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Newsletter #6

18 July 2021

This issue

Editorial and Organizational Development

Editorial

The July flooding disaster in Central Europe affecting developed industrial nations once again shows the limitations of post-disaster emergency management. Looking back to recent events like the COVID-19 pandemic, the latest flooding and remembering the failures to cope with big earthquake and tsunami disasters in the past any person of common sense must understand that disaster prevention has to be preferred over disaster mitigation. Disaster prevention allows to avoid human and economic losses. Additionally, at the final end it is more economic than mitigation. This is the reason why our organisation is focussed on disaster prevention using very robust and conservative approaches for seismic hazard assessment as well as for earthquake engineering rather than on risk analysis, which allows to tolerate disaster as "natural, common events people have to live with". Besides an overview on our latest activities this newsletter contains a section showing how easy it is to obtain PSHA results for any site in the world. Although the methods and the commentaries given in this section may look very funny (indeed they contain a certain amount of irony and gallows humour) the results obtained look very similar to the hazard curves as obtained from an expansive SSHAC level 4 study (see US NRC NUREG/CR-6372 (1997) and NUREG-2213 (2018)). As you will see, only a very limited amount of information is needed to obtain such results. Paying for a PSHA is just the same as burning money.

Organizational Activities

Membership:

Our Secretary General has updated our membership list. Actually, ISSO is present in 15 countries of the world. Currently, our organisational charter/by-laws are under preparation. This will help us to amplify our efforts to communicate the need of seismic and other natural hazards disaster prevention.

Website:

www.issoquake.org . Our website got a refresher as some of you may have seen. Our webmaster, Dr. Nicola Venisti, is looking forward obtaining interesting information from our members to share with a broader public.

ISSO board meetings:

The ISSO board resumed its activities starting from May 28th, 2021. The ISSO board is meeting regularly once a month. The main objectives of the next meetings are the preparation of the next general assembly meeting and the ISSO charter.

Next General Assembly meeting:

The next General Assembly meeting will be hold in the format of a ZOOM conference on November 6th, 2021. Together with this newsletter you will get a registration form for the General Assembly meeting. Please register before October 6th.

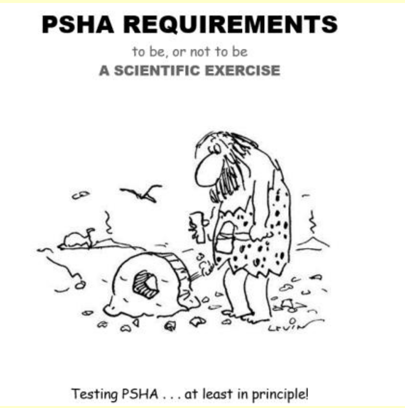
PSHA for Dummies. A simplistic and satirical introduction to "modern" seismic hazard analysis.

PSHA for Dummies. A simplistic and satirical introduction to "modern" seismic hazard analysis.

Looking at the large number of books and publications, of regulations and normative documents one may believe that performing a PSHA represents a huge scientific exercise. The topic gets even more complex if we will decide to involve several experts in performing a PSHA following the rules of the SSHAC procedures (NUREG/CR-6372 (1997)) on expert elicitation and of combining expert judgments. Large PSHA studies are very time-consuming and cost a large amount of money, for example, the project to define a new seismic hazard for Swiss nuclear power plants lasted from 1998 till 2016. In the meantime the plants were operated. Not to think about that a real strong earthquake exceeding the original design basis of Swiss plants would have happened during this time period! We may ask the question whether such an effort is really needed (regulators may require this) looking at the uncertainties, the main topic to be addressed by the SSHASC procedures. Indeed results of a large-scale PSHA can be produced with a significantly lower effort.

Here, we will construct PSHA seismic hazard curves for a site in Europe having the following information available:

