

1.2 Models Used for the Calculations

The calculations were performed with a FRISK software version developed to meet the PRP specificities (version frisk88m_2_5_1_57_Atten1_12). [redacted] performed a quality assurance check of all used input files necessary for the intermediate hazard (QC-QA-1021).

SP1 - Seismic Source Characterization

In the framework of the PRP the SP1 expert groups have revised and updated their models based on the new Earthquake Catalogue of Switzerland (ECOS09). So far, only three out of four PRP SP1 models are finalized and thus can be included in the evaluation of the intermediate hazard. The available SP1 models are: EG1b, EG1c and EG1d. They were assigned equal weights. [redacted] (resource expert in charge of the evaluation of the SP1 models) had delivered the last input files for EG1c by April 1, 2011. The SP1 experts could not resolve the remaining issues for the EG1a model by the time the intermediate hazard needed to start and the EG1a model was therefore not considered for this hazard computation. Furthermore, for the EG1d model only the same parts of the logic tree as in PEGASOS have been used, as no new validated tree trimming has been done for this large model in the framework of the PRP. The Rock hazard Input Files for the intermediate hazard calculations were derived from the following documents:

- EG1-HID-1002 EG1b (08.03.2011)
- EG1-HID-1003 EG1c (31.03.2011)
- EG1-HID-1004 EG1d (08.03.2011)

SP2 - Ground Motion Attenuation Modelling

As the SP2 models have not yet been fully finalized for the PRP, only the mean hazard is evaluated and for the sake of comparability to the PEGASOS results, the integration of the hazard is based on $M_{min} = 5$. Furthermore, only the horizontal component of motion is evaluated for the intermediate hazard.

The PRP SP2 logic tree for the median horizontal models actually includes eight published ground motion prediction equations (GMPE) and a parameterized version of the extended Swiss stochastic model. The expert evaluation of the ground motion prediction equations is not final and no weights are known up to now. Furthermore, all eight prediction equations need to have a V_S-κ correction which has not yet been developed and agreed upon by the experts. As the new Swiss stochastic model doesn't require a full host-to-target V_S-κ correction, only the parameterized Swiss stochastic model (PSSM) [Edwards et al., 2010], [Chiou, 2011] has been used for the intermediate hazard runs. A conservative best estimate version of the PSSM has been defined by swissnuclear, covering the center and range of PRP models. The PSSM model can be defined by expert judgment or be based on the intensity testing results from [Kühn, 2011], [Al Atik, 2011a] and [Al Atik, 2011b]. The intensity testing results from [redacted] (TP2-TB-1078) and [redacted] (EXT-TB-1077 & EXT-TB-1079) were available by April 15, 2011. Based on the evaluation of those preliminary intensity testing results, three models seem to be dominant in terms of performance: [Abrahamson and Silva, 2008], [Campbell and Bozorgnia, 2008] and the PSSM with a stress drop of 60 bar and magnitude cut-off of 4.5. Testing of all 20 possible combinations for the PSSM has shown that, besides the 60 bar model, the 30 and 120 bar models are also candidates, although support of the tested data is much smaller. For the intermediate hazard evaluation, swissnuclear decided to use a model which represents an average of the proposed best estimate PSSM (from [redacted] which has 64 bar) and the average eight PRP GMPEs. The whole frequency range was considered when making the selection. The following PSSM has been selected as it seems to best fit the criteria mentioned above:

Cut-off magnitude for constant stress drop at Mc=4.5 with median stress drop at high magnitudes of SD=120 bar.

Furthermore, the following assumptions and boundary conditions were used for the intermediate hazard:

- The PSSM is used together with the simulation based R_{eff}-Model of [redacted] (TFI-TN-1148), which is based on R_{rup} and was developed on the basis of the simulated data for the Swiss stochastic model.
- The rock hazard was evaluated for each NPP based on the specifically defined $V_{S30,rock}$ and κ values (Table 1). For Gösgen, two rock hazard runs needed to be performed as, due

Table 1: NPP coordinates and plant specific V_{S30} and κ values used for the intermediate hazard computation

NPP	Beznau	Gösgen - deep	Gösgen - shallow	Leibstadt	Mühleberg
Latitude	[redacted]				
Longitude					
κ [s]	0.013	0.0083	0.0083	0.010	0.020
V_{S30} [m/s]	1800	2500	2500	2200	1100
Depth [m]	145	588 (530)	28	100	44

to the different depths of the SP3 soil profiles, two different target V_S-κ corrections needed to be applied.

- The V_S-κ adjustments under development (and still under discussion) that correct the eight selected GMPEs to the generic Swiss rock conditions, or NPP rock conditions, were not necessary. Nevertheless, for the PSSM a V_S-κ adjustment for the transfer from the generic Swiss rock (V_S=1000m/s, κ=0.017) to the NPP specific rock conditions needed to be applied as no NPP specific PSSM has yet been developed. The correction factors were developed by the resource expert [redacted] and verified independently using a second set of correction factors evaluated by [redacted] based on the same procedure, but using a different implementation. The preliminary version of the V_S-κ correction factors for the NPP specific conditions is given in TP2-SUP-1035 (20.04.2011, for the PSSM). After the SP2 workshop WS8 on May 12, 2011 the SP2 experts have decided to also consider alternative target κ values based on a second V_{S30}-κ model of [Silva et al., 1998]. Furthermore, [Edwards et al., 2011] give a log(κ) and linear κ relationship for Switzerland and indicate that, for the foreland, higher values than the Swiss average (0.016) are expected. Thus, for the intermediate hazard, the average of the linear V_{S30}-κ relationship of [Edwards et al., 2011] and [Silva et al., 1998] was taken, resulting in the κ values indicated in table 1. The final V_S-κ correction functions (01.06.2011) are shown in figure 1-2.1. Further information and explanations on the V_S-κ correction factors can be found in [redacted] (PMT-TB-1083).

- The V_{S30} input value to be used in FRISK for the prediction equation is the V_{S30} corresponding to the background model. Thus, for the PSSM: 1000 m/s.

- No Maximum Ground Motion Truncation model was applied. This gives conservative results and decreases the computation time by a factor of approx. four. Furthermore, the impact of the new model on the hazard results has been shown to be relatively small.

- The Sigma model available by the end of April 2011 was used [Rodriguez and Cotton, 2011] (EXT-TB-1058), but without the distance dependant Φ_{SS} model. The native τ model values for the PSSM given in table 5.4 in the report EXT-TB-1058 were used.

- A simplified version of the aleatory uncertainty (σ) logic tree was developed in order to save computation time. The intention of the simplified version was to only keep the bounding cases. The full logic tree, as well as the reduced version to be used for the intermediate hazard computations, are shown in figure 1-2.2. The weights for the global alternatives are also specified on the right hand side of the figure.

- As only the PSSM was used, it was not necessary to apply the small magnitude adjustments made for the other eight PRP GMPEs.

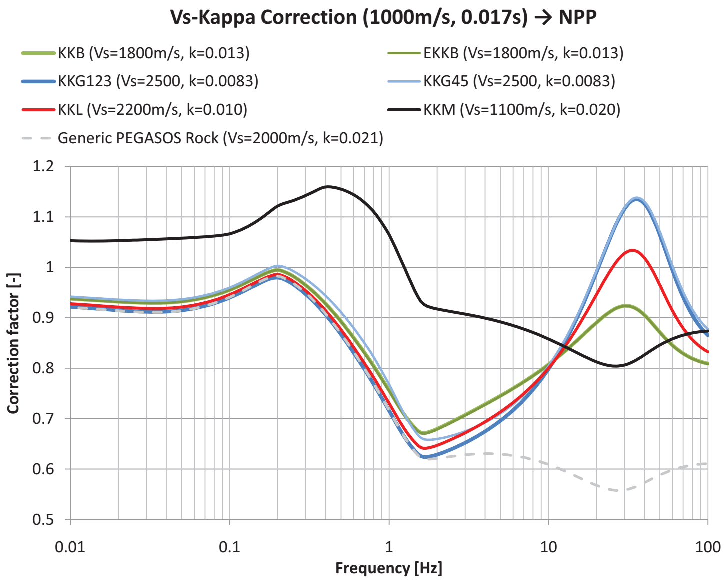

Fig. 1-2.1: V_S-κ correction functions used for the intermediate hazard

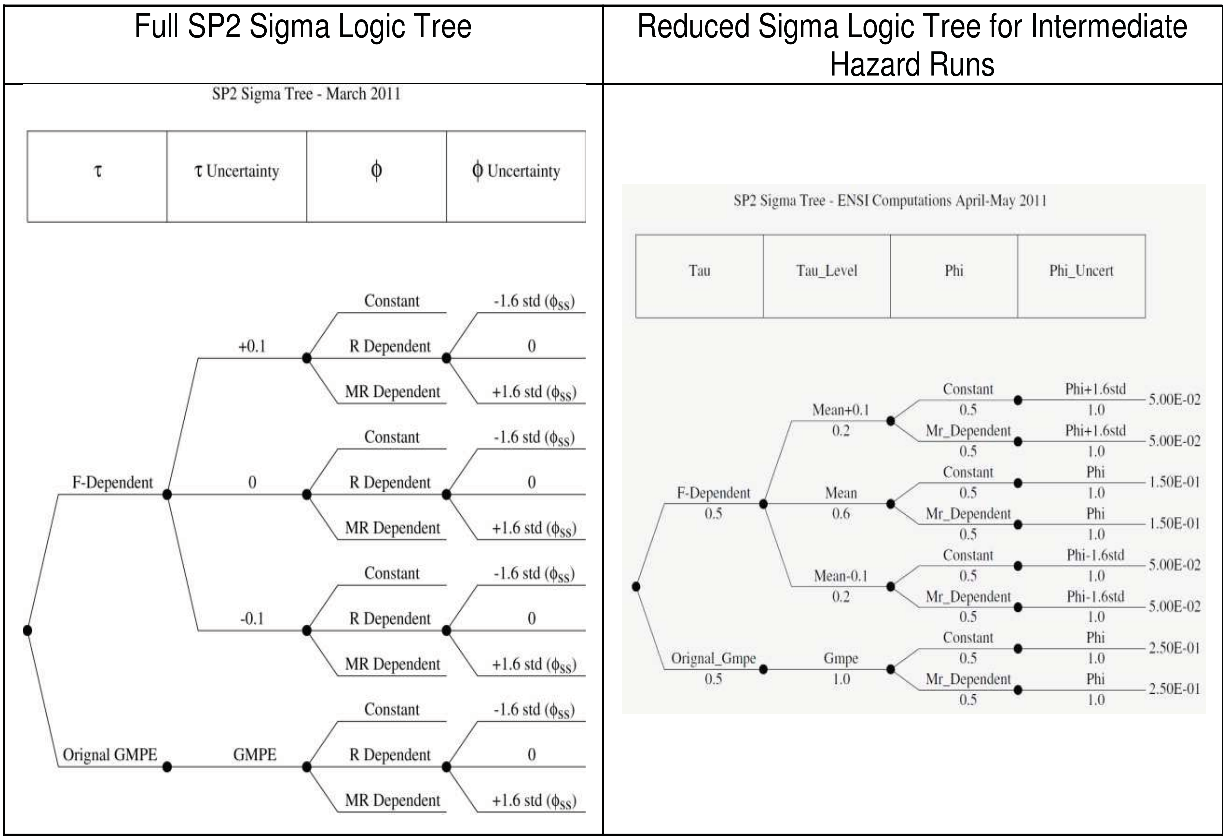

Fig. 1-2.2: Original SP2 logic tree for aleatory variability (status April 2011) and simplified tree used for the intermediate hazard.

SP3 - Site Response

The new amplification functions for the PRP are available, but the new revised SP3 logic trees are not final yet. The SP3 workshop where the final horizontal logic trees should have been presented was scheduled for May 10-11, 2011. This workshop had to be canceled in accordance with the SSHAC Level 4 guidelines as one SP3 expert could not attend. By mid May 2011, the three available SP3 experts had only delivered parts of their logic trees with some preliminary weights to swissnuclear.

Given this issue, swissnuclear decided to discard the SP3 expert based models for the intermediate hazard for soil. Especially as the SP3 experts have changed parts of their logic trees in the framework of the PRP, which have not been tested or revised yet, it is preferable to check all implications with the SP3 experts in the framework of the PRP again before performing any safety relevant computation with those models. Thus, this intermediate hazard report does not contain any soil hazard.

Intermediate soil hazard results at the surface and sub-surface levels can be obtained by combining the given intermediate rock hazard results with a best-estimate assessment of the NPP specific site response. Therefore, in order to be consistent with the given rock hazard, the site amplification needs to be based on the already available new site specific soil profiles, material properties (TP3-TN-1067 to 1071) and PRP amplification functions (RDZ-ASW-1003). Thus, each NPP making use of the intermediate hazard results has to perform a simplified soil hazard evaluation at the surface and necessary depth levels independently, but taking into consideration the newly available information and data.

1.3 Seismic Hazard Evaluation for Relevant Dam Sites

For the consideration of extreme flooding events and the combination of earthquake with flooding hazard, the seismic hazard at dam sites of relevance for the NPPs has been evaluated (Figure 1-3.1). The dam sites for which the seismic hazard was evaluated are based on the same models and assumptions as for the NPP sites and are listed in table 2.

The UHS for an annual probability of exceedance of 10^{-4} at the base of the dam is relevant for the evaluations to be performed by the NPPs. The issue is that the site conditions (V_{S30}) at the dam site locations are unknown to swissnuclear and the NPPs. Thus, only an approximate rock (resp. soil) hazard can be computed. No site specific rock hazard evaluation is possible as no dam specific V_S-κ correction factors have been derived. Furthermore, a detailed soil hazard evaluation as in SP3 is not possible within the given time frame. For this reason, the ground motion prediction equation was used directly to evaluate the seismic hazard at the base of the dam based on the assumption that a generic $V_{S30} = 1000$ m/s (with κ=0.017s) is applicable. This corresponds to the generic Swiss rock profile defined by SED and also used in the framework of the PRP for comparisons. Furthermore, in order to allow a relative comparability of the investigated dam sites, a common definition of the rock bases is simpler. The assumed V_{S30} for the dams is consistent with the rock defined by the Swiss BFE for dam sites. Nevertheless, it should be noted that the resulting ground motions are quite high as the reference "rock" V_S used is softer than defined at the NPP sites. As no V_S-κ correction has been applied, the results need to be used with caution for further analyses.

In addition to the UHS for an annual probability of exceedance of 10^{-4} and to a deaggreagation for PGA, a deaggreagation for the frequency of 5 Hz was evaluated under the assumption that 5 Hz would be the closest frequency to the dominant range of eigenfrequencies of the dams.

Table 2: Names and coordinates of dams considered for the hazard evaluation

Dam sites	Lat.	Long.
Bremgarten-Zufikon	[redacted]	
Rossens		
Rupperswil-Auenstein		
Schiffenen		
Wettingen		
Wildegg-Brugg		

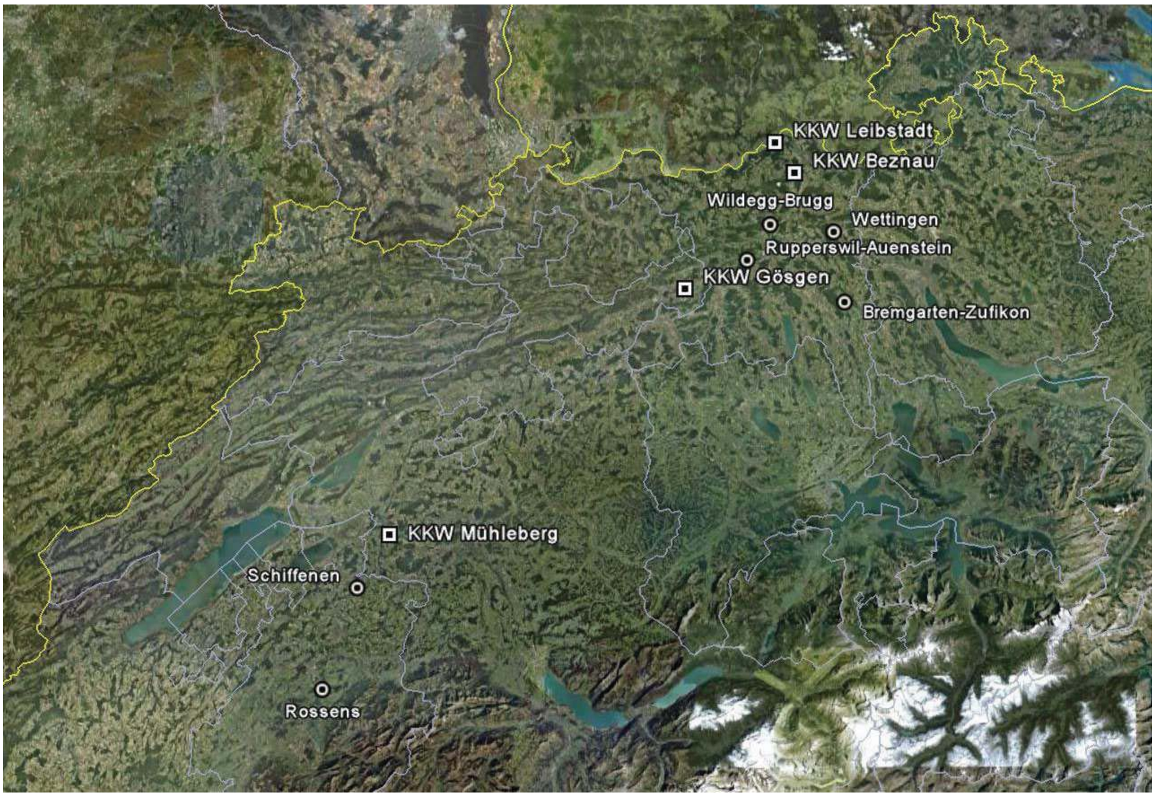

Fig. 1-3.1: Aerial view of northern Switzerland with locations of NPPs and evaluated dam sites

1.4 Comparison at Rock Interface with PEGASOS

The figures 1-4.1 to 1-4.4 show a comparison of the mean intermediate rock hazard UHS and the PEGASOS UHS for an annual probability of exceedance of 10^{-4} for all four sites. (The UHS for Gösgen with deep soil profiles is not shown, as the curve is almost identical to the shallow configuration). A dashed rock UHS representing spectral accelerations reduced by 20% compared to the PEGASOS UHS is also shown. The comparison and interpretation of the curves of the intermediate hazard with the PEGASOS curves need to be performed with caution, as the underlying definition of "rock" is not the same between the two studies. The PEGASOS results are based on a generic rock condition with a V_{S30} of 2000 m/s and corresponding κ which was used for all sites. The intermediate rock hazard is defined, as in the PRP, for each NPP individually based on the new site investigations and a different generic shear-wave velocity profile at each site (see the V_{S30} and κ values given in table 1). A true comparison of the hazard results is only possible at the soil surface (or sub-surface levels) where the ground motion then results from the full source to site path, independent of different rock interface definitions.

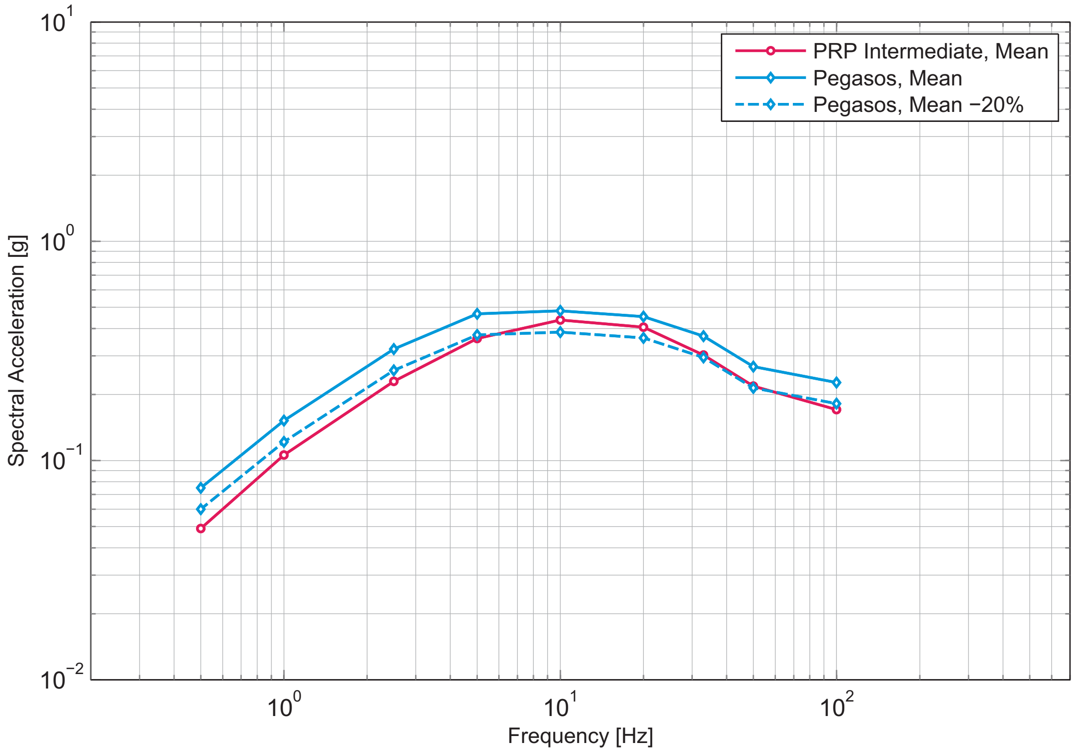

Fig. 1-4.1: Beznau, horizontal component, rock, surface, PEGASOS – PRP comparison. Mean UHS for an annual probability of exceedance of 1E-04 and 5% damping.

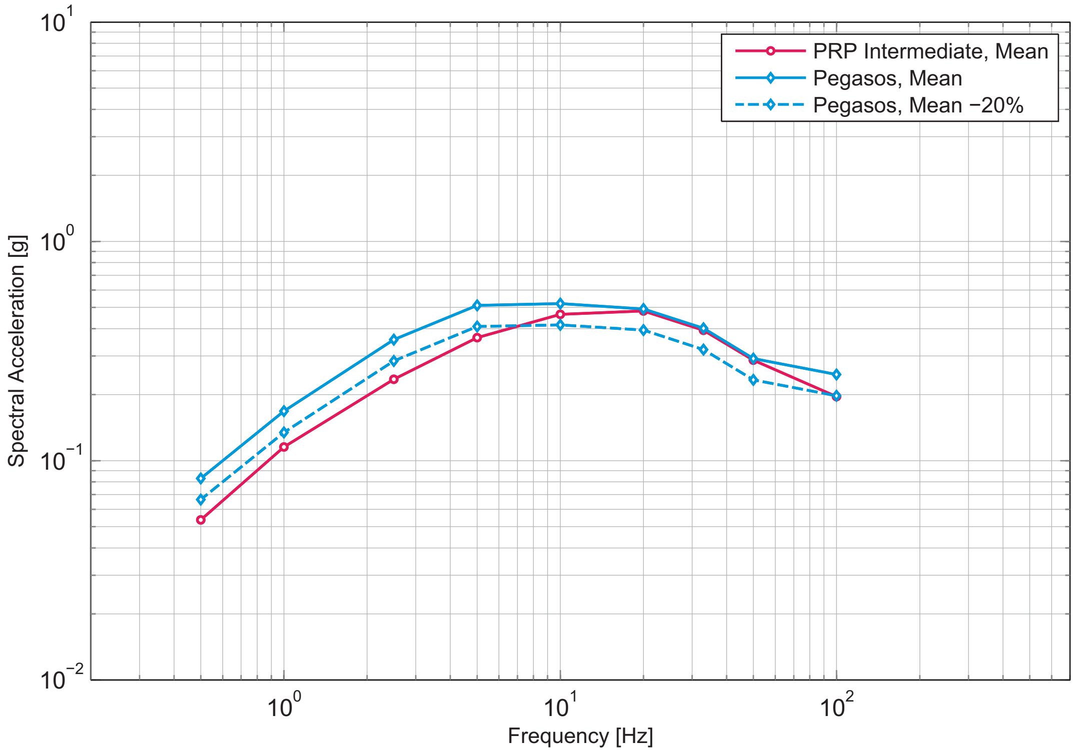

Fig. 1-4.2: Gösgen, horizontal component, shallow rock, surface, PEGASOS – PRP comparison. Mean UHS for an annual probability of exceedance of 1E-04 and 5% damping.

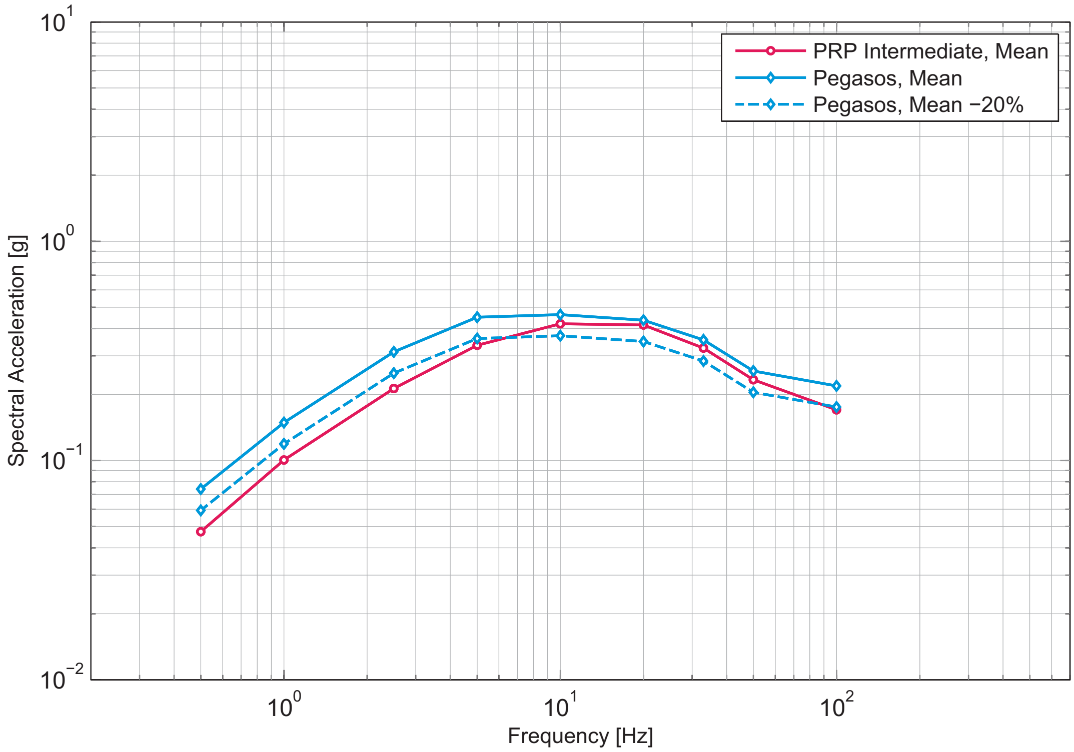

Fig. 1-4.3: Leibstadt, horizontal component, rock, surface, PEGASOS – PRP comparison. Mean UHS for an annual probability of exceedance of 1E-04 and 5% damping.

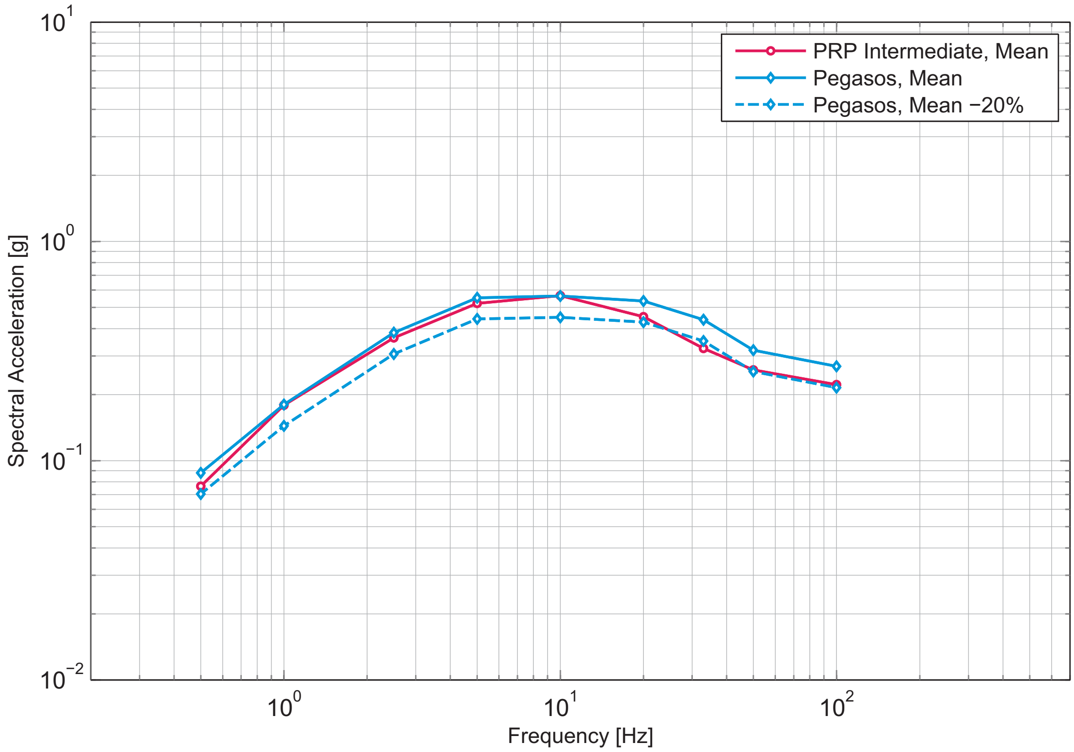

Fig. 1-4.4: Mühleberg, horizontal component, rock, surface, PEGASOS – PRP comparison. Mean UHS for an annual probability of exceedance of 1E-04 and 5% damping.

1.5 Figures and Tables

This report contains the full suite of hazard results as specified in the Administrative Note PMT-AN-1100, Ver. 9 in the form of figures and numerical values (tables). The figures consist of mean hazard curves, mean hazard spectra and deaggregation plots. Each set of hazard curves and uniform hazard spectra exists as a numerical table with the file naming corresponding to the figure numbering in the report. These numerical tables are provided as electronically stored ASCII-files in the associated ZIP file.

The structure in the attached ZIP file closely follows the outline of this report and of volume 2 of the final PEGASOS report. There is one file per figure and the file name directly refers to the figure number (e.g. Fig._2-10.07.asc). For the dams not all the results are shown as figures and, consequently, there are more tables than figures. However, the table and figure numberings are still consistent.

Each file contains a header describing the content of the figure, followed by a first section with matrices (actually vectors as only the mean hazard is given) of the X- and Y-data, and a second section listing X- and Y-vector pairs for each curve of the figure. This should allow great flexibility in loading the data into data processing and visualization software.

Figures and tables of uniform hazard spectra (UHS) were only produced if the mean hazard existed at all frequencies for the given level of annual probability of exceedance. Any requirement for extrapolation of the data to cover a missing value for a particular level of exceedance probability led to the exclusion of the associated figure.

Since the deaggregation figures show percentile contributions to the total hazard in magnitude - distance - epsilon bins, the numerical values of these data were considered to be of little interest. Therefore, no associated tables were generated for these figures.

2 BEZNAU

2.1 Rock Hazard, Horizontal Component, Surface

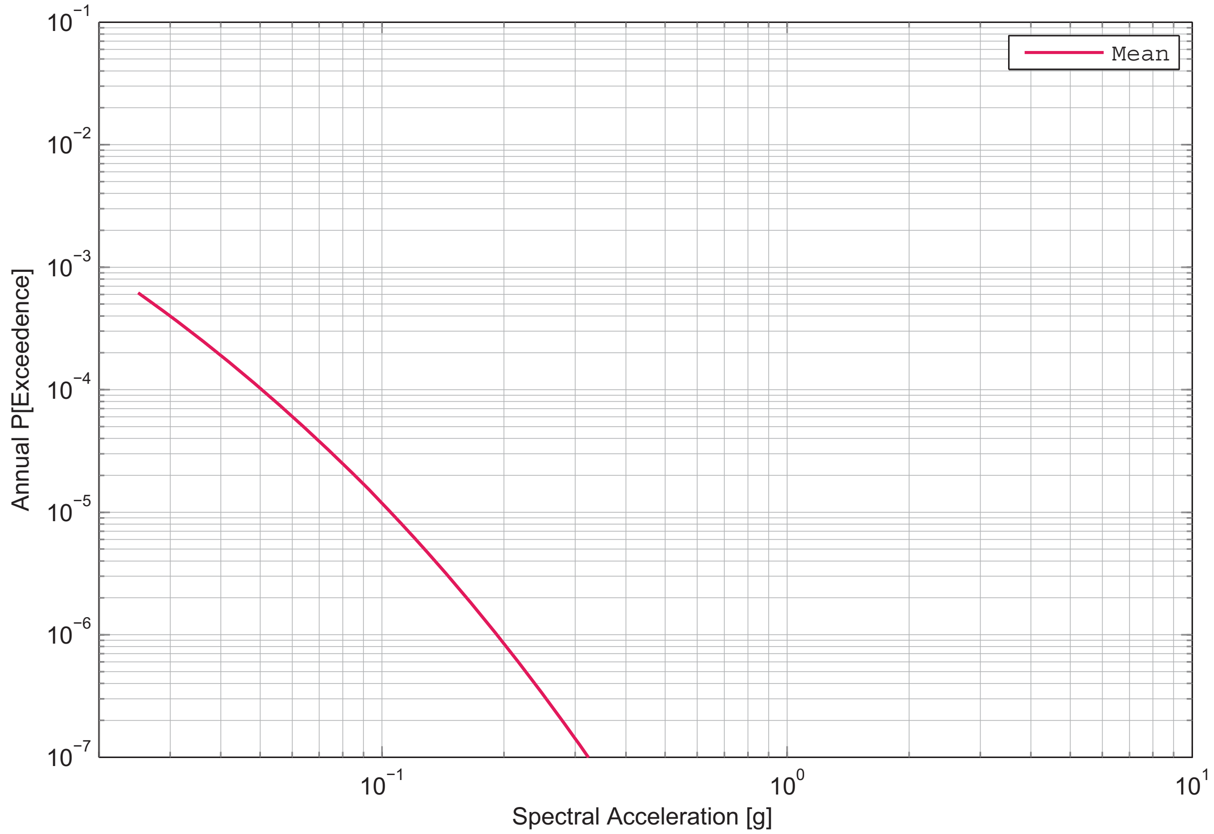

Fig. 2-1.1: Beznau, horizontal component, rock, surface, mean hazard, 0.5 Hz.

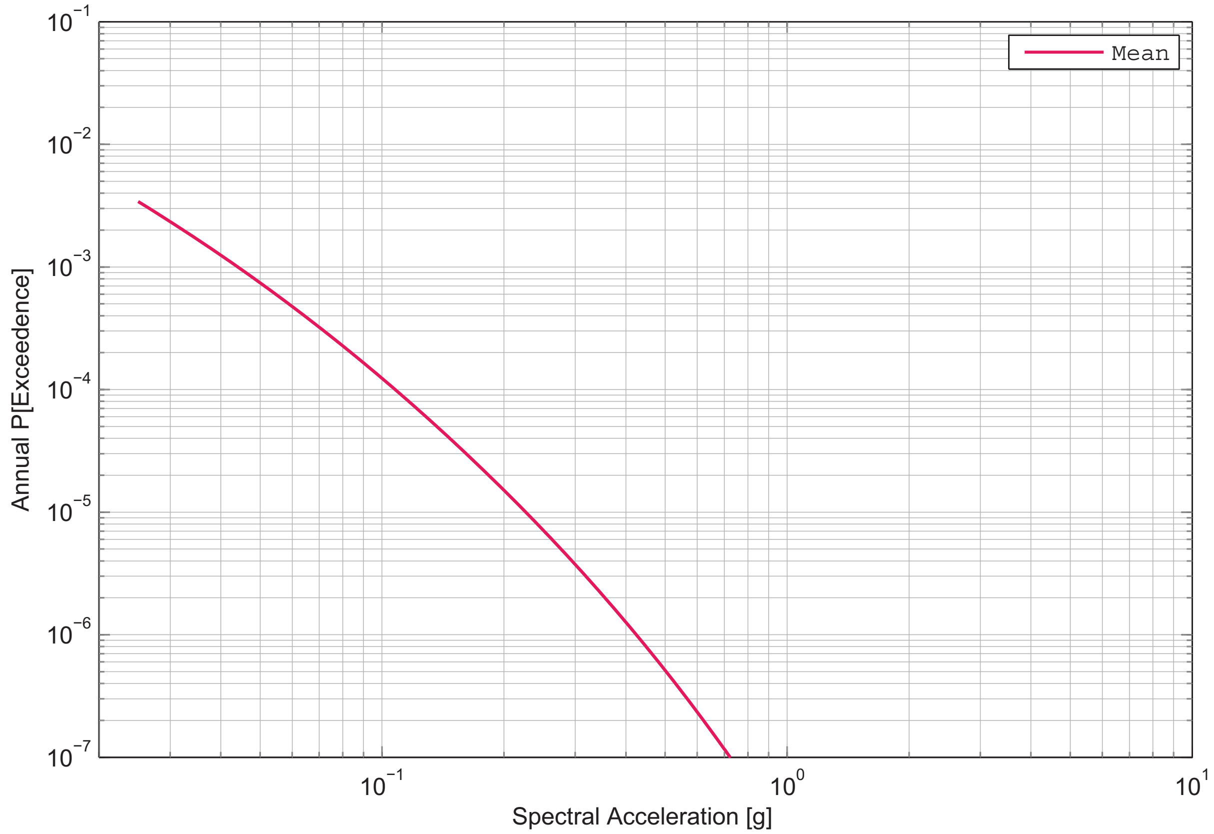

Fig. 2-1.2: Beznau, horizontal component, rock, surface, mean hazard, 1 Hz.

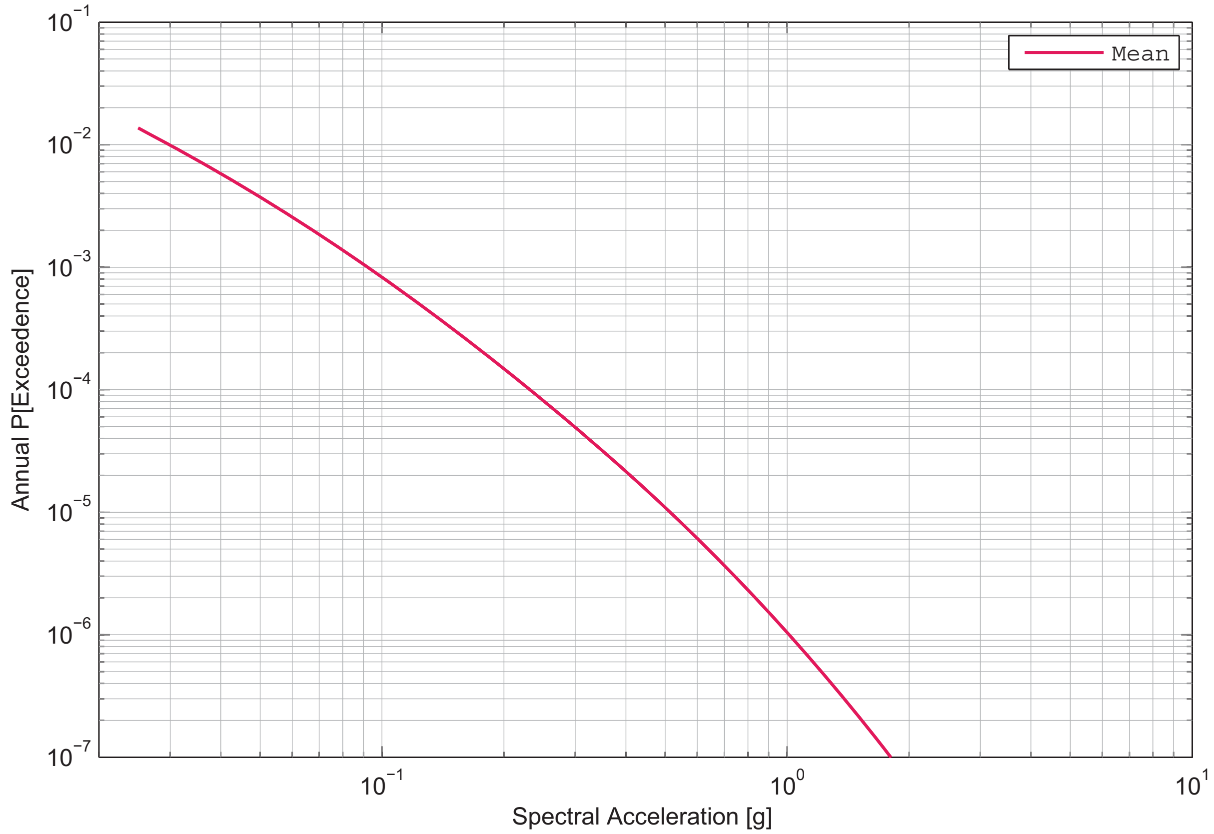

Fig. 2-1.3: Beznau, horizontal component, rock, surface, mean hazard, 2.5 Hz.

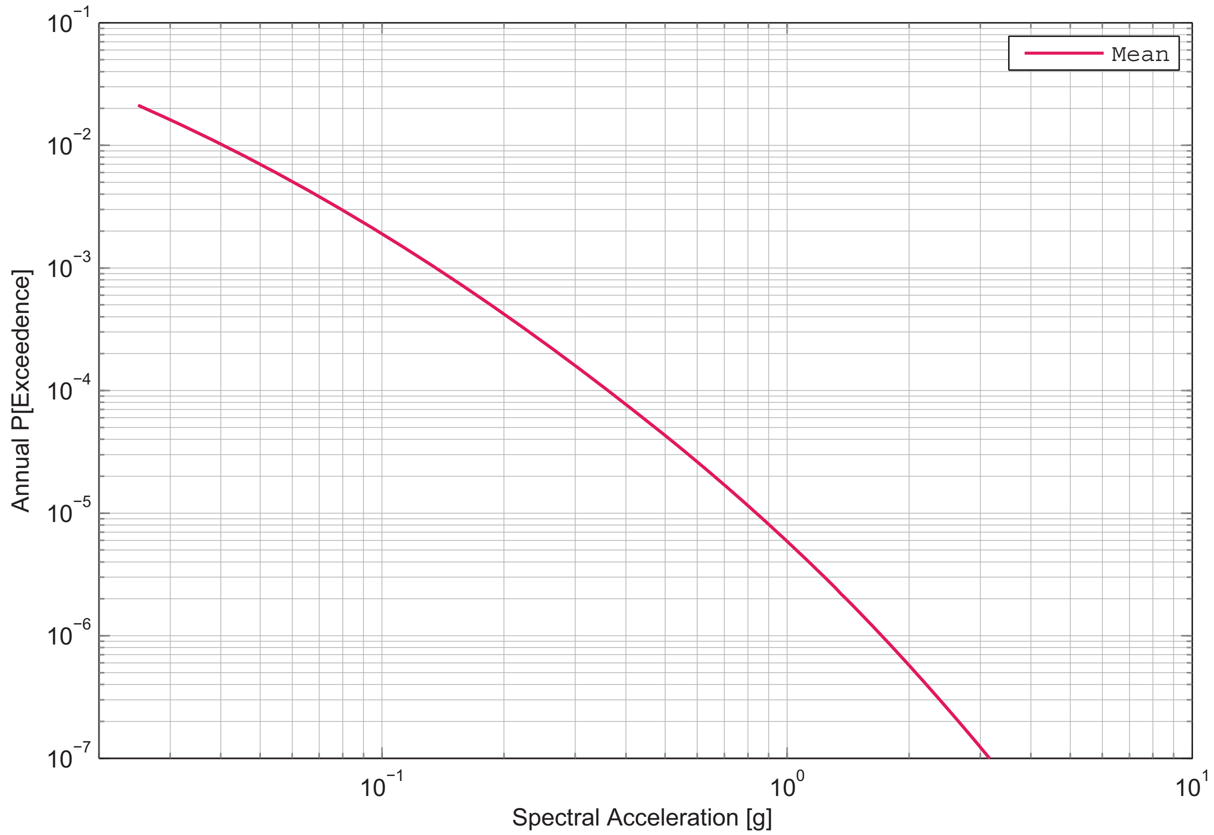

Fig. 2-1.4: Beznau, horizontal component, rock, surface, mean hazard, 5 Hz.

