Introducing site effects into PSHA in engineering context : Implementations, Challenges and Implications

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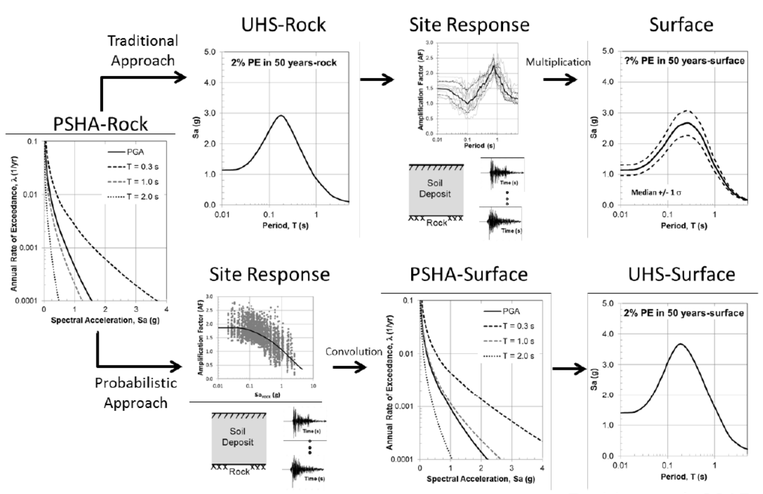
Summary

Incorporating site effects in hazard analysis using a probabilistic framework has been highlighted by numerous researchers. Partially non-ergodic PSHA is an increasingly well established method, further reinforced by the recent applications in the high impact engineering projects (ex: Hanford Sitewide PSHA in 2014)
This approach allows more:

- rigorous treatment of uncertainties;
- accurate representation of the seismic hazard at a specific site.

We explored the various methodology in each steps of the site effects assessment within PSHA, for their plausibility, challenges, and implications of their implementation for typical engineering purposes through a simple case study:

- Methodology for the development of amplification functions (mean, regressions and uncertainties);
- Hazard at surface: hybrid and/or convolution vs traditional approach.



Rathje et. al, 2015

The case Study : 1D SRA Non-linear Domain after PSHA at Reference Rock

Variabilities considered in the case study

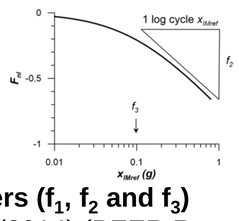
- ❑ Motions (SRA results from 7 of time histories (2 horizontal components) for multiple hazards (RP ➔ 475, 2475 and 4975 years).
- ❑ Soil profiles (e.g. lower bound, best estimate and upper bound of velocity Vs)

Possibility of full propagation of epistemic uncertainties on the soil profile
➔ not retained, but considered for further application

- Toro et. al (1992,95)
- Full propagation: PSRA (with logic tree)

Model for Non-linear Site Amplification Functions

$$\ln \overline{Y}(f) = f_1 + f_2 \ln\left(\frac{x_{IMref} + f_3}{f_3}\right)$$



Methods to compute model parameters (f_1, f_2 and f_3)
Procedure enlightened by Stewart et al.(2014) (PEER Report)

Retained methods of regression:

- ❑ f3 constrained (beginning of non linearity) : Implemented and preferred one
- ❑ Simultaneous inversion of f_1, f_2 and f_3 through non-linear model fitting (Seber et al.,2003)

Treatment of Amplification Functions with Rock Hazard

Deterministic

❑ Traditional Approach (Deterministic):
UHRS(Rock) x Mean AF = Surface Response spectrum (deterministic)

