Seismograms from the 2002 Interactive Deaggregation Web page

Introduction

The 1997 ATC 35-3 workshop on improved characterization of strong ground shaking for seismic design recommended that suites of time series of ground motion should be available to engineers, in the form of an internet-accessible jukebox of strong-motion records and their characteristics (Applied Technology Council, 1999). Several such internet sites now exist. One of the most comprehensive is COSMOS, with address http://www.cosmos-eq.org.

ATC-35 further suggested that time-domain earthquake records could be tied to the USGS seismic hazard deaggregation web-site so that accelerograms for specific tectonic regimes and for modal-event magnitude and distance pairs could be published on demand. The deaggregation web site does not currently access COSMOS seismograms, but interested engineers are encouraged to do so. Instead, in this demonstration project, we generate synthetic seismograms using a well-tested method. Random-component horizontal accelerograms are generated from the program SMSIM_TD, version 2.20, by David M. Boore. SMSIM_TD uses the stochastic method and assumes a point source. Here, SMSIM_TD is modified to run in the context of a PSHA deaggregation. Boore (2000) describes his program and input parameters, and gives several references to the methodology. We note that many modal-event magnitude, distance, or (M,R), pairs, especially for sites in the central and eastern U.S. (CEUS), but also for many sites in Alaska, the Pacific Northwest, and even parts of California, correspond to potential earthquakes for which no strong-motion records from similar historical earthquakes exist at COSMOS or other strong-motion data Web sites. Synthetic seismograms may be useful for filling gaps in empirical data.

At this web site you can now obtain six seismograms for the most likely (M,R) or for the mean (M,R) that is determined during the interactive seismic hazard deaggregation from your specific input parameters. To exercise this option, answer “Yes” to the question, “Do you want seismograms for the modal or mean event?” The result will be two files, one containing ASCII seismograms and parameter information, and the other containing pictures of those six records. The records are generated assuming an event (M,R) equal to the mean or modal pair for your site/spectral period/return time.

Synthetic Seismograms No Longer Scaled

At the 1996 deaggregation web site, each of the records was scaled to the ground motion [spectral acceleration (SA) or peak horizontal ground acceleration (PGA)] whose period and probability of exceedance (PE) were those that you requested in the interactive deaggregation menu. At the 2002 interactive deaggregation web site, we no longer scale the records. The records are selected, however, by trying to match the record's SA with the input probabilistic SA as much as possible. For example, if the probabilistic SA is 1.0 g, then records are selected that have SA near 1.0 g if these are available from the given suite of simulations. Some other selection criteria are discussed below. Anyone can and should scale the seismograms such that the scaled version has the spectral acceleration at the period of interest that is needed for his or her application.

This change from the 1996 approach allows you to look at the output of SMSIM_TD as if you yourself were generating the seismograms for a given magnitude, distance, and input file. Of course, the resulting amplitudes may vary considerably from probabilistic amplitudes, because the given distance, magnitude pair may not tend to generate motion corresponding to your probability of exceedance. Instead, the distance, magnitude pair tends to generate median motion plus variability for a given input file, discussed below. Median motion and probabilistic motion can be quite different.

Source, Path, and Site Effects

All of the parameters that are required by SMSIM_TD are reported in the header information which precedes the ASCII seismogram data. For sites in the CEUS, and for some sites in the WUS east of the Intermountain Seismic Belt, the deaggregation version of SMSIM_TD invokes the “Frankel” attenuation model and other parameters that were used to generate data for the 2002 national seismic hazard maps (Frankel *et al*, 2002).

For most sites in the western U.S., one of four source/propagation/site models is currently used. (Boore, 2000). For most WUS sites in non-extensional tectonic regions and (M,R) pairs having **M**<7.75 and R<100 km, the input parameters correspond to Boore’s coastal California input file For most WUS sites in extensional tectonic regions and (M,R) pairs having **M**<7.75 and R<100 km, the input parameters correspond to a modification of Boore’s coastal California input file. This modification uses a Basin-and-Range attenuation model and is discussed further in the "readme" link to this web page . For subduction events in Cascadia and Alaska, and for other Pacific Northwest and Alaska seismicity (latitude > 41^o N, longitude > 120^o W), we use parameters based on those reported in Atkinson and Boore (1997). For many other (M,R) pairs, the input parameters are those of the WUS point source, described by Atkinson and Silva (1997) and Atkinson and Boore (1998). The rule for using a CEUS attenuation model for certain sites in the WUS is that CEUS-catalog sources contribute more than 50% to the ground motion exceedances at that site, and the dominating (modal) event is not from a WUS fault. WUS faults occur west of the Rocky Mountain Front Range. The Cheraw fault in southeast Colorado is considered a CEUS fault, and CEUS attenuation models are currently associated with this source for hazard calculations and for synthetic seismogram generation.