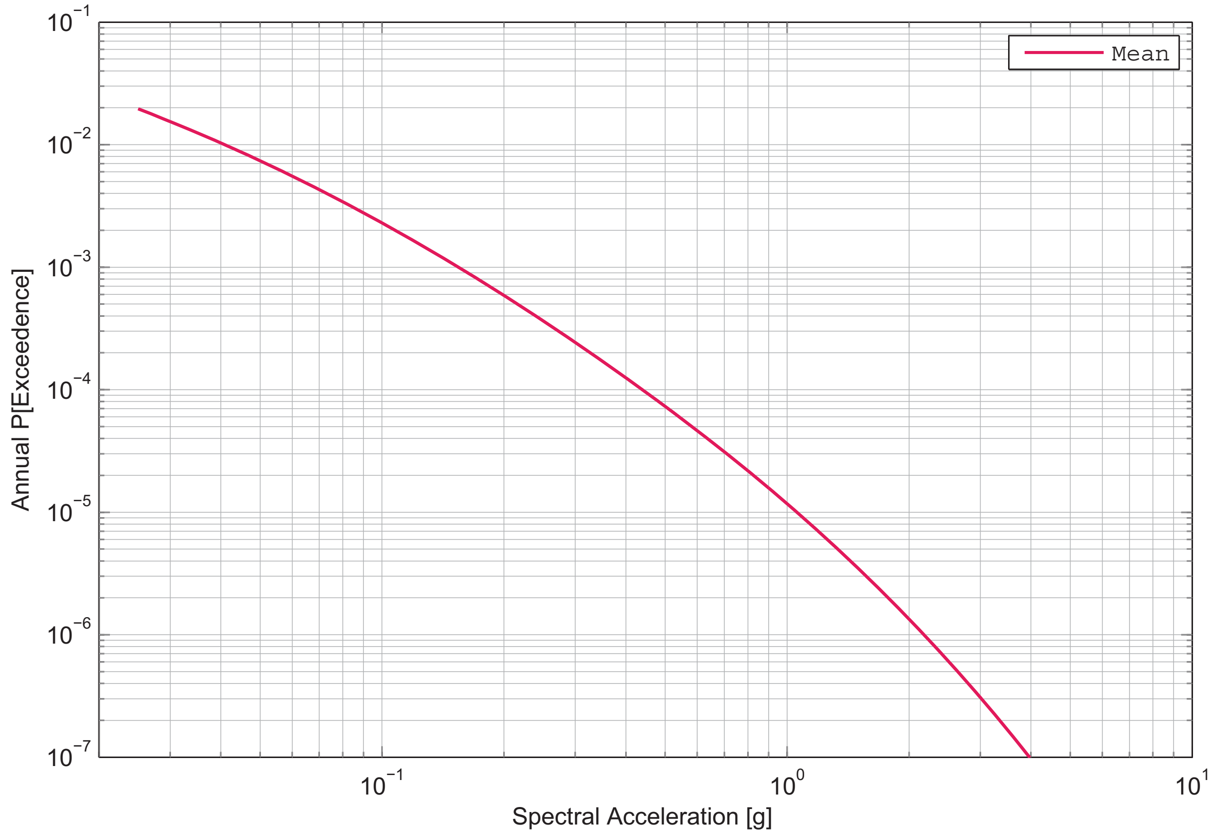

Fig. 2-1.5: Beznau, horizontal component, rock, surface, mean hazard, 10 Hz.

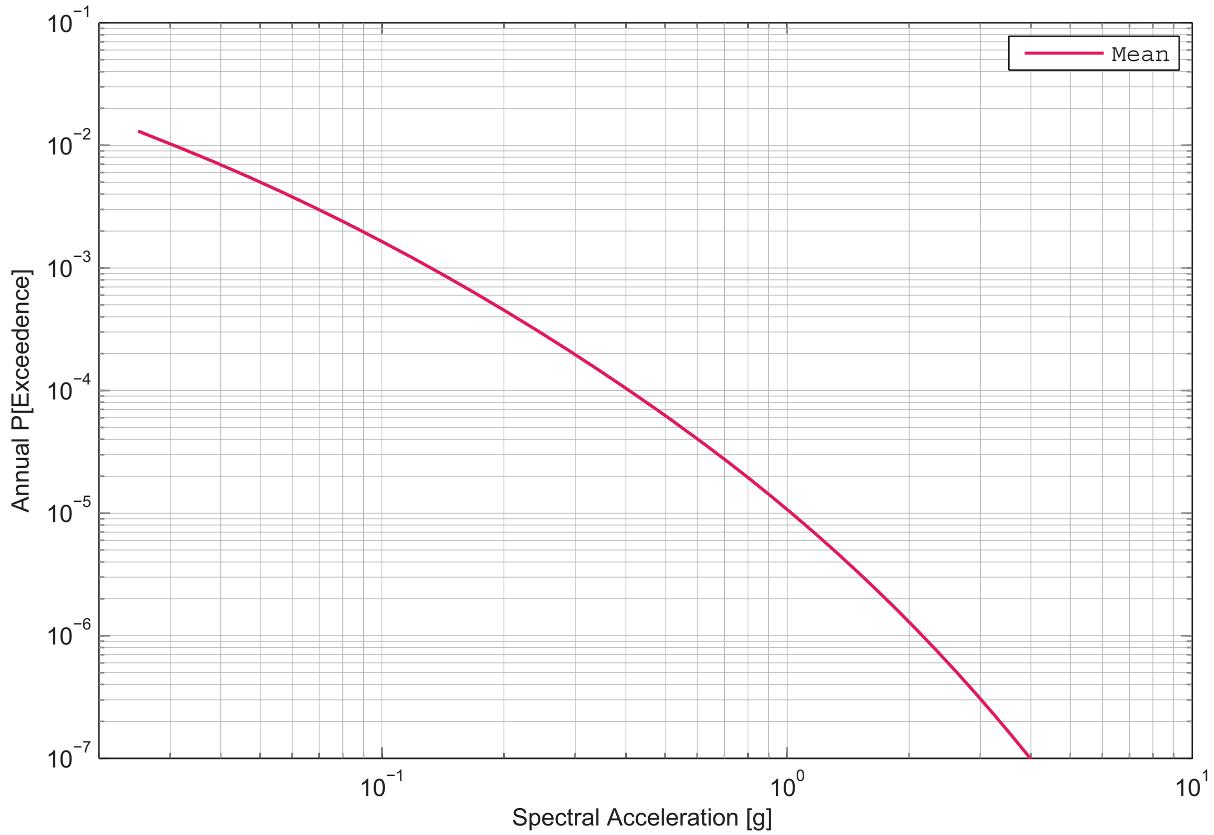

Fig. 2-1.6: Beznau, horizontal component, rock, surface, mean hazard, 20 Hz.

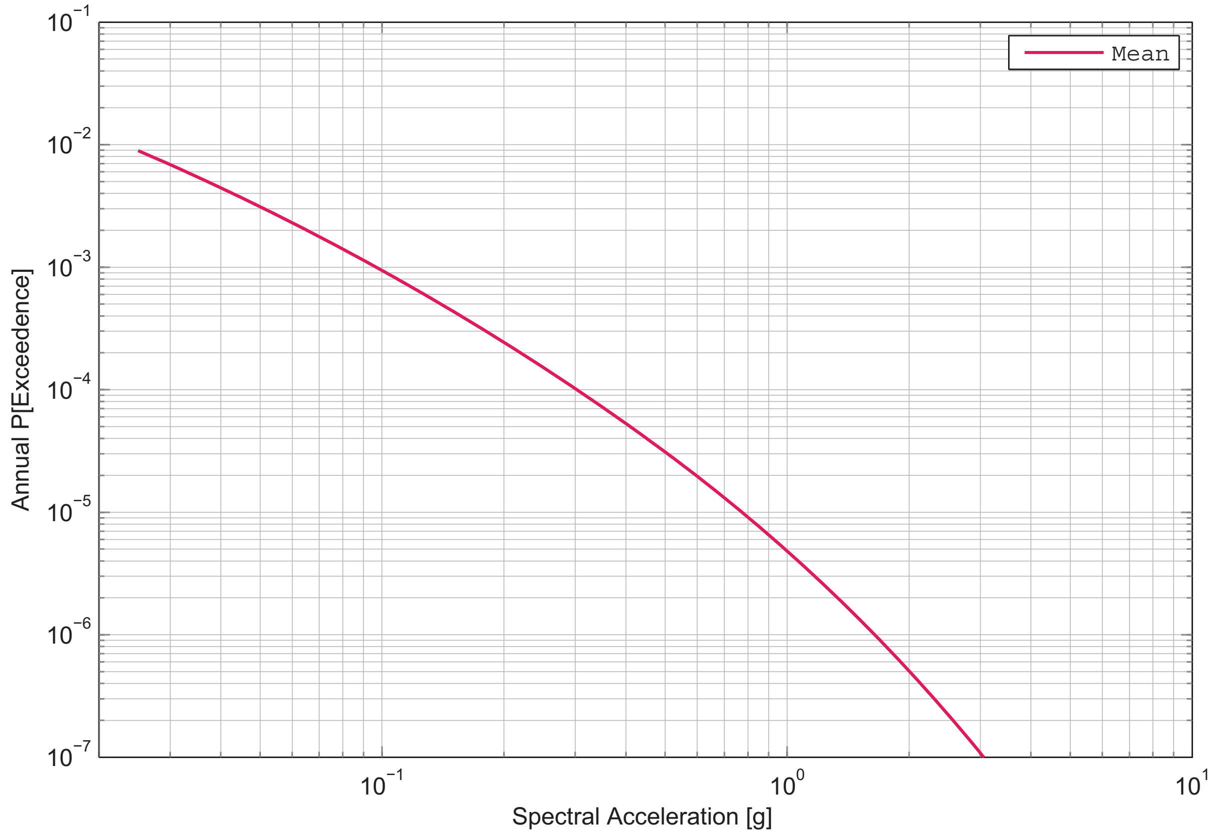

Fig. 2-1.7: Beznau, horizontal component, rock, surface, mean hazard, 33 Hz.

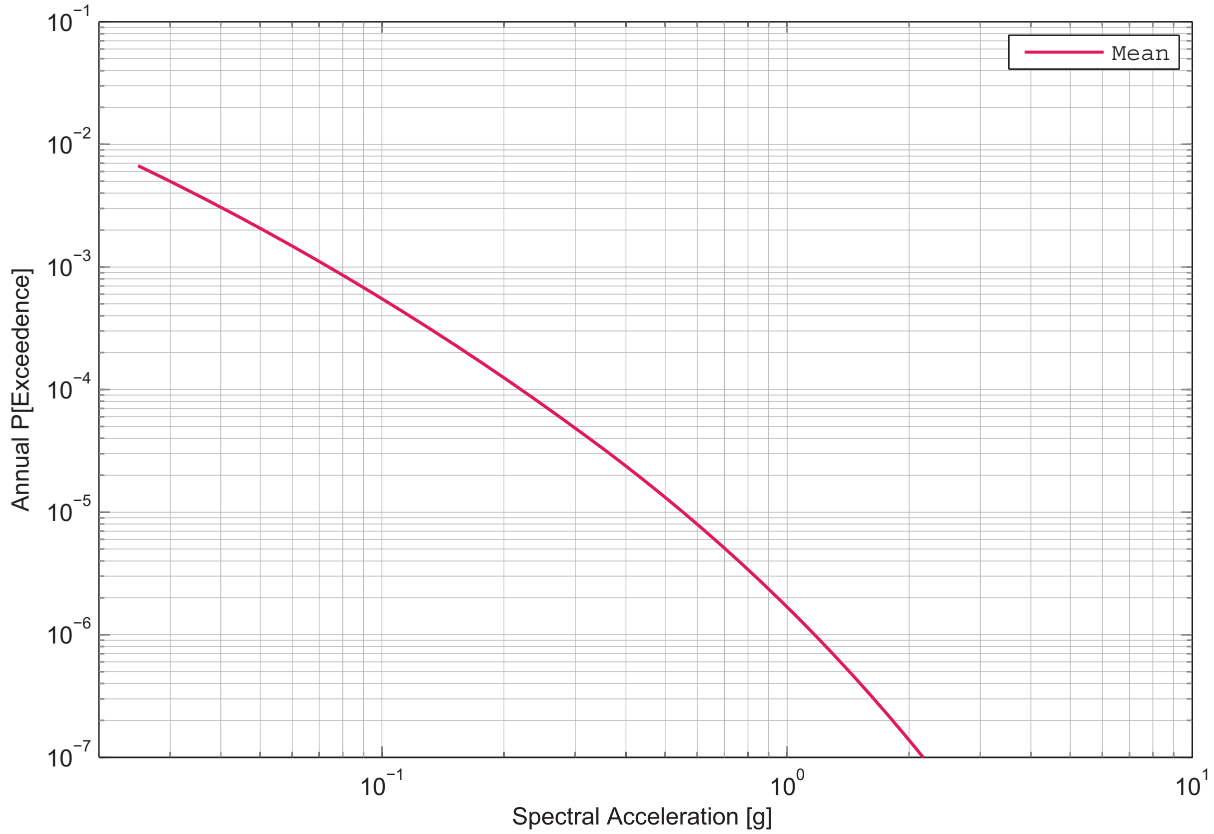

Fig. 2-1.8: Beznau, horizontal component, rock, surface, mean hazard, 50 Hz.

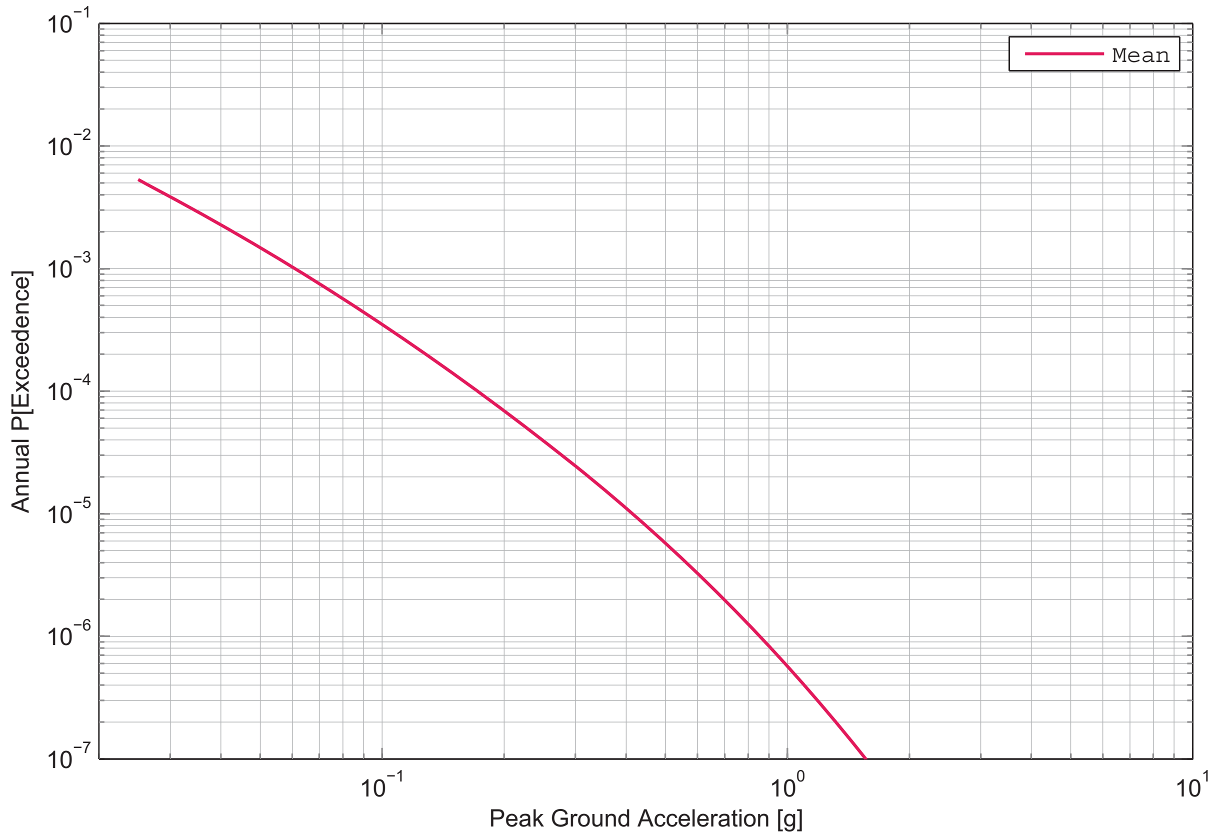

Fig. 2-1.9: Beznau, horizontal component, rock, surface, mean hazard, PGA.

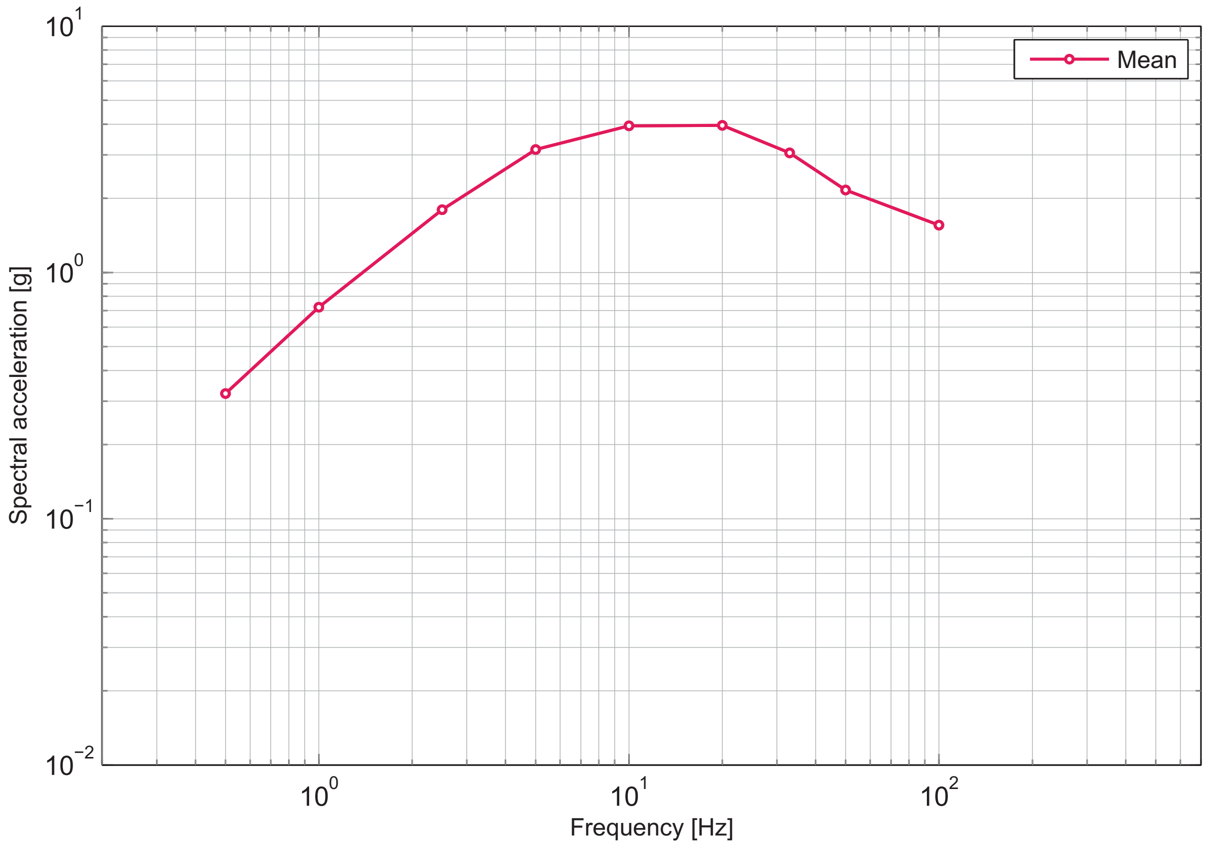

Fig. 2-1.10: Beznau, horizontal component, rock, surface, uniform hazard spectra for an annual probability of exceedance of 1E-07 and 5% damping.

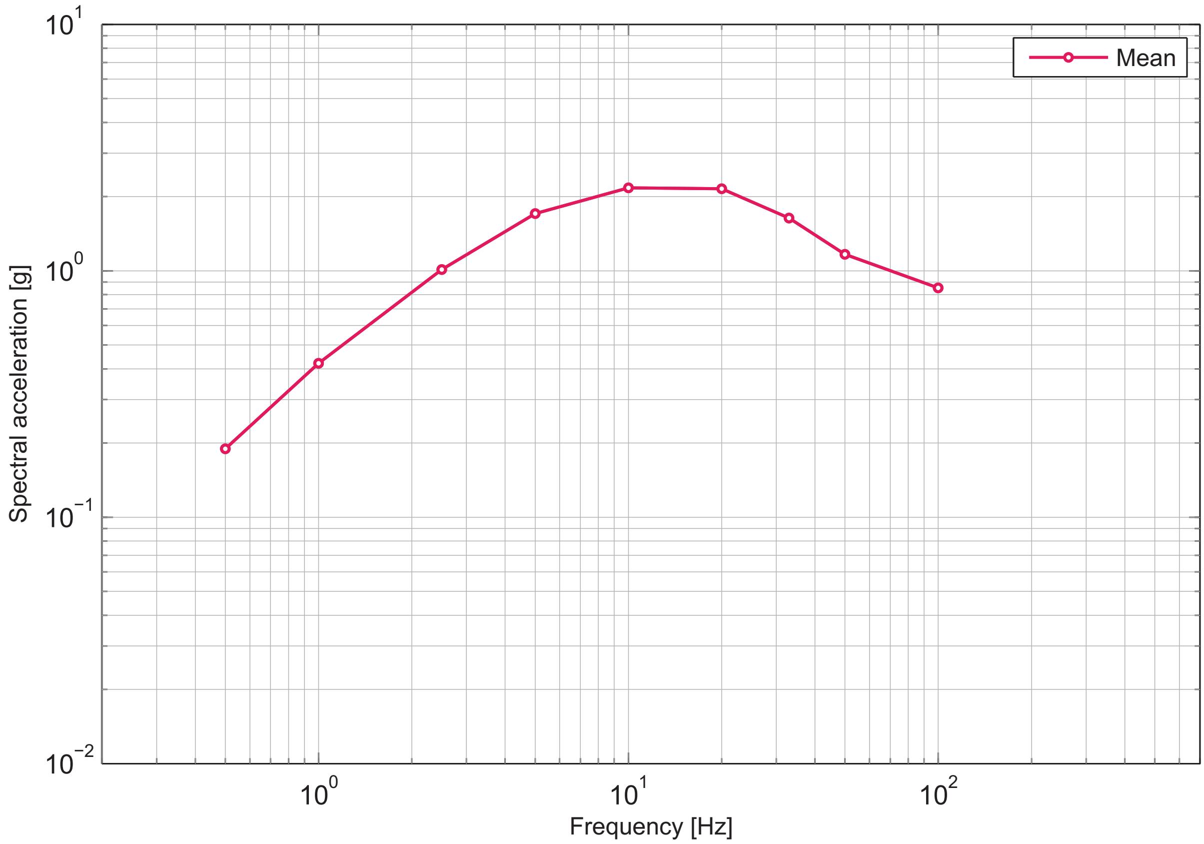

Fig. 2-1.11: Beznau, horizontal component, rock, surface, uniform hazard spectra for an annual probability of exceedance of 1E-06 and 5% damping.

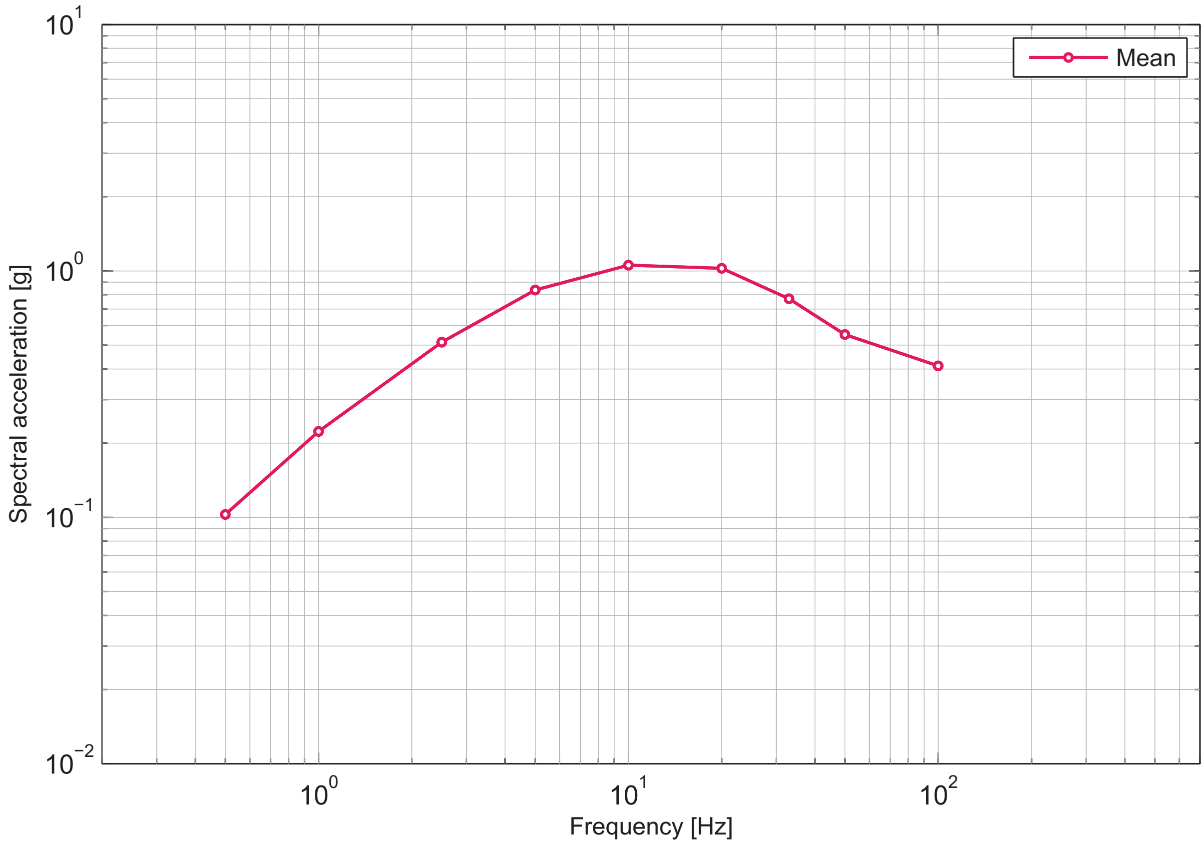

Fig. 2-1.12: Beznau, horizontal component, rock, surface, uniform hazard spectra for an annual probability of exceedance of 1E-05 and 5% damping.

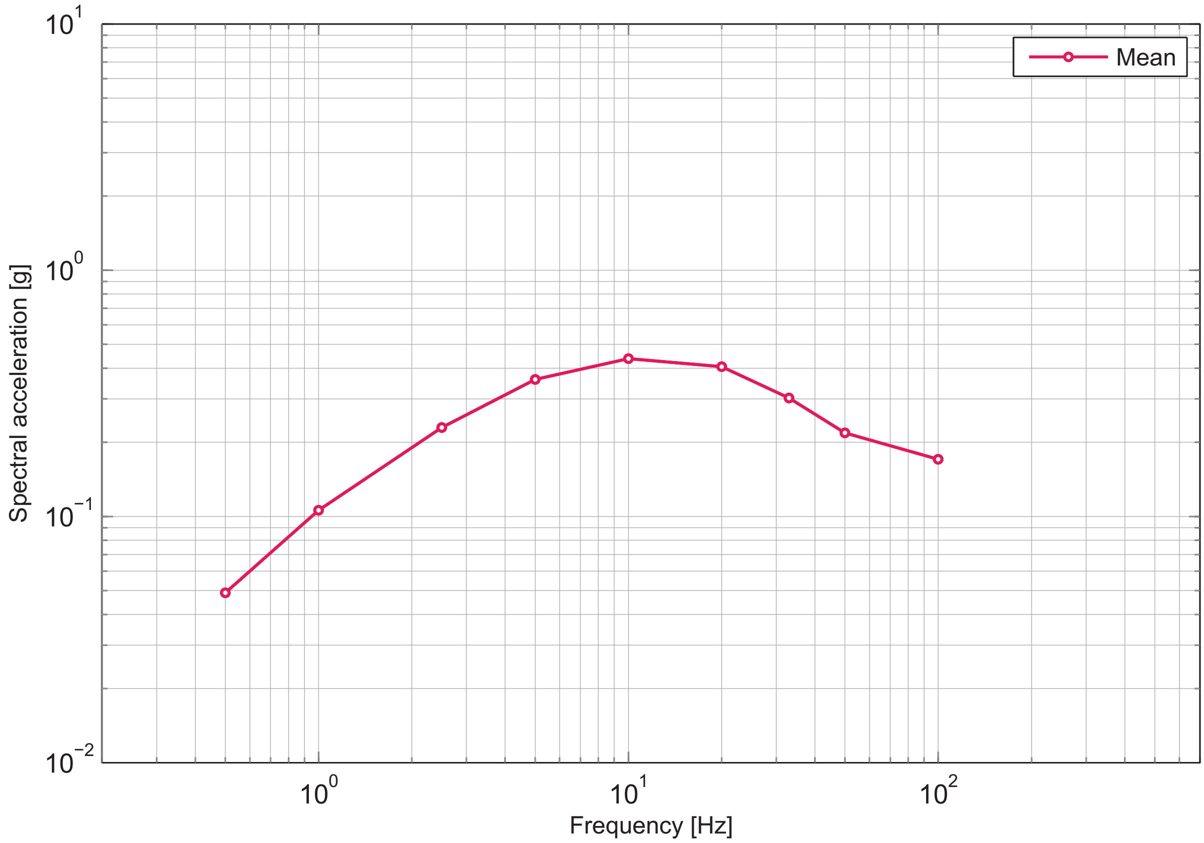

Fig. 2-1.13: Beznau, horizontal component, rock, surface, uniform hazard spectra for an annual probability of exceedance of 1E-04 and 5% damping.

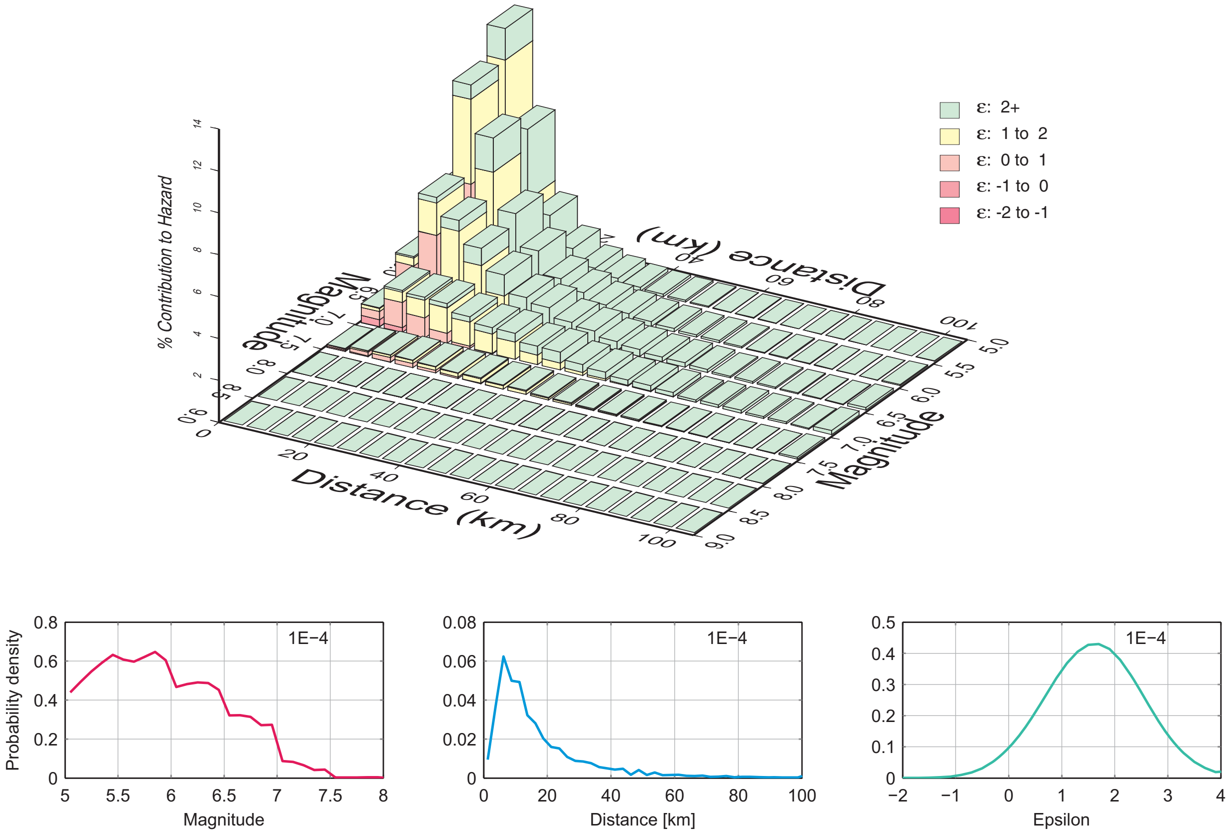

Fig. 2-1.14: Beznau, horizontal component, rock, surface, hazard deaggregation by magnitude, distance and epsilon for ground motion level 1E-4, 5 Hz.

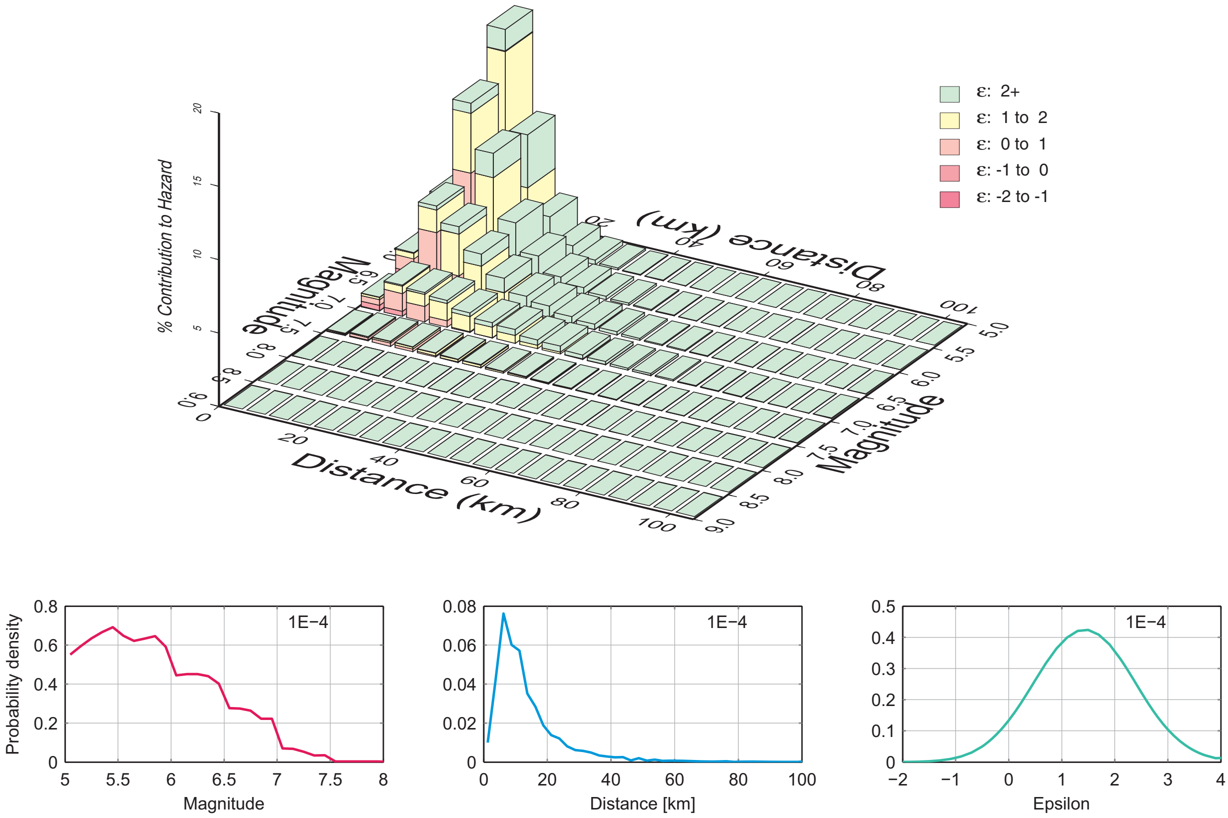

Fig. 2-1.15: Beznau, horizontal component, rock, surface, hazard deaggregation by magnitude, distance and epsilon for ground motion level 1E-4, PGA.

3 GÖSGEN DEEP

3.1 Rock Hazard, Horizontal Component, Surface

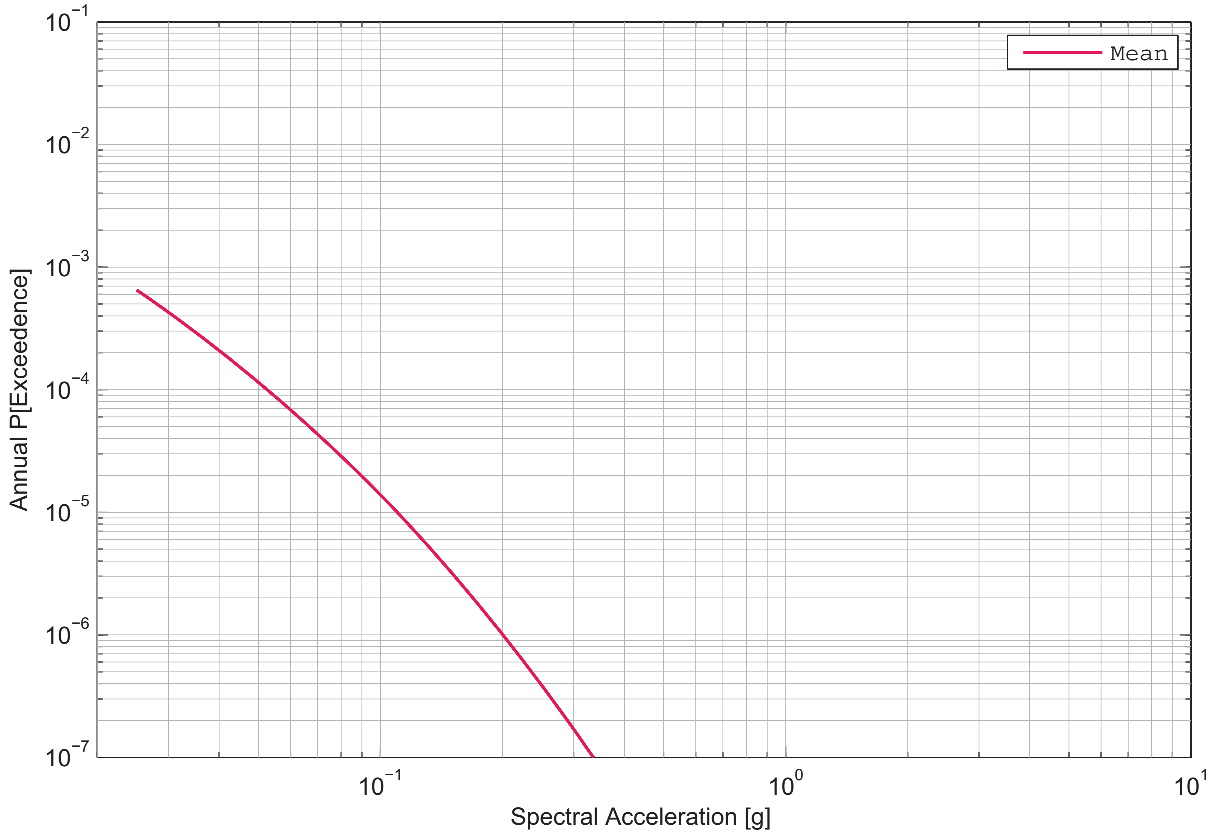

Fig. 3-1.1: Gösgen deep, horizontal component, rock, surface, mean hazard, 0.5 Hz.

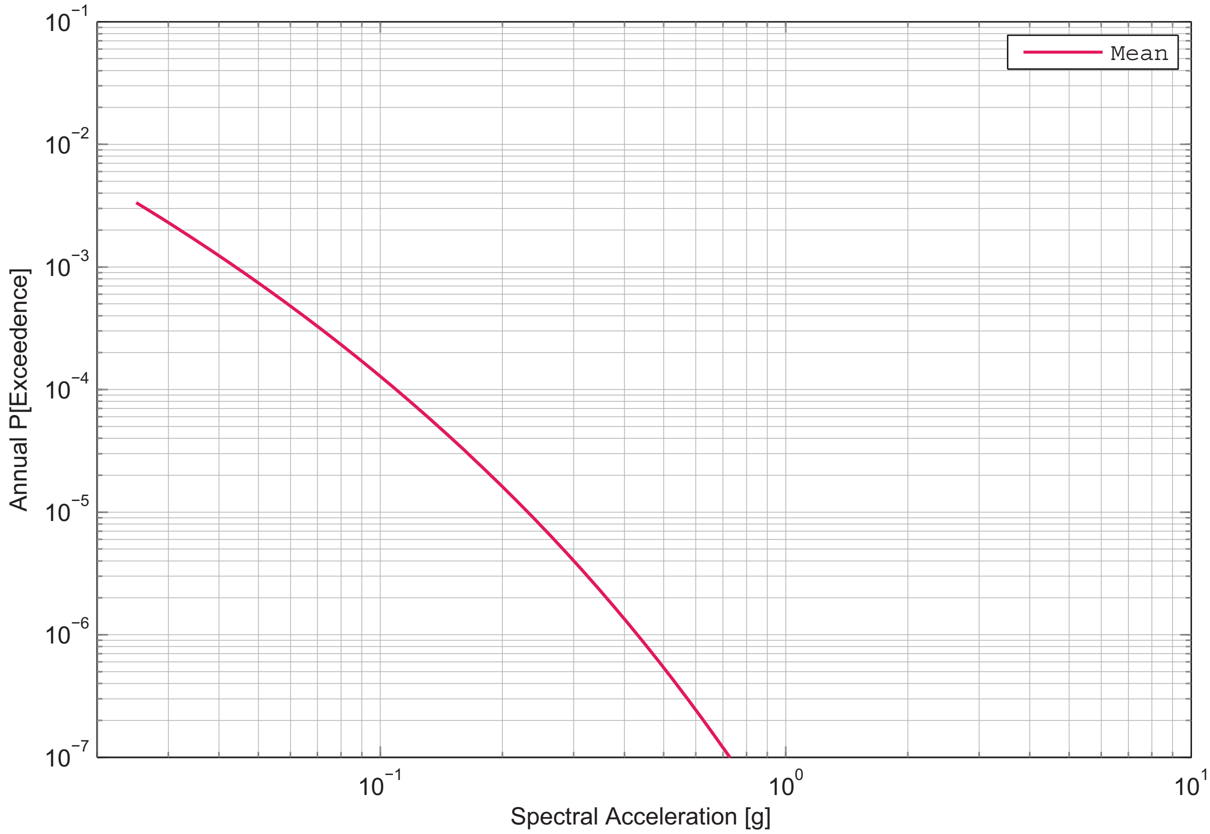

Fig. 3-1.2: Gösgen deep, horizontal component, rock, surface, mean hazard, 1 Hz.