1) We have a published empirical ground motion prediction equation (GMPE) available, that contains at least some European data. If you do not have one, there are many compilations available in the literature or at Google, just make a search looking for authors like J. Douglas, J. Bommer or N. Ambraseys. You can also use an older one, the differences between new and old data are not so large, as some researchers will make you believe. By the way you can even combine a few of published correlations into a new equation, completely without any own data. The only thing to do is to run a few thousand random samples (Monte Carlo method)) for each of the equations varying magnitude, distance and (if used as a parameter) soil factors treating the aleatory variability (in normal statistics, the standard regression error of the equation) also as random (e.g. varying $\varepsilon\sigma$, the number of standard deviations. In lognormal scale a good value for σ is 0.52, while ε can be varied between – 3.5 and +3.5 (not uniformly of course but using as a simplification the standard normal distribution) – recall PSHA is so "good" because it allows to "encompass all the uncertainty". Of course you can also use different weights for the different equations you want to use. This has the same effect as using a logic-tree. Of course you may run all the Monte-Carlo samples for a set of spectral ordinates, not just PGA. This looks more like "science". Now you fit the obtained data sets with a nonlinear fitting programme (e.g. using MATLAB©) using a standard format of an empirical GMPE for all the spectral ordinates. Your new, best-estimate model is ready, notably even without any new data but with "sufficient" uncertainty! Of course you can avoid this effort by just using a published equation. It will not have a very large effect on the results.



Courtesy of J. Bela

2) Now you need some information from a single historical earthquake, if possible, with an assessment of the location of the causative fault. So you know the distance range between the fault to your site (of course with some uncertainty, do not forget!) and you have a guess on the magnitude (with some uncertainty e.g. 0.5 magnitude units).

3) Now you make an "intelligent" guess on the most important topic of PSHA, the return (recurrence) period of the historical earthquake. Such an estimate is easy once you know when the event happened.

PSHA – For Dummies

So the lower bound of the recurrence interval is obtained by assuming it will repeat the next day. You assign this to be the 5% quantile of the uncertainty distribution of the “recurrence interval”. Now you assess the upper bound of the “recurrence interval”. Assuming that your level of knowledge (or better of technical “ignorance”) is distributed uniformly (e.g. your position as an earthquake observer is random and uniformly distributed in time), than the 95% quantile of the distribution of the “recurrence interval” will be about 40 times your worst case assessment (that is good, a lot of uncertainty, your PSHA will be “perfect”). The median “recurrence period”, which we will treat as “return period”, can easily be calculated from these two points assuming that the “return period” is lognormally distributed. If you have a better guess for the “return period” available, you of course may use it.

4) With the information on the historical earthquake and your “Best-estimate” GMPE you calculate an estimate of the ground motion for the historical event (e.g. best guess for all spectral ordinates). To be a little bit conservative you calculate it for the shortest distance from the causative fault to your site. According to PSHA methodology (use of subjective probability) this best guess represents the “median” of the epistemic uncertainty distribution. Similarly, you calculate a “guess” for the upper bound of ground motion using the “best guess” from your equation and adding 2.5 standard deviations σ. You may consider this the 95% quantile of your ground motion distribution which is assumed to be a lognormal one (usual assumption for GMPE). For the lower guess you do the same, but this time you just subtract 1.5 σ. This you assign to be the 5% quantile of your ground motion distribution. Now the mean hazard can be calculated from the two estimates assuming again a lognormal distribution for the ground motion distribution for a fixed distance.

Battle of ISSO – Disaster Prevention (DSHA) vs. High Risk Tolerance (PSHA)

5) Now you can start constructing hazard curves. For this you apply the simple rule of thumb (this is a finding from PSHA studies) that your median hazard in terms of PGA (valid approximately for all spectral ordinates) doubles with each increase of the “return period” by a factor 10, e.g. moving from the “1000 years” earthquake with a PGA let us say of 0.2g to the “10000 years” earthquake will result in a PGA of 0.4g. For the upper bound curves you do the same, but you are using a factor of 2.1 instead of doubling. For the lower estimate, the approach is similar, you just use a lower factor of 1.8 instead of doubling with an increase of the “return period” by a factor of 10. In case of a soil site (average shear wave velocity $v_{s,30}$< 720m/s) you may incorporate a little bit more of knowledge into your study by reducing the increase factor once you approach the area of nonlinear soil response (PGA>0.4g for M>6) a little bit, converging to a maximum PGA of 3g (due to the very high probability of shear failure of moderately stiff soil under these conditions). You may also decide not to do so, as most “PSHA experts” do not understand that the behaviour of nature is always nonlinear, because linear models are so “nice” (experience from the PEGASOS project in Switzerland).

How frequently shall seismic disasters repeat?