Thus, some tectonic-regime specificity exists for parameters used to generate seismograms. Earthquakes associated with some seismo-tectonic regimes that we would like to model are not currently modeled. Earthquakes in volcanic source regions such as several parts of the island of Hawaii, and Coso and Long Valley Calderas in California are examples. Earthquakes in geothermal areas may also require localized source parameters.

Modeled site conditions for synthetic seismogram input files should approximately equal firm rock. In the CEUS, rock with average Vs=760 m/s in the upper 30 m is modeled, whereas in the WUS, the exact NEHRP site class is not specified. This web site does not model variable site conditions such as local soil amplification and attenuation.

Selecting Records for Publishing

We believe that the response spectra, $PSA(f)=\omega PSRV(f)$, of the seismograms that we publish should have a limited variability at frequencies of greatest engineering interest. A set of 60 seismograms is generated by SMSIM_TD, and each is scored by how closely its pseudo spectral acceleration (*SA* or *PSA*) at the specified wave period matches the probabilistic ground motion. Each score is also affected by how closely the response spectrum matches an approximate uniform hazard response spectrum, *U(f)*, over most of its domain. Scoring is explained in greater detail in the next paragraph.

U(f) is defined in Leyendecker *et al*. (2000) Here, we assume that *U(f)* has ordinates at 1.0 Hz and at 5.0 Hz equal to those of the Frankel *et al.* (2002) PSHA model. Call these ordinates *SA*1 and *SA*5, respectively. *SA*1 and *SA*5 correspond to the PE that you choose in your interactive seismic hazard deaggregation. Your choice may or may not equal the 2% in 50 year PE of the IBC-2000, discussed by Leyendecker *et al*. (2000). Because the accelerograms represent random motion, we cannot expect any given record's *PSA(f)* to closely approximate *U(f)*. We compute *PSA(f)* for those 60 seismograms and select the half dozen which most closely approximate *U(f)* in the 1 Hz to 5+ Hz (0.2- to 1.0 sec period) band, using an L_1 norm (least absolute percent deviation). That is, for j=1,2,3,…,60, we compute $S_j=\sum_i k_i \left|\log[PSA_j(t_i)/U(t_i)]\right|$ where

$t_i=1/f_i$ is sampled at 0.1-sec intervals in the 0.2 to1 sec period band, and at the short-period corner of $U(t)$, t_s, where $t_s=0.2\cdot SA1/SA5$.

k_i is 1 for frequencies other than the input frequency to the interactive deaggregation, and is 3 at the input frequency. In other words, the scoring algorithm weighs goodness-of-fit three times more heavily at the input frequency as at any other frequency. We sort S_j and publish the six records having the smallest *S*. Outside that period or frequency band, we do not attempt to fit *U(t)*. At the 2002 web site we no longer scale seismograms. Because of this, this attempt to fit *U(t)* purely by selection is no longer guaranteed to give a relatively good approximation to *U(t)*. Best fit is achieved in the cases where the probabilistic motion is not too far from median motion. This will occur if the modal epsilon or mean epsilon is close to zero. Close here means , epsilon-sub-0 is less than 0.5 or so in absolute value. In the output files, simulated accelerograms are labeled by their L_1 rank: A1 is the best fit, and A6 the 6^{th}-best fit. At this 2002 web site there is no "tweaking" of the data from SMSIM_TD, merely selection based on a criterion that we hope is helpful to structural engineers.

The above seismogram selection process based on spectral-ordinate matching only occurs if the user is calculating hazard for a non-zero spectral period.

If PGA (which is often plotted as 0.0-second period SA) is selected on the menu page, only six accelerograms are computed. If PGA is selected on the menu page, no effort is currently made at this web-site to fit *U(t)* for $t>0$. If you just want to look at some synthetic seismograms, but don't care about *U(t)*, select PGA for a faster run. If you consider PGA to be equivalent to a 0.01-sec SA, the stochastic seismograms' PGA appears to be consistent with *U(.01 s)*, i.e., we find no anomalous behavior of SA at very short periods. Boore (2000) shows close agreement between PSA from time domain simulations and that determined using random vibration theory at periods as short as 0.01 seconds.

Caveats

Please read the "stochastic seismogram" caveat section in the 1996 interactive deaggregation web site for a discussion of limitations of the stochastic seismogram method used here.

References

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