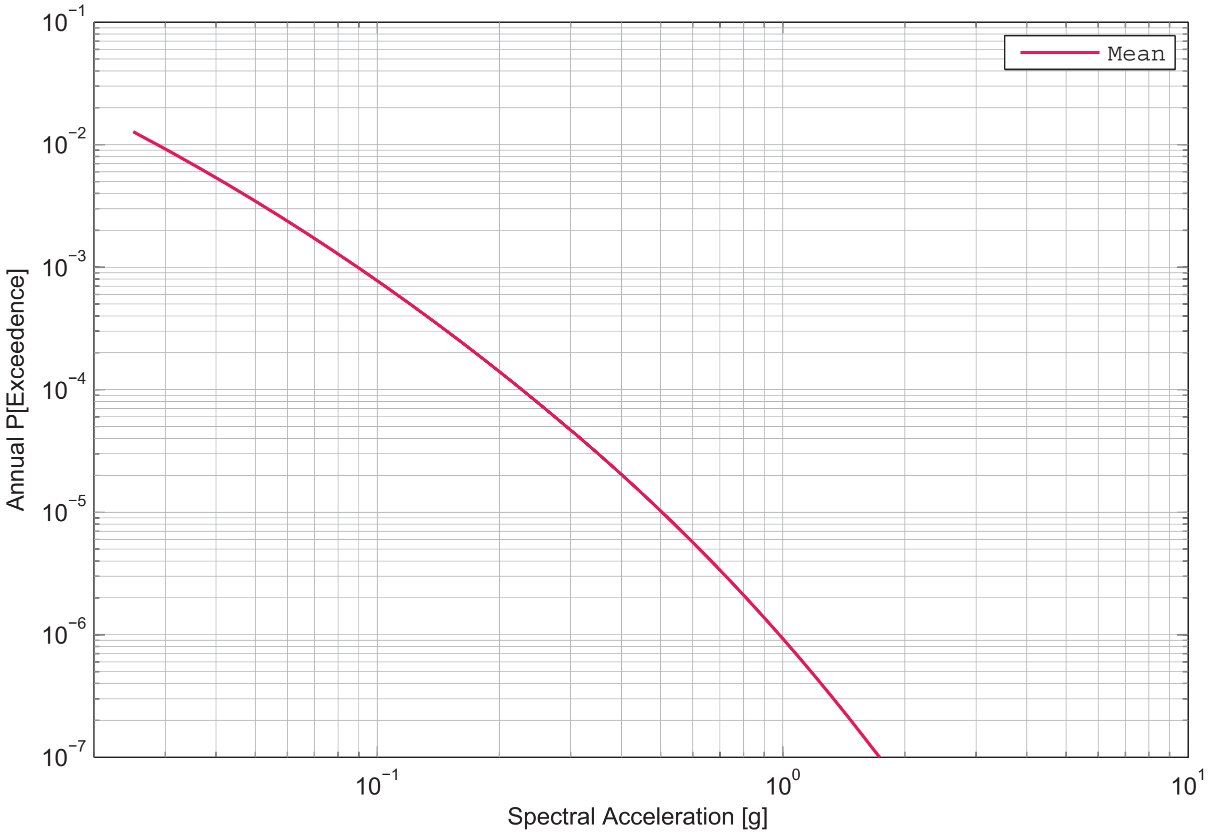

Fig. 3-1.3: Gösgen deep, horizontal component, rock, surface, mean hazard, 2.5 Hz.

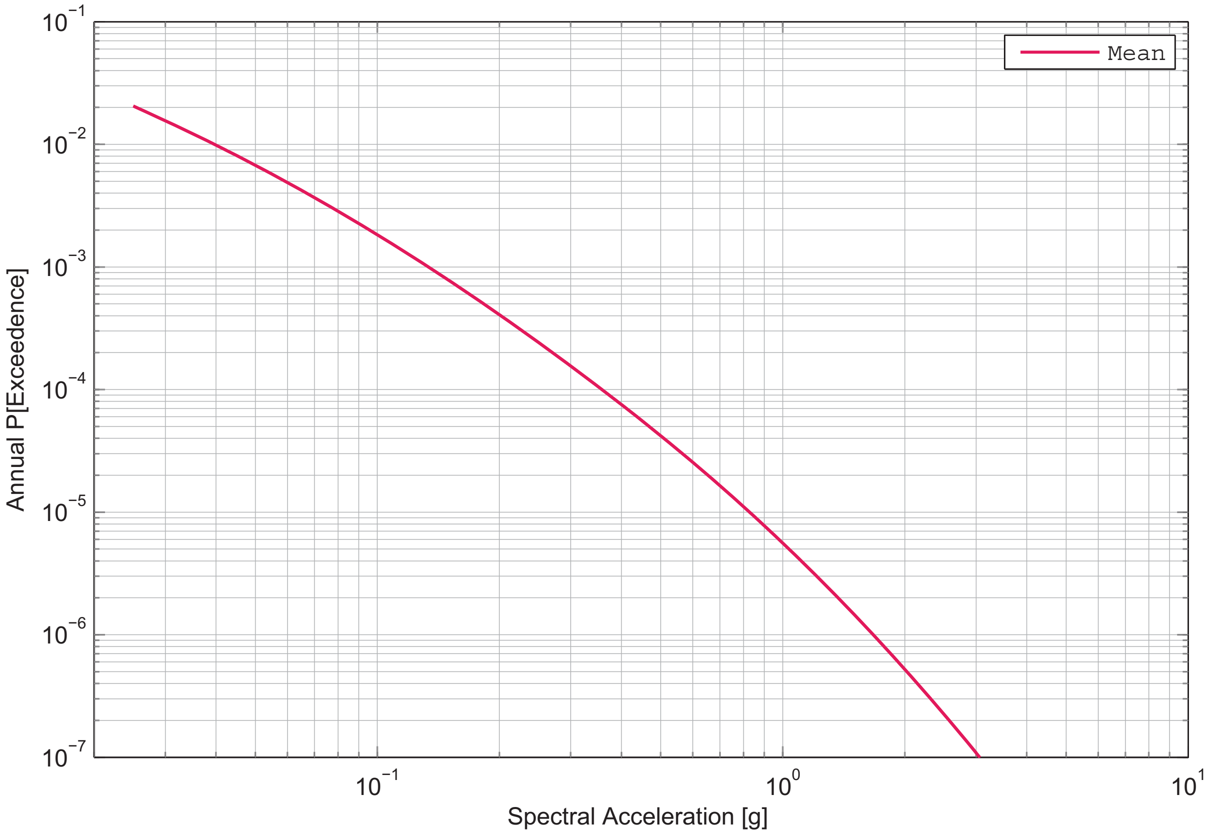

Fig. 3-1.4: Gösgen deep, horizontal component, rock, surface, mean hazard, 5 Hz.

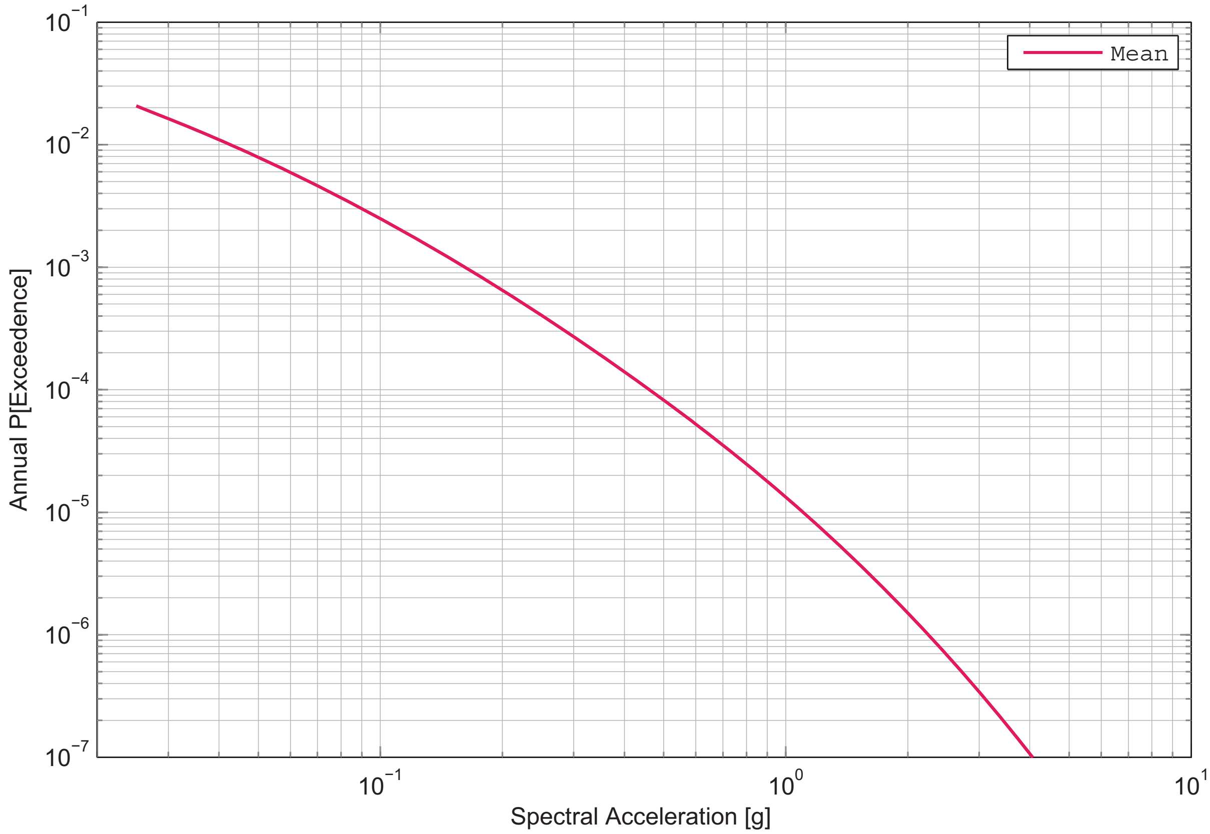

Fig. 3-1.5: Gösgen deep, horizontal component, rock, surface, mean hazard, 10 Hz.

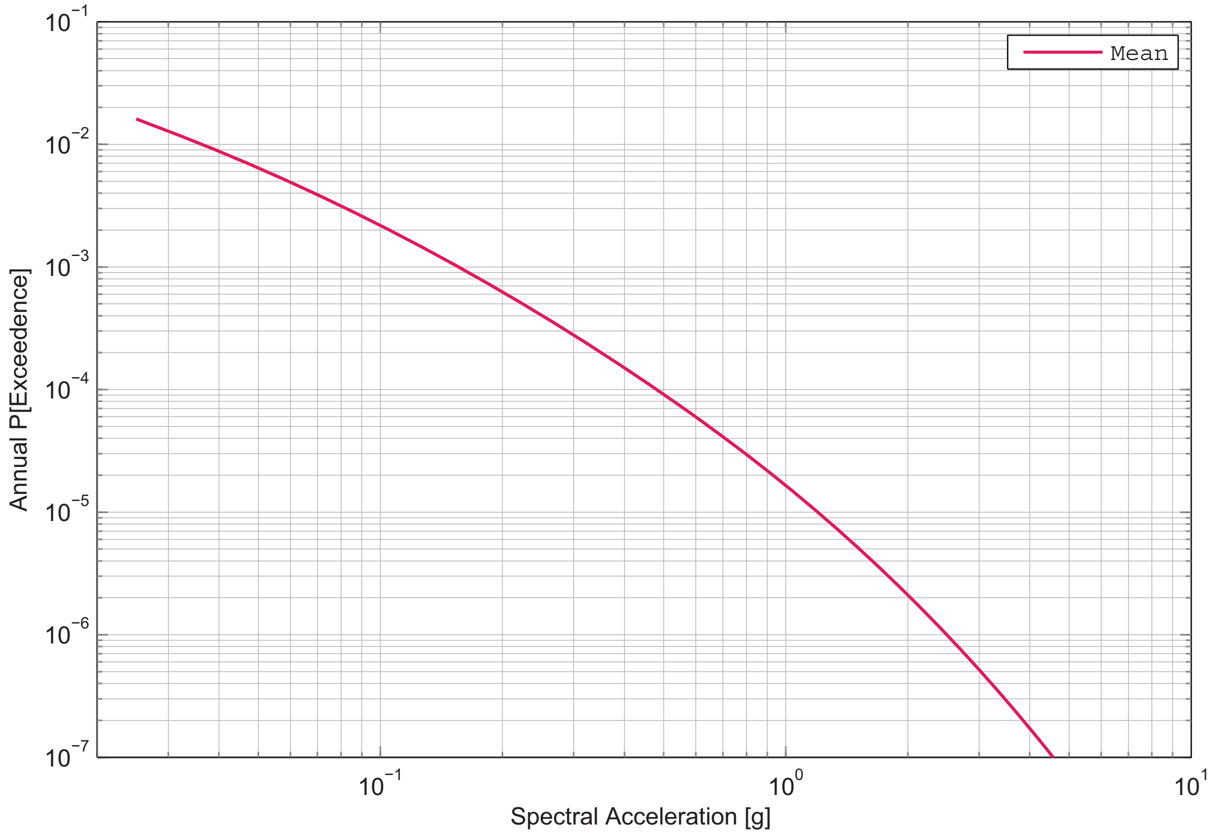

Fig. 3-1.6: Gösgen deep, horizontal component, rock, surface, mean hazard, 20 Hz.

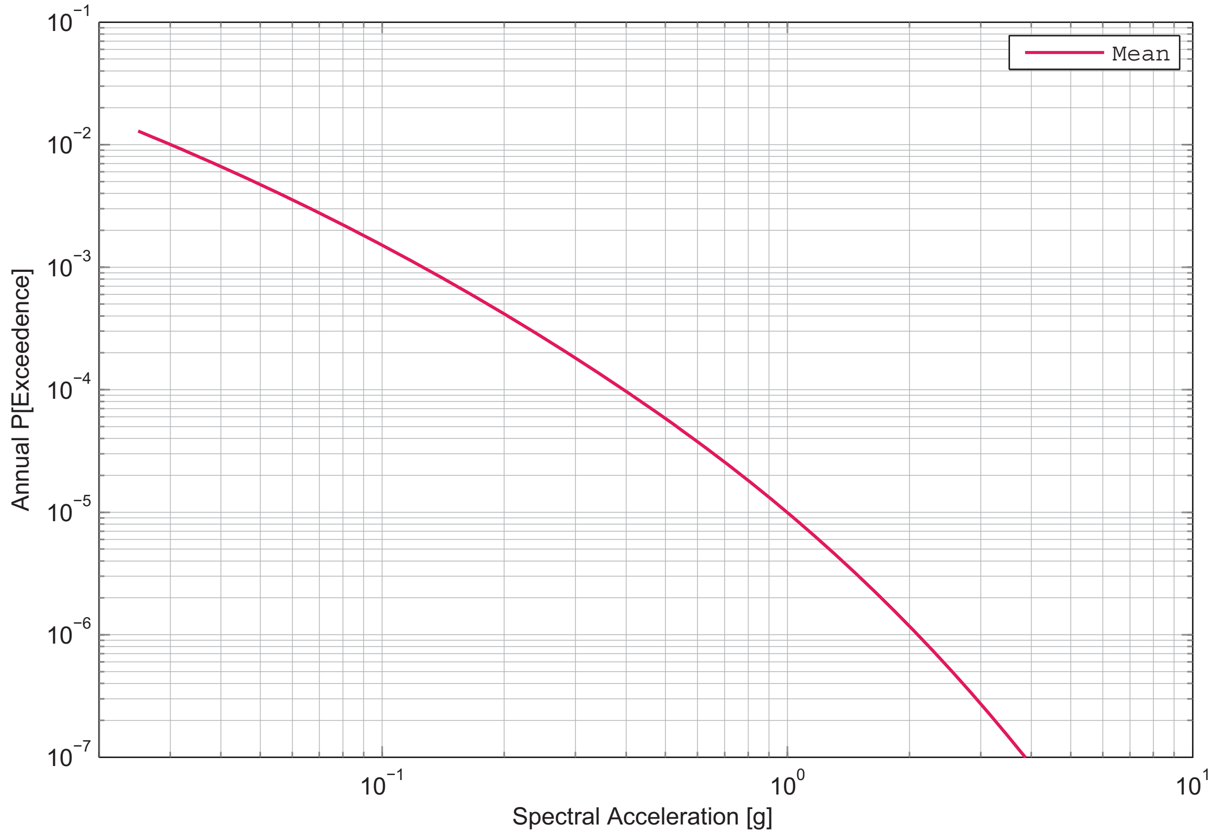

Fig. 3-1.7: Gösgen deep, horizontal component, rock, surface, mean hazard, 33 Hz.

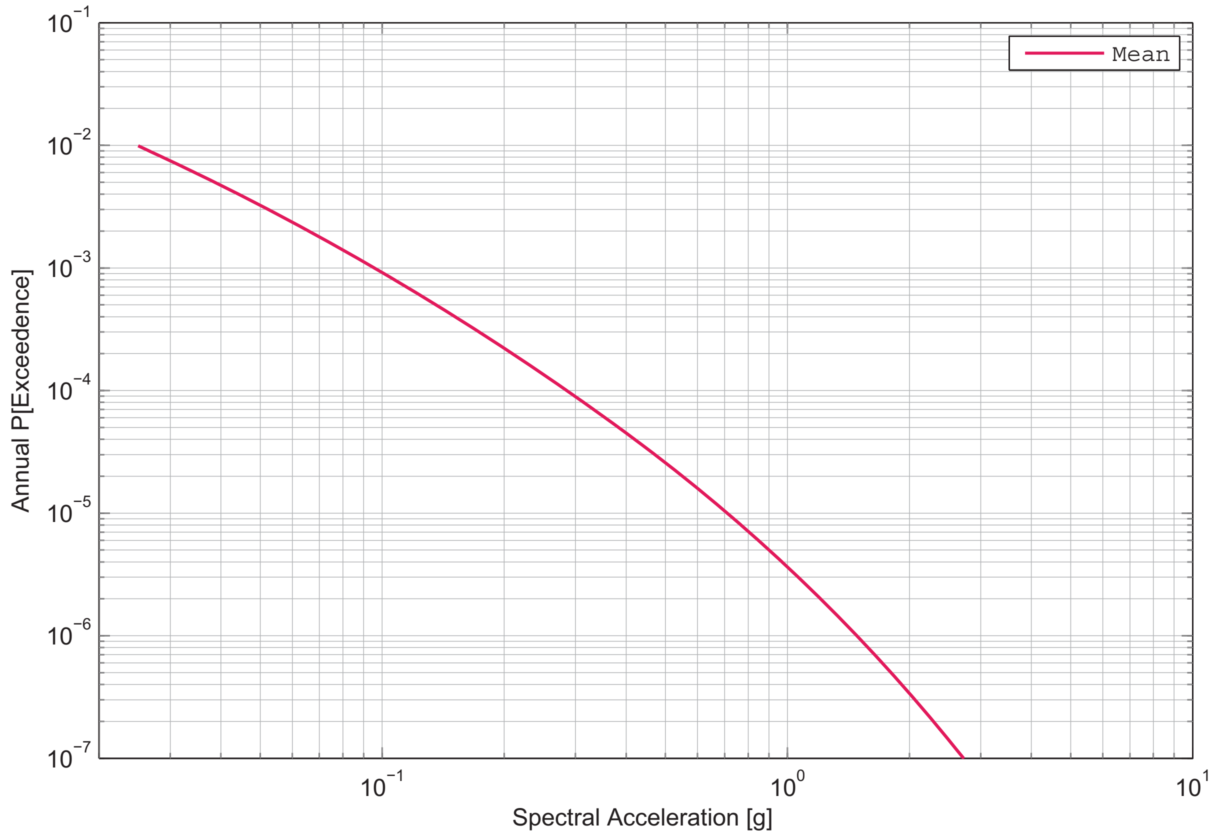

Fig. 3-1.8: Gösgen deep, horizontal component, rock, surface, mean hazard, 50 Hz.

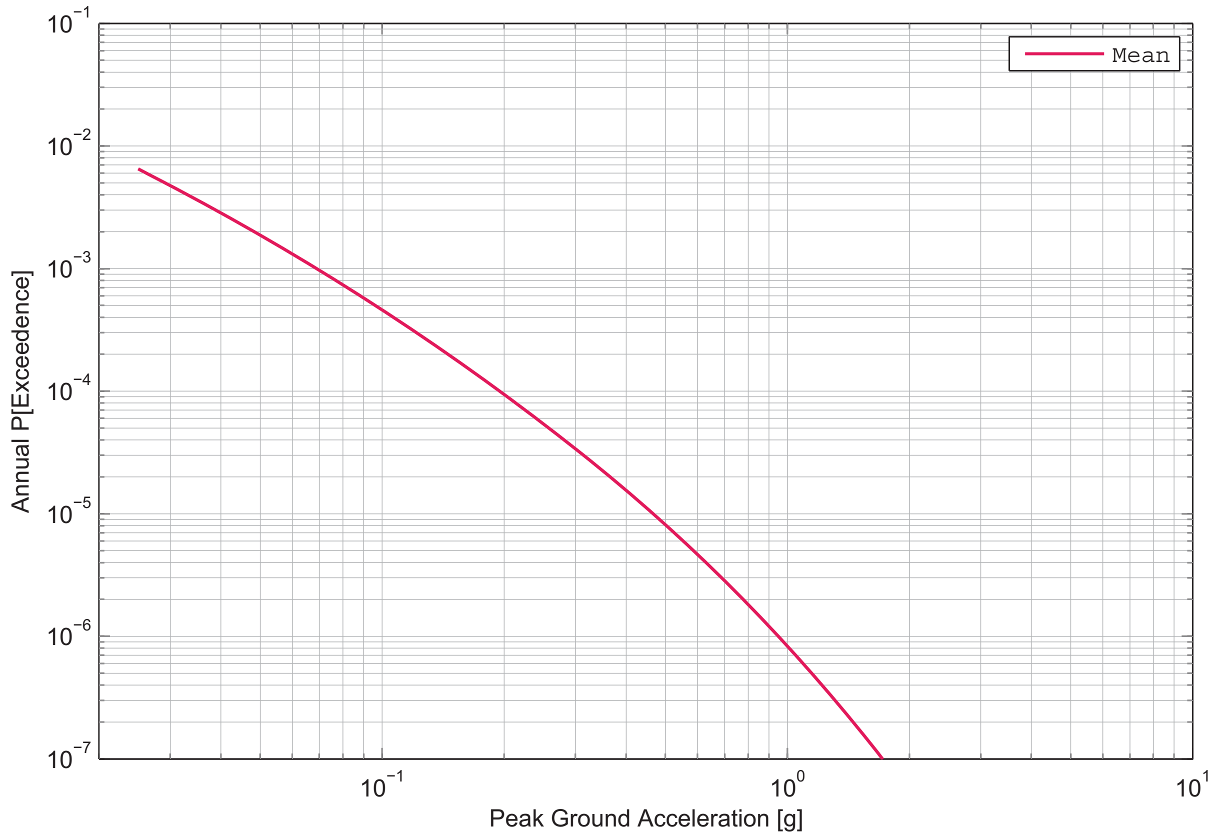

Fig. 3-1.9: Gösgen deep, horizontal component, rock, surface, mean hazard, PGA.

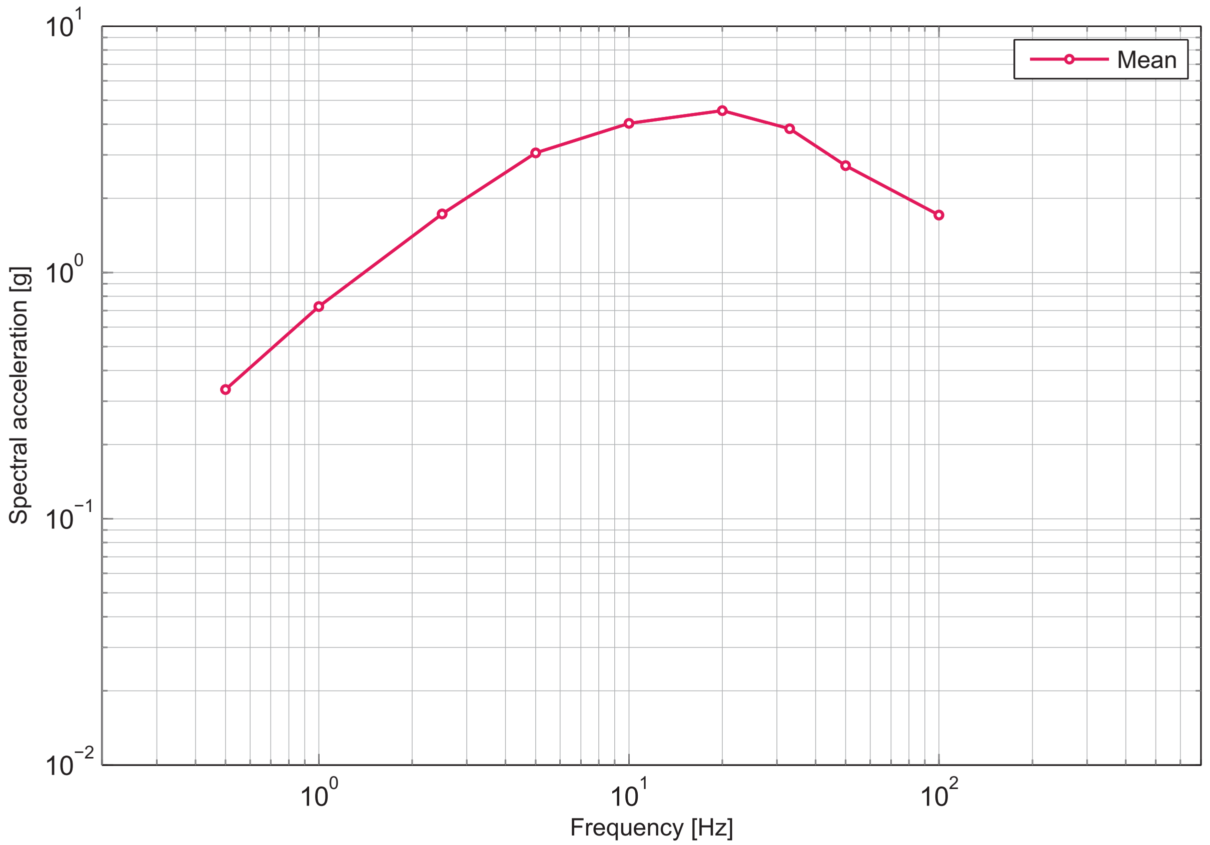

Fig. 3-1.10: Gösgen deep, horizontal component, rock, surface, uniform hazard spectra for an annual probability of exceedance of 1E-07 and 5% damping.

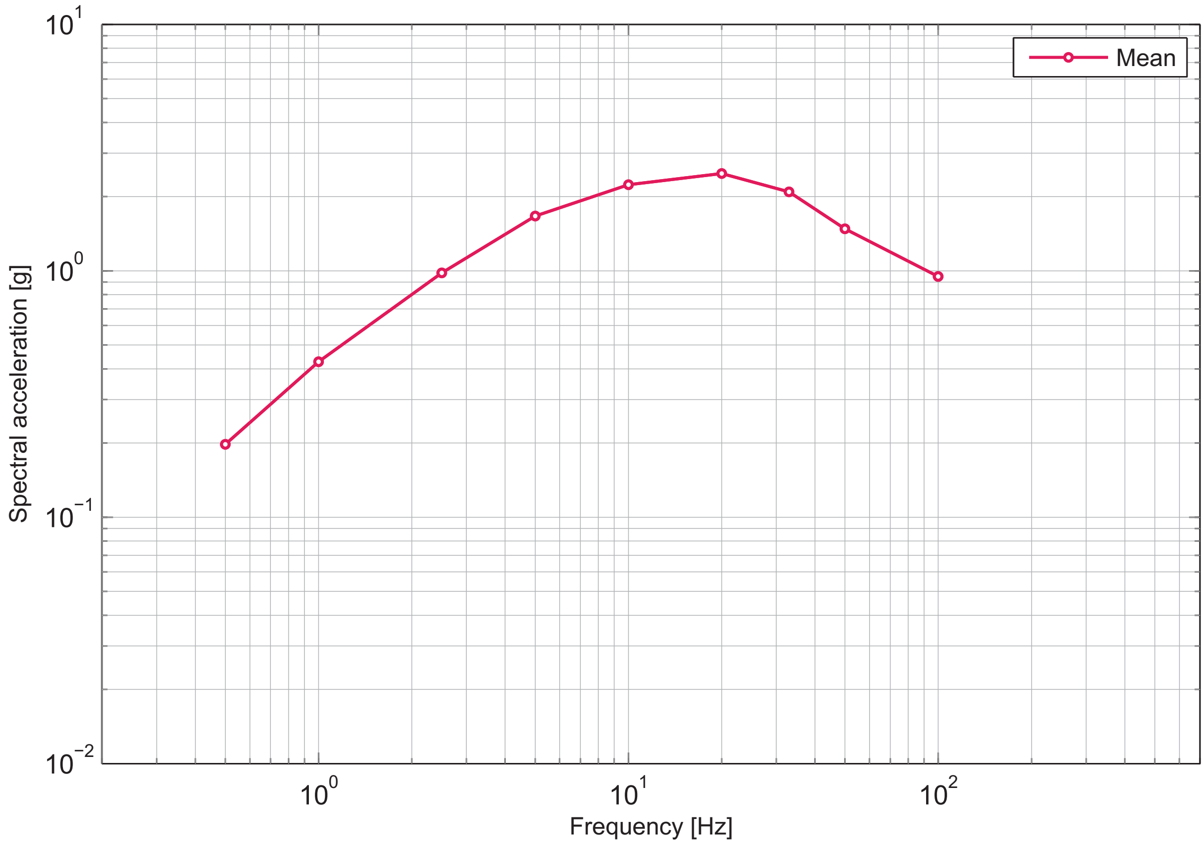

Fig. 3-1.11: Gösgen deep, horizontal component, rock, surface, uniform hazard spectra for an annual probability of exceedance of 1E-06 and 5% damping.

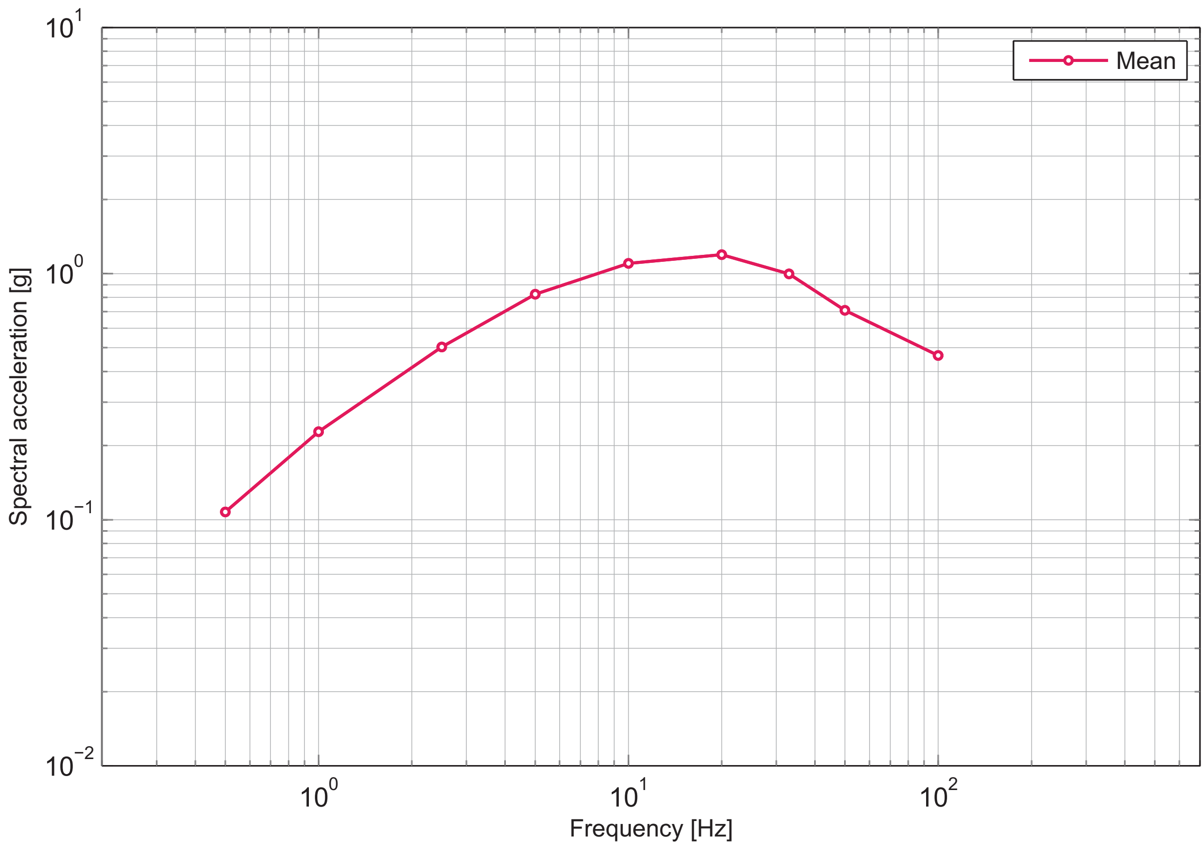

Fig. 3-1.12: Gösgen deep, horizontal component, rock, surface, uniform hazard spectra for an annual probability of exceedance of 1E-05 and 5% damping.

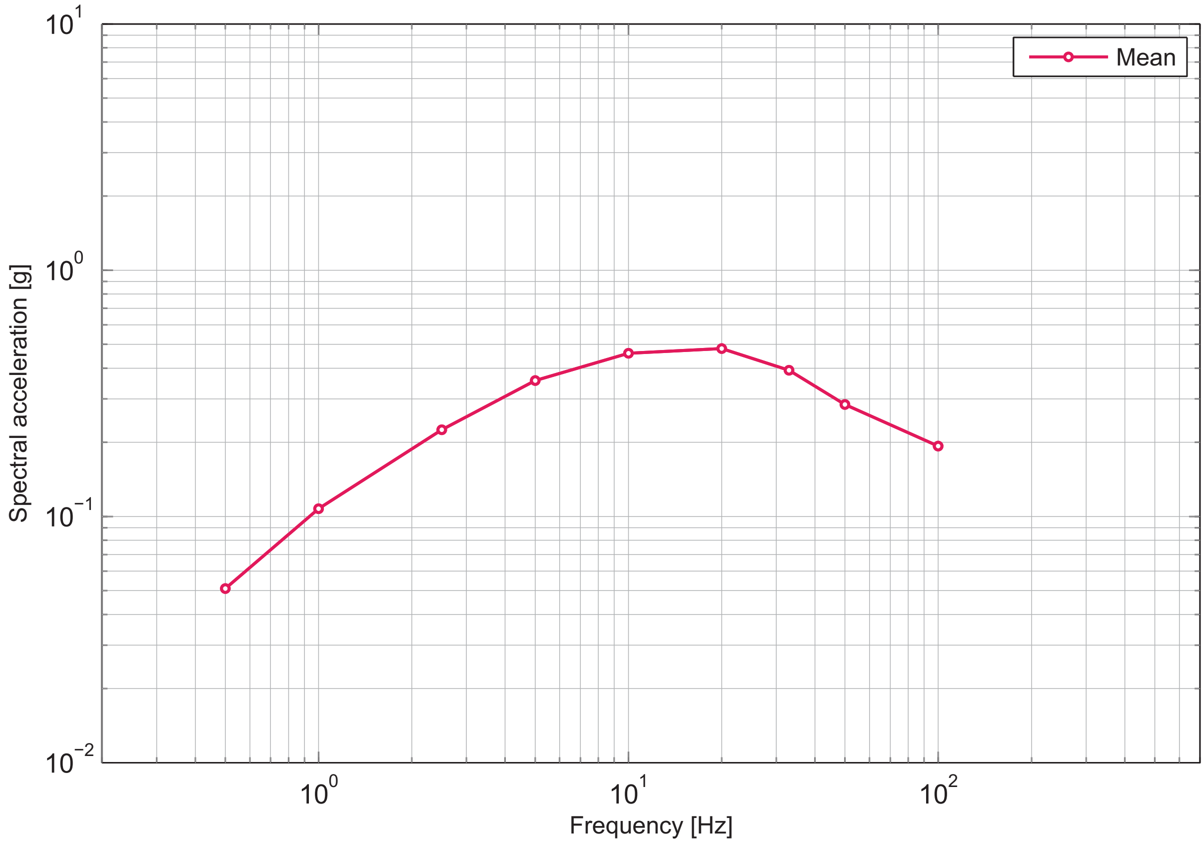

Fig. 3-1.13: Gösgen deep, horizontal component, rock, surface, uniform hazard spectra for an annual probability of exceedance of 1E-04 and 5% damping.

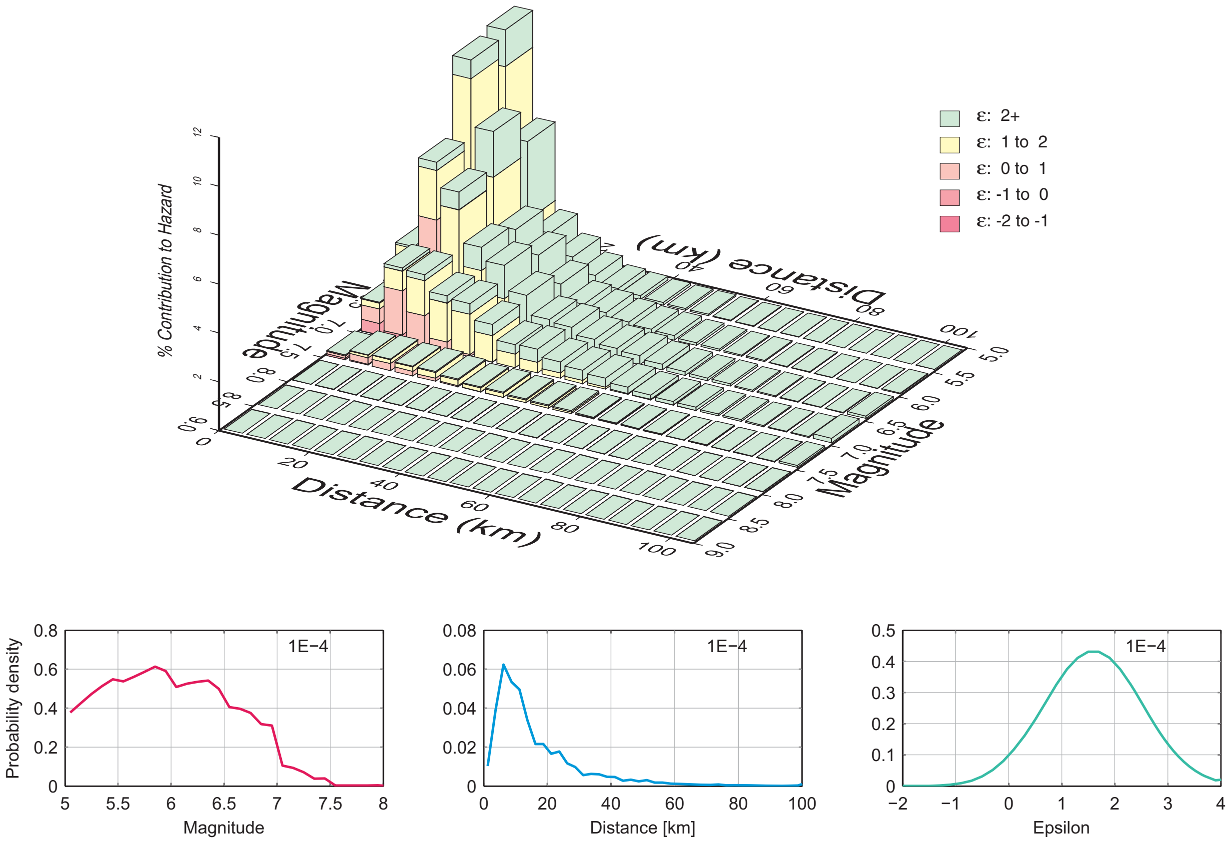

Fig. 3-1.14: Gösgen deep, horizontal component, rock, surface, hazard deaggregation by magnitude, distance and epsilon for ground motion level 1E-4, 5 Hz.

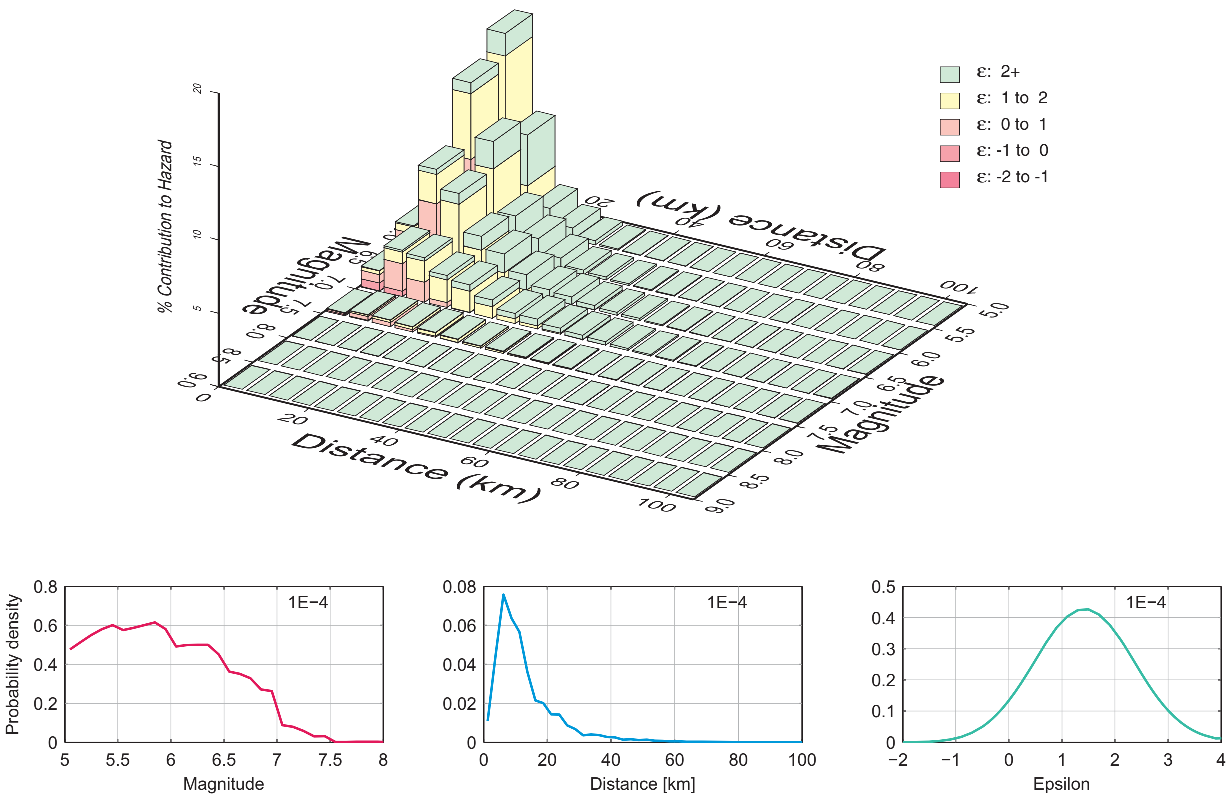

Fig. 3-1.15: Gösgen deep, horizontal component, rock, surface, hazard deaggregation by magnitude, distance and epsilon for ground motion level 1E-4, PGA.