Probabilistic

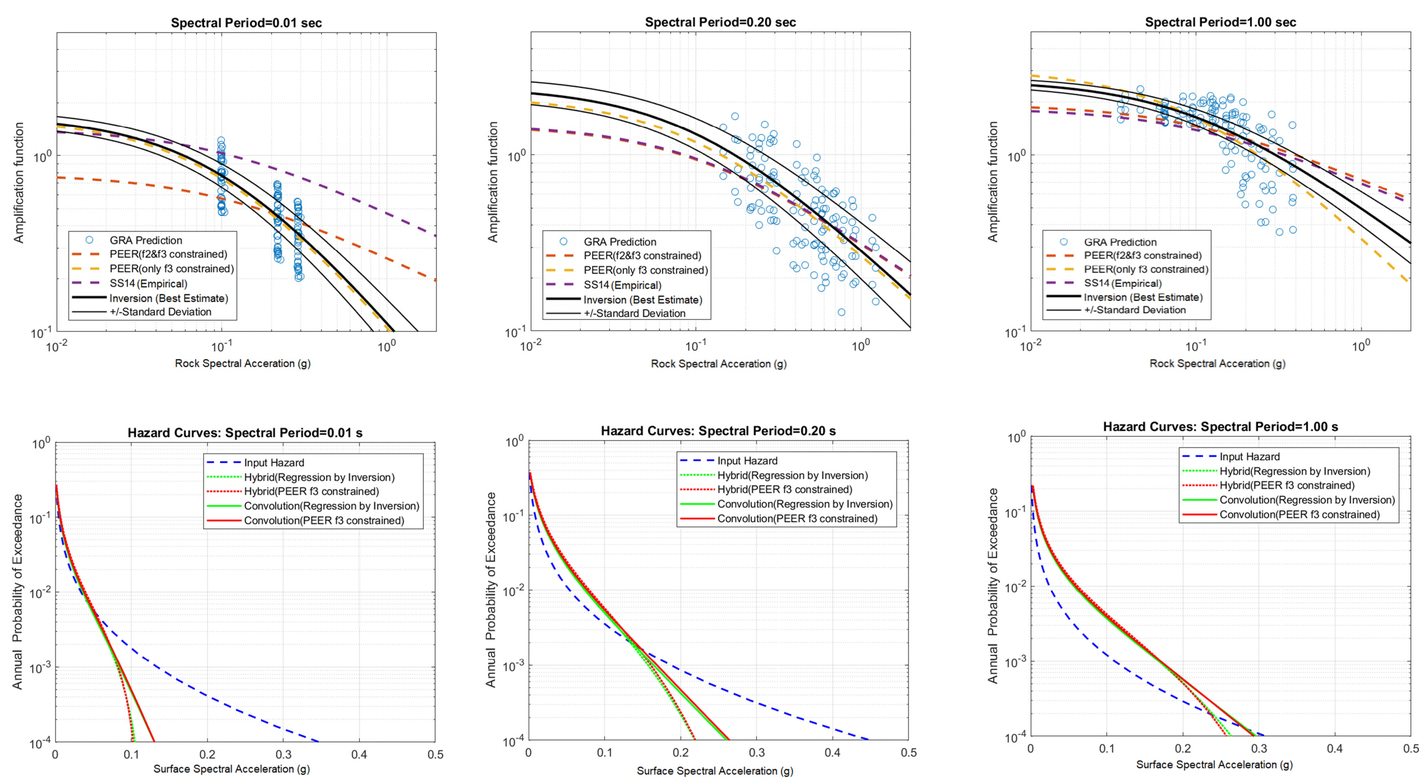
❑ Hybrid (Cramer,2003):
Rock hazard multiplied with mean amplification functions

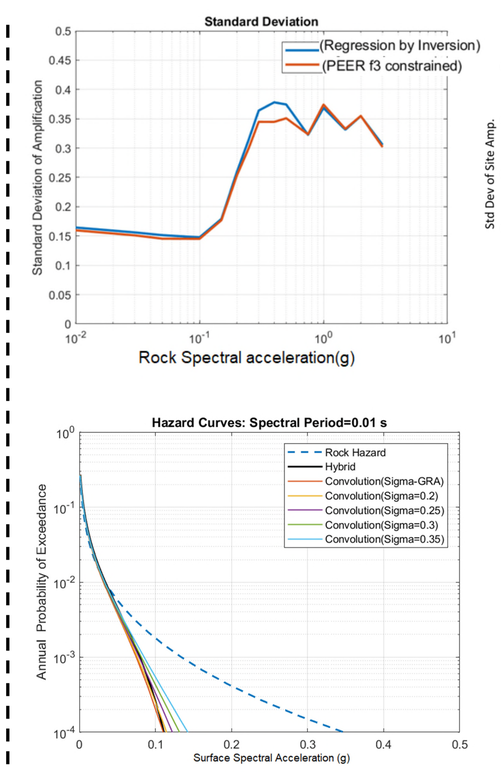
$$P:\ \ln(z) = \underbrace{\ln\left(\overline{Y}\,|\,x_{IMref}\right)}_{\text{Mean site amplification given x from hazard curve}} + \underbrace{\ln(x)}_{\text{Read from hazard curve}}$$

❑ Convolution (Bazzurro and Cornell, 2004) :
Rock hazard convolved with amplification functions taking into account the uncertainties in amplification functions.

$$P(Z > z) = \int_0^{\infty} P\left(Y > \frac{z}{x} \,|\, x_{IMref}\right) f_X(x)\,dx \qquad \lambda_s(z) = \sum_{x_j} P\left[AF > \frac{z}{x_j} \,|\, x_j\right] \cdot p_{Sa_r}(x_j)$$

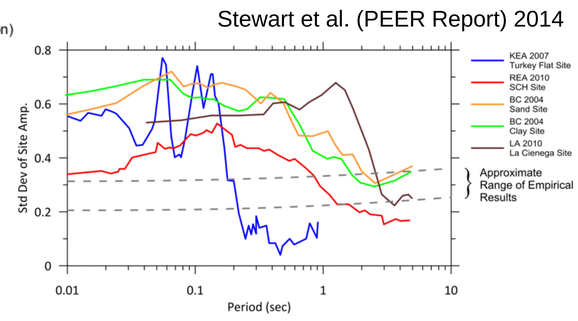
Implementation : Regression, surface hazard curves and Sigma





Sigma analysis and comparison with litterature :