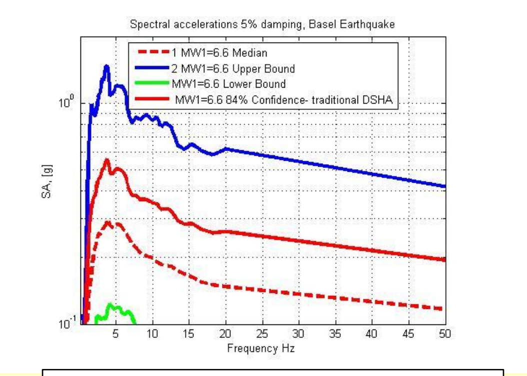
6) Now you will have to assign the return periods to the 3 sets of hazard estimates. The upper bound of ground motions will be assigned to your lower estimates of the “return period”, the estimates of the median ground motions are assigned to your estimates of the “median return period” and the estimates of your lower bound of ground motions are assigned to the largest estimates of “return period”. Now you have 3 sets of hazard curves for all spectral ordinates. By assuming that for a fixed “return period” (or “frequency of exceedance” to use the right terms) the distribution of ground motions is lognormal you may calculate any intermediate quantile of the ground motion distribution.

An example how typical results of this approach look like is discussed below. Let us summarize what knowledge do you need for constructing a PSHA with "comprehensive" treatment of uncertainty.

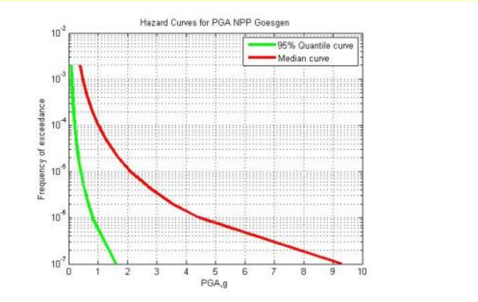
1) You need some information on a single historical earthquake (approximate location and magnitude).

2) You need an empirical GMPE published for a larger area including your site (e.g. Europe, Easter US, Western US etc.) or you can create a new one from published GMPEs using nonlinear fitting using the Monte Carlo resampling technique described above.

3) You need some limited information on the site conditions (rock, soil).



Example: Estimated response spectra from the Basel earthquake, site of NPP Goesgen (5% damping)- figure 1



Example: Hazard Curves for PGA, NPP Goesgen (95% quantile and median)- figure 2

Of course, from basic school knowledge you should know the lognormal distribution (or at least the normal distribution and logarithmic calculus).

Now we look at the example. We attempt to estimate the probabilistic seismic hazard at the site of NPP Goesgen in Switzerland. For this site, the results of the large scale PSHA study PEGASOS (2004) and the results according to the ordinance of the Swiss Federal Nuclear Inspectorate (ENSI), ENSI-2015 (2016) are publicly available. Therefore, we can compare our "PSHA for Dummies" method with the results of multi -million Dollar studies. As the starting point for our estimates we use the actual information of the Basel earthquake. The magnitude of the earthquake is estimated to be Mw=6.6, the distance to the site of NPP Goesgen is 30km (shortest distance). We obtain the required ground motion estimates using the GMPE of Ambraseys et al (2005), which contains European data, assuming thrust faulting conditions. Using our "PSHA methodology for Dummies" method, we obtain the response spectra shown in figure 1. Figure 1 compares the upper bound , best estimate (median) and lower bound with the traditional results of a DSHA which bases on the largest historical event using a safety factor of +1 standard deviation σ. Thanks to our consequent dealing with large uncertainties the range of possible hazard ground motions encloses the rather robust deterministic estimate. This is fine for our "PSHA for Dummies" method, plausibility tests will hardly refuse our results once we take uncertainty into account in testing. PSHA results will always include the true but unknown hazard. Such uncertain results are difficult to use by the decision-maker (DM). Frequently public DMs have to save money. Therefore, he may use any result and save a lot of money just by selecting a proper quantile of the distribution of ground motions (lognormally distributed) fitting his wants. Figure 2 shows an example of the calculated hazard curves for PGA. It is obvious that the shape of the curves closely resembles the typical results of a PSHA. From the curves the mean PGA value for a frequency of exceedance of 10^{-4}/a can be calculated using our assumption that for a fixed frequency of exceedance spectral accelerations are distributed lognormally. The obtained mean value is **0.426g** (10^{-4}/a). The PEGASOS study (2004) resulted in a PGA value of **0.461g** for the same frequency of exceedance, the refined ENSI-2015 study (2016) in a value of **0.406g**. As anybody can see we are able to reproduce the results of multi-million dollar PSHA studies with just basic knowledge and an effort of about 5 hours for programming**. So the question is: Is PSHA science?** Does it have any relationship to the state of the art in seismology and geophysics? **Certainly,**

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