4 GÖSGEN SHALLOW

4.1 Rock Hazard, Horizontal Component, Surface

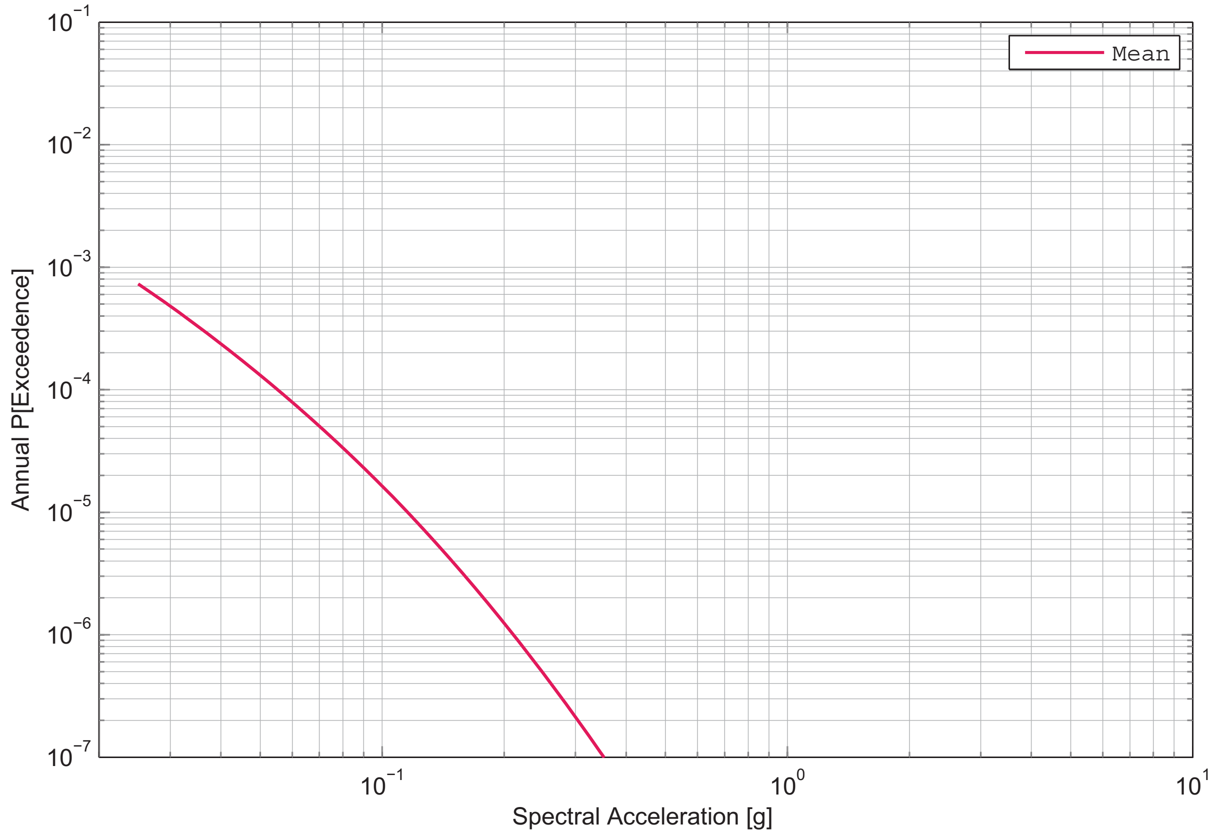

Fig. 4-1.1: Gösgen shallow, horizontal component, rock, surface, mean hazard, 0.5 Hz.

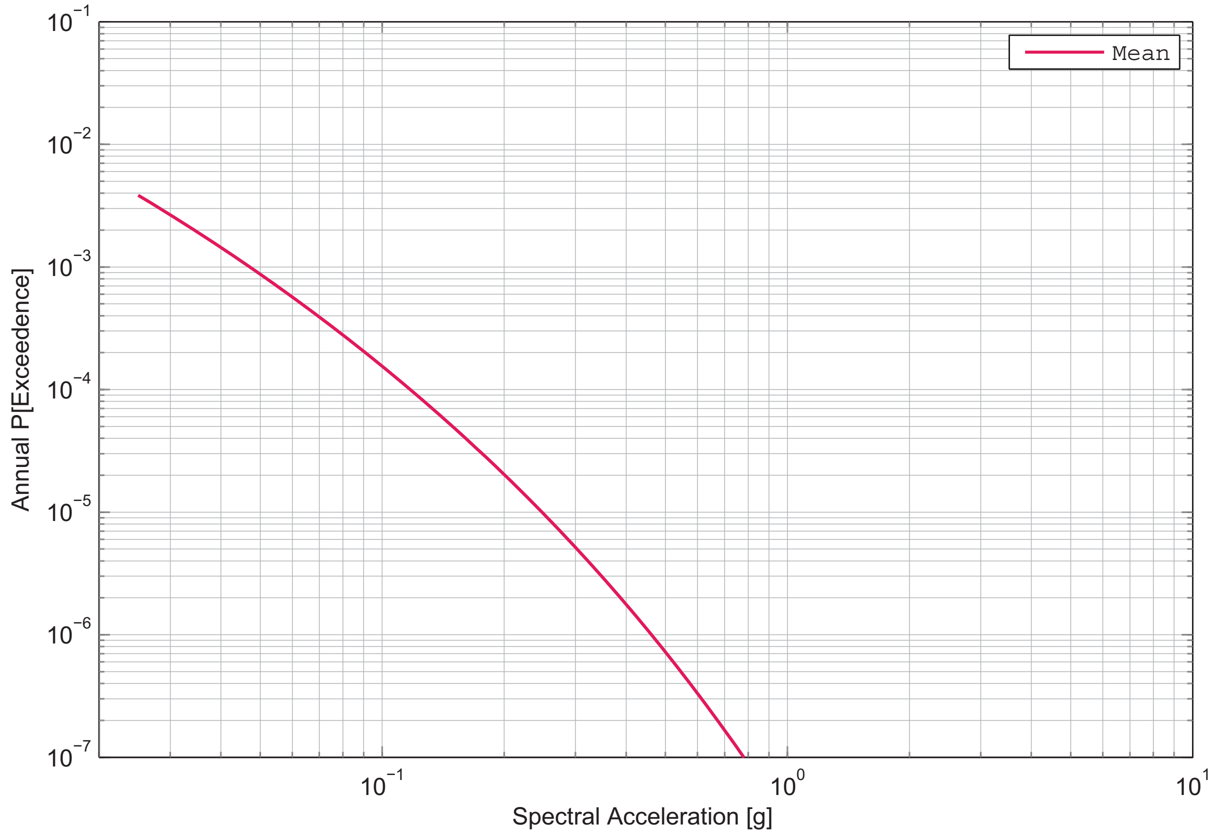

Fig. 4-1.2: Gösgen shallow, horizontal component, rock, surface, mean hazard, 1 Hz.

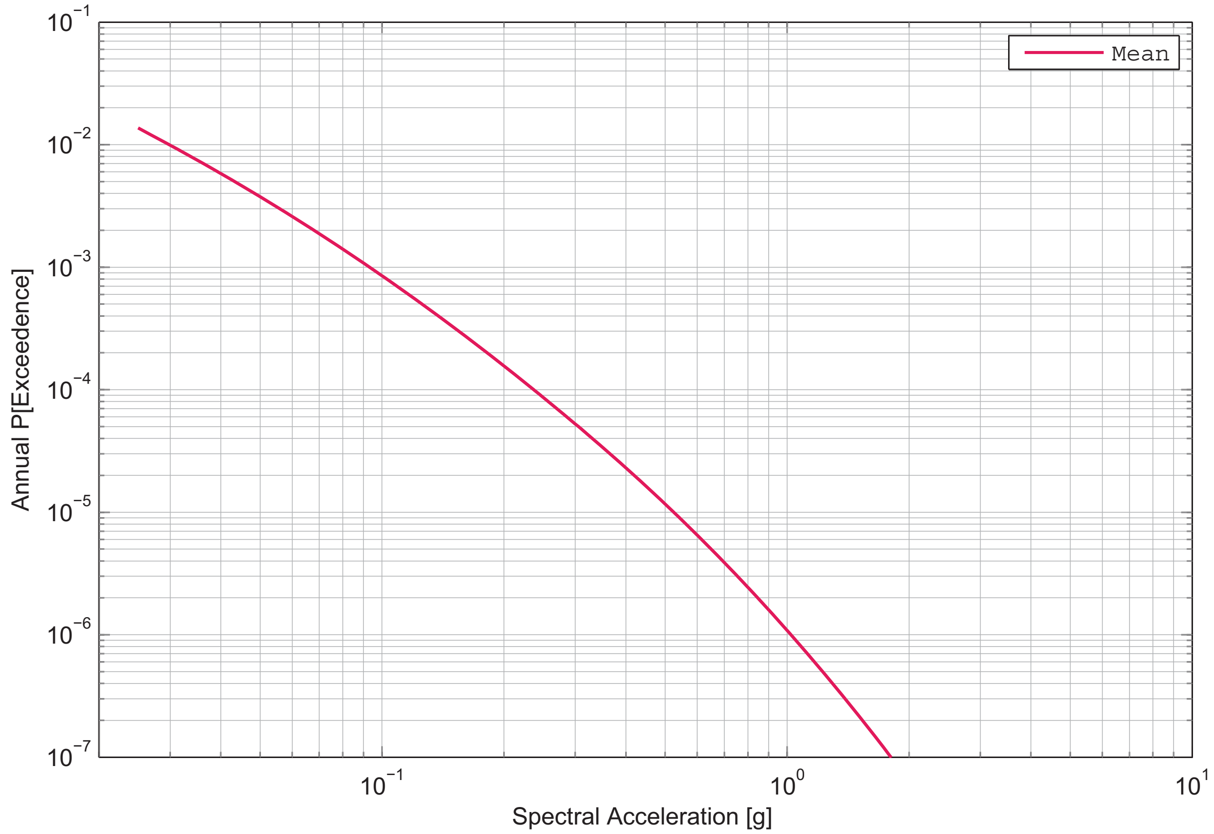

Fig. 4-1.3: Gösgen shallow, horizontal component, rock, surface, mean hazard, 2.5 Hz.

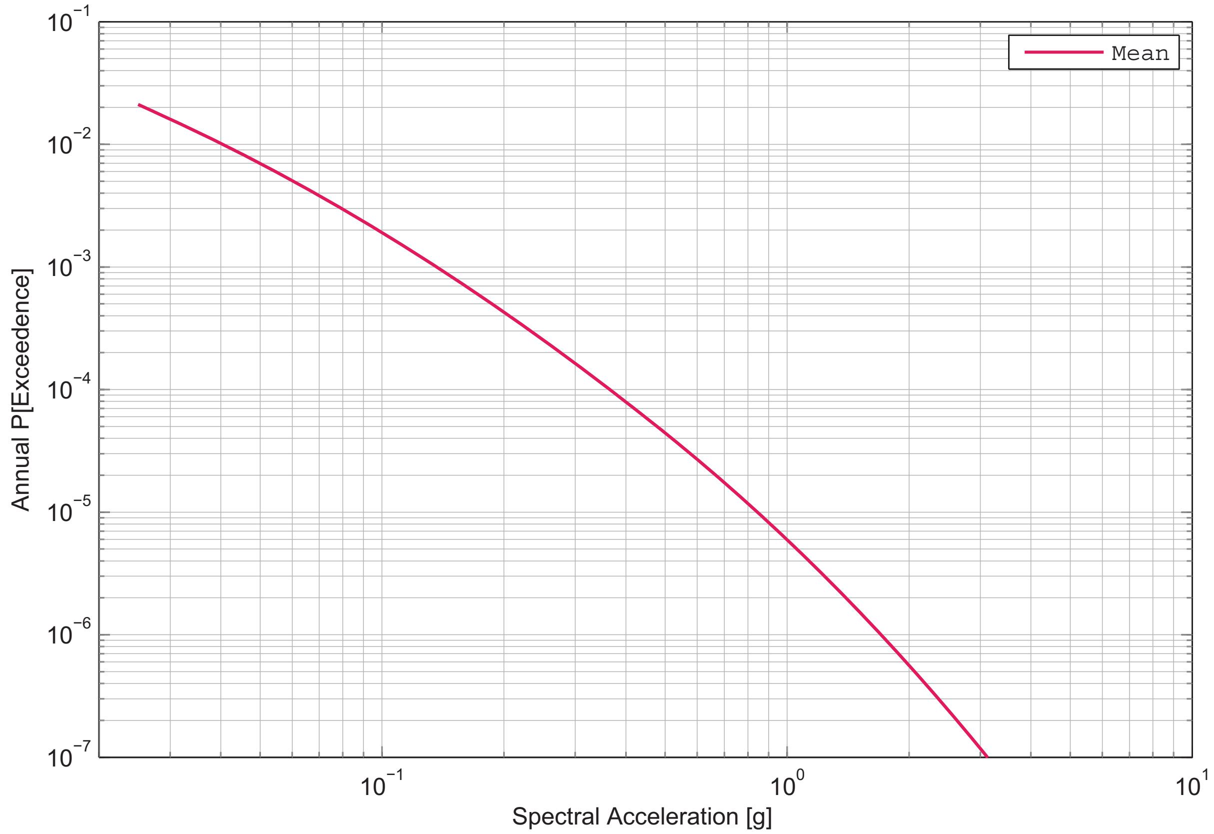

Fig. 4-1.4: Gösgen shallow, horizontal component, rock, surface, mean hazard, 5 Hz.

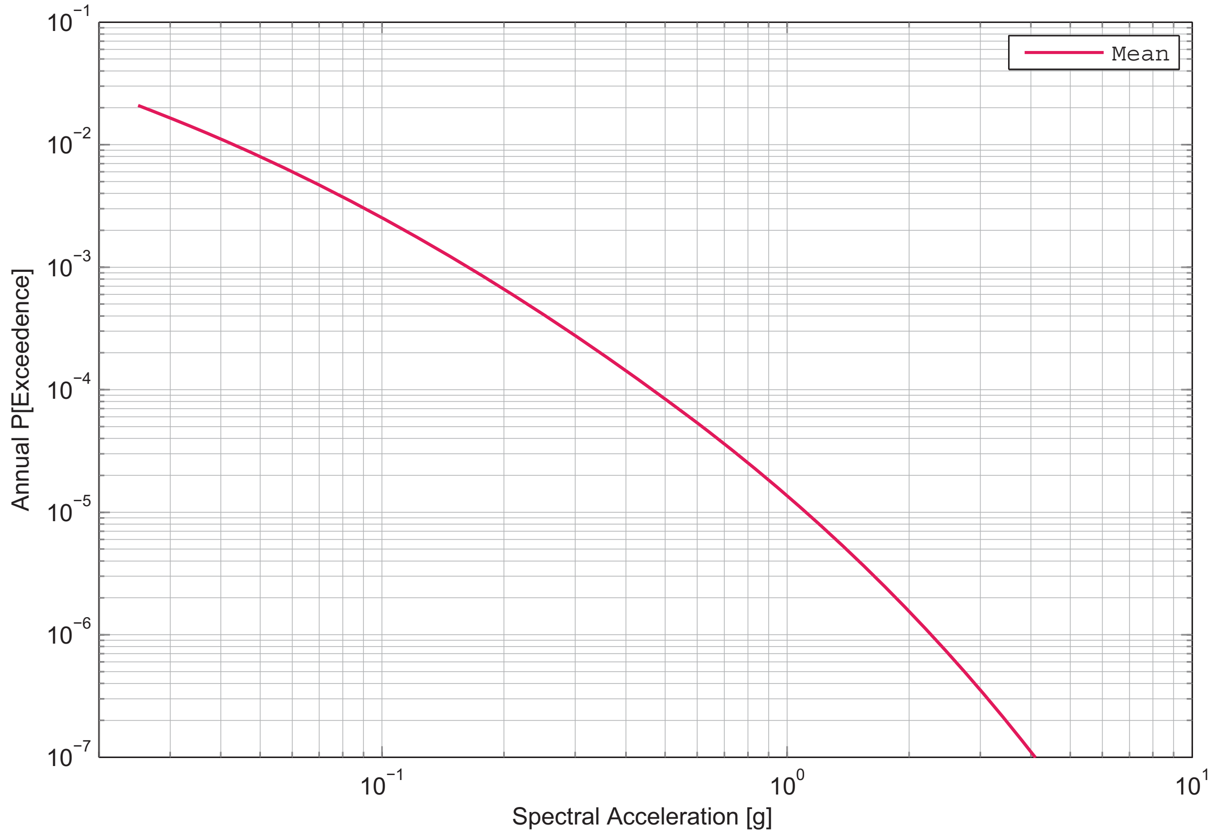

Fig. 4-1.5: Gösgen shallow, horizontal component, rock, surface, mean hazard, 10 Hz.

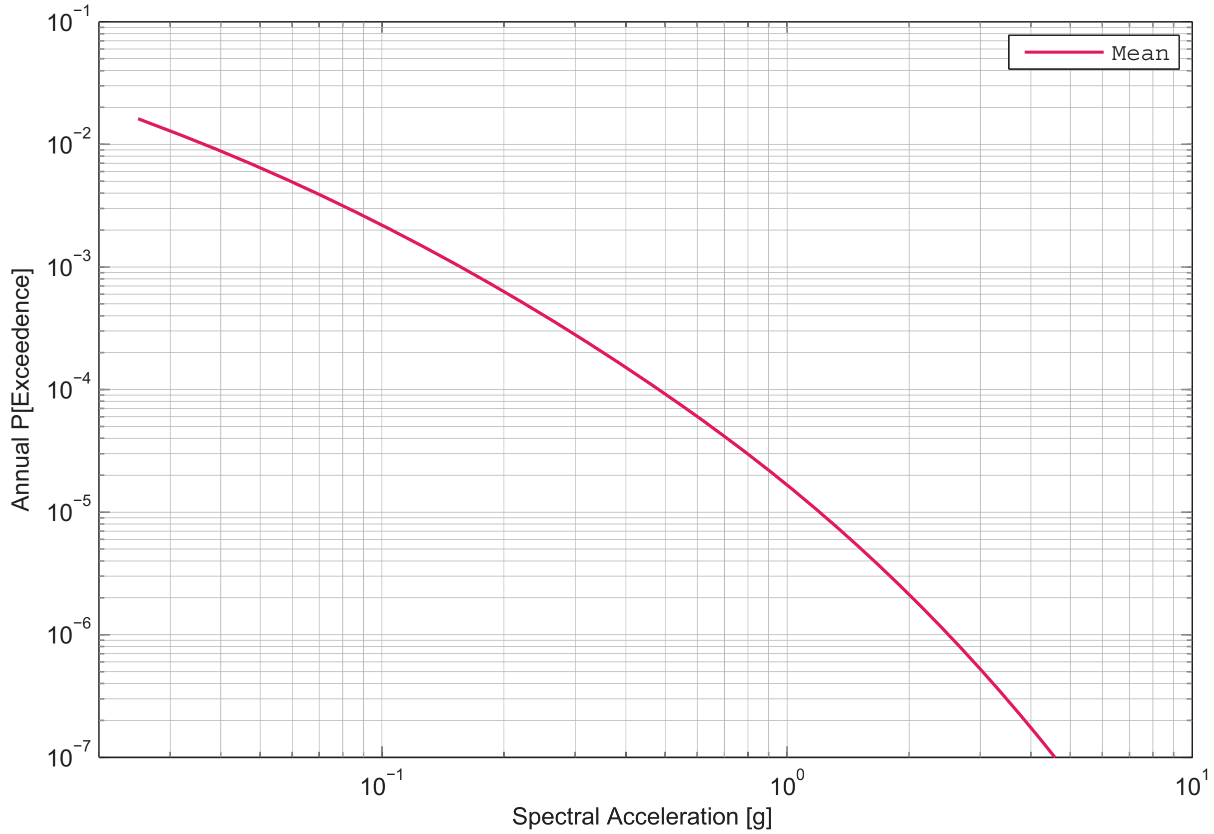

Fig. 4-1.6: Gösgen shallow, horizontal component, rock, surface, mean hazard, 20 Hz.

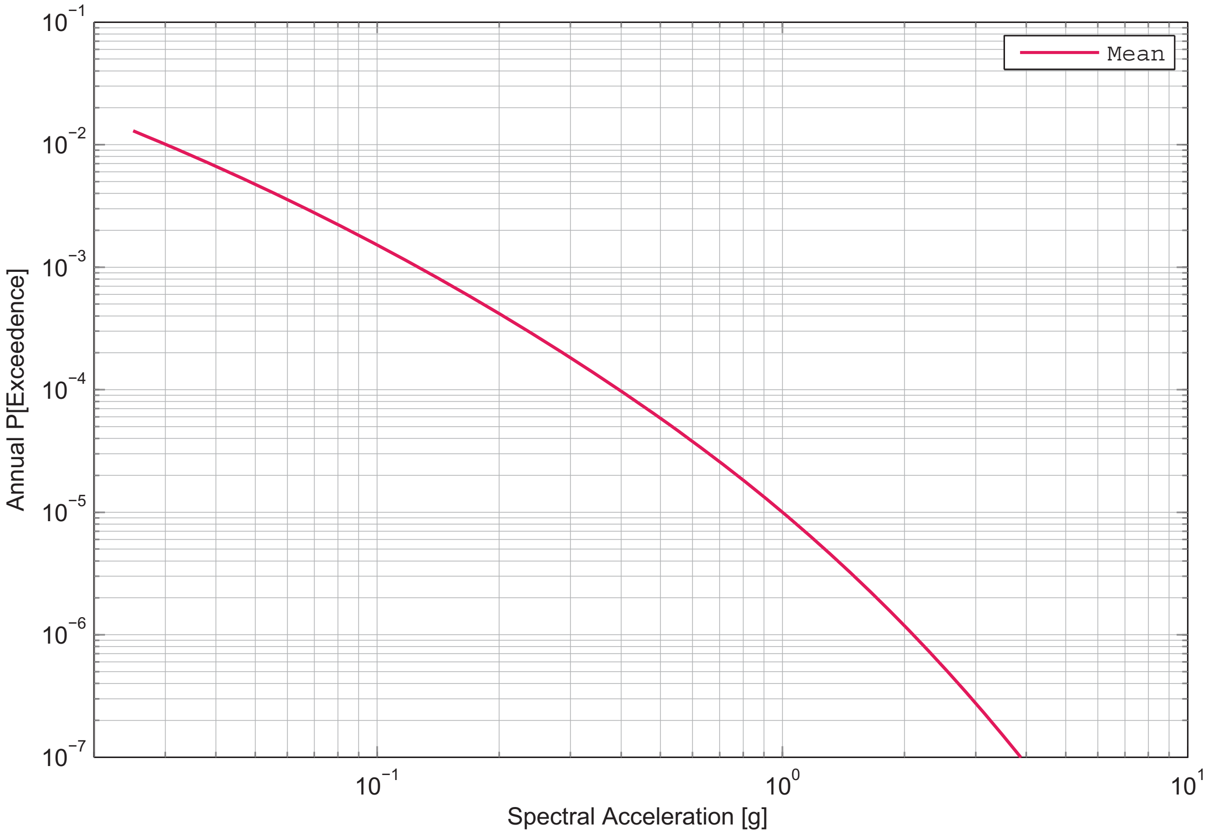

Fig. 4-1.7: Gösgen shallow, horizontal component, rock, surface, mean hazard, 33 Hz.

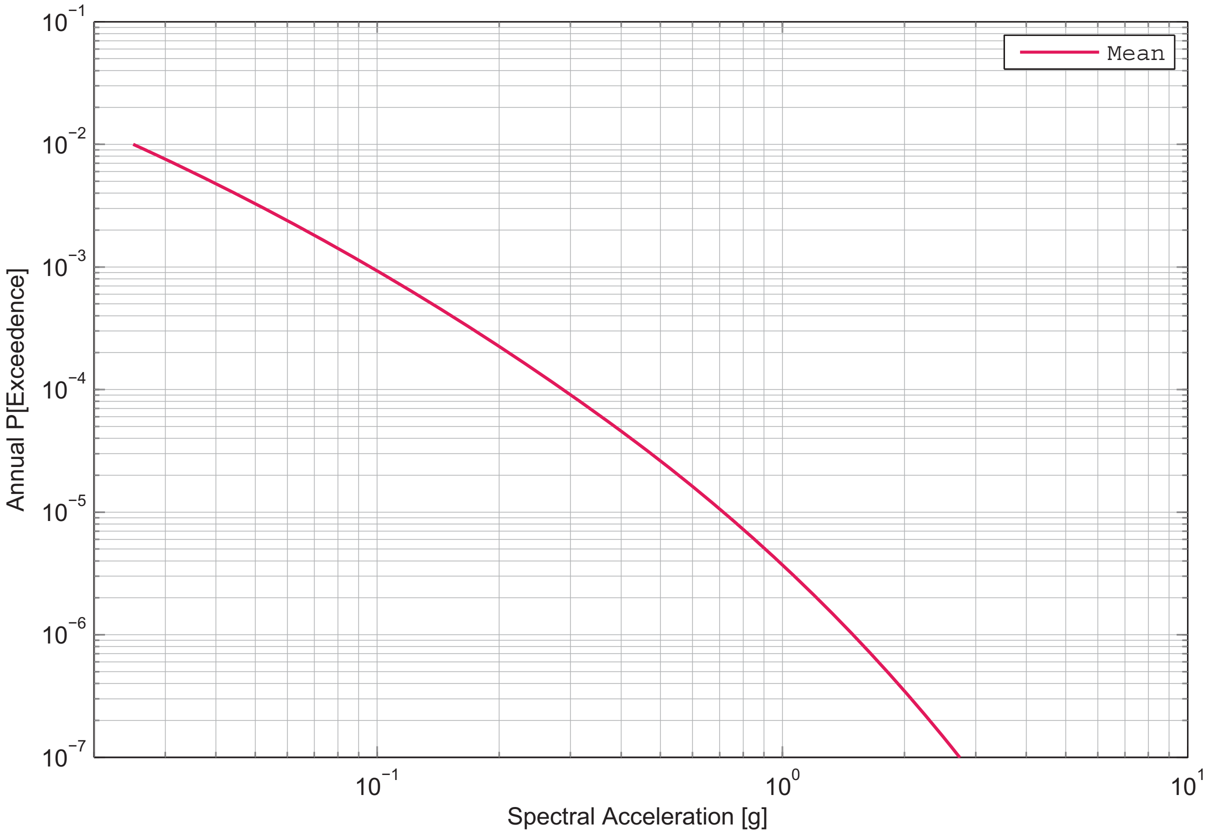

Fig. 4-1.8: Gösgen shallow, horizontal component, rock, surface, mean hazard, 50 Hz.

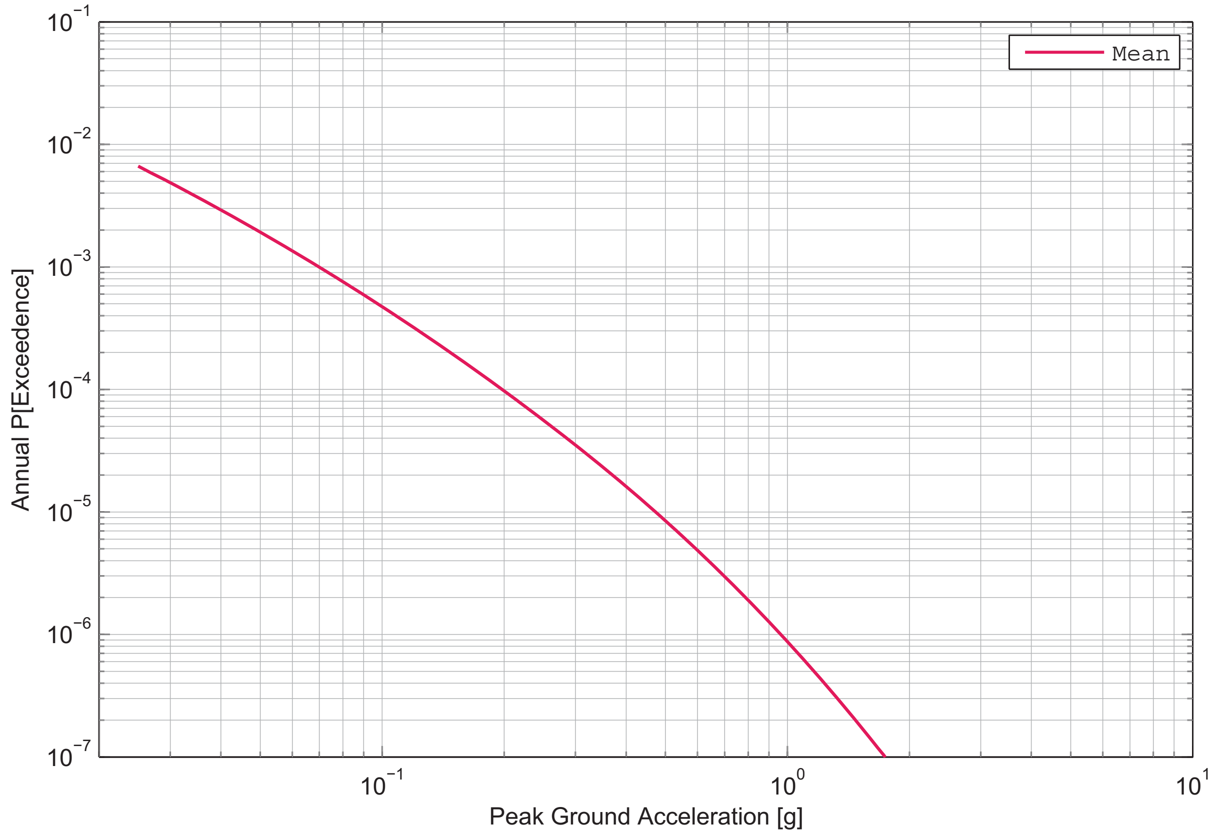

Fig. 4-1.9: Gösgen shallow, horizontal component, rock, surface, mean hazard, PGA.

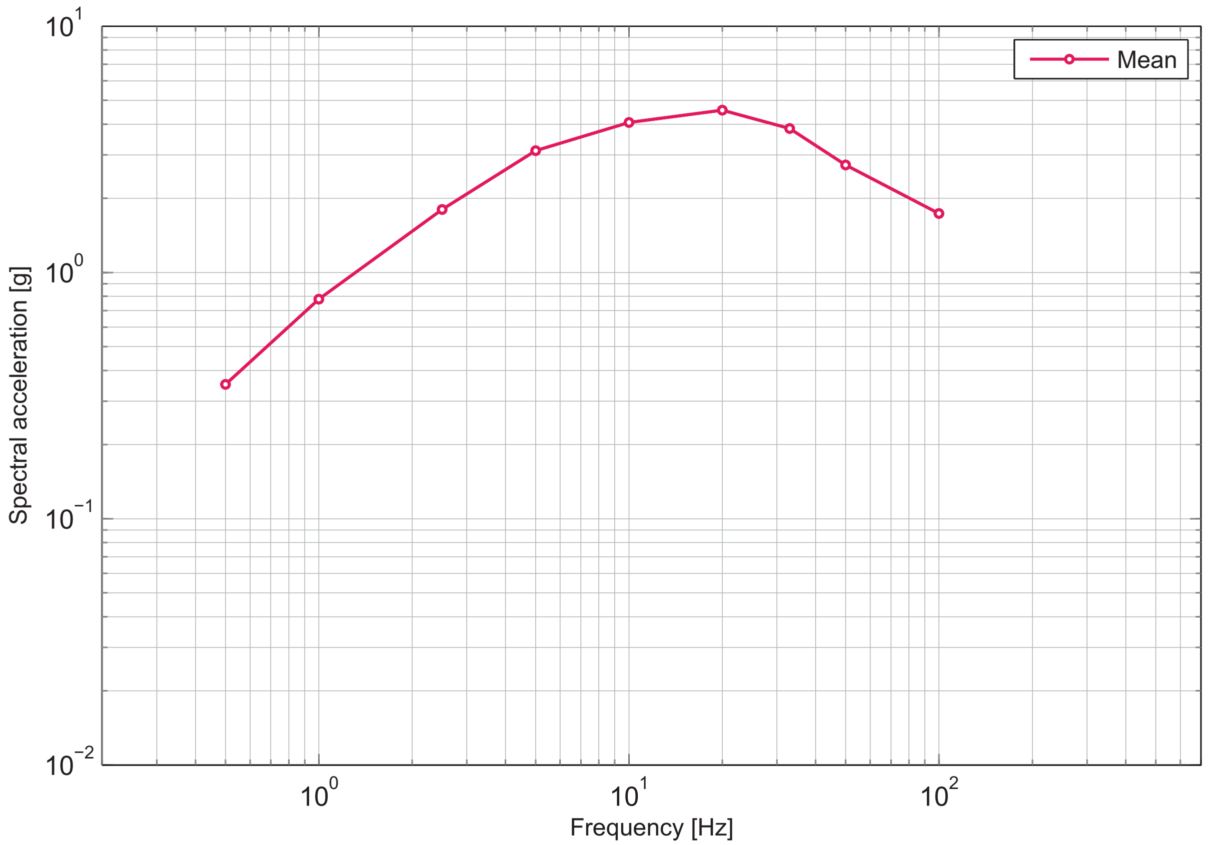

Fig. 4-1.10: Gösgen shallow, horizontal component, rock, surface, uniform hazard spectra for an annual probability of exceedance of 1E-07 and 5% damping.

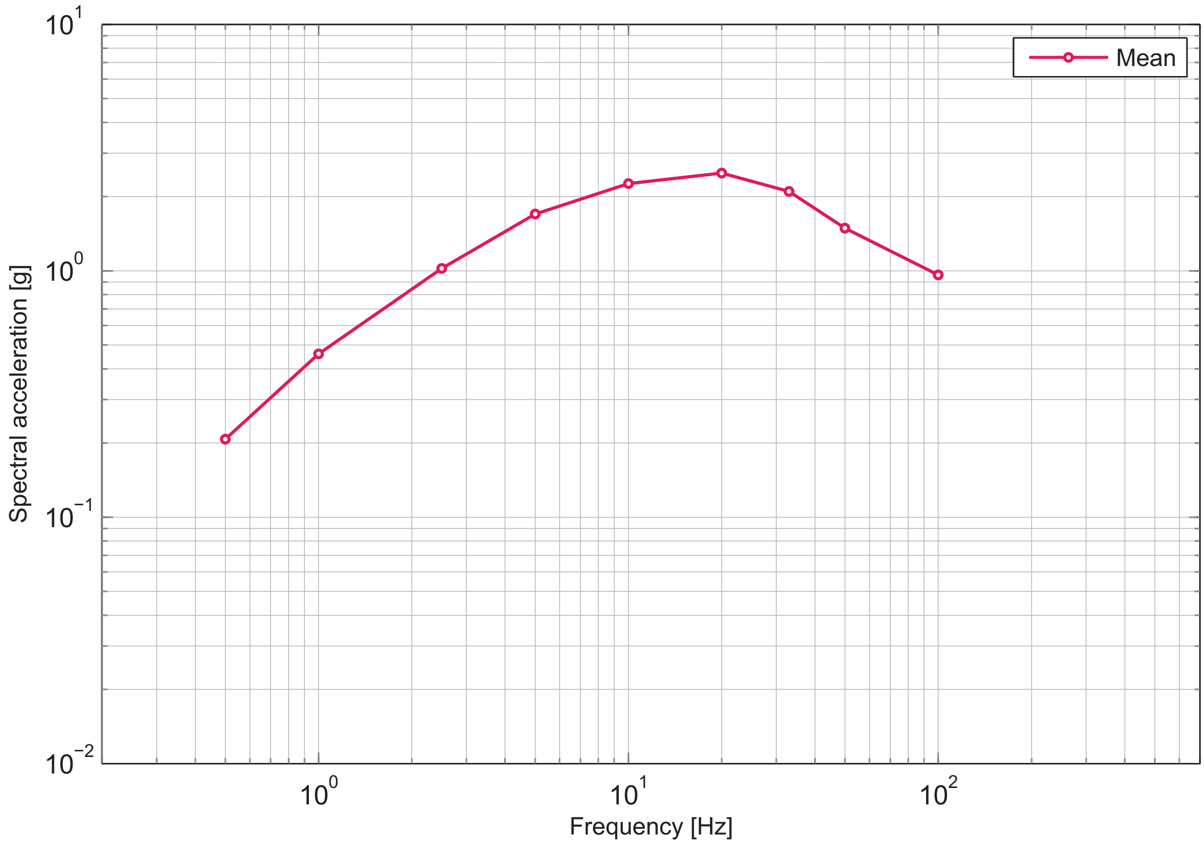

Fig. 4-1.11: Gösgen shallow, horizontal component, rock, surface, uniform hazard spectra for an annual probability of exceedance of 1E-06 and 5% damping.

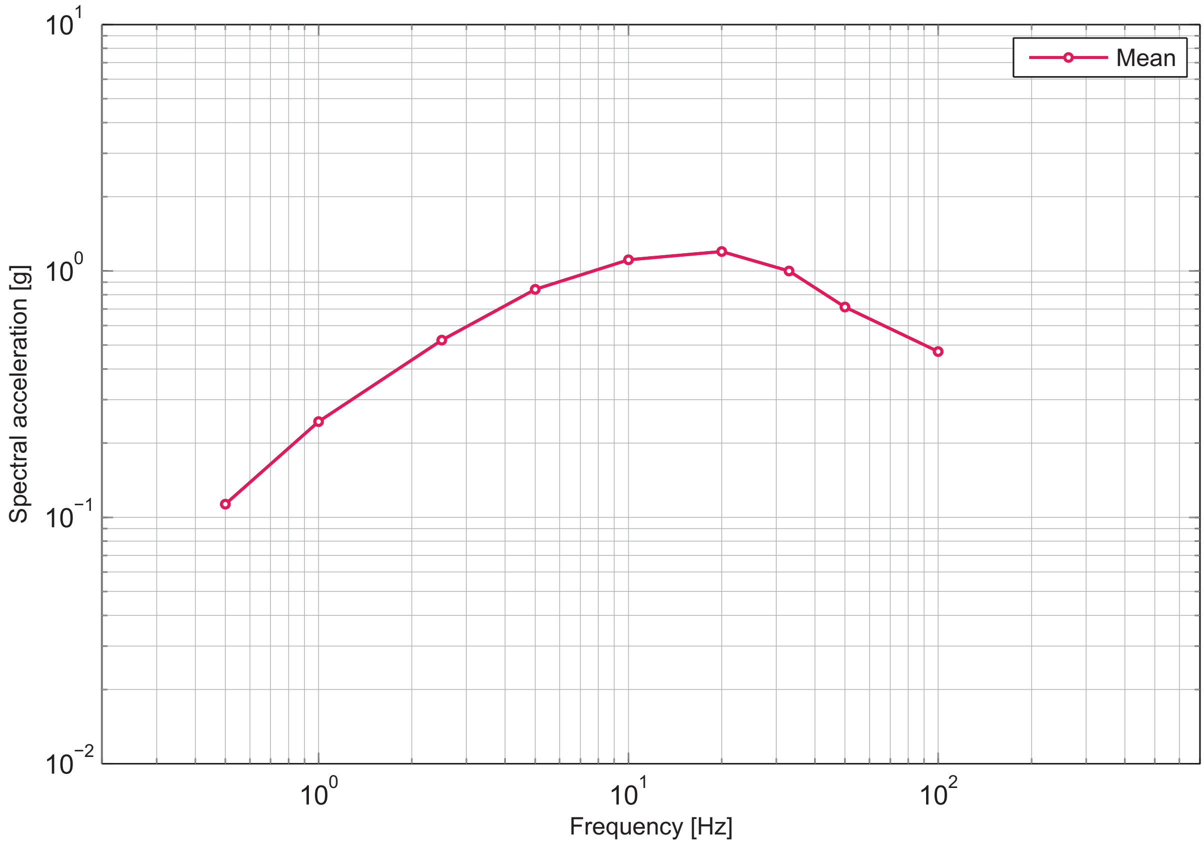

Fig. 4-1.12: Gösgen shallow, horizontal component, rock, surface, uniform hazard spectra for an annual probability of exceedance of 1E-05 and 5% damping.

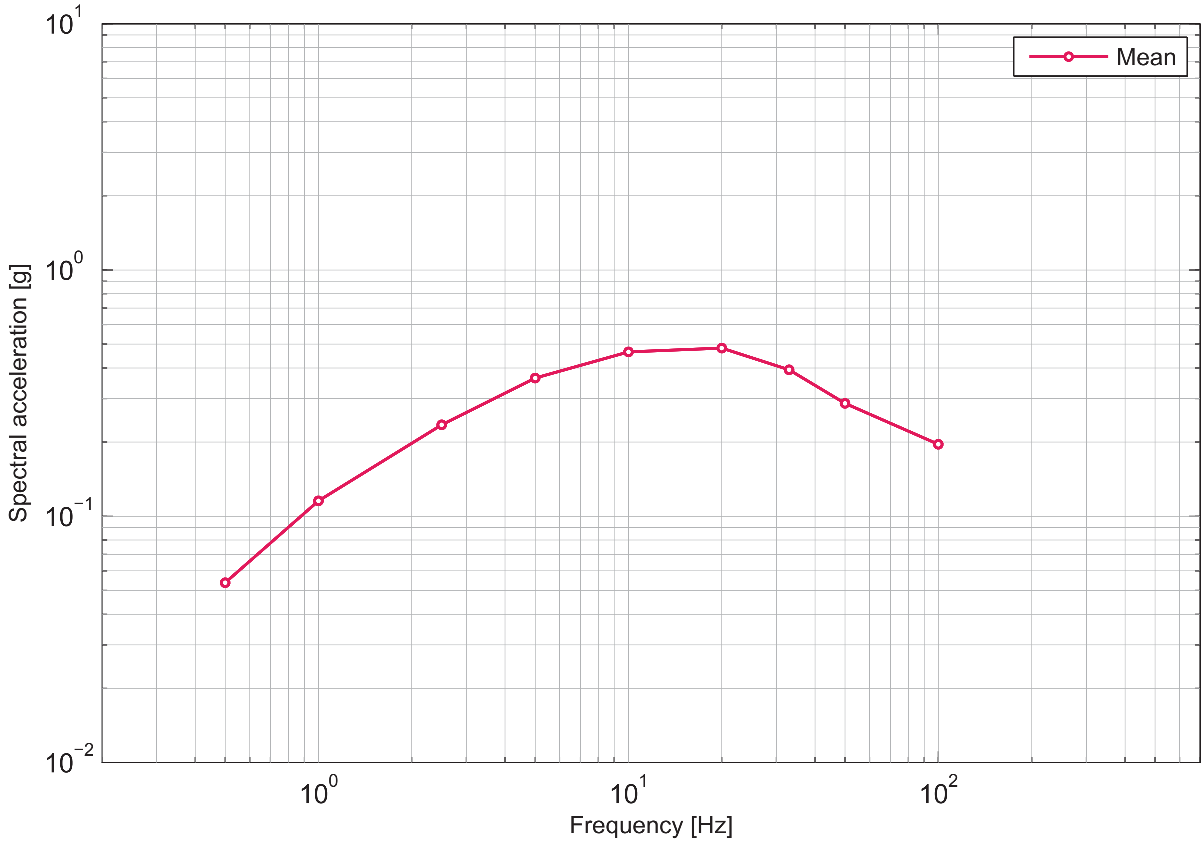

Fig. 4-1.13: Gösgen shallow, horizontal component, rock, surface, uniform hazard spectra for an annual probability of exceedance of 1E-04 and 5% damping.

