**UNCERTAINTIES IN SITE SPECIFIC RESPONSE ANALYSIS**

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**ABSTRACT**

Definition of the uniform hazard acceleration response spectrum on the ground surface has primary importance for performance-based design of structures and assessment of seismic vulnerabilities in urban environments. The approach requires a probabilistic local seismic hazard assessment, probabilistic definition of representative site profiles down to the engineering bedrock, and probabilistic 1D or 2D equivalent or nonlinear, total or effective stress site response analyses depending on the complexity and importance of the structures to be built. Thus, a site-specific response analysis starts with the probabilistic estimation of local seismicity and earthquake source and path characteristics that would yield probabilistic uniform hazard acceleration response spectrum on the engineering bedrock outcrop. Thus, site specific response analyses need to produce a probabilistic uniform hazard acceleration response spectrum on the ground surface.

The major uncertainties in site-specific response analysis arises from the variability of (a) local seismic hazard assessment, (b) selection and scaling of the hazard compatible input earthquake acceleration time histories, (c) soil stratification and corresponding engineering properties of encountered soil and rock layers, and (d) method of site response analysis.

The uncertainties related to local seismic hazard assessment, even though it has significant effect on the outcome of the site-specific response analyses, will not be considered in this study.

The second source of uncertainties are related to selection and scaling of the hazard compatible input earthquake acceleration time histories. One option is to select large number of acceleration records compatible with the local earthquake hazard in terms of fault mechanism, magnitude and distance range recorded on stiff site conditions to account for the variability in earthquake source and path effects. It was observed that if the number of selected acceleration records are in the range of 20-25, the calculated mean response spectrum is consistent with only minor changes with additional input records.

However, hazard compatibility with respect to magnitude and source to site distance ranges may also be considered as one source of variability. Bazzuro and Cornell (2004) observed that the match with engineering bedrock uniform hazard spectrum is more important than the hazard compatibility with respect to magnitude and source to site distance compatibility. It was observed that the importance of source to site distance compatibility varies with the adopted scaling procedure based on a parametric study conducted to observe the effects of source to site distance compatibility.

The other source of variability is the scaling procedure adopted to modify the selected earthquake acceleration records to match with the uniform hazard acceleration response spectrum calculated on the engineering bedrock outcrop. The scaling procedure may have three goals, (a) to obtain the best match with respect to rock outcrop target uniform hazard acceleration spectrum, (b) to match the target acceleration spectrum within the considered period range (c) to decrease the scatter in the acceleration spectra after scaling. Parametric studies were conducted to observe the effects of different scaling parameters and procedures.

The third source of uncertainty are site conditions with respect to soil stratification and engineering properties of soil layers. Site conditions may play an important role in modelling site response (Li and Assimaki, 2010). Thus, one option may be conducting site response analyses for large number of soil profiles for the investigated site to assess design acceleration spectra with respect to different performance levels. One may also consider using Monte Carlo Simulations to increase the number of soil profiles to account for the possible variability of site conditions.

The fourth source of uncertainty stems from the adopted method of site response analysis. There has been significant amount of work done related to the sources of variability and bias in site response analysis. Kaklamanos et al. (2013) conducted a detailed study based on the data obtained in the Kiban- Kyoshin network (KIK-net) to determine the critical parameters that contribute to the uncertainty in site response analysis. They observed that 1D equivalent-linear site-response method generally yields underprediction of ground motions, except in the range of 0.5-2s, where the bias is slightly negative. Relative to empirical site amplification factors, site specific ground response analyses offer a reduction in the total standard deviation at short spectral periods.

In general, site-specific response analyses are deterministic computations of site response given certain input parameters. The results of these calculations need to be merged with the probabilistically derived ground motion hazard for rock outcrop site conditions. Bazzurro and Cornell (2004) recommended a convolution method for combining a nonlinear site amplification function with a rock hazard curve to estimate a soil hazard curve. The principal advantage of this approach is that uncertainties in the site amplification function are directly incorporated into the analysis. Another more simplified approach may be to evaluate site response analyses results adopting a probabilistic interpretation.

Site-specific probabilistic ground-motion estimates should be based on the full site-amplification distribution instead of a single deterministic median value. A probabilistic methodology using site- amplification distributions to modify rock ground-motion attenuation relations into site specific relations prior to calculating seismic hazard need to be considered. The use of a completely probabilistic approach can make about a 10% difference in ground motion estimates over simply multiplying a bedrock probabilistic ground motion by a median site-amplification factor even larger differences at smaller probabilities of exceedance.

However, site response is considerably more complex including surface waves, basin effects (including focusing and basin edge-generated surface waves), and topographic effects. Thus, 1D site-specific response analyses may not always be effective for accurately modelling and/or predicting site effects, however, in comparison to alternatives of GMPEs and empirical amplification factors, site response analysis would model the probable surface uniform hazard spectrum more adequately.

**References**

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