18TH WORLD CONFERENCE ON EARTHQUAKE ENGINEERING
WCEE2024
MILAN

MILAN, ITALY
30TH JUNE - 5TH JULY 2024
www.wcee2024.it

IMPLEMENTATION AND BENCHMARKING OF CS APPROACH(ES) FOR NUCLEAR SAFETY ASSESSMENTS

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Abstract: *In nuclear engineering, the UHS (Uniform Hazard Spectrum) is often used to define the target spectral content for ground motion selection and simulation. The UHS defines, for a given return period, the set of spectral acceleration values for the frequency range of interest for the engineer. Then, the Conditional Spectra (CS) approach allows for the decomposition of the UHS into a series of conditional scenario spectra. Following the pioneering work of Baker and Cornell, the conditional spectrum approach utilizes the correlations between spectral accelerations at different frequencies to compute, for a given conditioning PSA, and under the common assumption of a lognormal distribution, the mean response spectrum, and its standard deviation. Despite its advantages, it has not yet found large interest in the nuclear sector, partly due to increased computational burden, in particular when applied to complex structures, but also some understandable resistance to changes in regulation. This paper presents the project of a benchmark, to be launched in 2024 to assess different implementations techniques of the CS-approach, in particular in terms of feasibility and cost-benefit and to illustrate prospective application framework(s).*

1. Motivation and goals of the benchmark

In nuclear engineering, the UHS (Uniform Hazard Spectrum) is often used to define the target spectral content for ground motion selection and simulation. The UHS defines, for a given return period, the set of expected ground spectral acceleration values for the frequency range of interest for the engineer. The UHS is the envelope of spectra of real events and – as such – has a shape that can be hardly associated with an observed response spectrum.

The Conditional Spectra (CS) approach allows for the decomposition of the UHS into a conditional mean spectrum (CMS) and conditional standard deviation, which can be used to develop a series of conditional scenario spectra. Following the pioneering work of Baker and Cornell, the conditional mean spectrum matches the UHS at a given spectral frequency and then utilizes the correlations between spectral accelerations at different spectral frequencies to compute the expected spectral accelerations for the rest of the spectrum conditioned on the given spectral frequency. The conditional standard deviation of spectral accelerations

around the CMS are developed using these correlations, standard deviation in the ground motion model, and the common assumption of a lognormal distribution.

The CS approach is seeing increased recent use worldwide in performance-based earthquake engineering applications such as the risk assessment of critical infrastructures. Only a few pilot applications of this approach have been reported.

Despite its advantages, the CS, it has not yet found large interest in the nuclear sector, partly due to some major bottlenecks of the approach when applied to complex and highly robust structures and components, partly due to computational burden, and partly due to the highly regulated nature of the industry and understandable resistance to paradigm shifts in analytical methods. Though, the possible benefit for safety assessments in nuclear is two-fold:

- More realistic and coherent seismic load characterization (can use existing records without excessive scaling/matching)

- Demonstrate possible margins (using the UHS which as envelope over many load scenarios can be very conservative when considering multimodal, nonlinear structures)

We propose to conduct a benchmark study to compare different implementation techniques of the CS approach to assess technical sufficiency, feasibility, cost-benefit, illustration of application framework(s).

2. Work plan

The benchmark studies should encompass

- Standardizing the definition of conditional target spectra from PSHA results (UHS, disaggregation)
- Comparing record selection, simulation and fitting procedures, benchmarking to spectrum-compatible (simulated) ground motion
- Comparing/confirming hazard consistency of the CS at multiple spectral frequencies
- Assessing the number of records required to assure both hazard consistency and convergence of response quantities, and for sufficiency of the risk assessment.
- Characterizing the impact on simulated responses of prototypical Structures, Systems and Components (SSCs), their fragility, and risk assessment of a tabletop nuclear system model.

This benchmark project starting in 2024 obtains support from EURATOM METIS (https://metis-h2020.eu/) and SIGMA-3 research initiative.