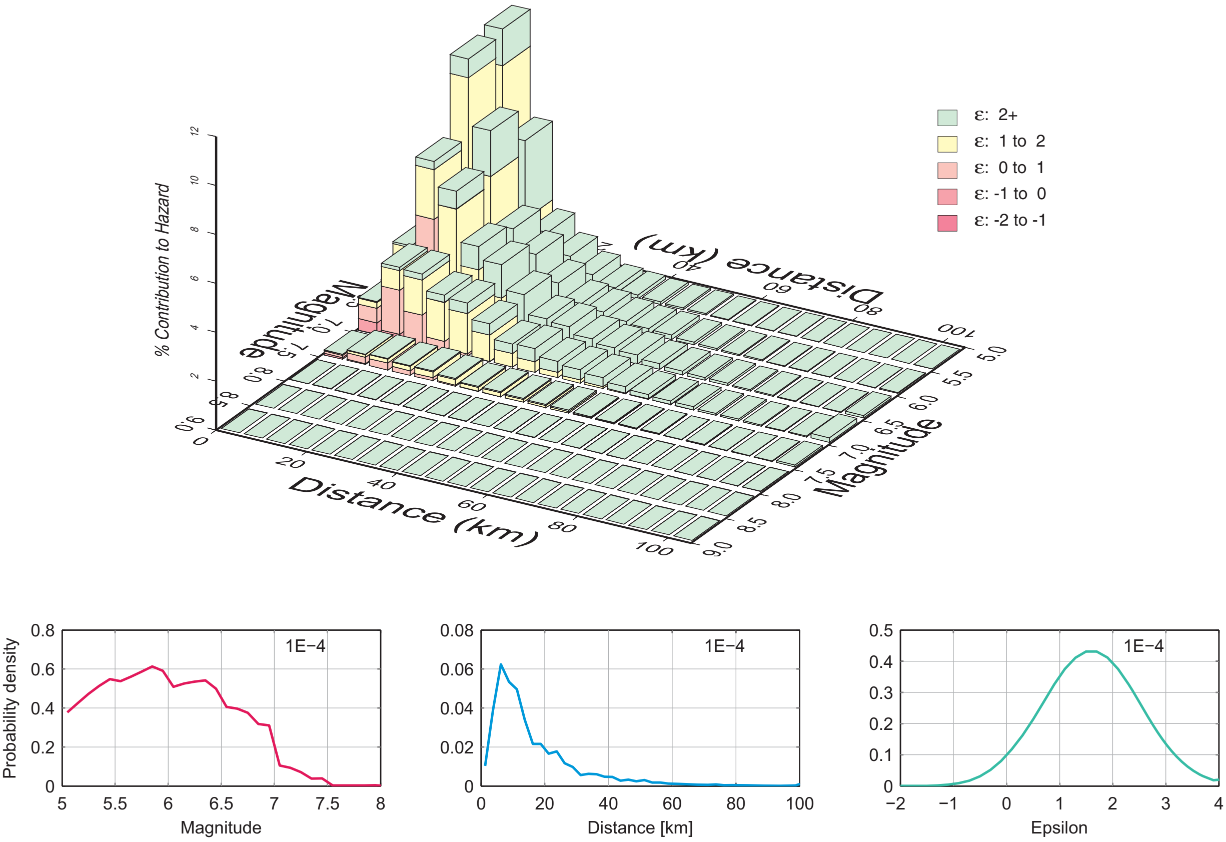

Fig. 4-1.14: Gösgen shallow, horizontal component, rock, surface, hazard deaggregation by magnitude, distance and epsilon for ground motion level 1E-4, 5 Hz.

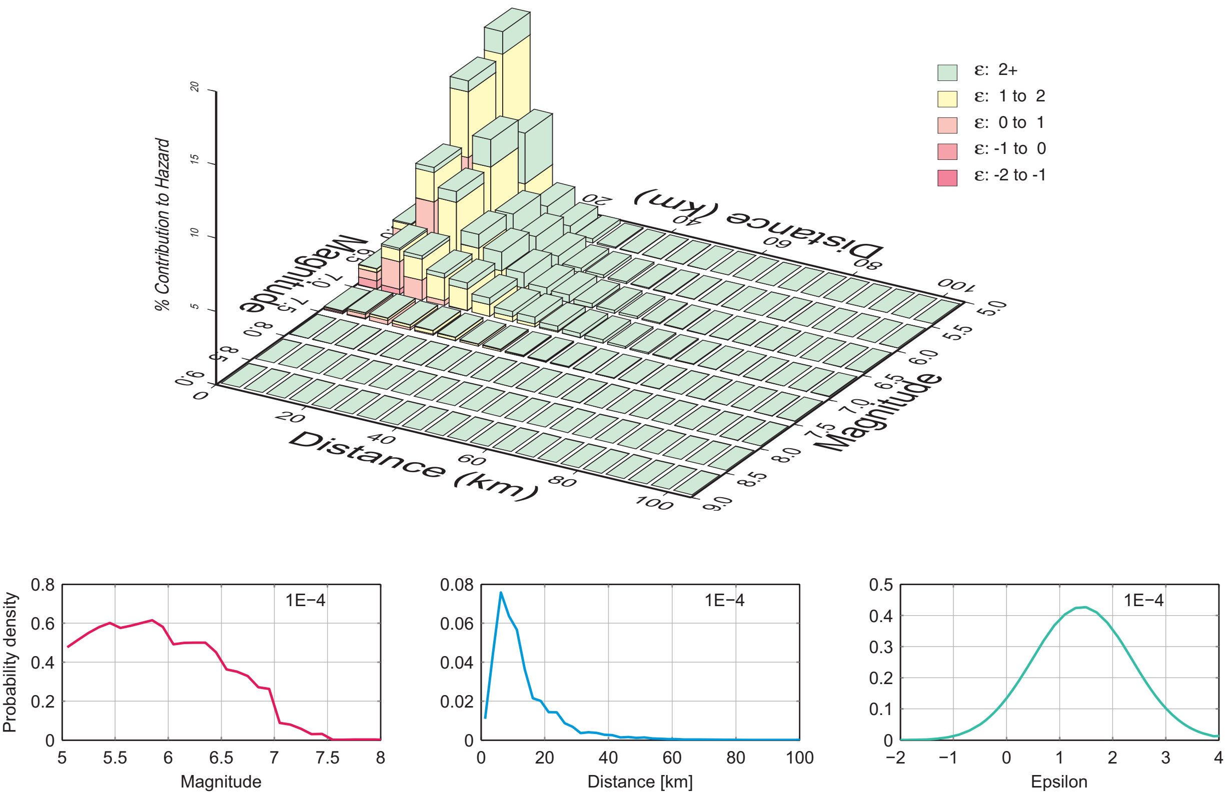

Fig. 4-1.15: Gösgen shallow, horizontal component, rock, surface, hazard deaggregation by magnitude, distance and epsilon for ground motion level 1E-4, PGA.

5 LEIBSTADT

5.1 Rock Hazard, Horizontal Component, Surface

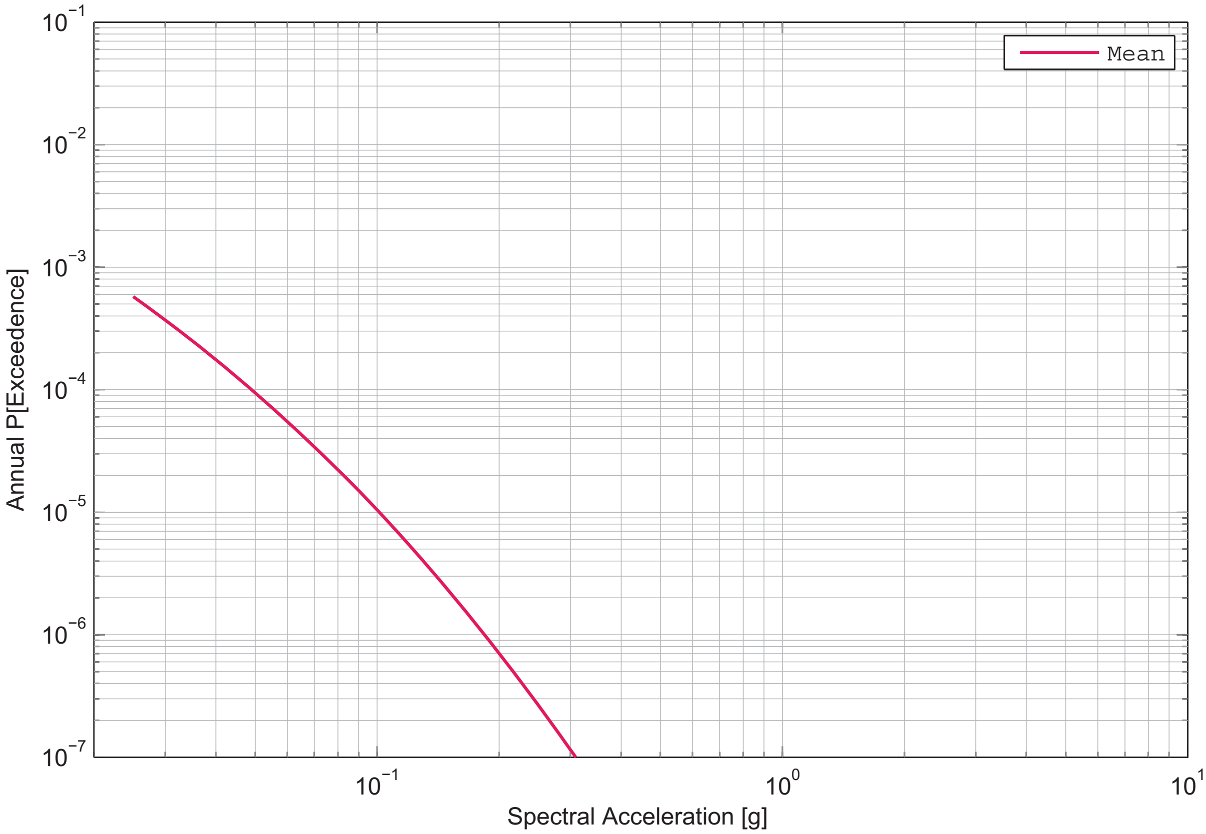

Fig. 5-1.1: Leibstadt, horizontal component, rock, surface, mean hazard, 0.5 Hz.

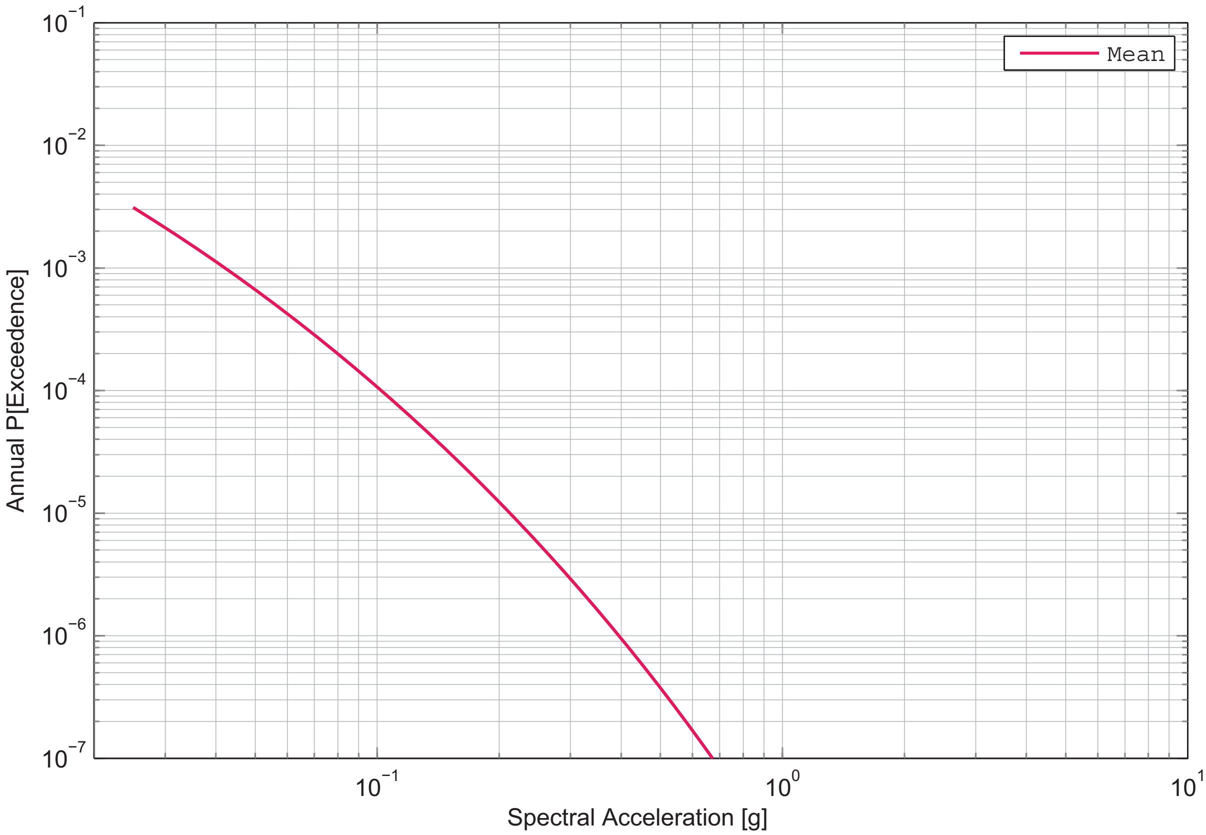

Fig. 5-1.2: Leibstadt, horizontal component, rock, surface, mean hazard, 1 Hz.

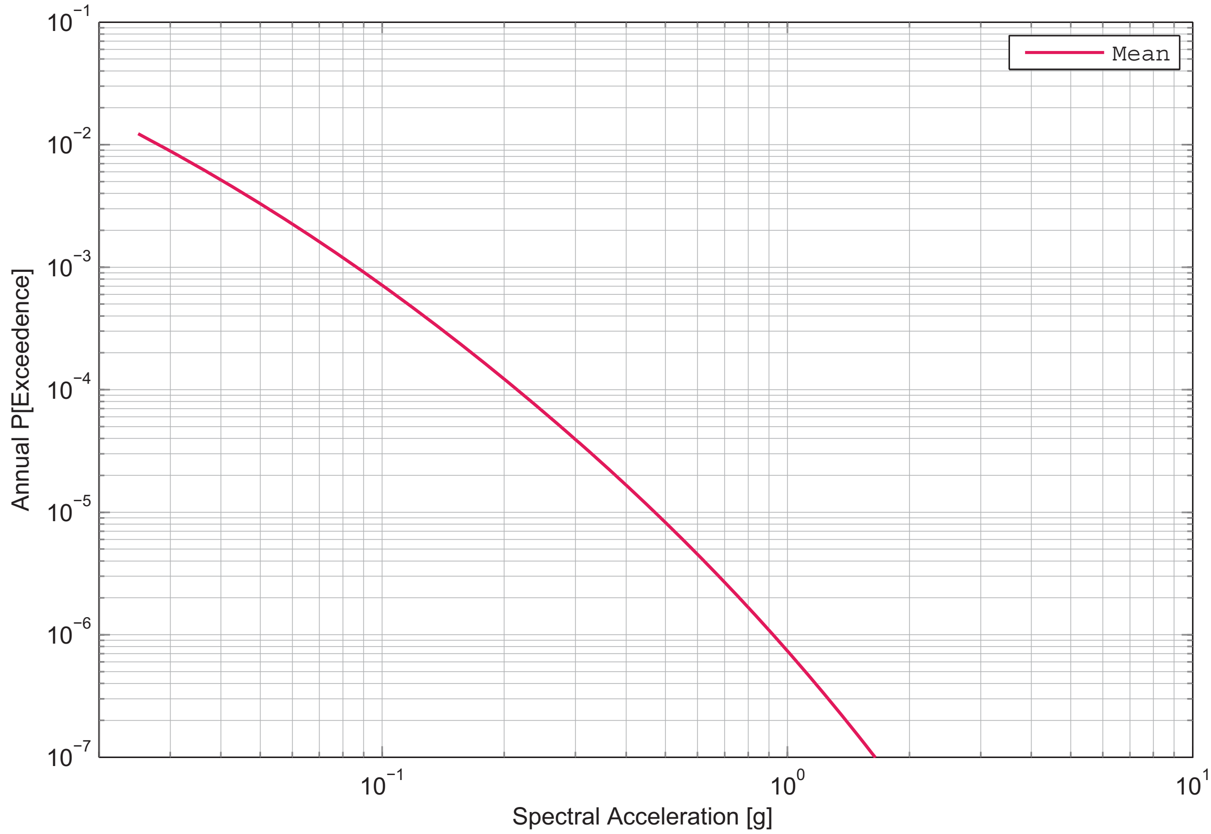

Fig. 5-1.3: Leibstadt, horizontal component, rock, surface, mean hazard, 2.5 Hz.

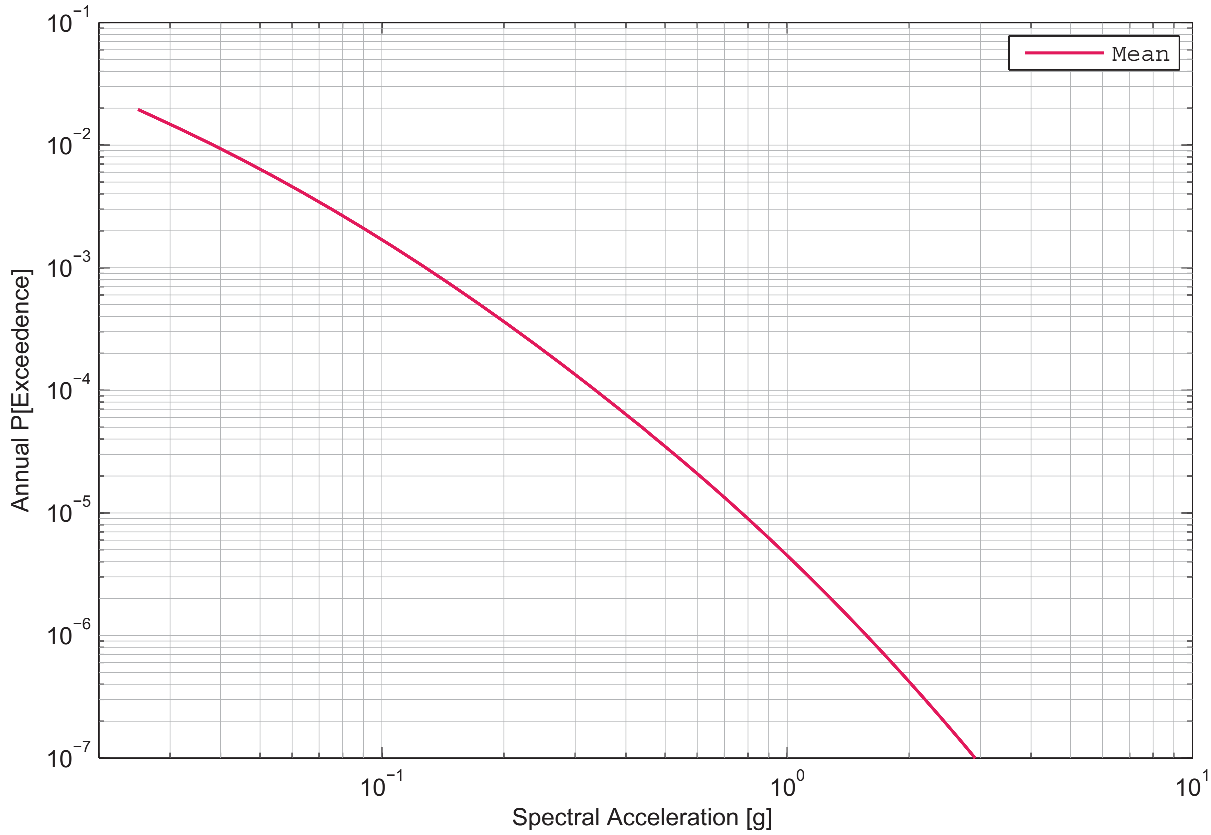

Fig. 5-1.4: Leibstadt, horizontal component, rock, surface, mean hazard, 5 Hz.

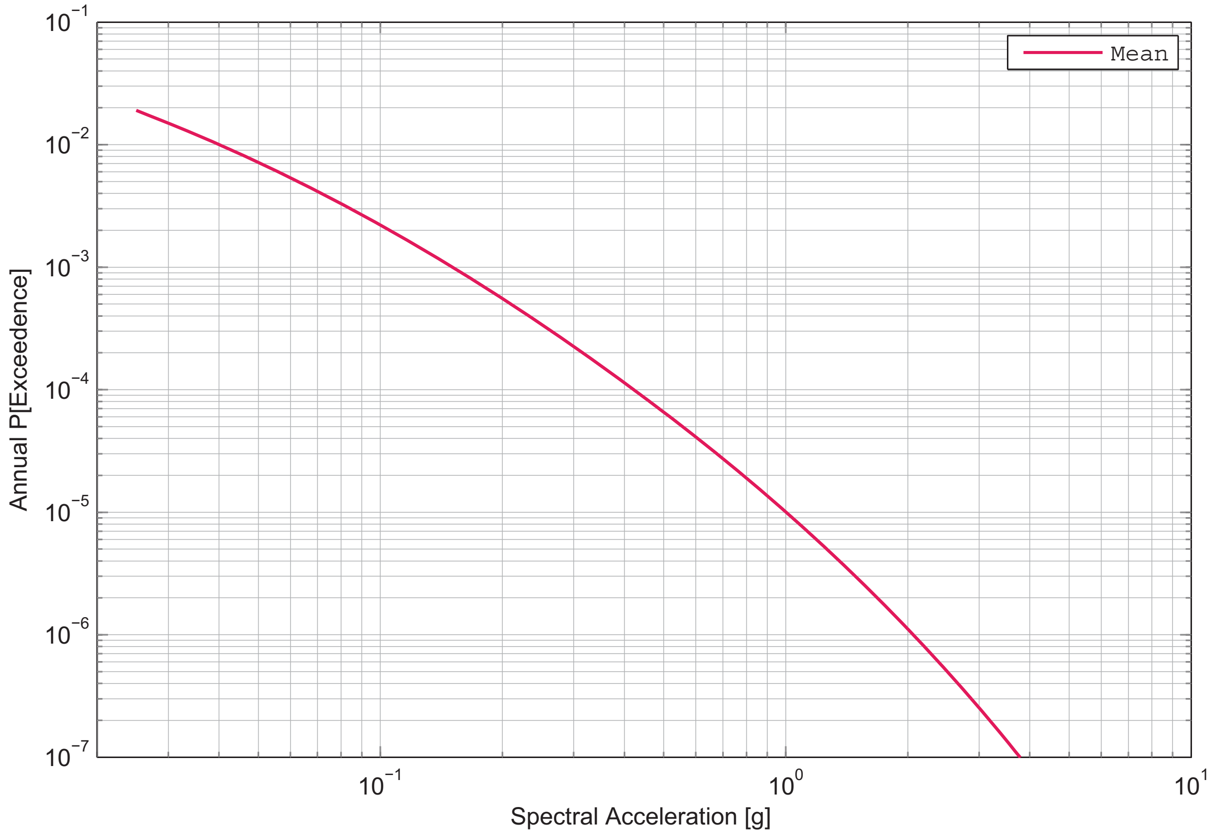

Fig. 5-1.5: Leibstadt, horizontal component, rock, surface, mean hazard, 10 Hz.

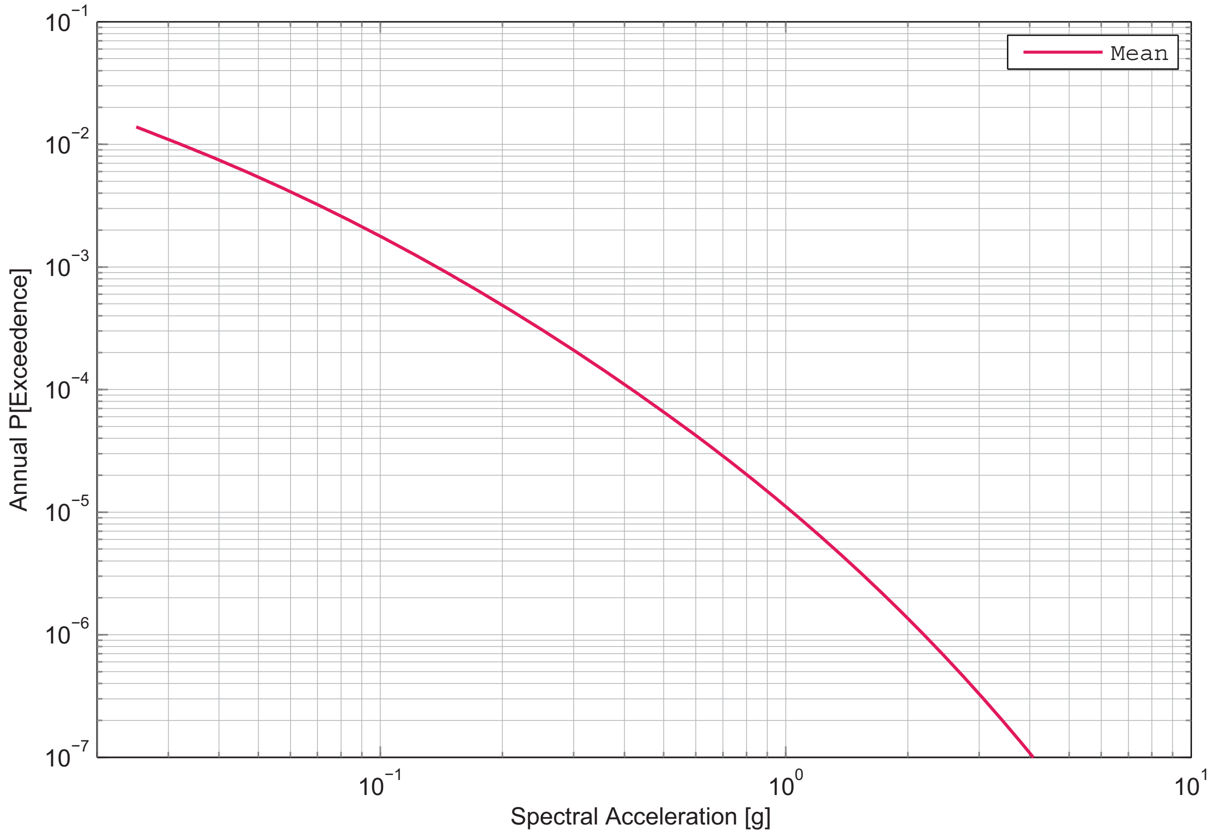

Fig. 5-1.6: Leibstadt, horizontal component, rock, surface, mean hazard, 20 Hz.

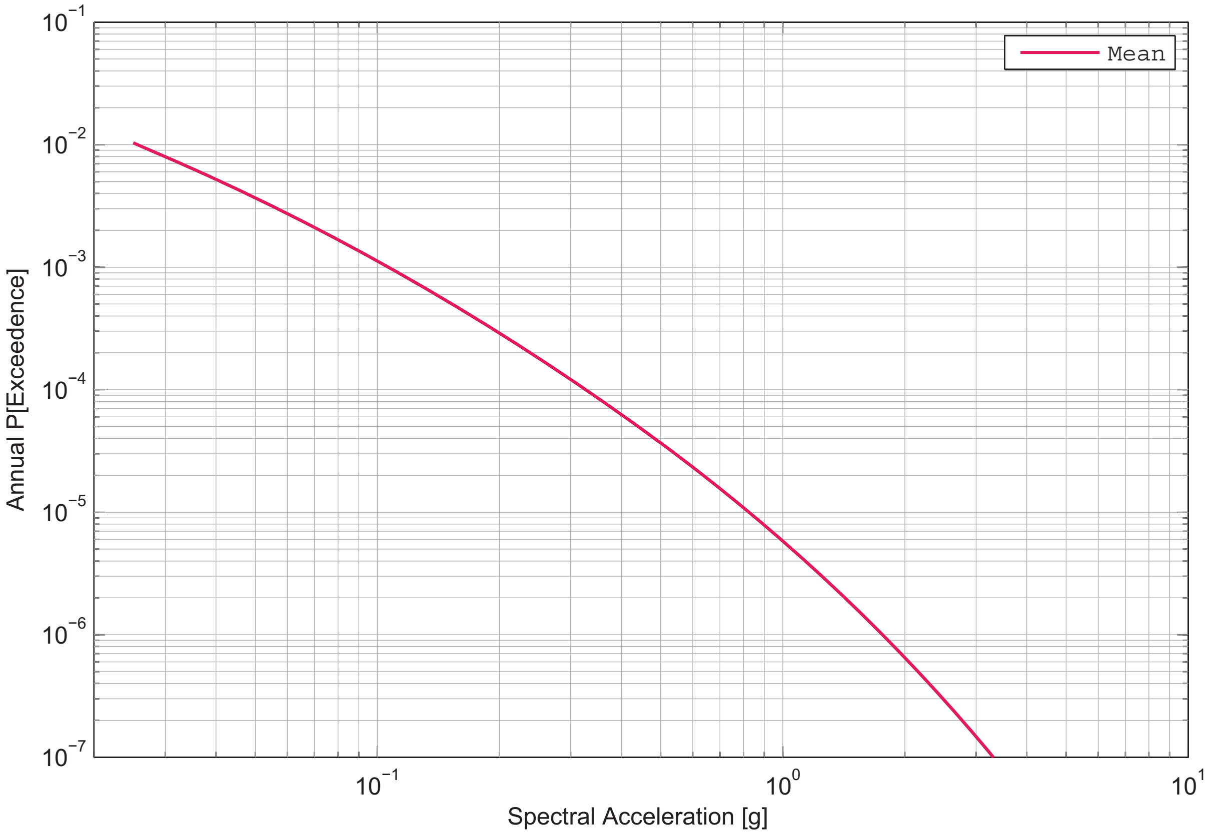

Fig. 5-1.7: Leibstadt, horizontal component, rock, surface, mean hazard, 33 Hz.

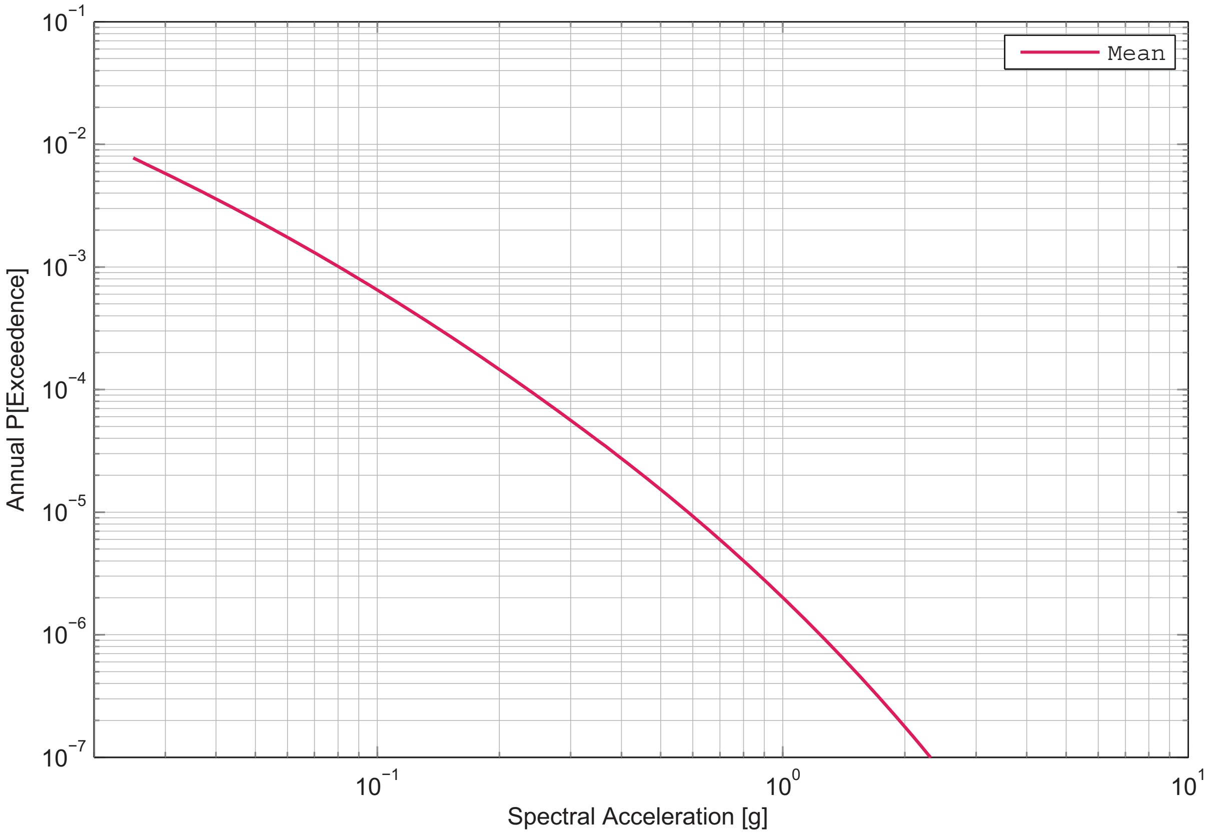

Fig. 5-1.8: Leibstadt, horizontal component, rock, surface, mean hazard, 50 Hz.

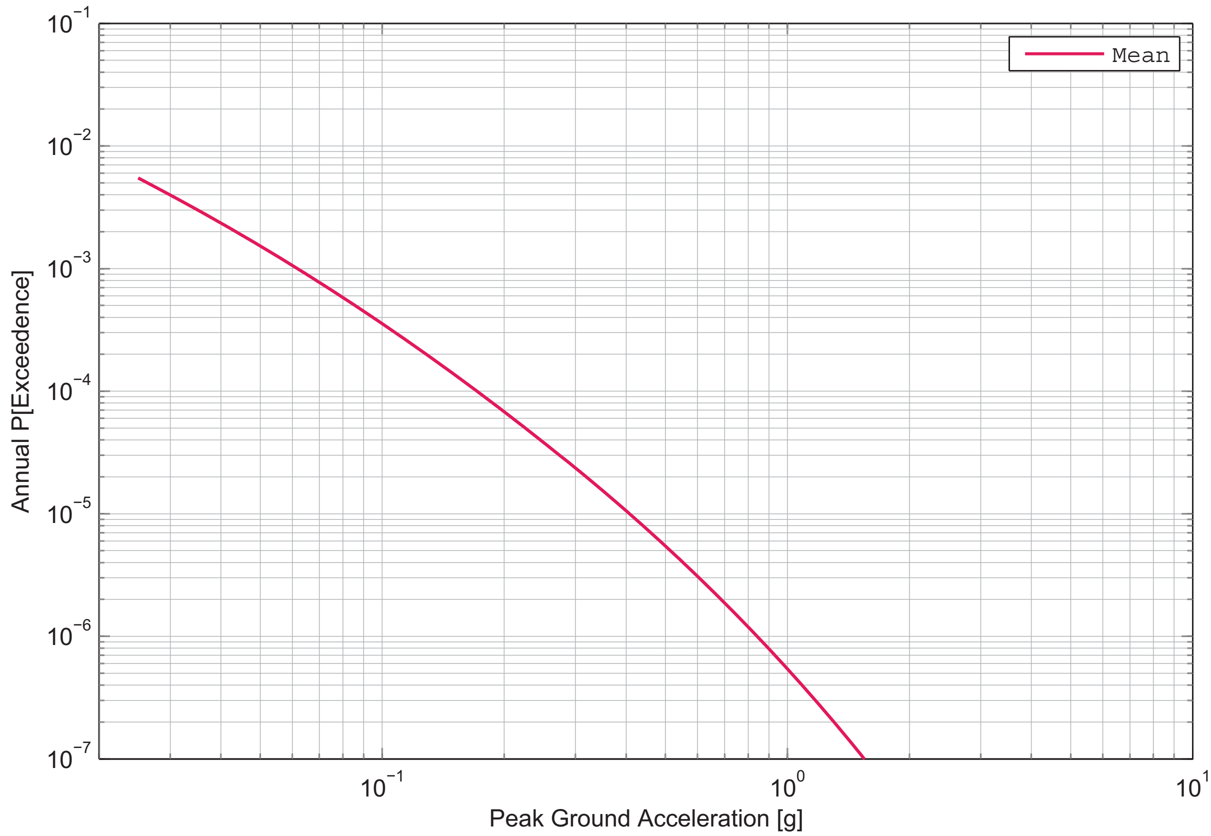

Fig. 5-1.9: Leibstadt, horizontal component, rock, surface, mean hazard, PGA.

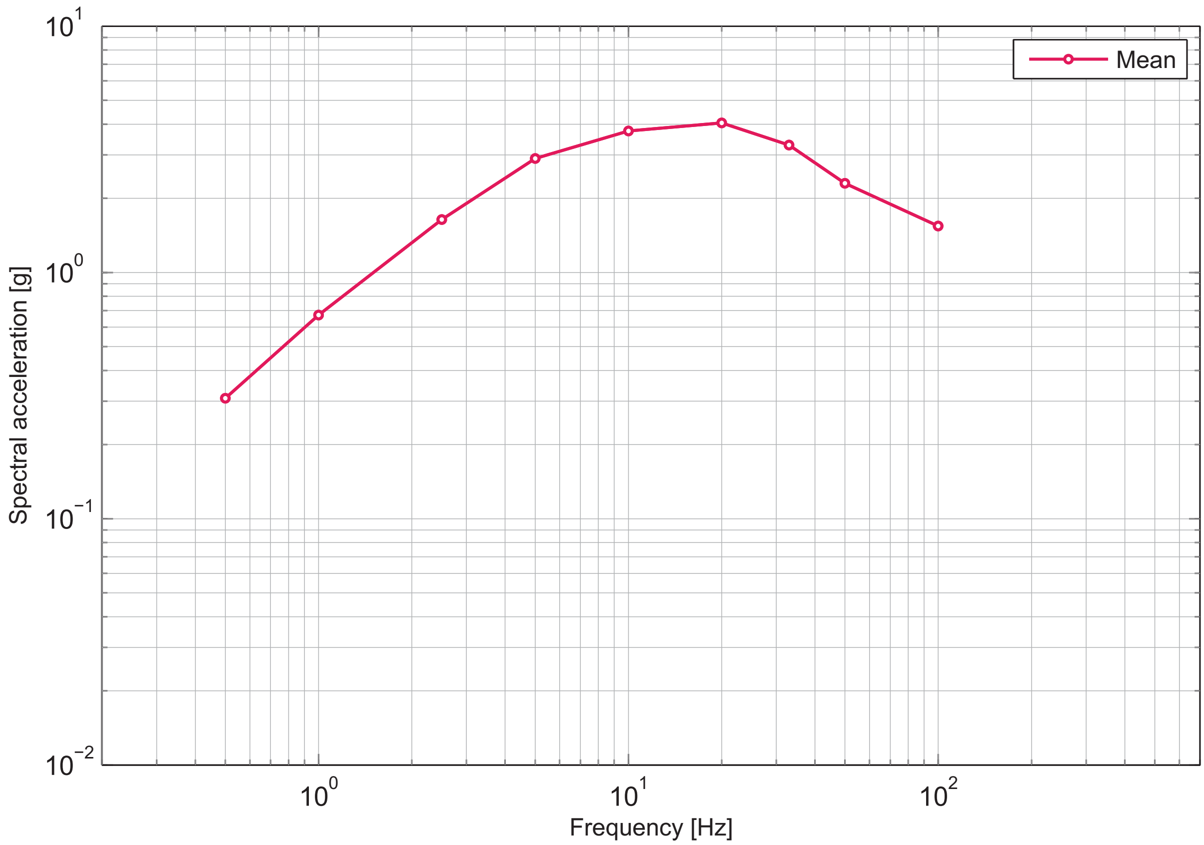

Fig. 5-1.10: Leibstadt, horizontal component, rock, surface, uniform hazard spectra for an annual probability of exceedance of 1E-07 and 5% damping.

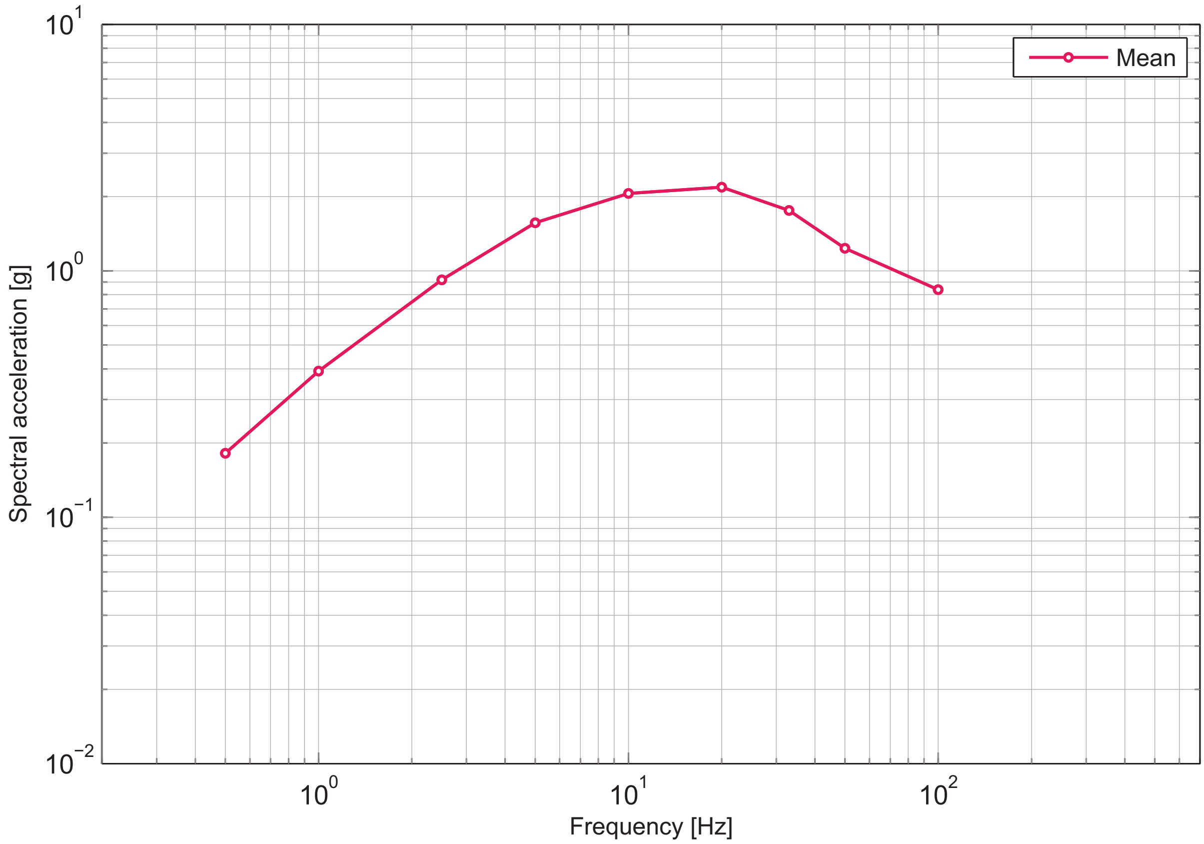

Fig. 5-1.11: Leibstadt, horizontal component, rock, surface, uniform hazard spectra for an annual probability of exceedance of 1E-06 and 5% damping.