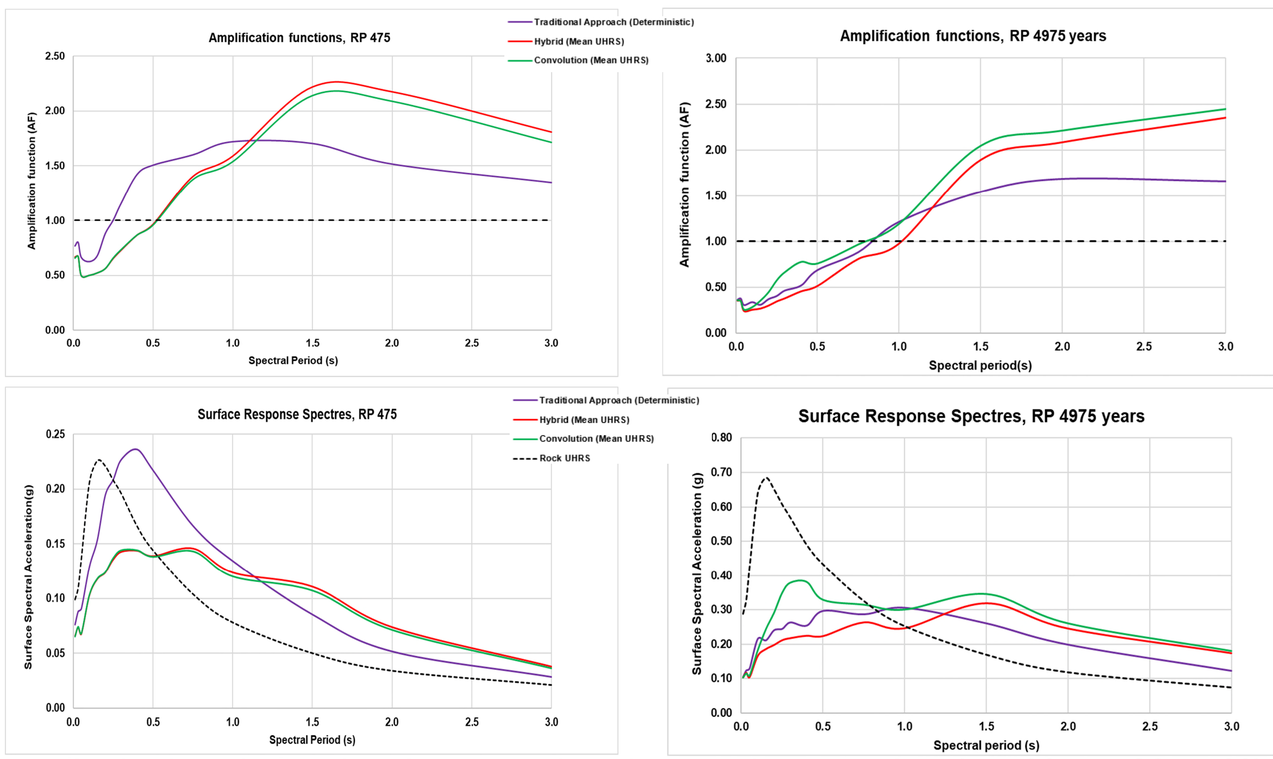
Stewart et al. (PEER Report) 2014



Extract from PEER Report (2014):

'Given the significant differences observed between simulation-based and data-based site amplification dispersion, and the apparent causes of the simulation results, we recommend avoiding the use of the simulation-based dispersion results. We recommend using 0.23 to 0.3 over the period range of 0 to 3.0 sec'

Analytical results



Application in typical engineering context based on classical regulations (ex: ICOLD, ASCE, EC8)
➔For convolution ⇔ σ of 0.3 considered (eg., upper bound from PEER recommendations);
➔yielded confidence to be systematically used in future PSHA.
The capability to capture the non-linear behaviour of the soil in PSHA with hybrid or/and convolution approaches are analyzed against the traditional approach. Significant differences are observed either in return periods and spectral periods considered ➔ Implications for the design are non-negligible.

Discussion and Implications

"**Partially non-ergodic PSHA allows component of site/site variability to be removed from GMPE, which has been referred to as single-station sigma**" (Atkinson, 2006).

➔ This case study doesn't include Single Station Sigma model and focused only on implementations of site effects assessments in PSHA.

➔ Implemented approaches allow the variability estimation of the site amplification:
⇔ entitled to remove the variability of the site/site term (Φ_{S2S}) on GMPEs
⇔ Futures investigations ➔ Implementing Stewart et al. (2017) approaches 1 and 2, depending on the needs on the PSHA project.

Discussion:
⇔ For typical engineering context, considering the lack of site specific data (e.g. weak and strong motions) ➔ Is Single Station Sigma model (Marek et al., 2013) appropriate ?
⇔ Nevertheless, can we consider that Hybrid approach is sufficient for typical engineering purposes instead of full convolution approach (more appropriate for NPP projects) ?

➔ Focus also on:
⇔ The impact on the deaggregation computed at the reference rock;
⇔ Taking into account the variability of the input motion considered for the SRA.