PEER "Research Nuggets"

Title: Correlation of Ground Motion Duration with Spectral Acceleration and Implications for Expected Bridge Performance

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Motivation: Construction or detailed evaluation of transportation infrastructure requires site-specific ground motions (GM) for input into nonlinear structural models. These site-specific GMs are generally selected based on the magnitude, distance, and site condition of the recorded GM. A preliminary study performed by Slate Geotechnical Consultants found that duration and spectral acceleration are negatively correlated for large-magnitude earthquakes recorded on soft-soil sites (Vs30<360 m/s). This means that if the target spectral acceleration is above average, then the average duration associated with that GM should be below average for the scenario magnitude and distance. This GM duration discrepancy means that the current state of the practice may be overestimating the probability of damage for structures in some instances.

Objectives: This project aims to improve the characterization of GM duration correlation to intensity and evaluate how the improved characterization affects bridge fragilities used in the PBEE framework.

Methodology: The correlation between spectral duration and spectral acceleration was determined using a correlation coefficient (ρ_{os}) calculated using intra-event residuals from four NGA-West2 ground motion prediction equations and three duration prediction equations. The correlated mean duration for a hazard level is calculated using the equation: $\mu_{dur|Sa} = \mu_{dur} + \varepsilon\rho_{os}\sigma_{dur}$. Figure 1 shows the normalized correlation coefficient of 3 duration prediction equations calculated against structural period. It shows that the correlation tends to decrease with increasing natural period.

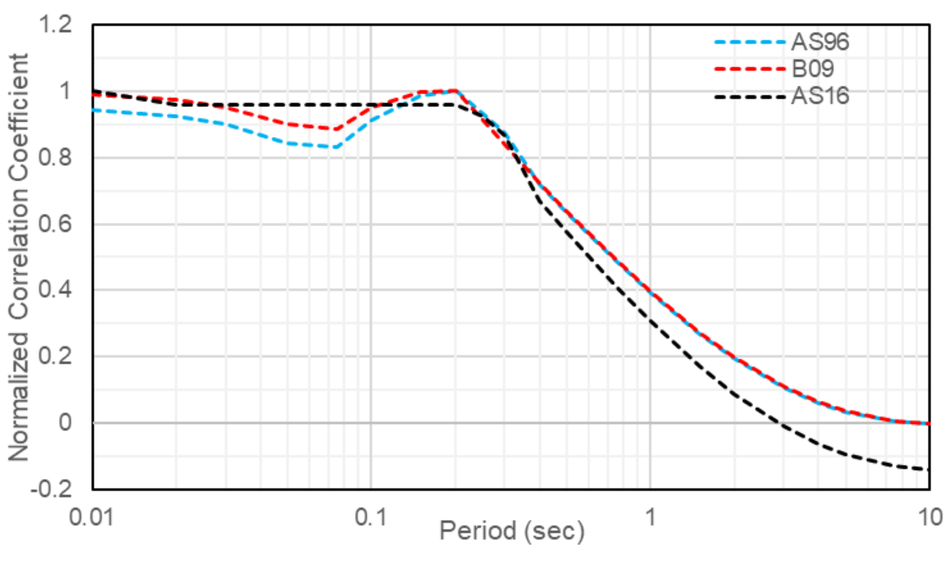
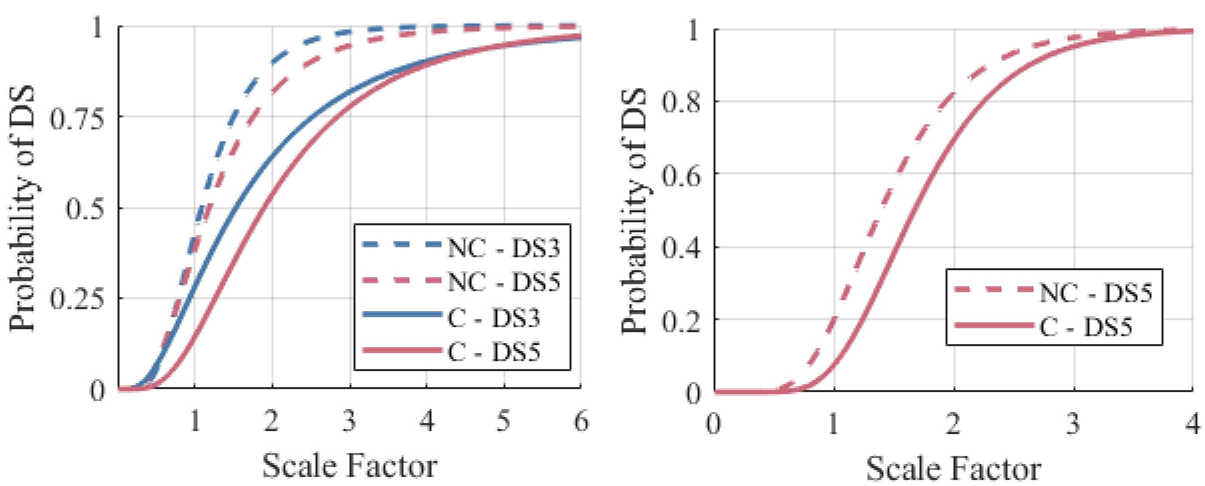


Figure 1. Comparison of three DPE smoothed correlation coefficients for D5-95%

Numerical models for two prototype structures, a major toll bridge and a typical highway overpass, are developed using OpenSees. The major bridge includes isolation bearings on top of 13 RC piers and has a total of 25 spans with a natural period of 1.5 seconds. The typical highway overpass is a two-span RC bridge with a single column bent. The bridge models were analyzed under an incremental dynamic analysis with 11 GMs at each hazard level. The seismic hazard analysis focused on the 2475-year return period. The GMs were scaled by factors of 1 to 4.5. Damage analysis used the pier drift and bearing shear strain as parameters. The pier damage was divided into two main damage states: moderate (DS-3) and major (DS-5) per Caltrans guidelines, and bearing damage was defined as 300% shear strain (DS-5) given the displacement at which there is no overlapping area in the bearing and bucking is expected.

Results: The fragility curves obtained for the major toll bridge and the typical highway overpass are presented in Figure 2. For both damage states, the mean probability of damage in the structure is lower for the GM's selected with a correlated duration (C) as compared to the typical analysis that overlooks this correlation (NC). This difference indicates an overestimation of the bridge's damage probability if ground motion duration is not considered in the hazard selection.



a) Major toll bridge b) Typical highway overpass

Figure 2. Damage fragility Curves under non-correlated and correlated ground motions.

Conclusions: The correlation coefficient between GM duration and intensity is related to the number of standard deviations from deterministic median ground motion (ε) and natural period. As such, both period and structural response influence the effects of incorporating ground motion duration correlation to hazard intensity. Examining the two case studies, this study shows a decrease in the median damage probability when duration correlation is considered. This report sheds light on the influence of ground motion duration on the structural damage expected of the two bridges considered. The findings contribute to more accurate performance predictions and inform decision-making for bridge performance analyses.

Keywords: bridge performance, damage probability, hazard intensity, ground motion duration.