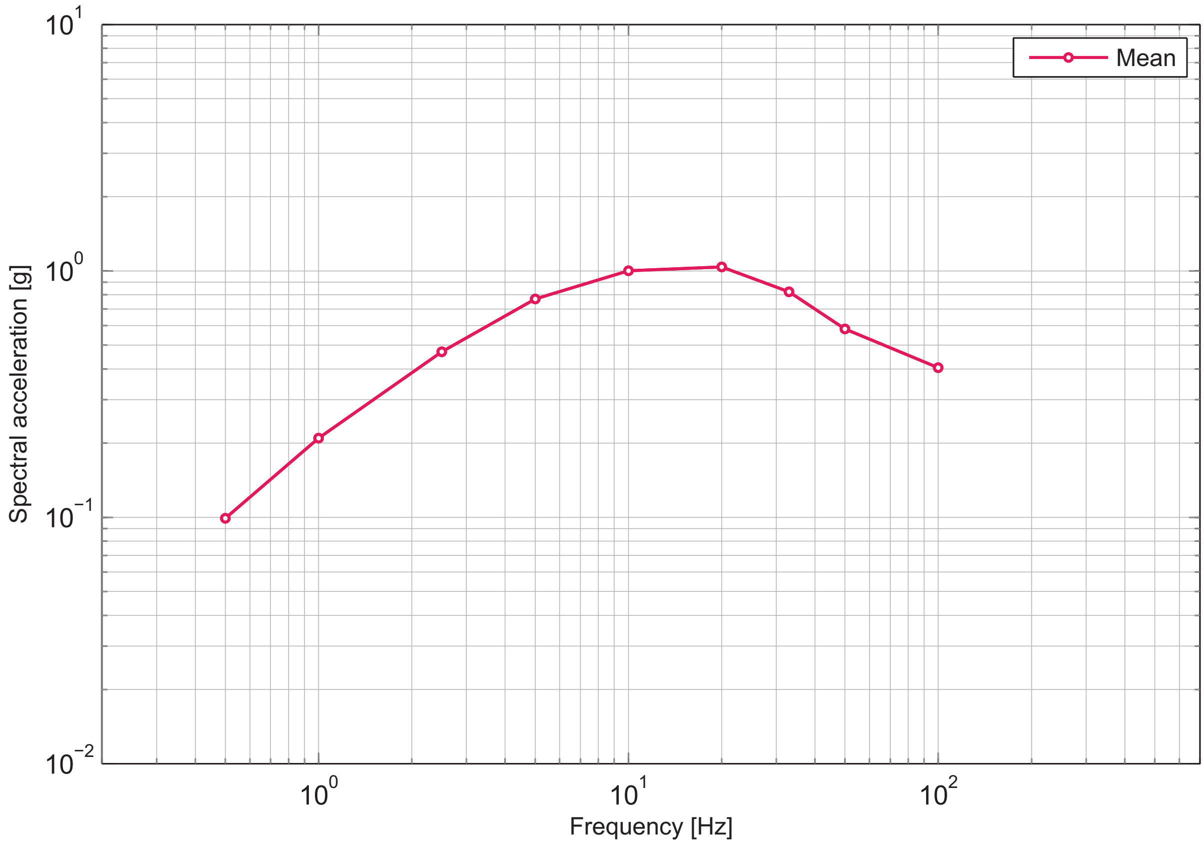

Fig. 5-1.12: Leibstadt, horizontal component, rock, surface, uniform hazard spectra for an annual probability of exceedance of 1E-05 and 5% damping.

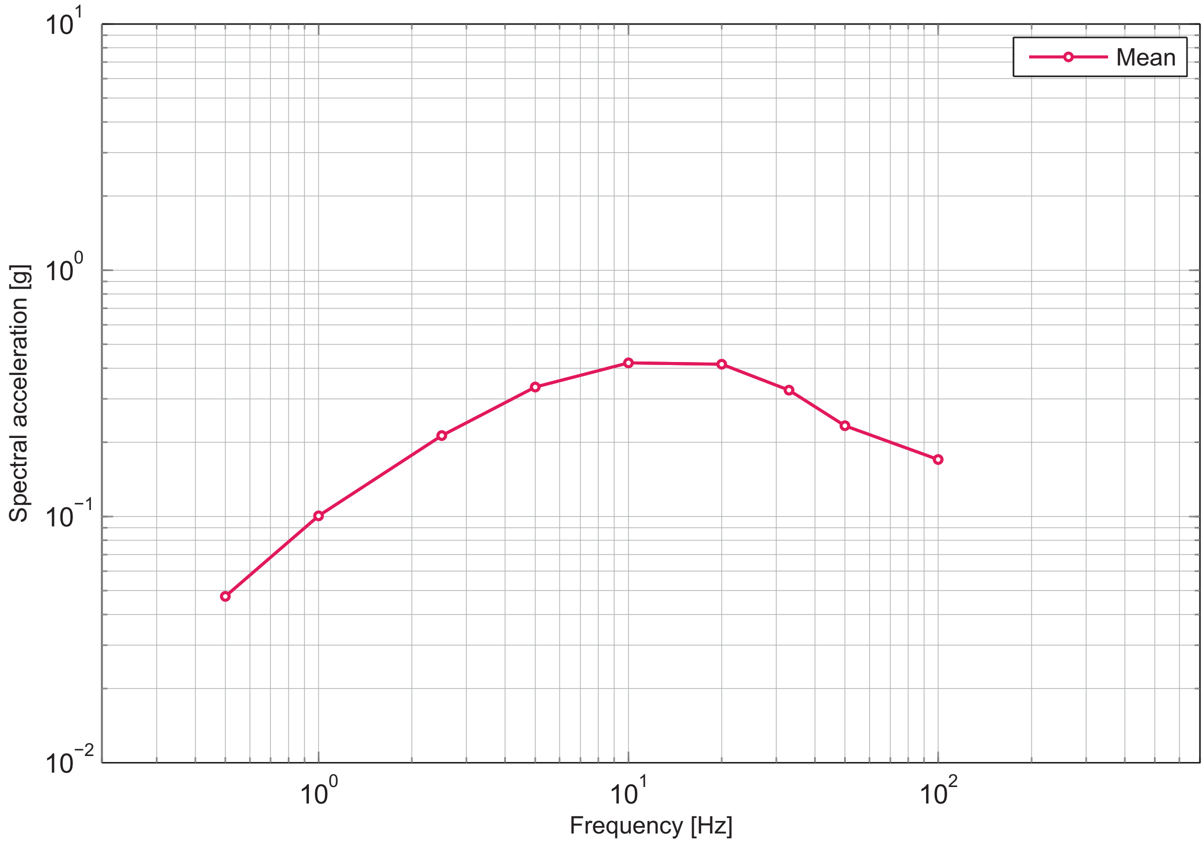

Fig. 5-1.13: Leibstadt, horizontal component, rock, surface, uniform hazard spectra for an annual probability of exceedance of 1E-04 and 5% damping.

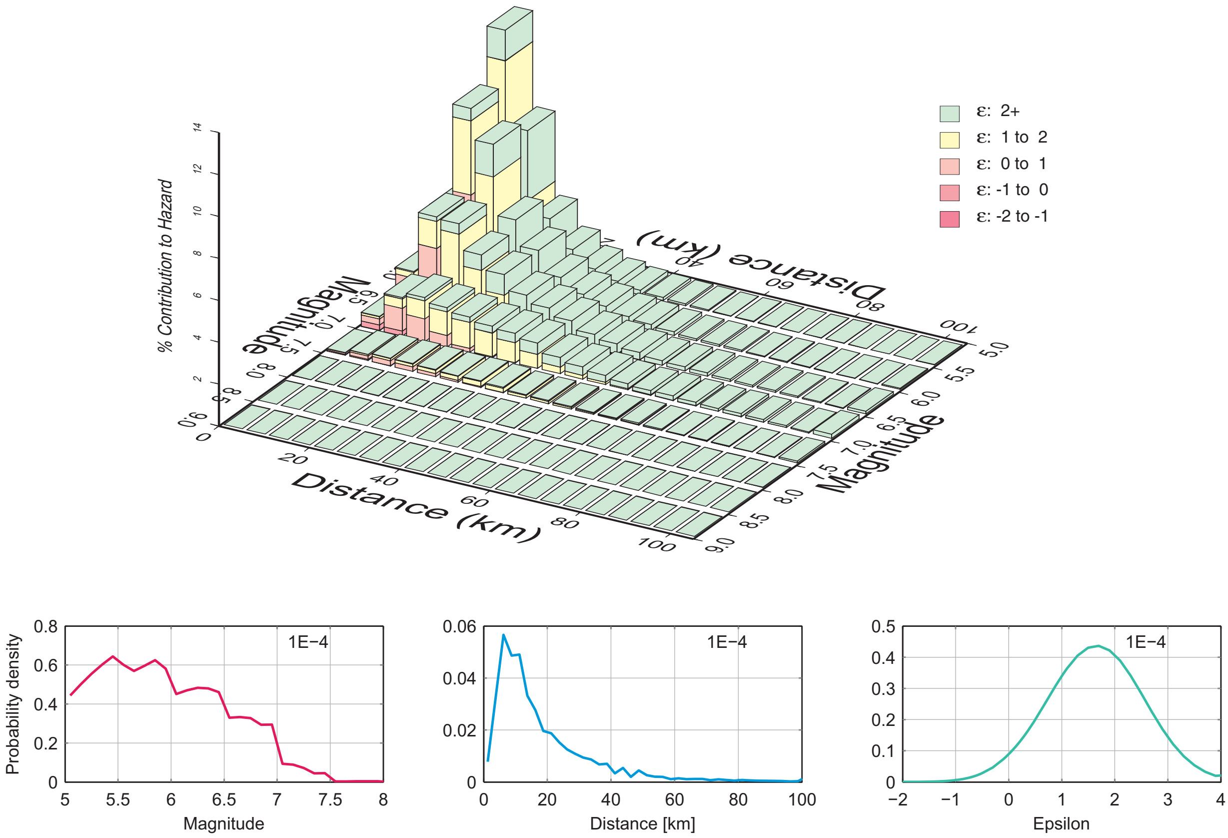

Fig. 5-1.14: Leibstadt, horizontal component, rock, surface, hazard deaggregation by magnitude, distance and epsilon for ground motion level 1E-4, 5 Hz.

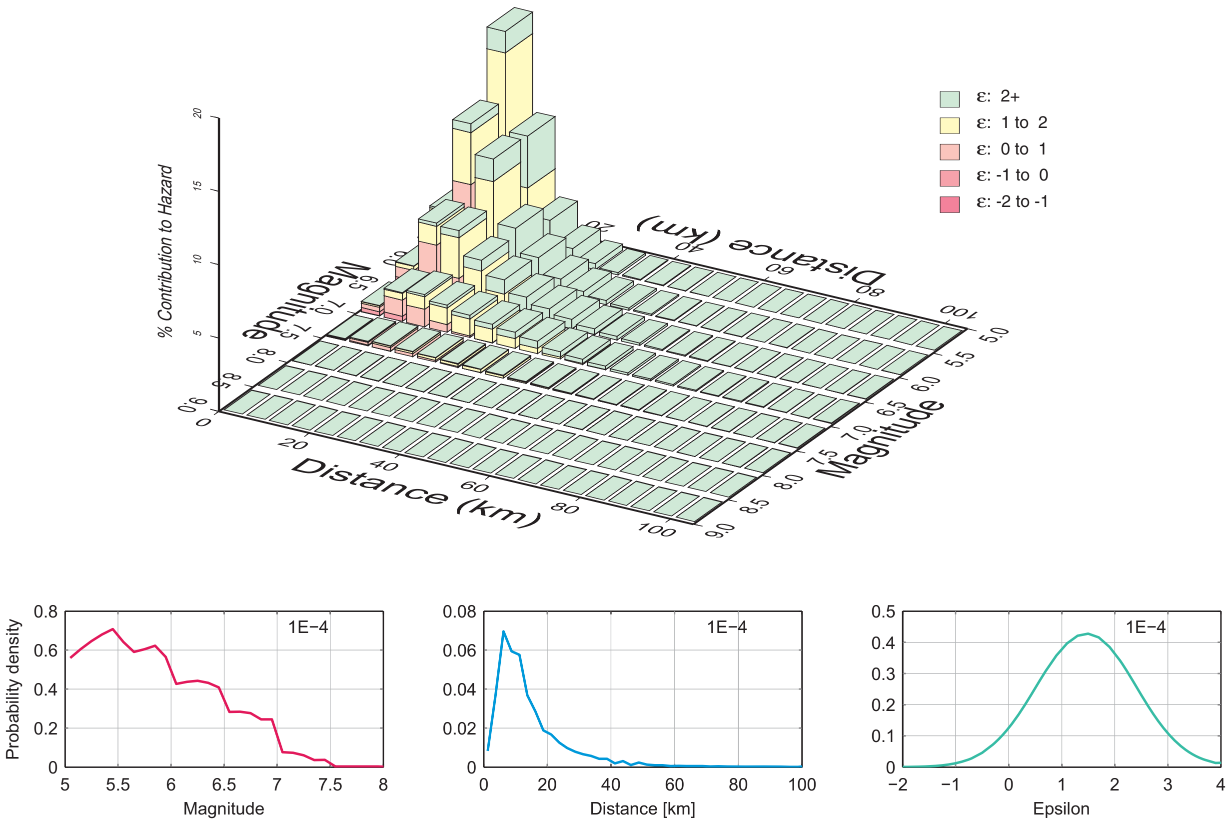

Fig. 5-1.15: Leibstadt, horizontal component, rock, surface, hazard deaggregation by magnitude, distance and epsilon for ground motion level 1E-4, PGA.

6 MÜHLEBERG

6.1 Rock Hazard, Horizontal Component, Surface

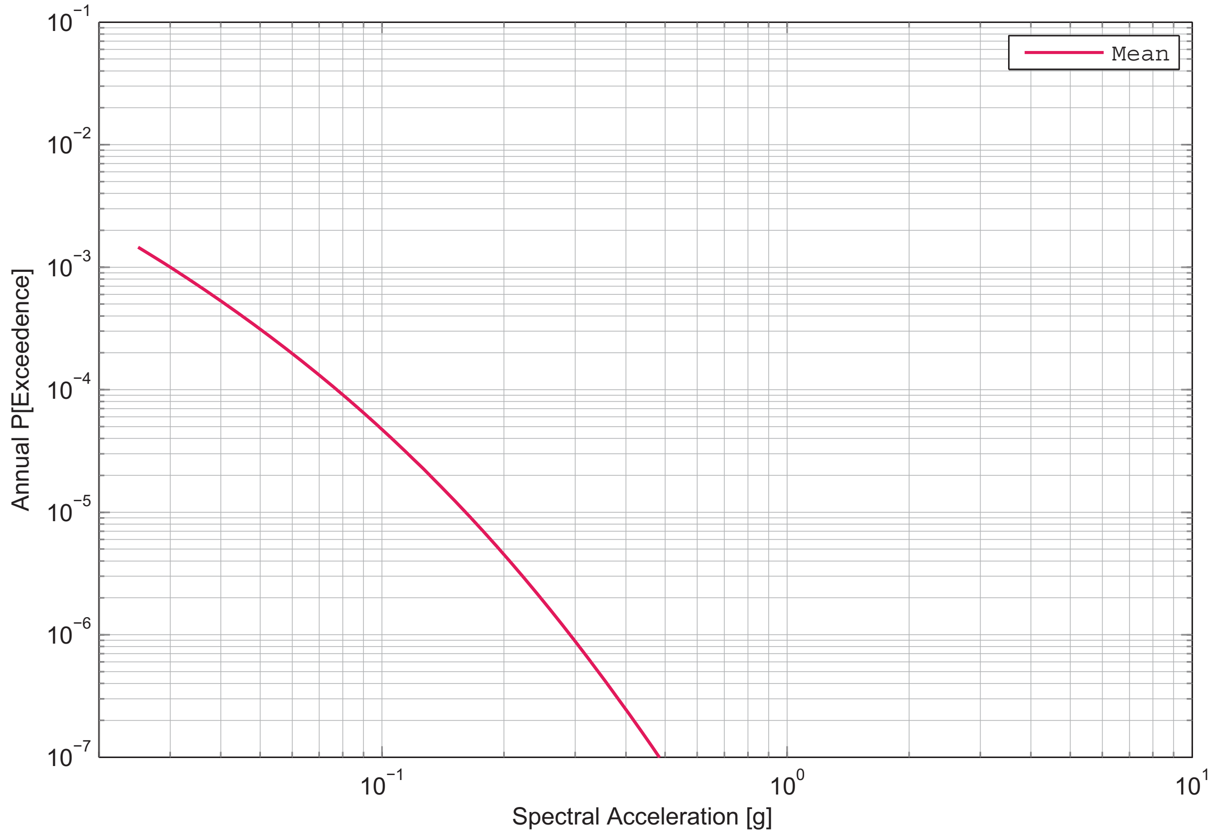

Fig. 6-1.1: Mühleberg, horizontal component, rock, surface, mean hazard, 0.5 Hz.

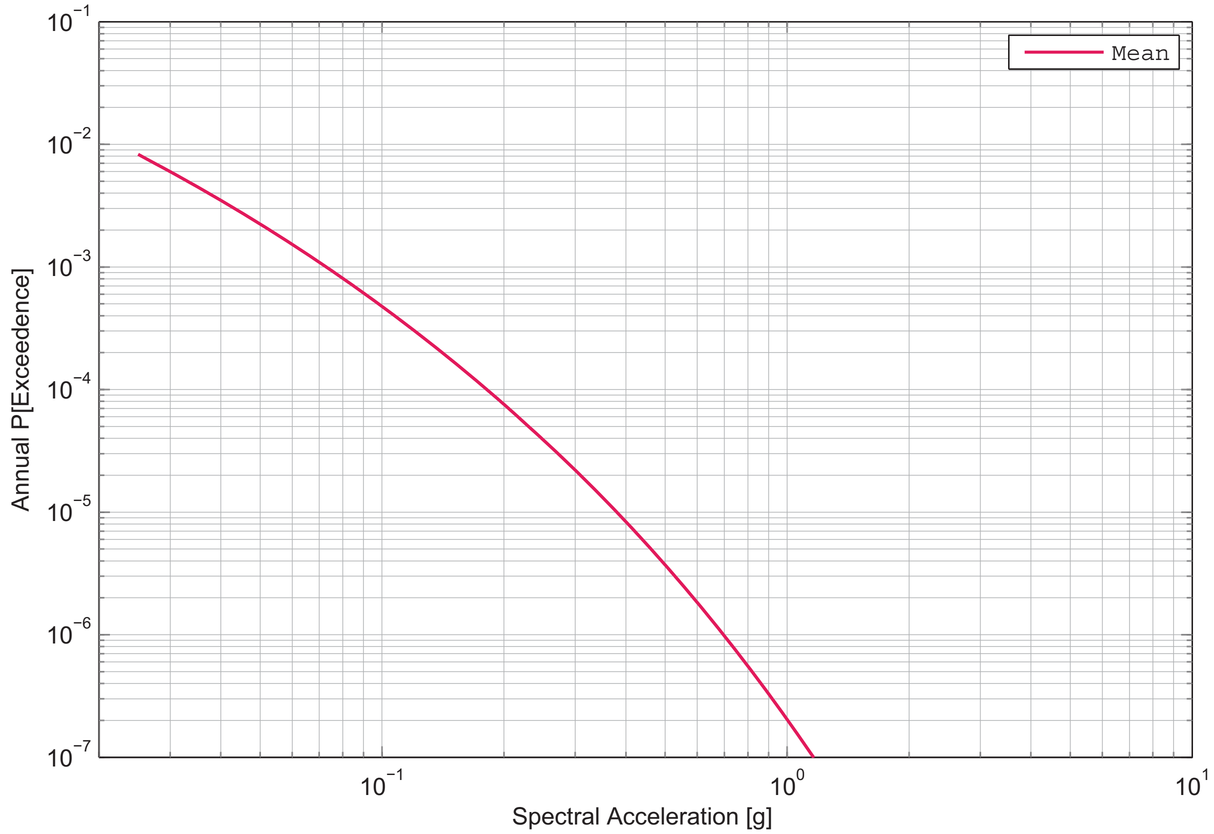

Fig. 6-1.2: Mühleberg, horizontal component, rock, surface, mean hazard, 1 Hz.

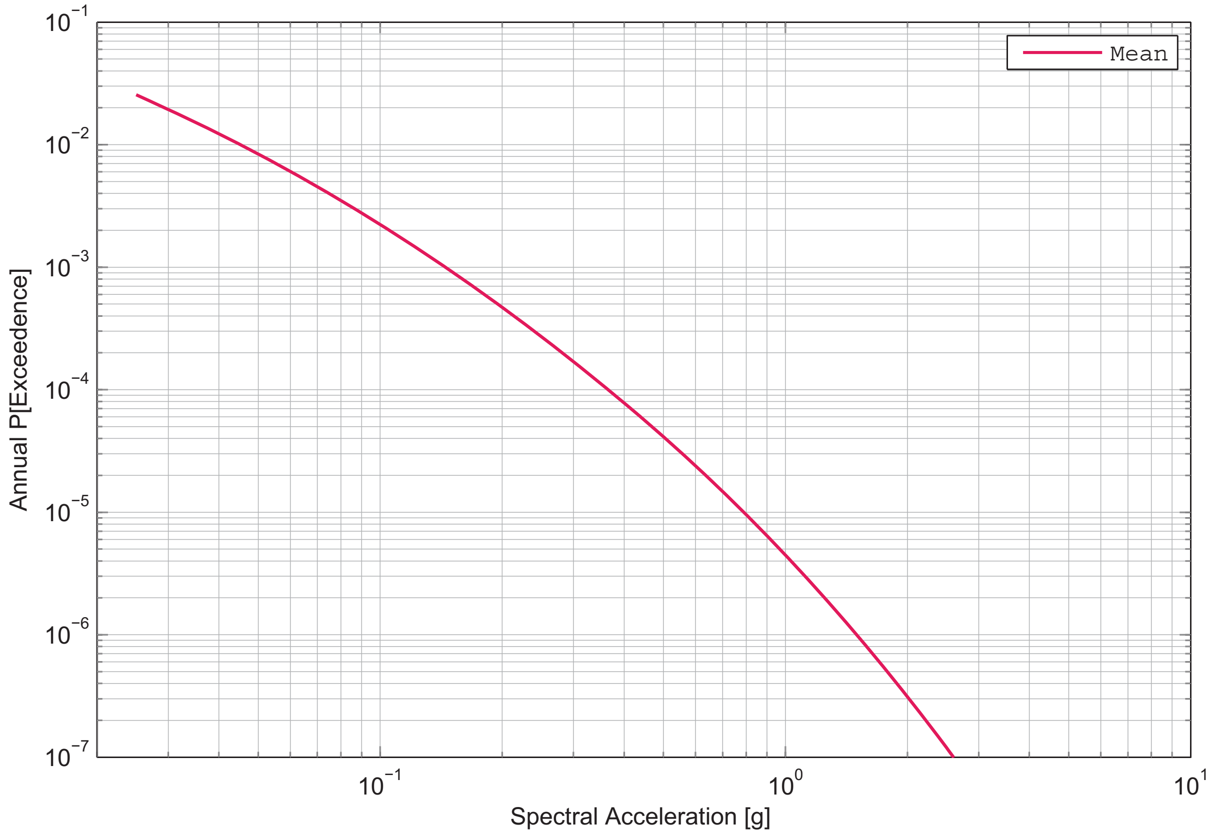

Fig. 6-1.3: Mühleberg, horizontal component, rock, surface, mean hazard, 2.5 Hz.

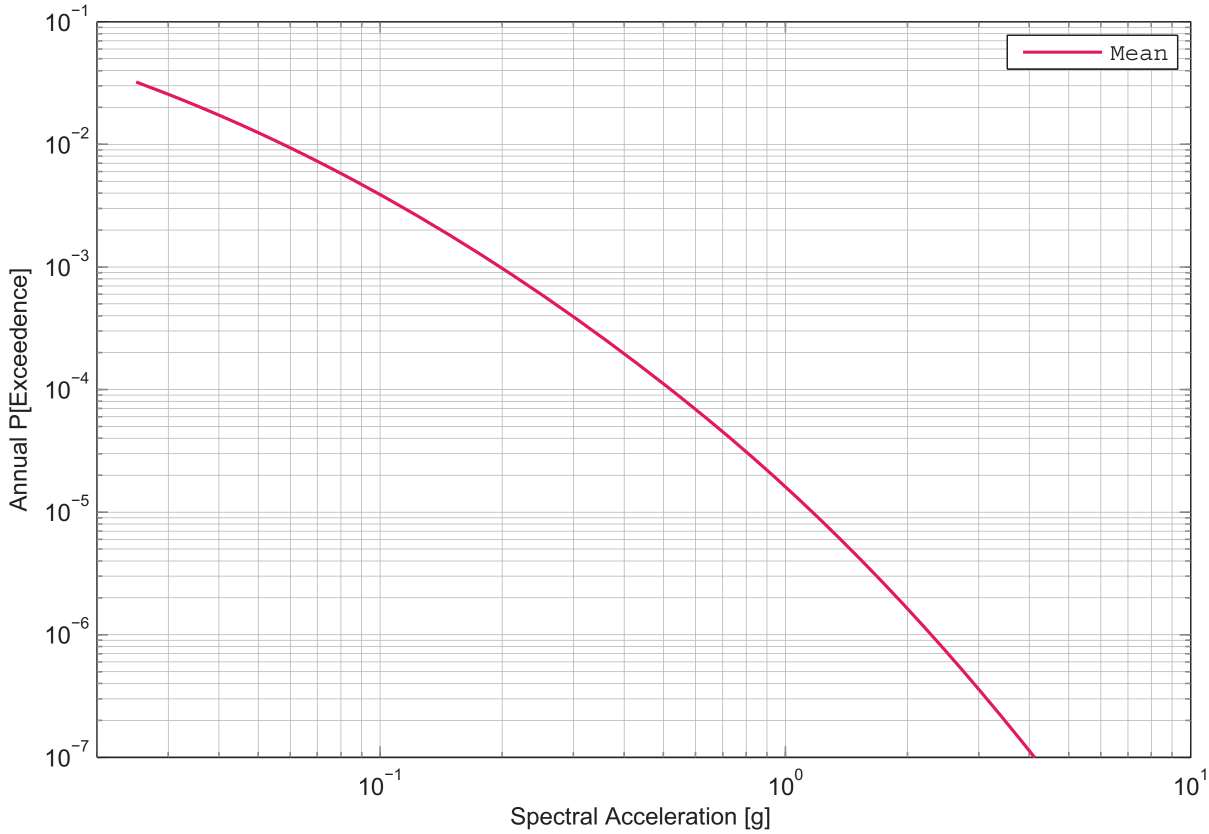

Fig. 6-1.4: Mühleberg, horizontal component, rock, surface, mean hazard, 5 Hz.

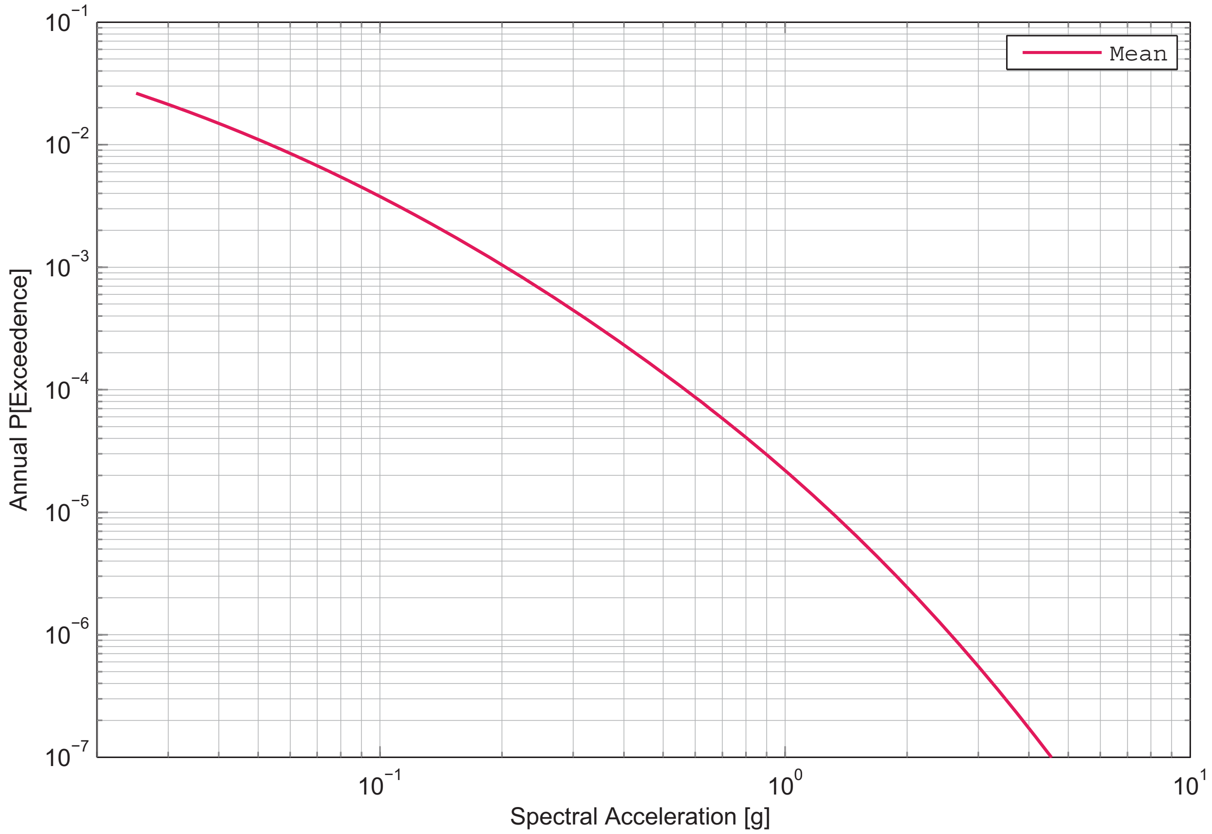

Fig. 6-1.5: Mühleberg, horizontal component, rock, surface, mean hazard, 10 Hz.

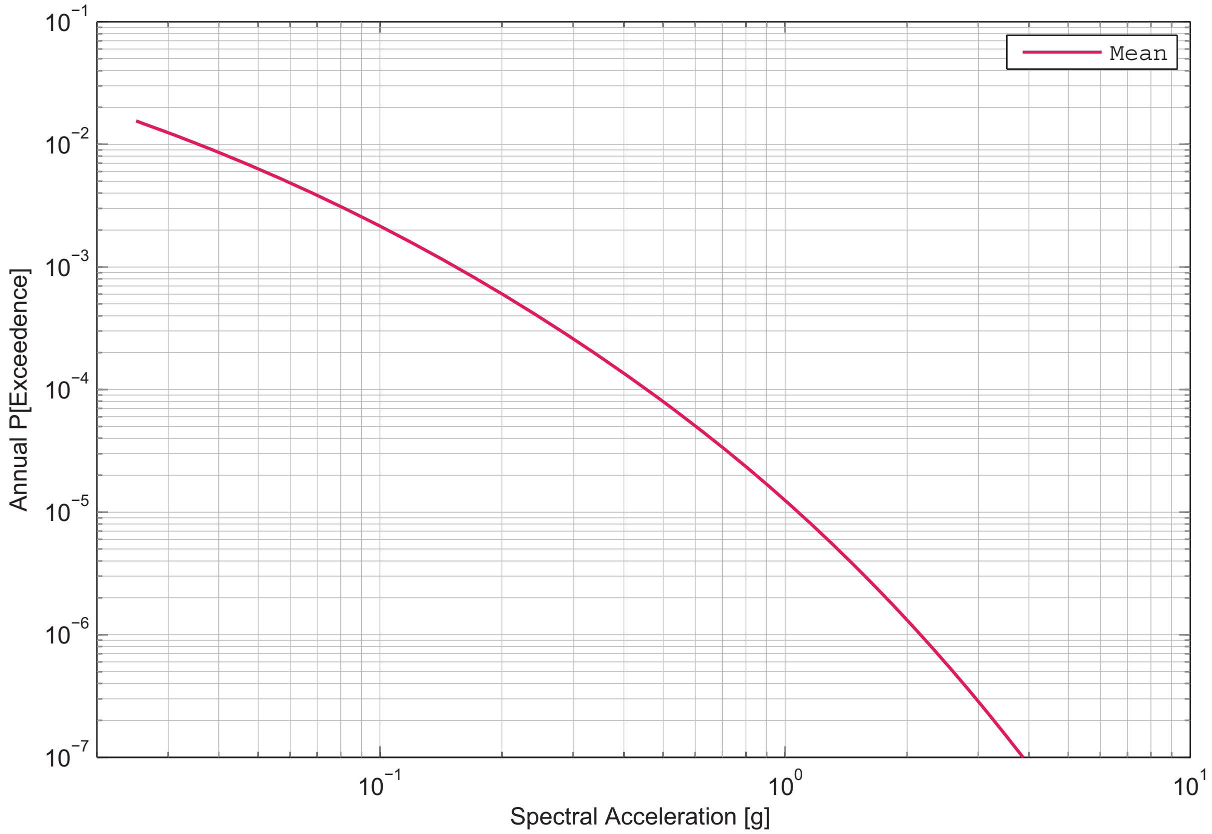

Fig. 6-1.6: Mühleberg, horizontal component, rock, surface, mean hazard, 20 Hz.

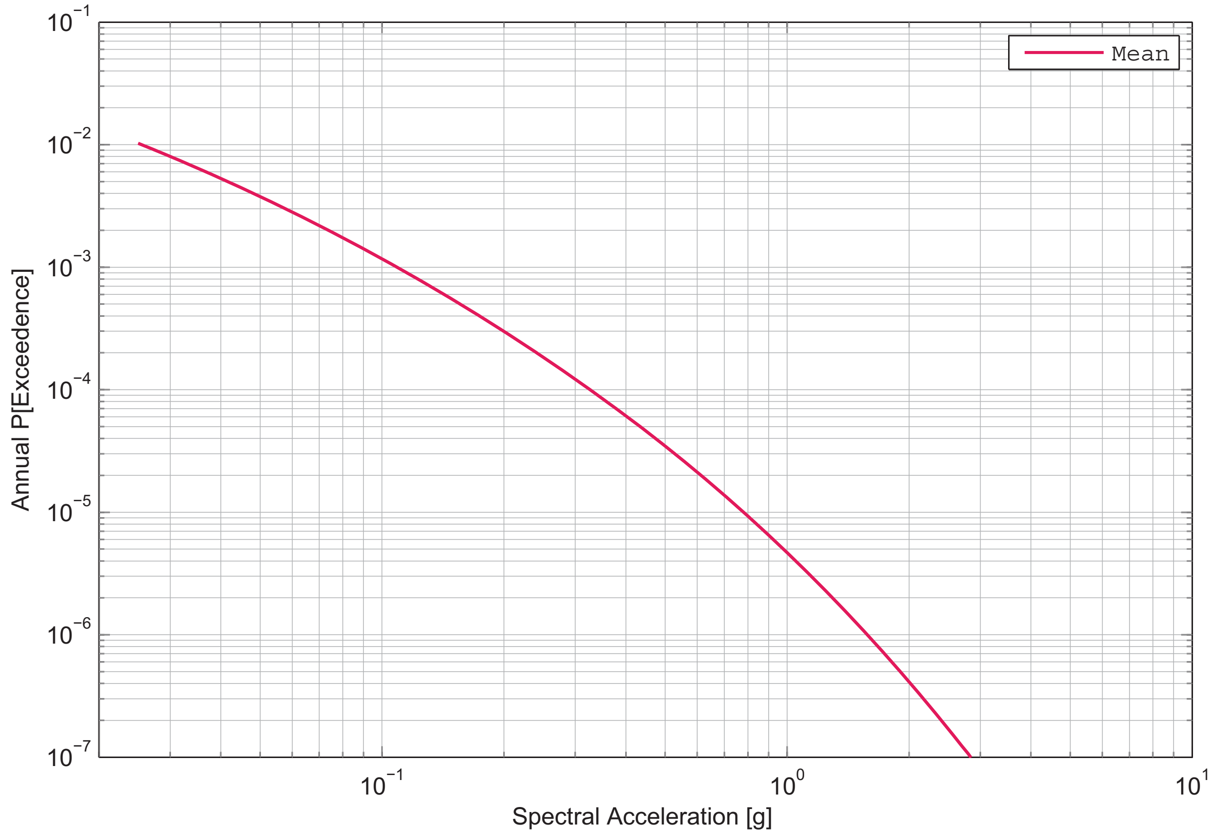

Fig. 6-1.7: Mühleberg, horizontal component, rock, surface, mean hazard, 33 Hz.

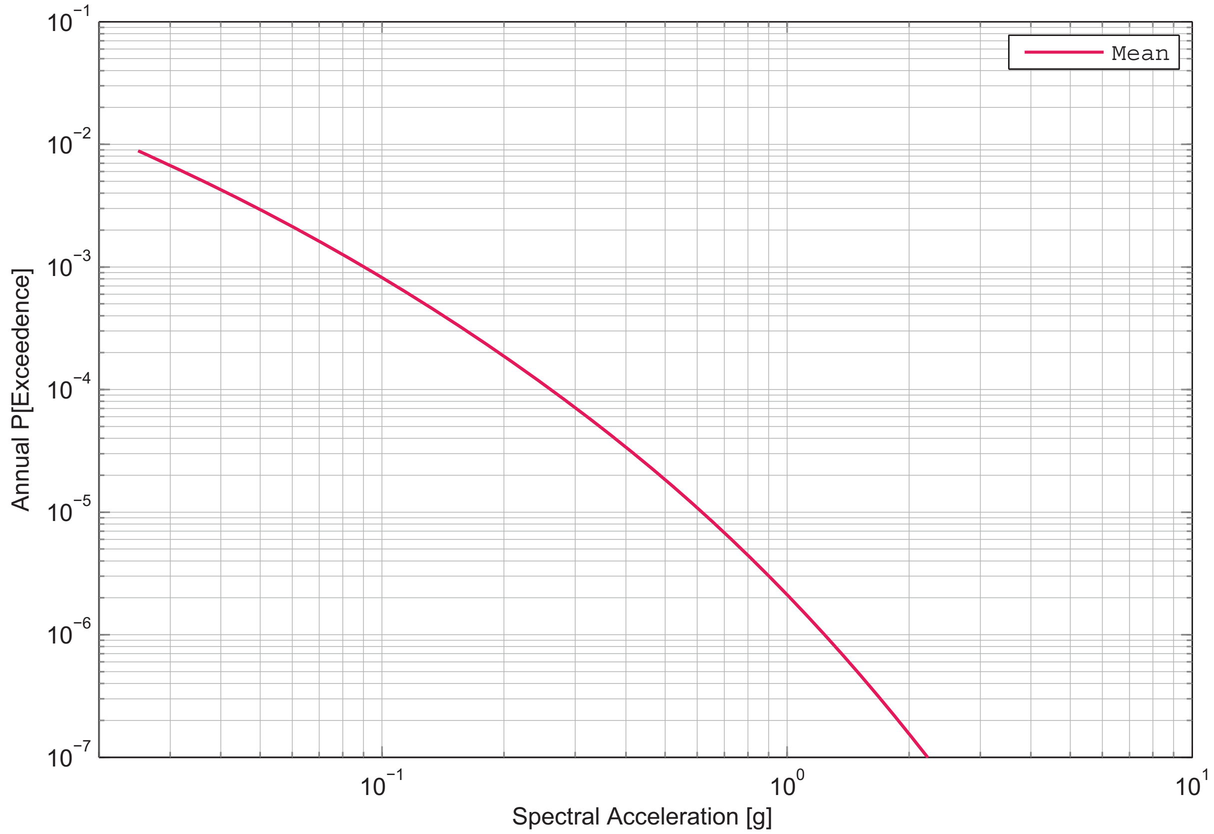

Fig. 6-1.8: Mühleberg, horizontal component, rock, surface, mean hazard, 50 Hz.

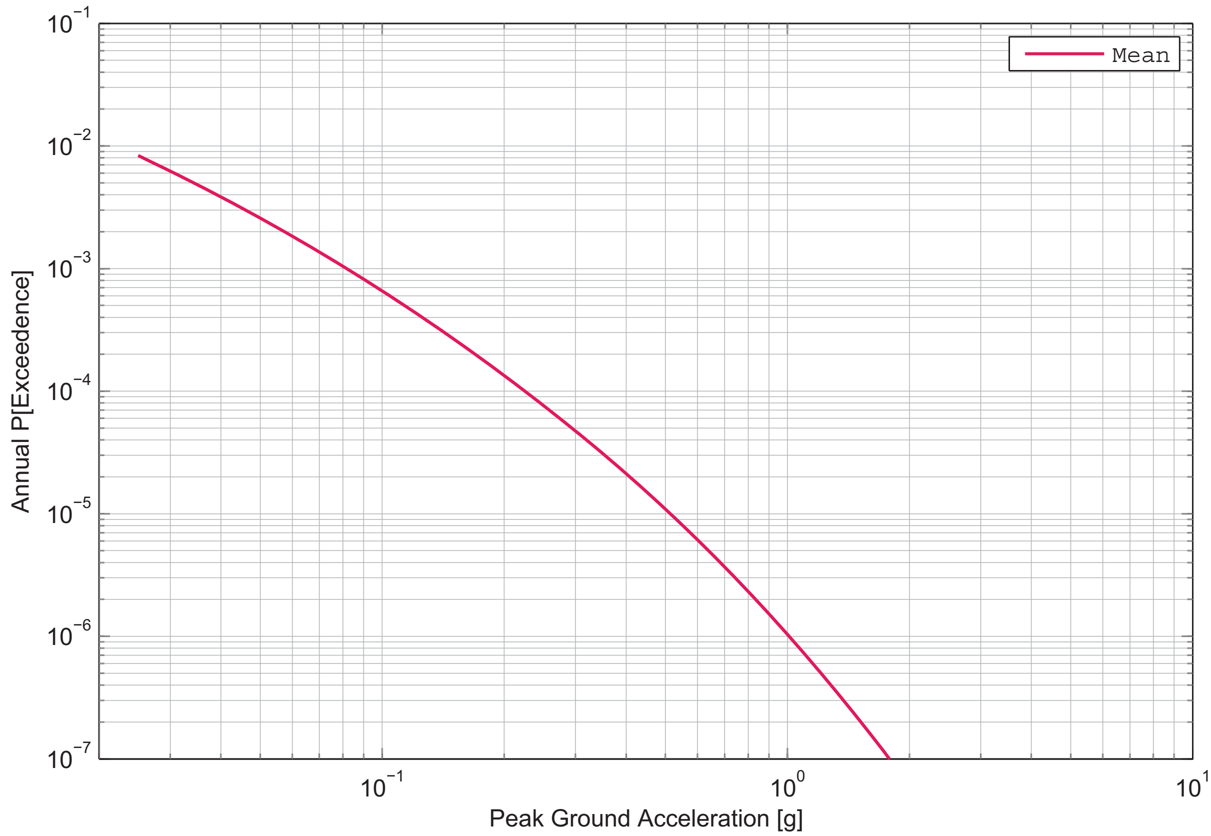

Fig. 6-1.9: Mühleberg, horizontal component, rock, surface, mean hazard, PGA.

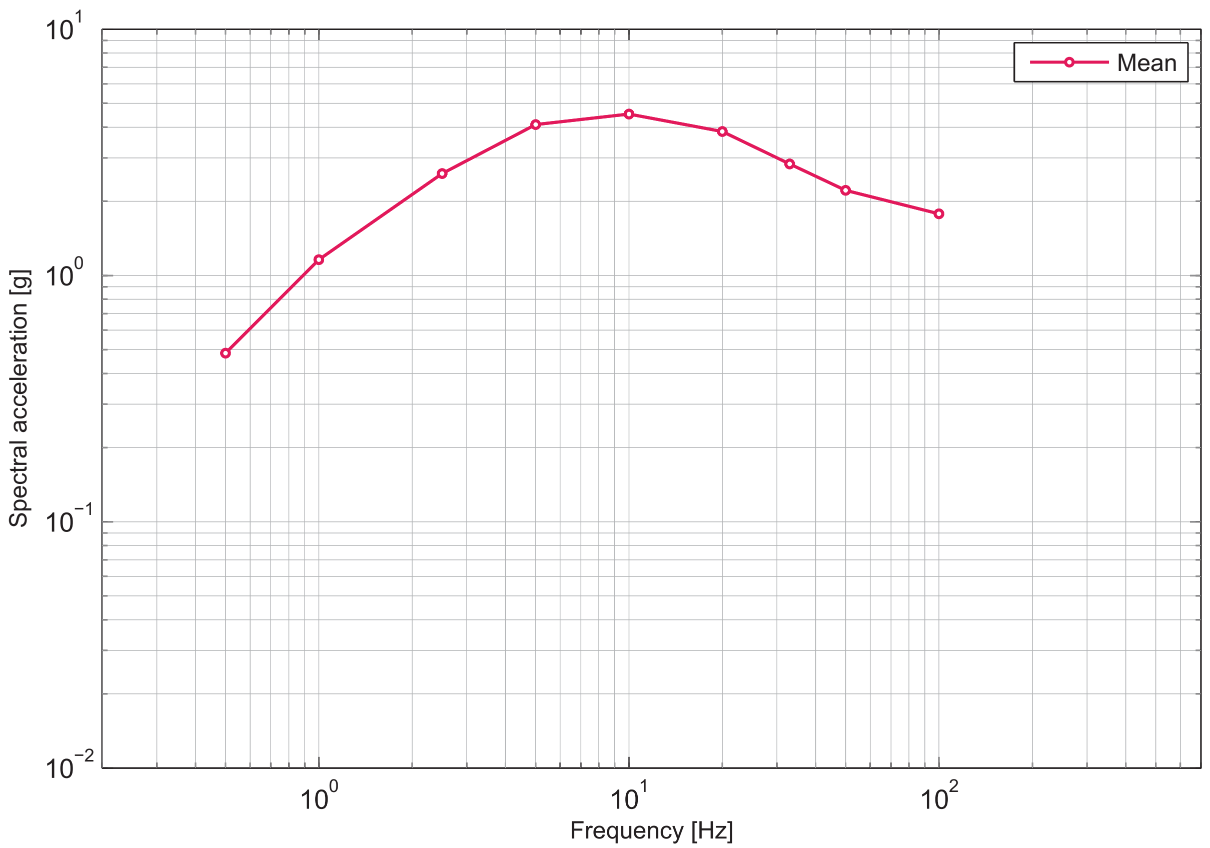

Fig. 6-1.10: Mühleberg, horizontal component, rock, surface, uniform hazard spectra for an annual probability of exceedance of 1E-07 and 5% damping.

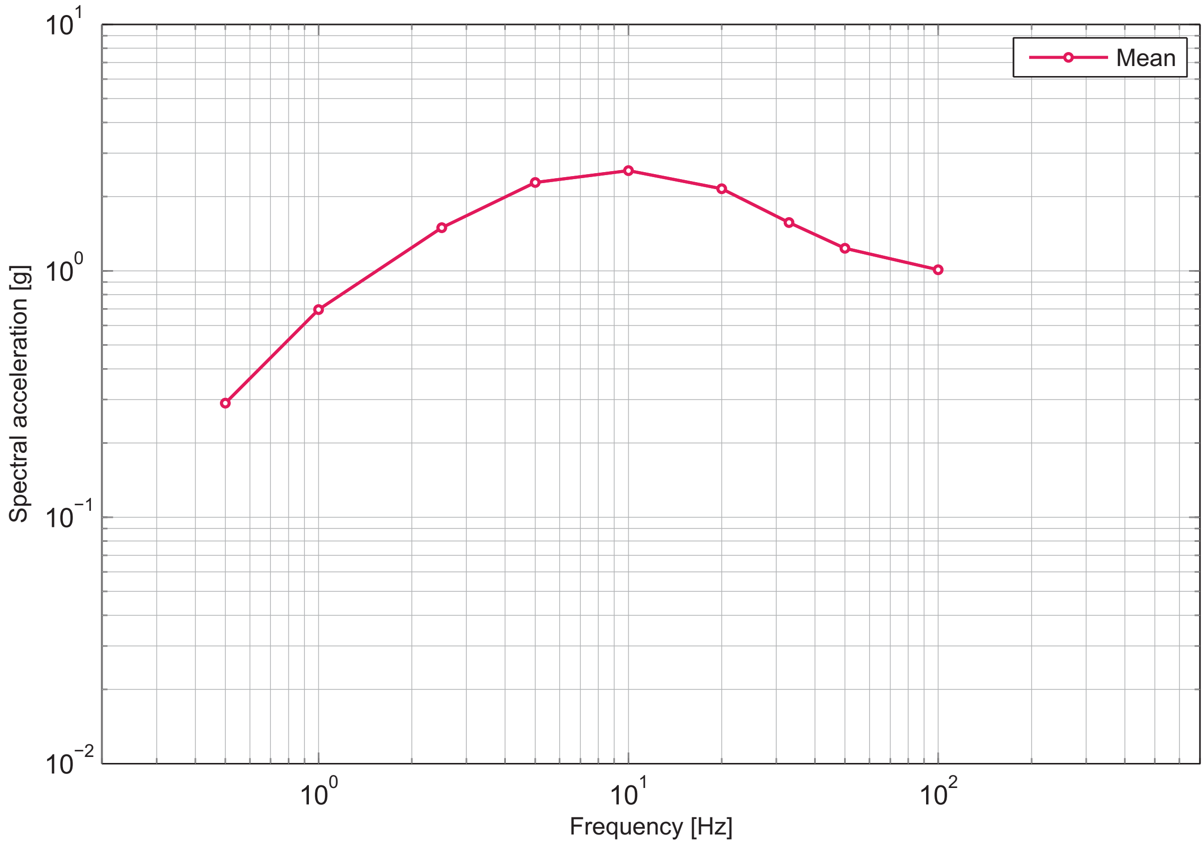

Fig. 6-1.11: Mühleberg, horizontal component, rock, surface, uniform hazard spectra for an annual probability of exceedance of 1E-06 and 5% damping.

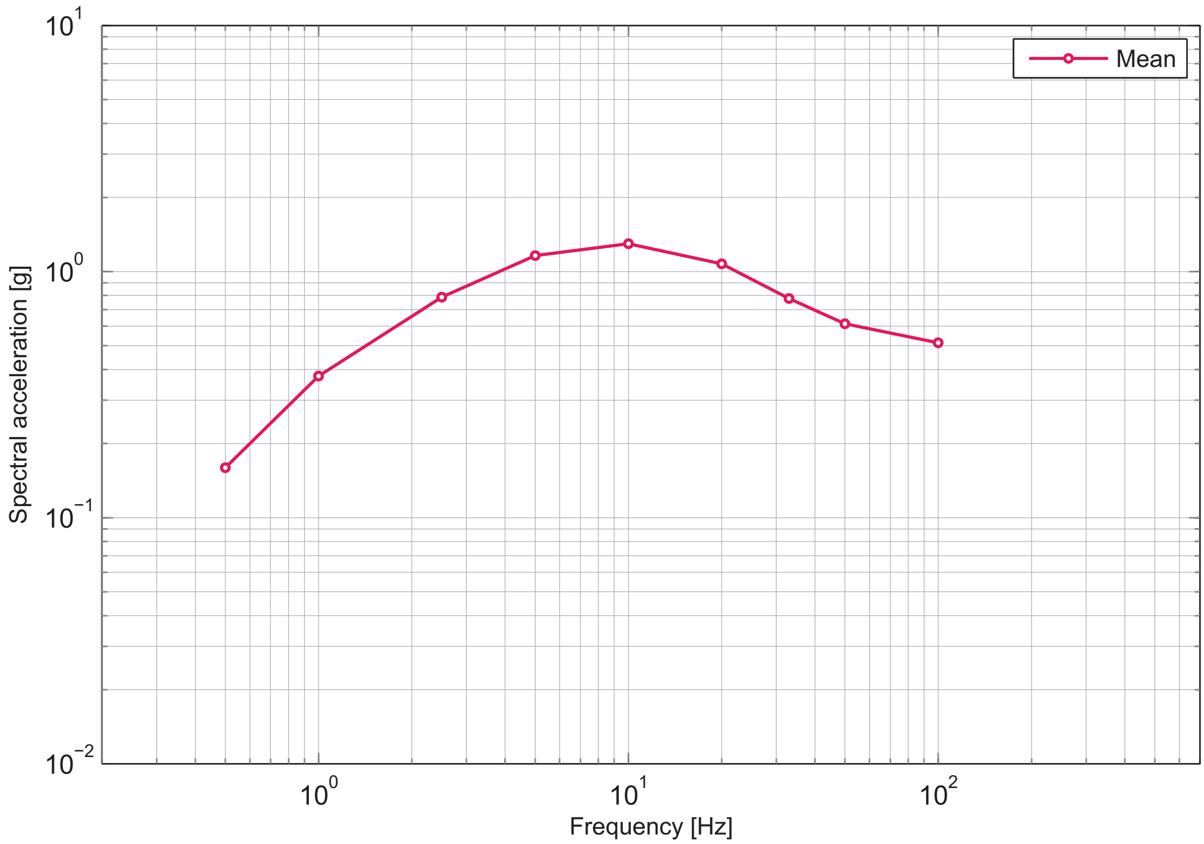

Fig. 6-1.12: Mühleberg, horizontal component, rock, surface, uniform hazard spectra for an annual probability of exceedance of 1E-05 and 5% damping.

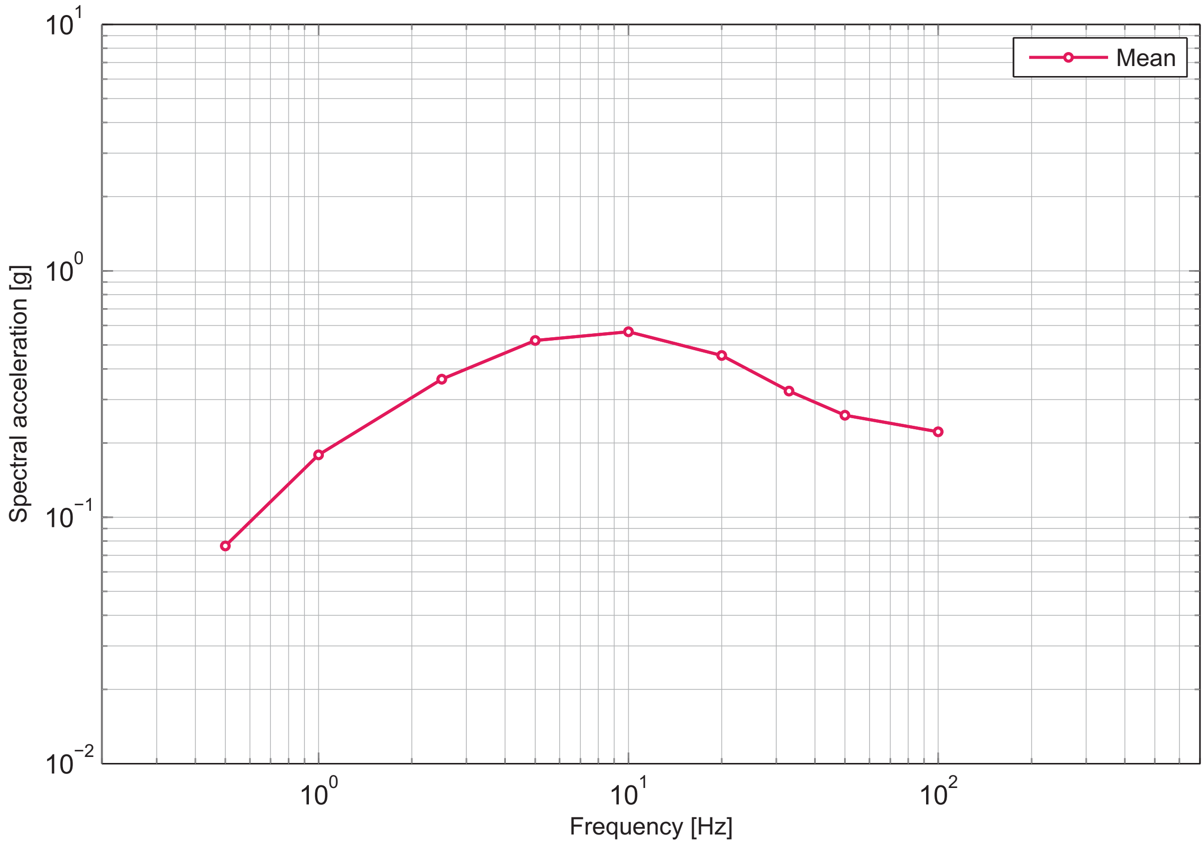

Fig. 6-1.13: Mühleberg, horizontal component, rock, surface, uniform hazard spectra for an annual probability of exceedance of 1E-04 and 5% damping.

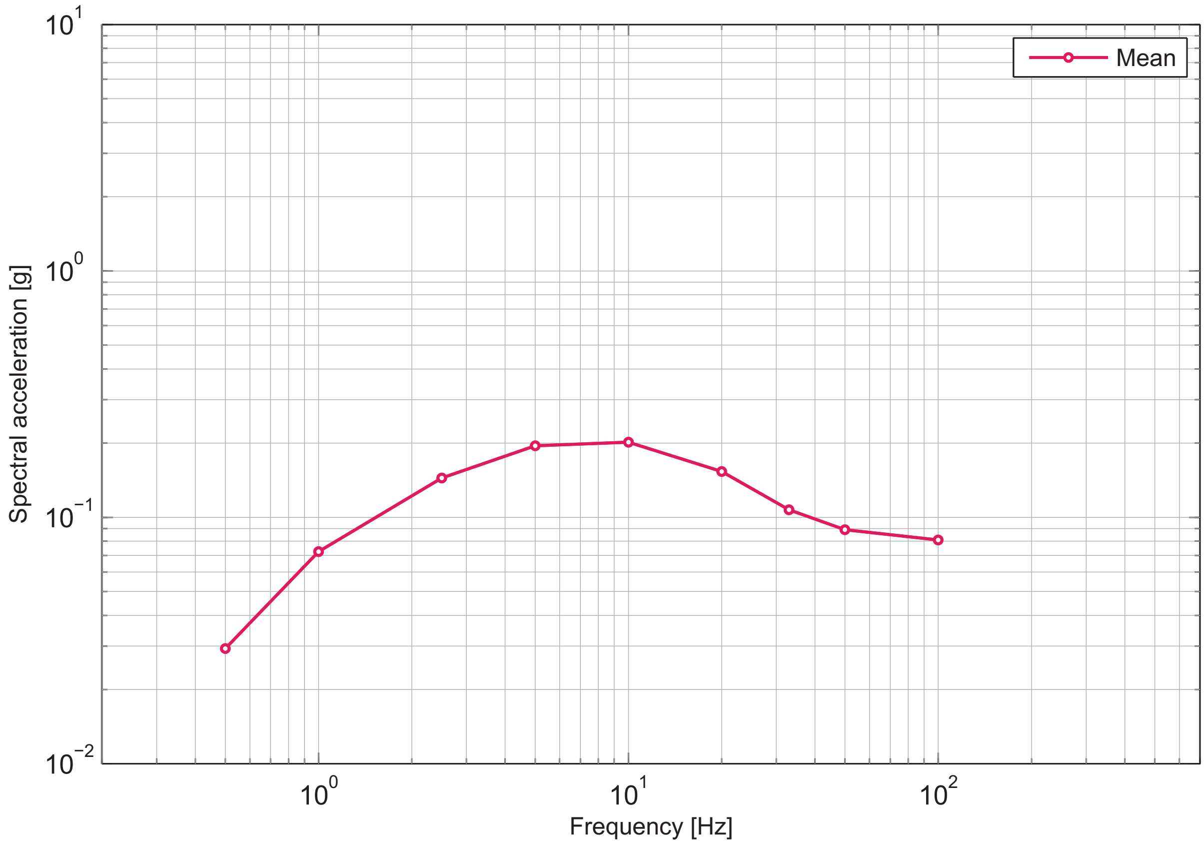

Fig. 6-1.14: Mühleberg, horizontal component, rock, surface, uniform hazard spectra for an annual probability of exceedance of 1E-03 and 5% damping.

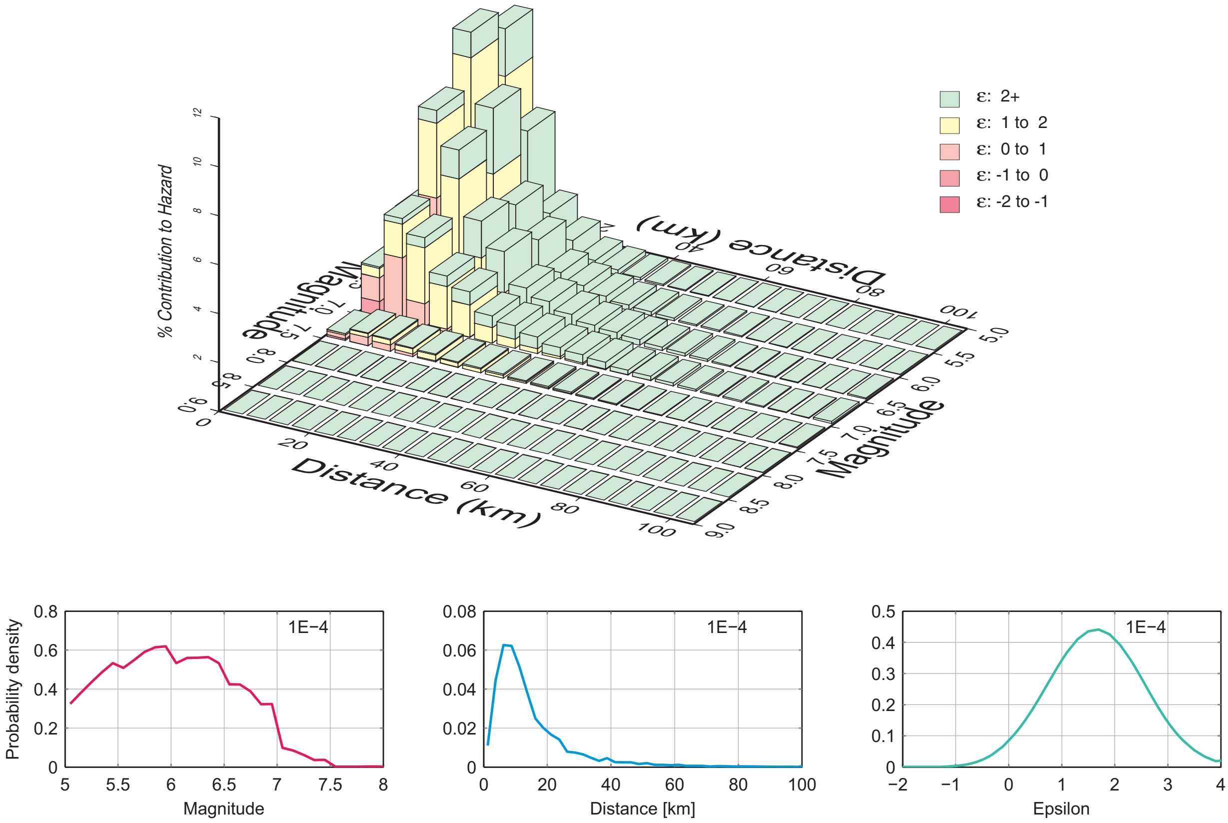

Fig. 6-1.15: Mühleberg, horizontal component, rock, surface, hazard deaggregation by magnitude, distance and epsilon for ground motion level 1E-4, 5 Hz.

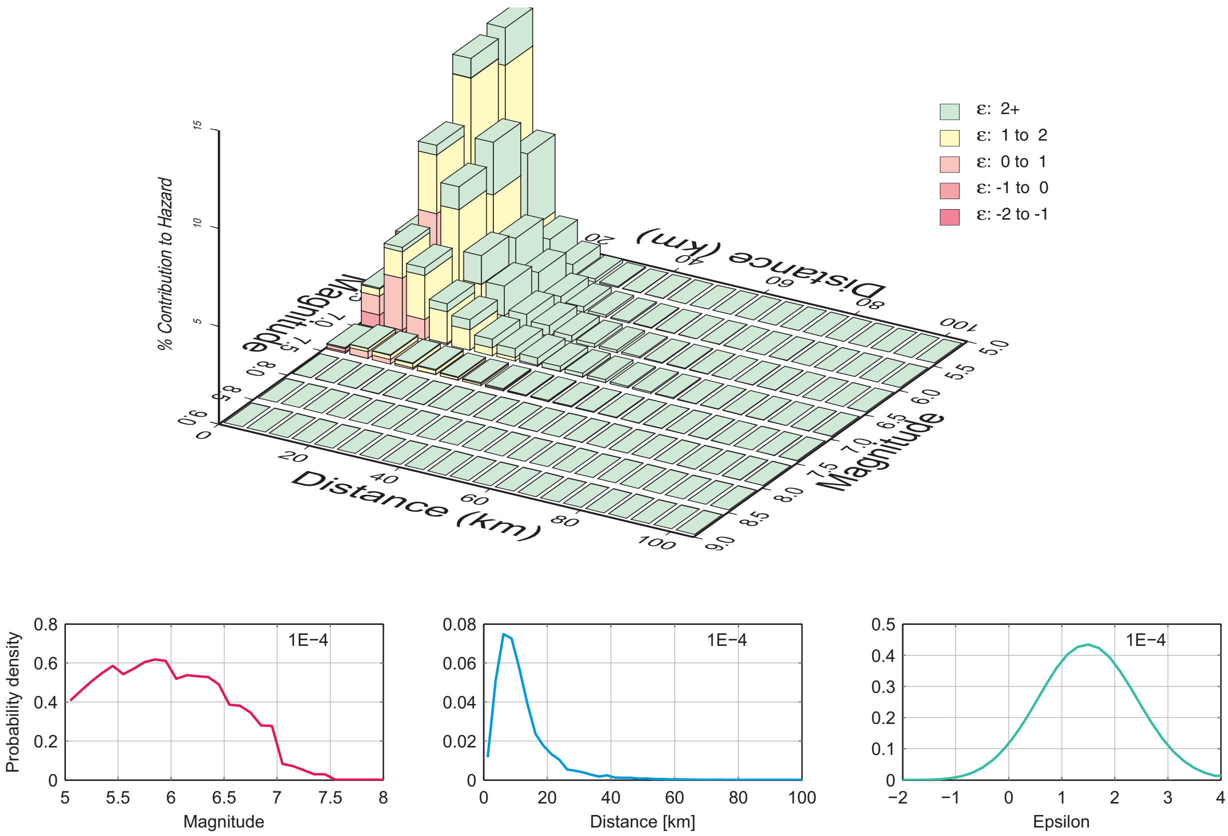

Fig. 6-1.16: Mühleberg, horizontal component, rock, surface, hazard deaggregation by magnitude, distance and epsilon for ground motion level 1E-4, PGA.

7 BREMGARTEN-ZUFIKON

7.1 Rock Hazard, Horizontal Component, Surface

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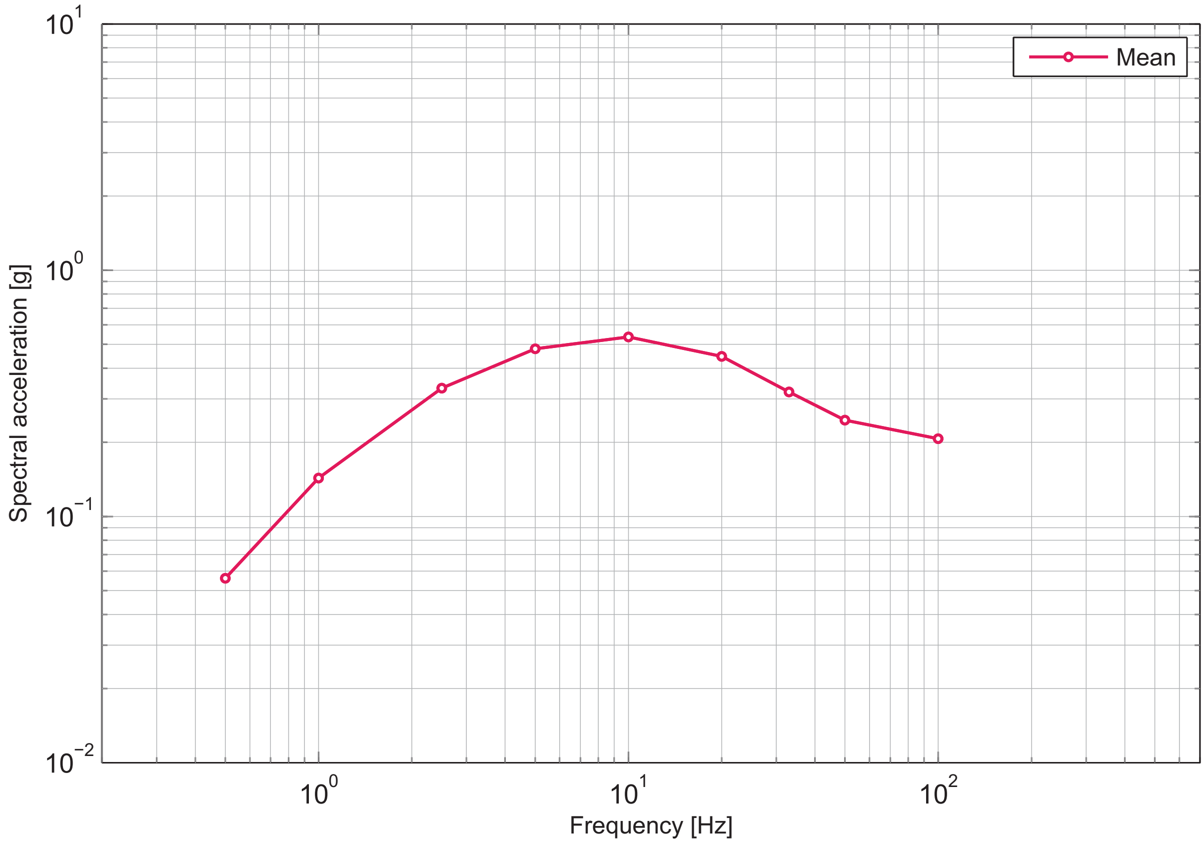

Fig. 7-1.13: Bremgarten-Zufikon, horizontal component, rock, surface, uniform hazard spectra for an annual probability of exceedance of 1E-04 and 5% damping.

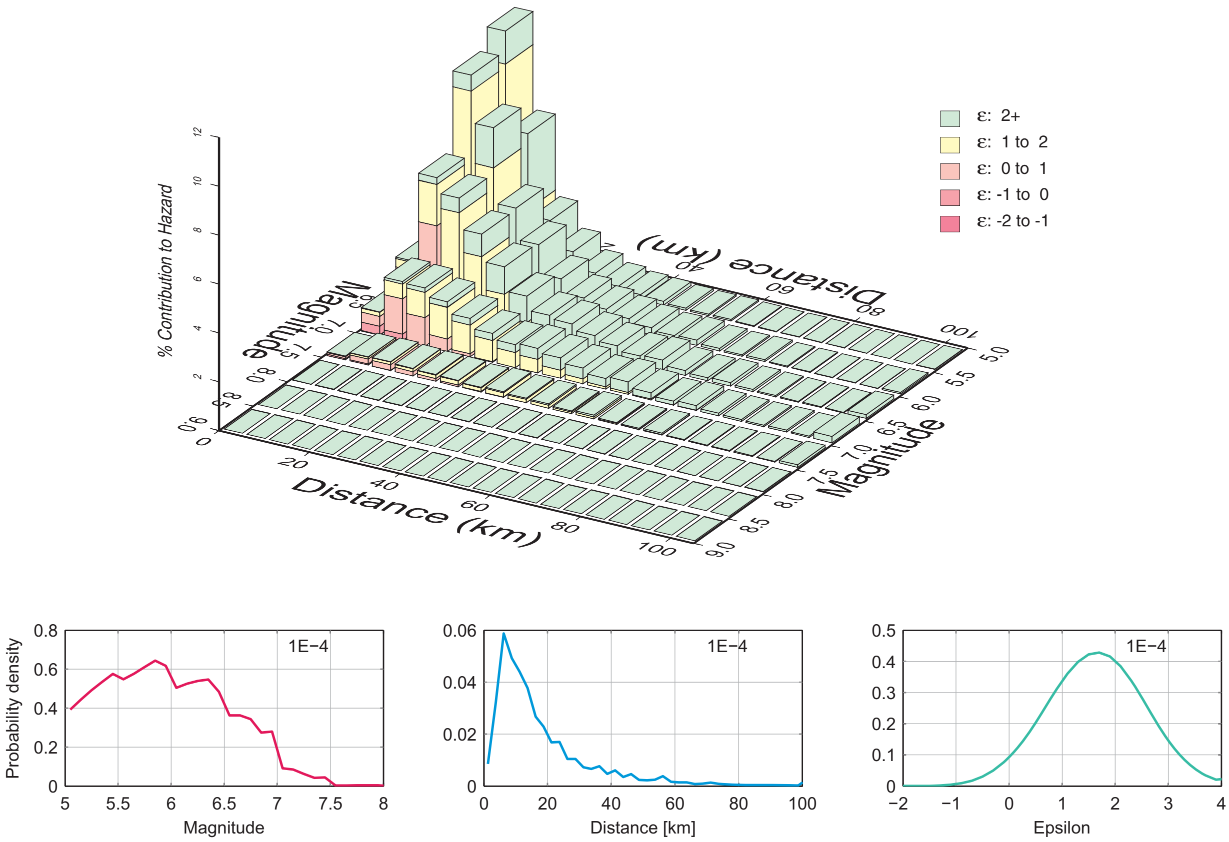

Fig. 7-1.14: Bremgarten-Zufikon, horizontal component, rock, surface, hazard deaggregation by magnitude, distance and epsilon for ground motion level 1E-4, 5 Hz.

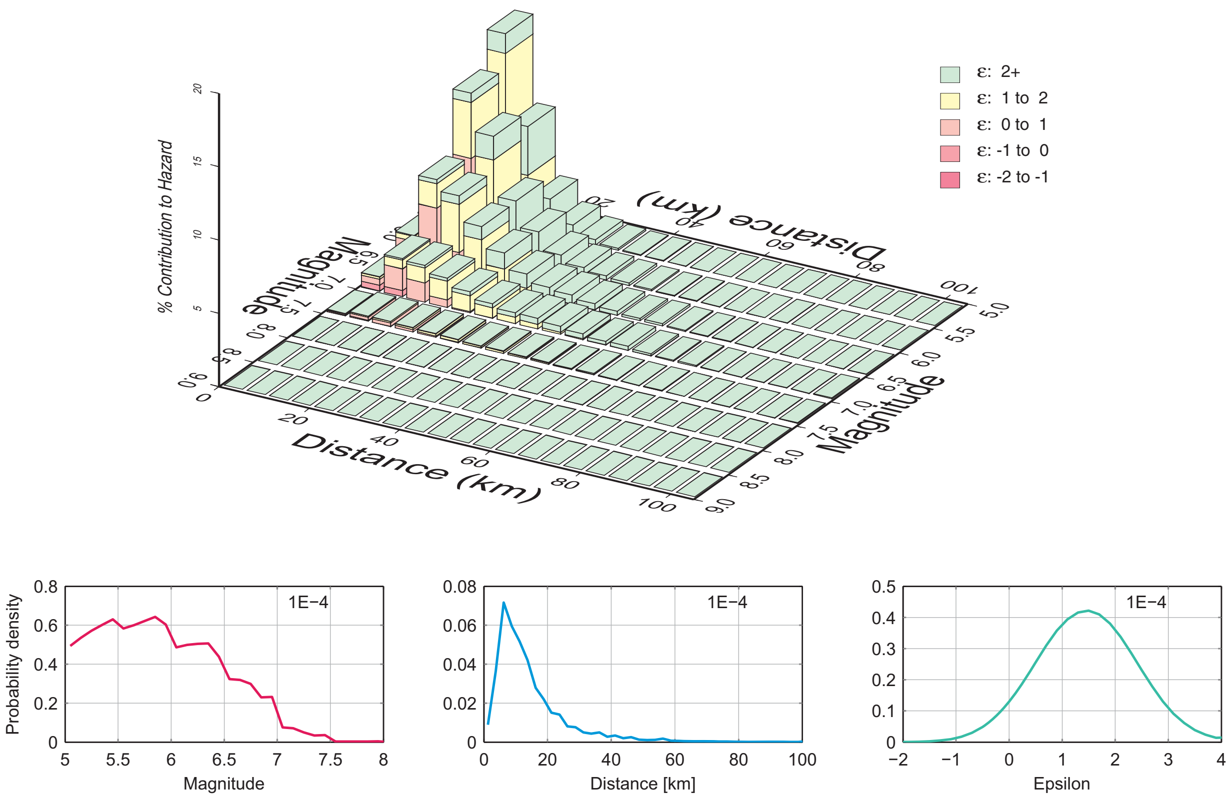

Fig. 7-1.15: Bremgarten-Zufikon, horizontal component, rock, surface, hazard deaggregation by magnitude, distance and epsilon for ground motion level 1E-4, PGA.

8 ROSSENS

8.1 Rock Hazard, Horizontal Component, Surface

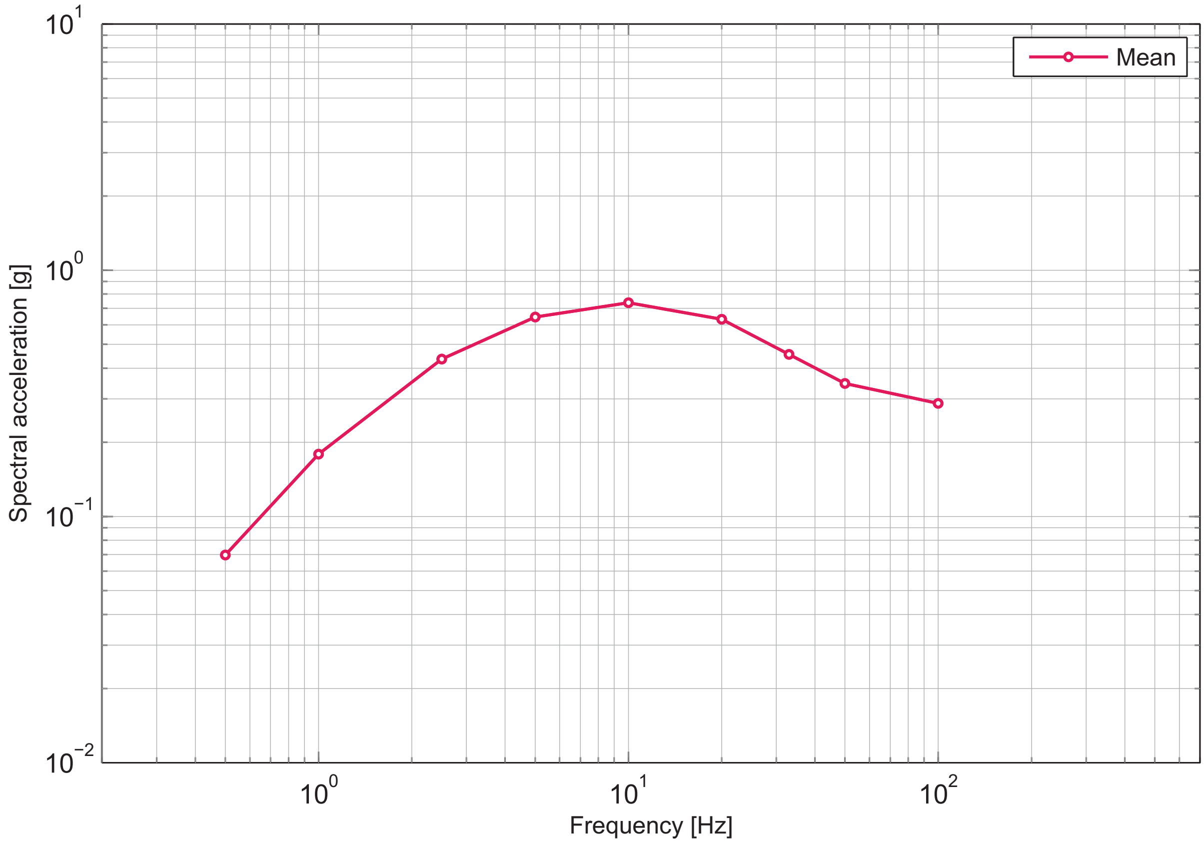

Fig. 8-1.13: Rossens, horizontal component, rock, surface, uniform hazard spectra for an annual probability of exceedance of 1E-04 and 5% damping.

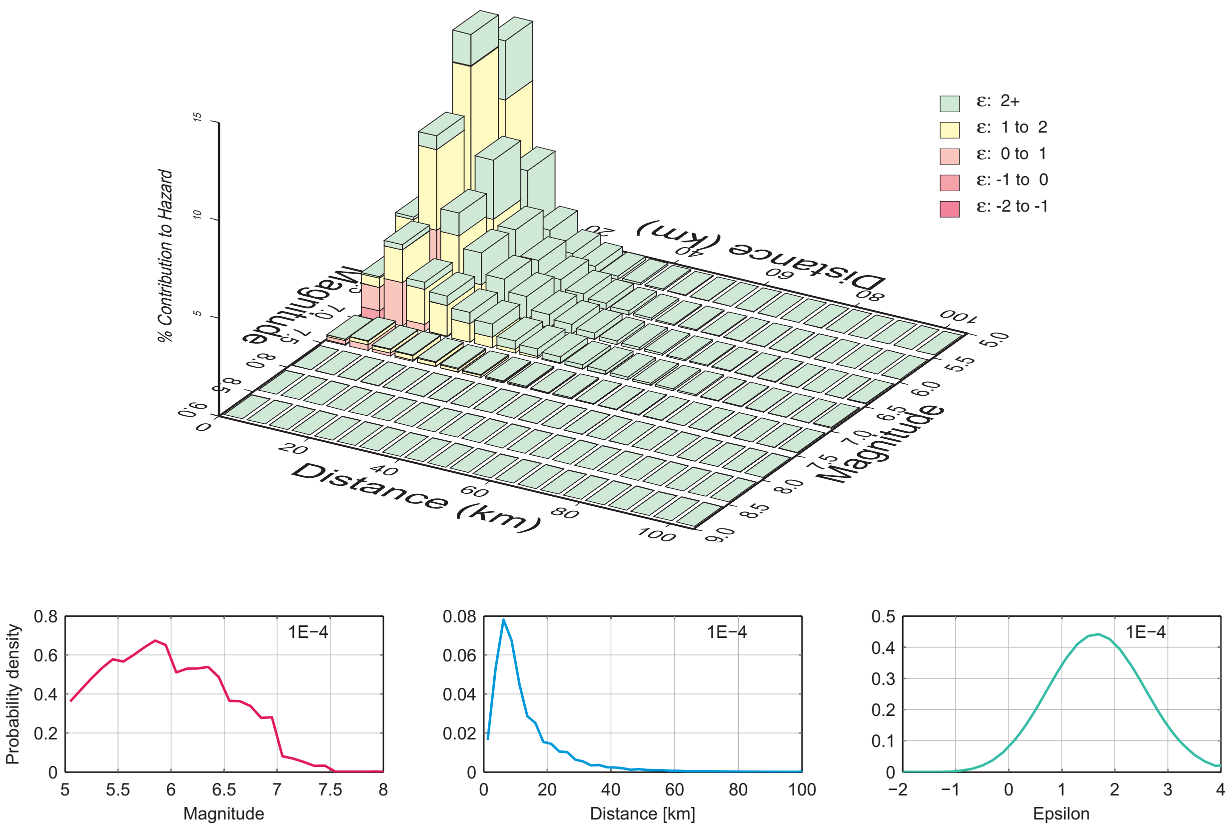

Fig. 8-1.14: Rossens, horizontal component, rock, surface, hazard deaggregation by magnitude, distance and epsilon for ground motion level 1E-4, 5 Hz.

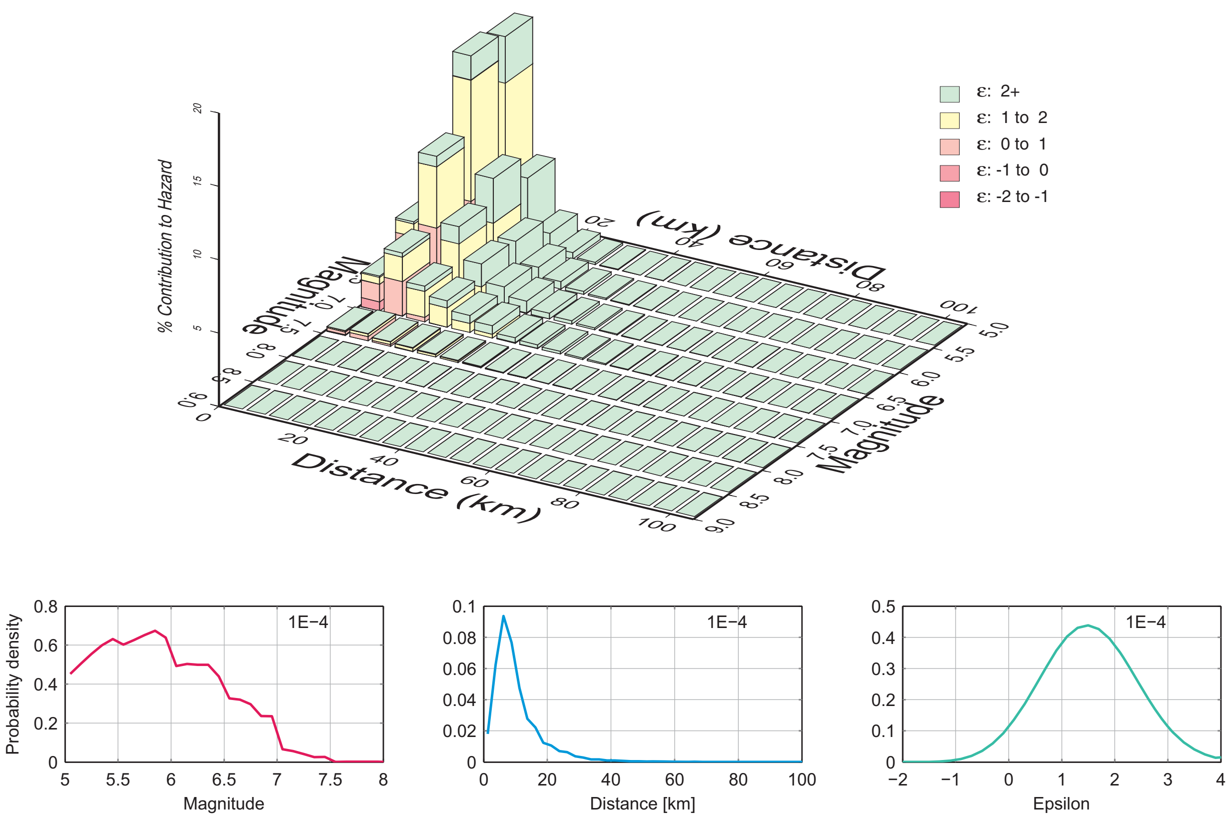

Fig. 8-1.15: Rossens, horizontal component, rock, surface, hazard deaggregation by magnitude, distance and epsilon for ground motion level 1E-4, PGA.

9 RUPPERSWIL-AUENSTEIN

9.1 Rock Hazard, Horizontal Component, Surface

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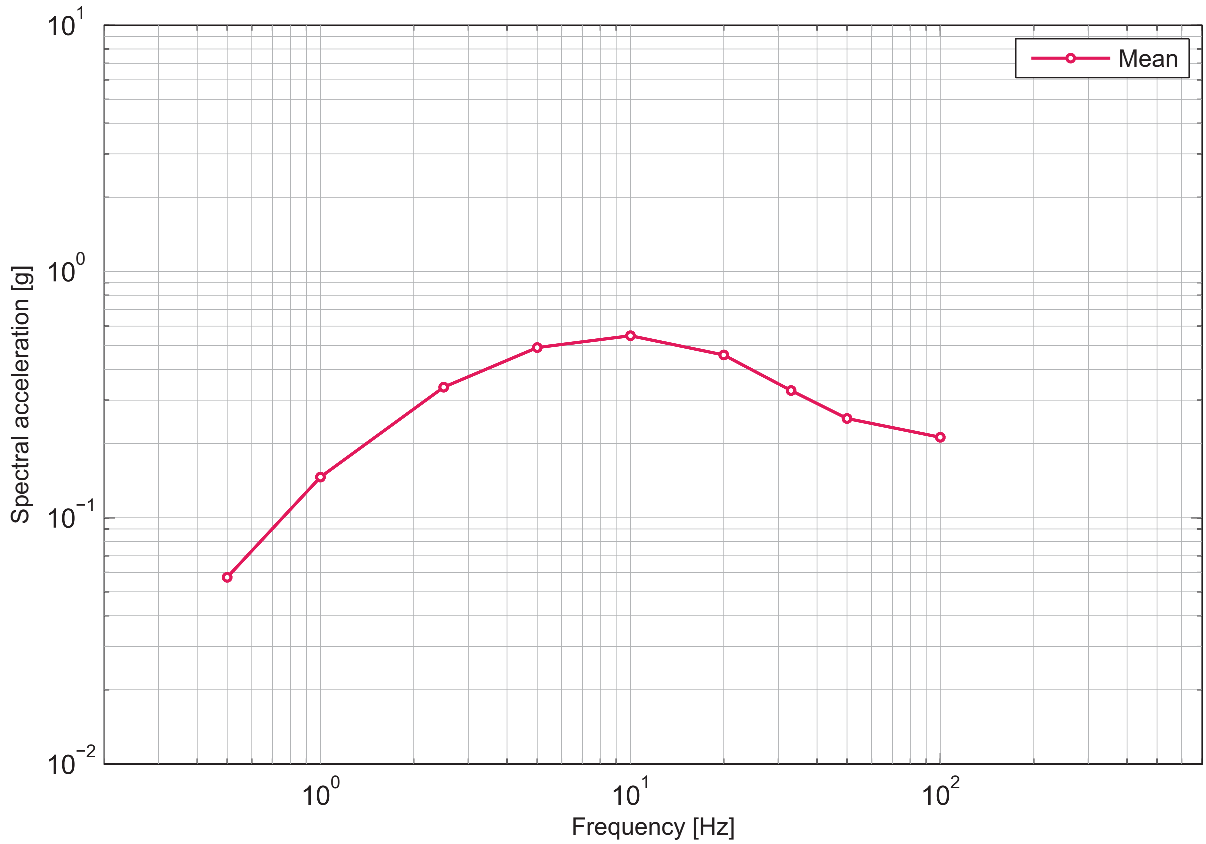

Fig. 9-1.13: Rupperswil-Auenstein, horizontal component, rock, surface, uniform hazard spectra for an annual probability of exceedance of 1E-04 and 5% damping.

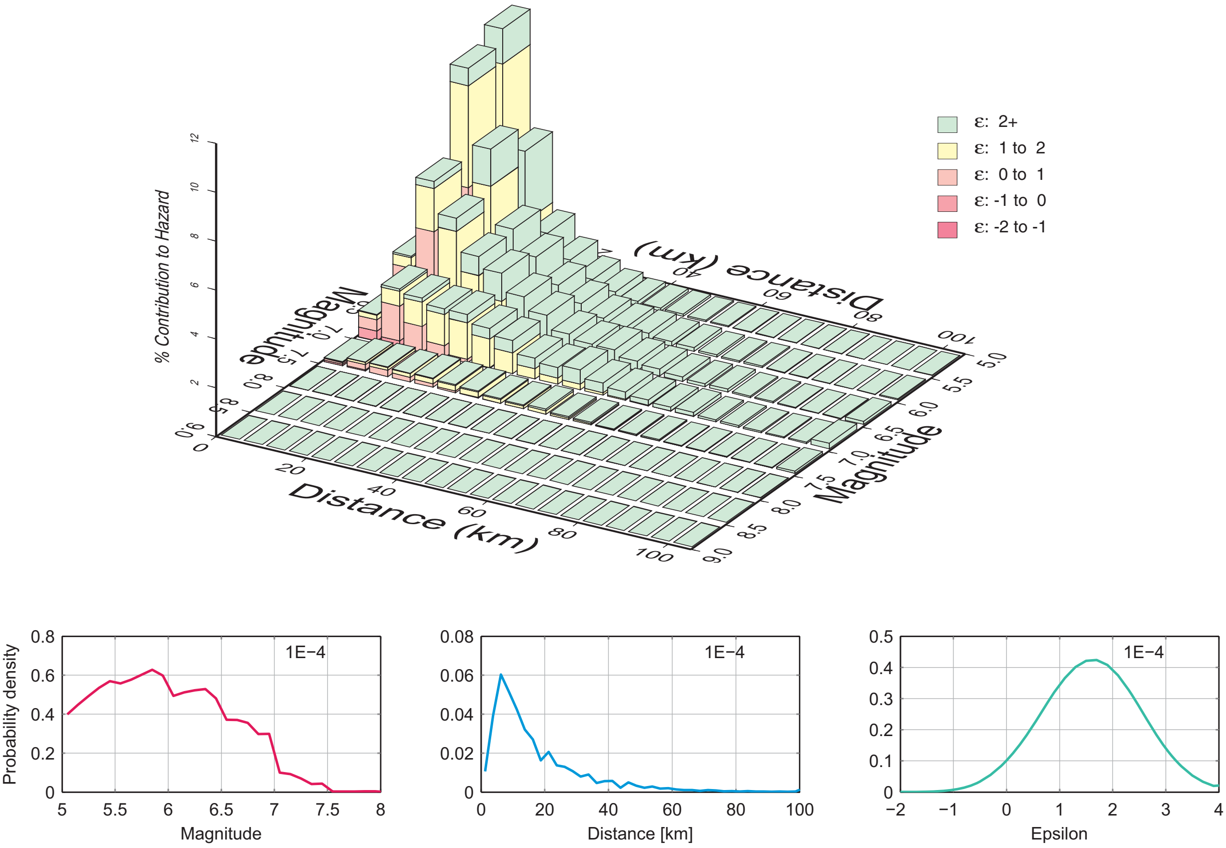

Fig. 9-1.14: Rupperswil-Auenstein, horizontal component, rock, surface, hazard deaggregation by magnitude, distance and epsilon for ground motion level 1E-4, 5 Hz.

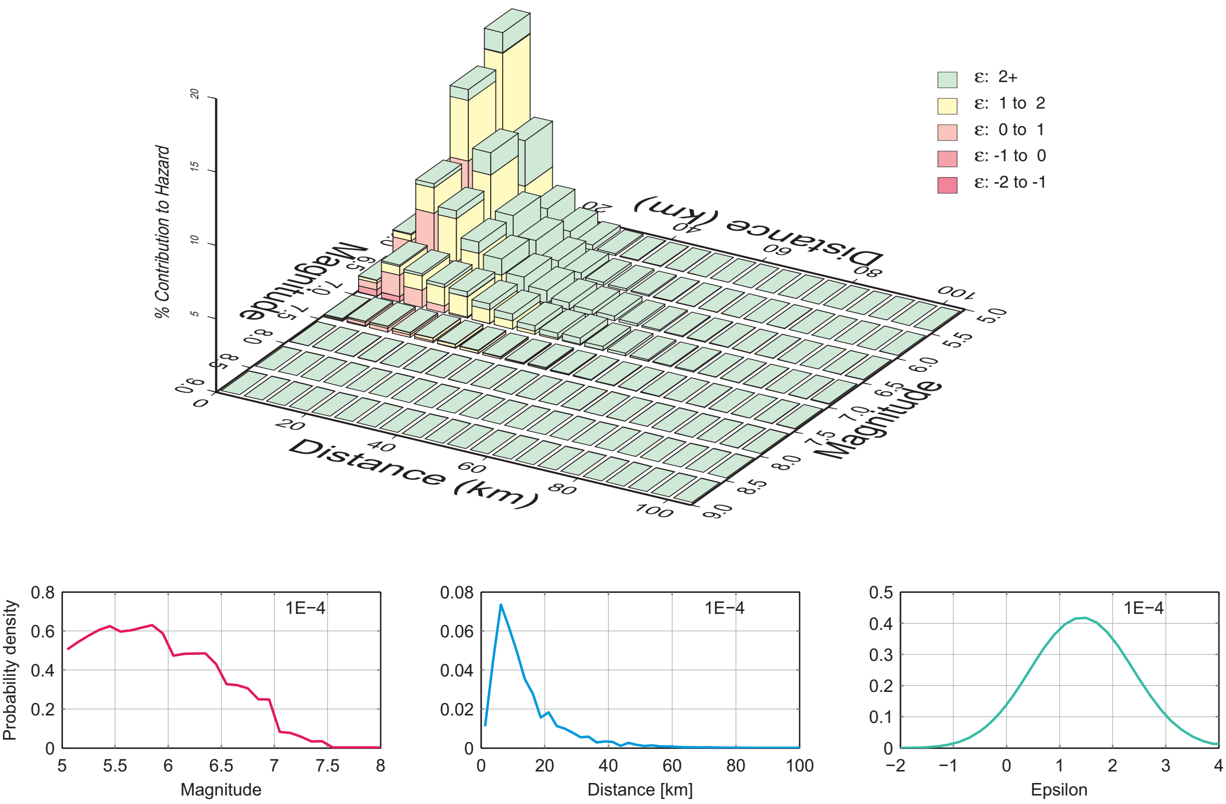

Fig. 9-1.15: Rupperswil-Auenstein, horizontal component, rock, surface, hazard deaggregation by magnitude, distance and epsilon for ground motion level 1E-4, PGA.

10 SCHIFFENEN

10.1 Rock Hazard, Horizontal Component, Surface

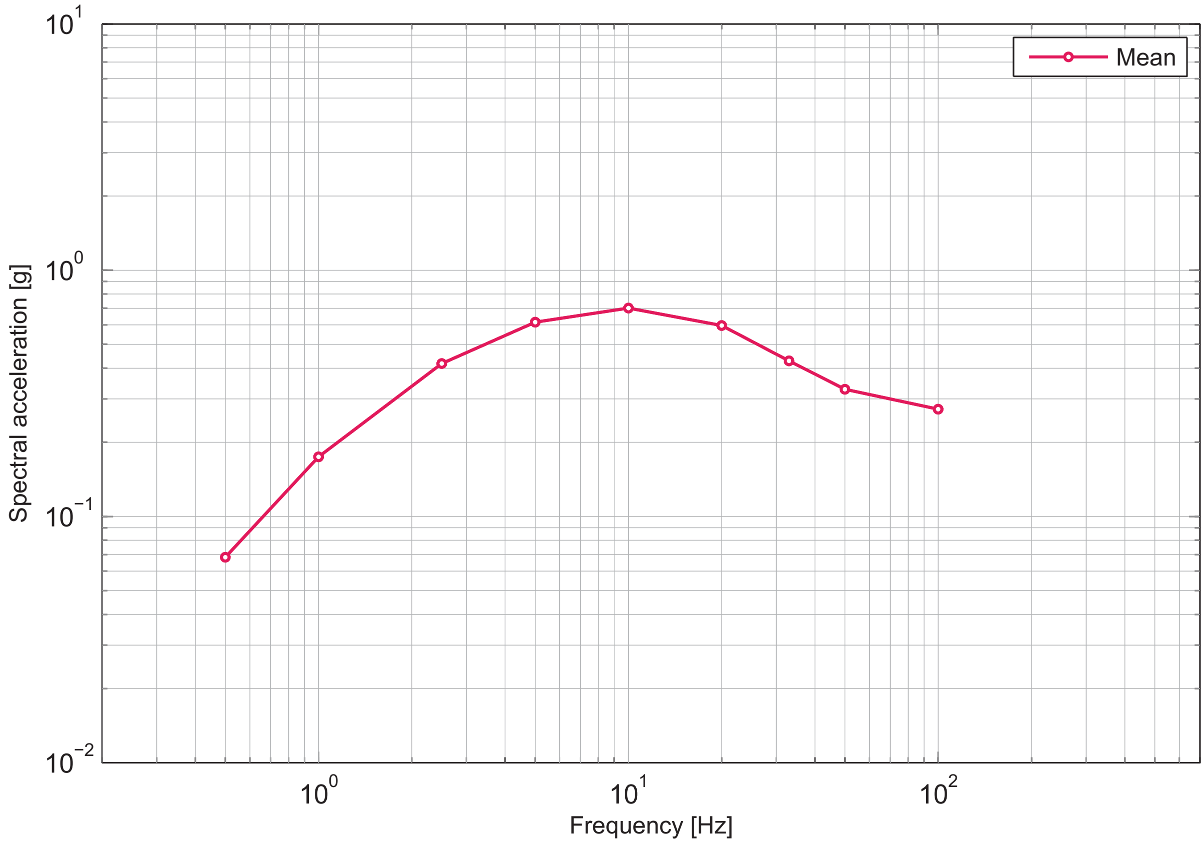

Fig. 10-1.13: Schiffenen, horizontal component, rock, surface, uniform hazard spectra for an annual probability of exceedance of 1E-04 and 5% damping.

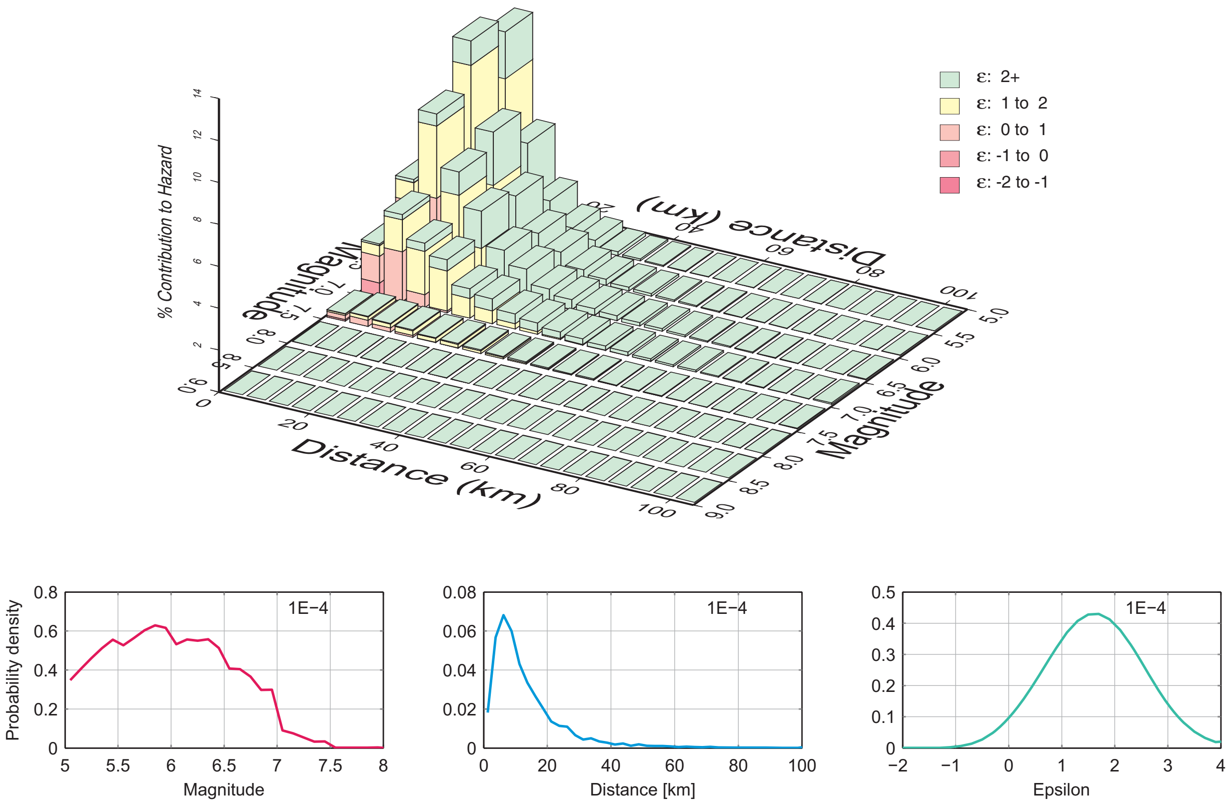

Fig. 10-1.14: Schiffenen, horizontal component, rock, surface, hazard deaggregation by magnitude, distance and epsilon for ground motion level 1E-4, 5 Hz.

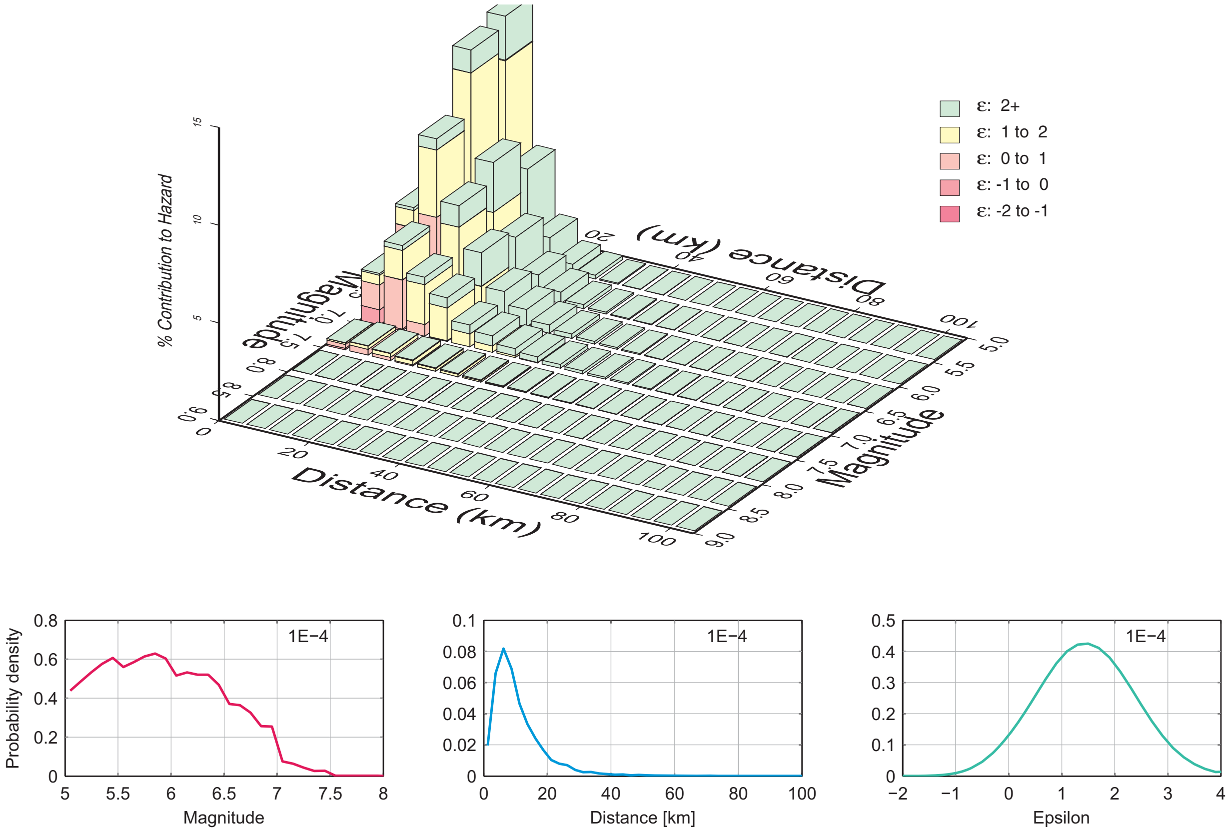

Fig. 10-1.15: Schiffenen, horizontal component, rock, surface, hazard deaggregation by magnitude, distance and epsilon for ground motion level 1E-4, PGA.

11 WETTINGEN

11.1 Rock Hazard, Horizontal Component, Surface

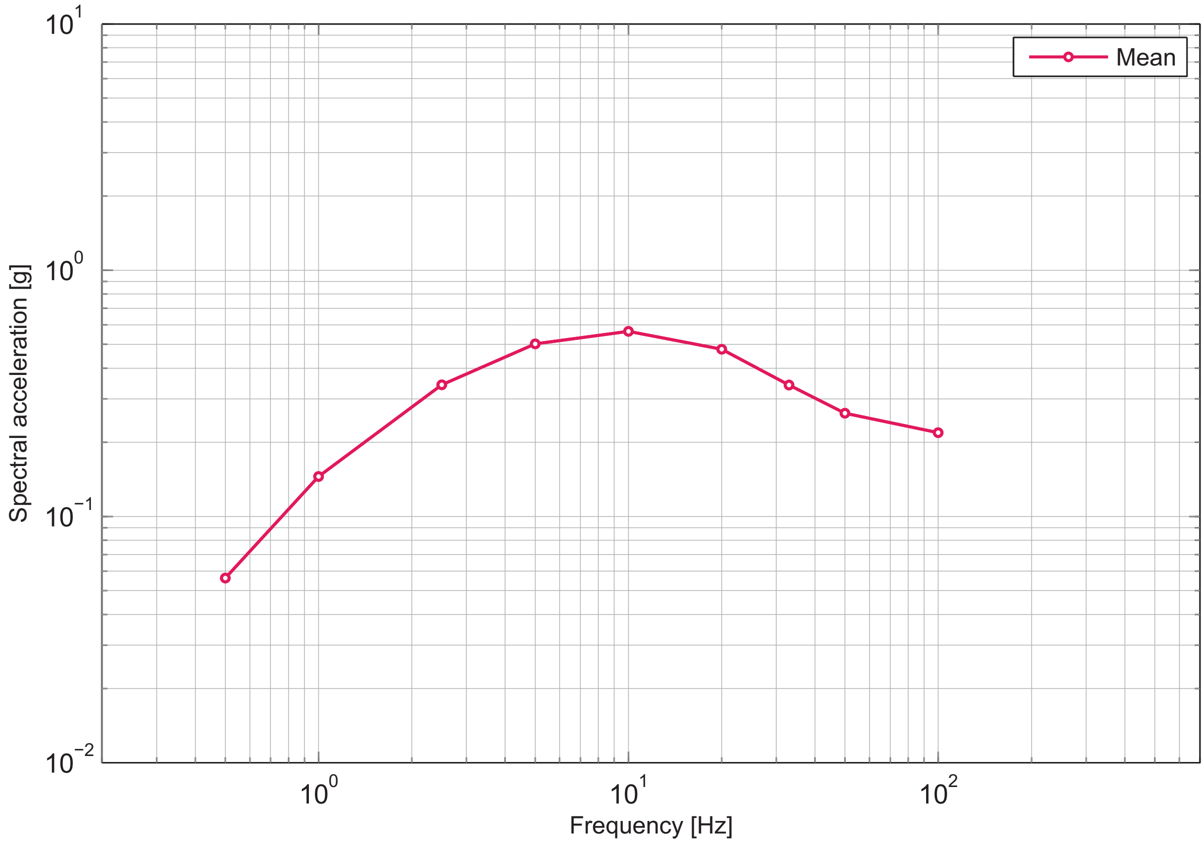

Fig. 11-1.13: Wettingen, horizontal component, rock, surface, uniform hazard spectra for an annual probability of exceedance of 1E-04 and 5% damping.

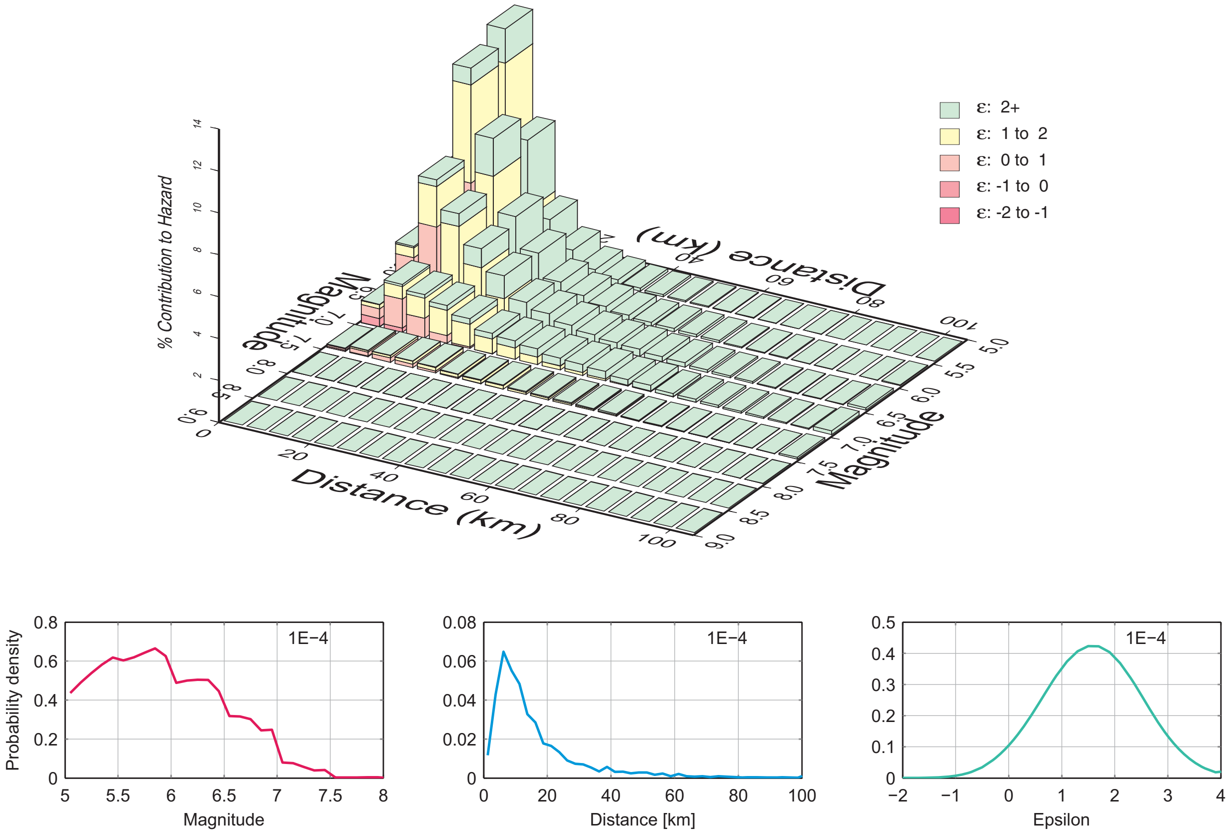

Fig. 11-1.14: Wettingen, horizontal component, rock, surface, hazard deaggregation by magnitude, distance and epsilon for ground motion level 1E-4, 5 Hz.

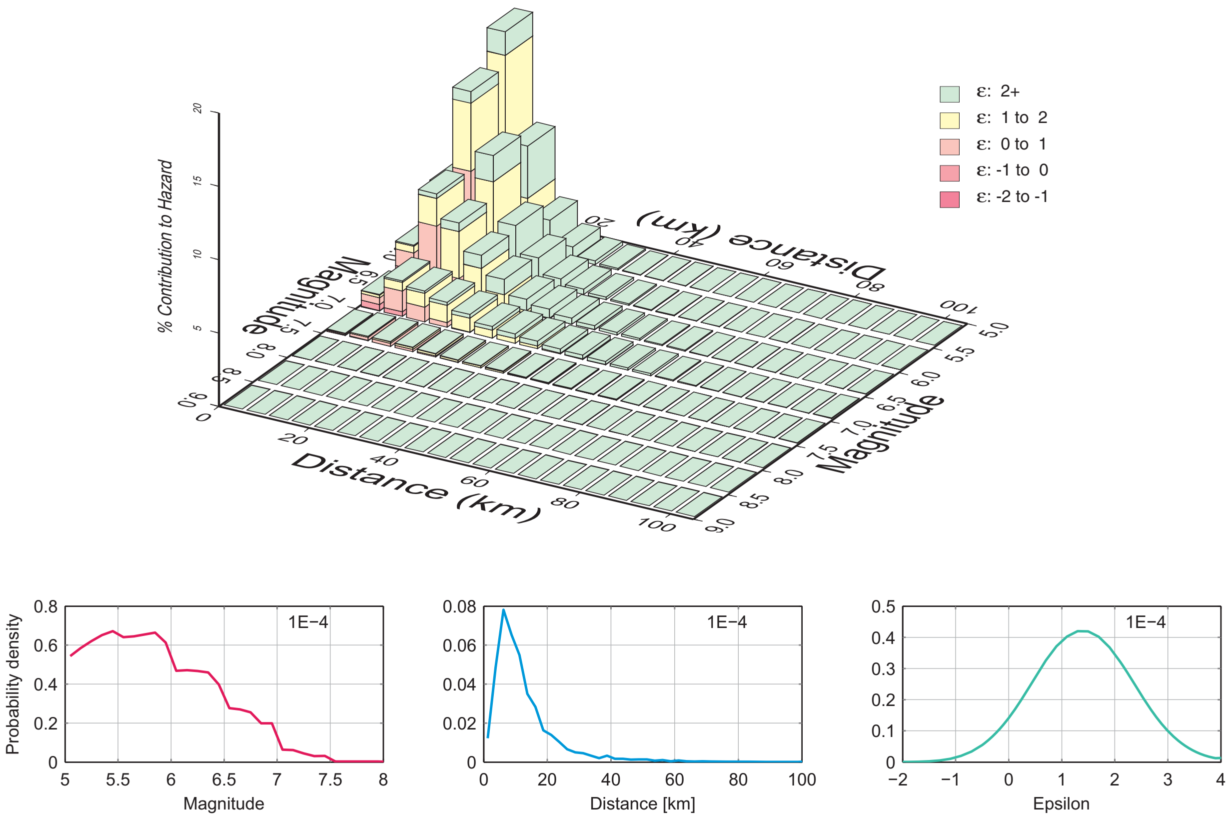

Fig. 11-1.15: Wettingen, horizontal component, rock, surface, hazard deaggregation by magnitude, distance and epsilon for ground motion level 1E-4, PGA.

12 WILDEGG-BRUGG

12.1 Rock Hazard, Horizontal Component, Surface

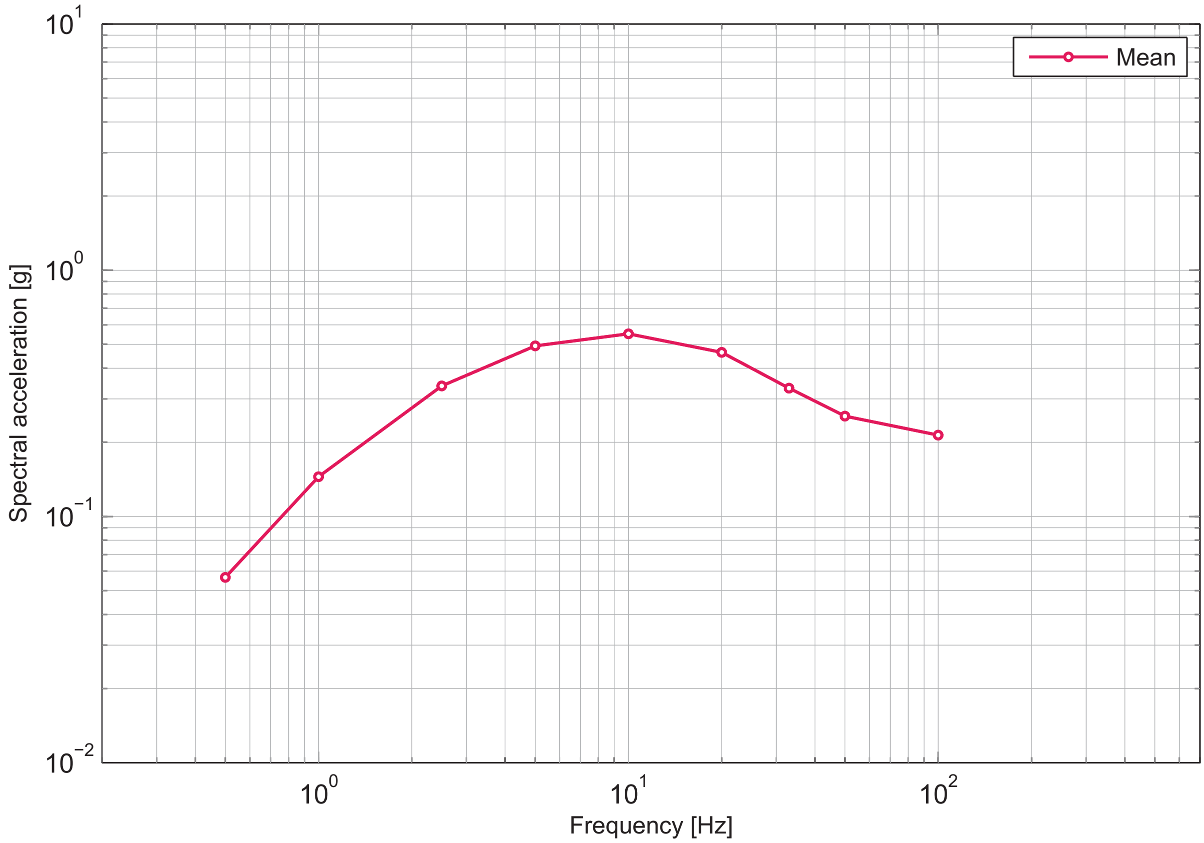

Fig. 12-1.13: Wildegg-Brugg, horizontal component, rock, surface, uniform hazard spectra for an annual probability of exceedance of 1E-04 and 5% damping.

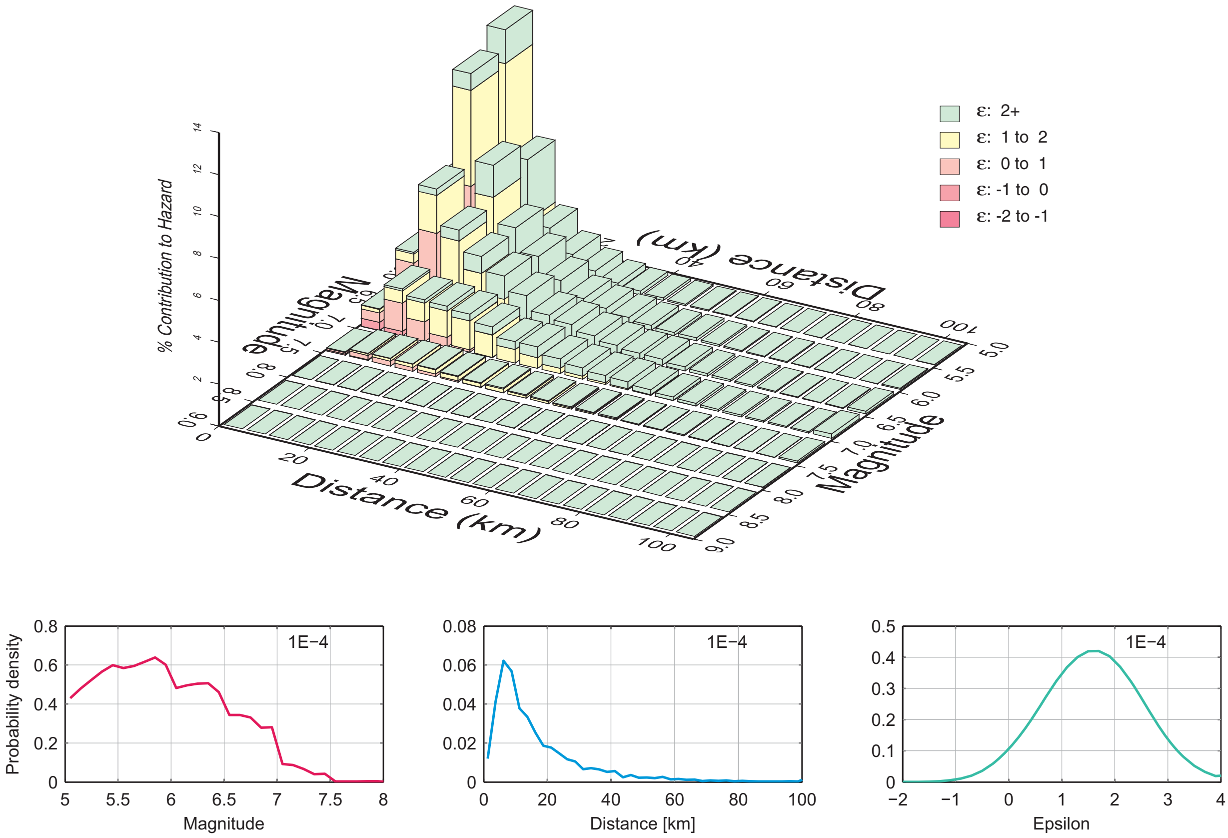

Fig. 12-1.14: Wildegg-Brugg, horizontal component, rock, surface, hazard deaggregation by magnitude, distance and epsilon for ground motion level 1E-4, 5 Hz.

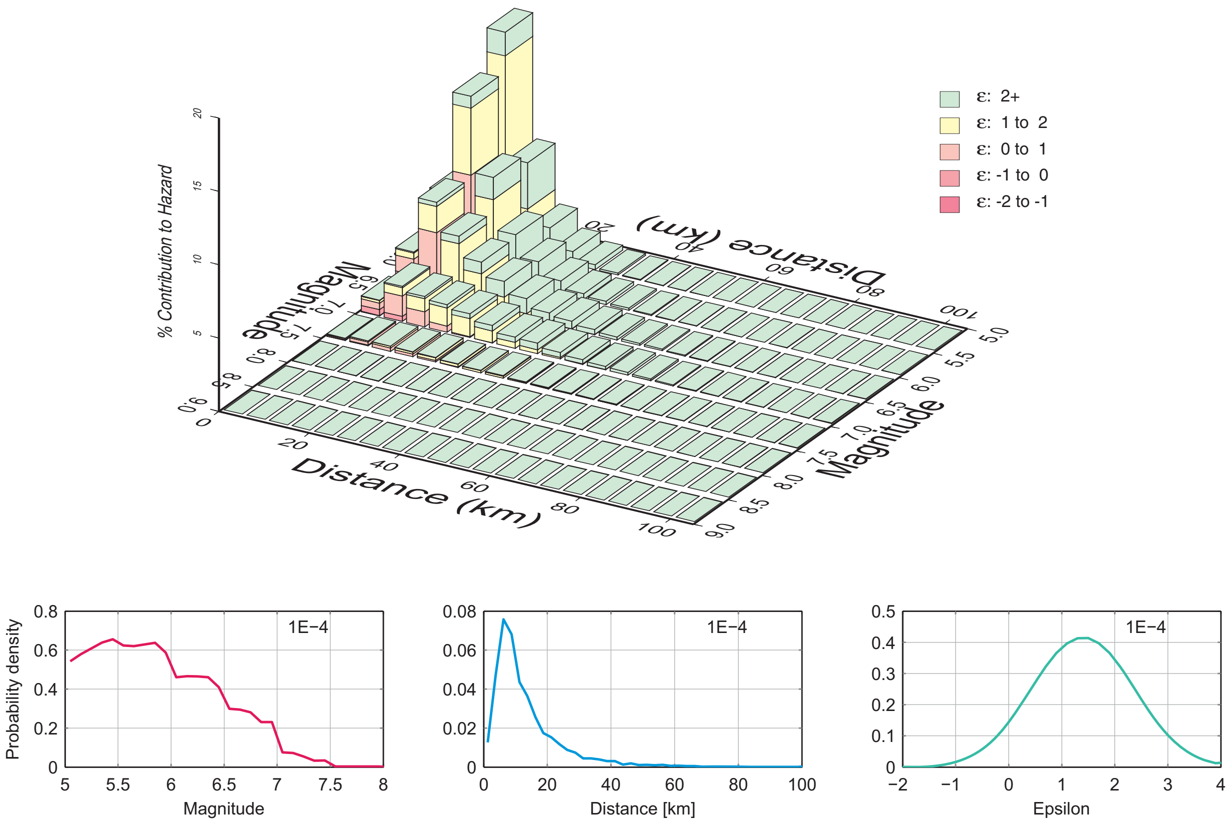

Fig. 12-1.15: Wildegg-Brugg, horizontal component, rock, surface, hazard deaggregation by magnitude, distance and epsilon for ground motion level 1E-4, PGA.

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