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TRANSFORMING IDEAS INTO SOLUTIONS

Research Results

Uncertainty Quantification for Meeting Bridge Design Objectives

Evaluating bridge seismic response variability due to ground motion scaling methodologies.

Geotechnical/ Structures

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Project Title: Uncertainty Quantification for Meeting Bridge Design Objectives

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WHAT WAS THE NEED?

The selection of ground motions for time series analysis of structures remains a topic of considerable debate. While both time domain method and spectral matching are permitted by the the California Department of Transportation (Caltrans) Seismic Design Criteria (SDC), the implications of the choice are not fully understood.

WHAT WAS OUR GOAL?

The research aimed to determine whether the method of ground motion scaling directly affects the structural performance prediction, and if so, it would determine the most appropriate method for use in design of California bridges. The project would result in two bridge case studies comparing the results of amplitude and spectral matching scaling methodologies.

WHAT DID WE DO?

This project began with the development of ground motion suites tailored to the seismic profiles of two Caltrans-managed bridges: a toll road bridge and a highway overpass. Using the third version of the Uniform California Earthquake Rupture Forecast seismic model (UCERF3), site-specific spectra for a 975-year seismic event were created for each bridge. These spectra then guided the creation of up to ten suites of seven ground motions for each bridge, using both amplitude scaling and spectral matching techniques. These suites were compared against the Conditional Scenario Spectrum (CSS) methodology to provide a risk-based framework for evaluating engineering demand parameter (EDP) risks.

Next, two 3D nonlinear bridge models underwent detailed computational analyses to simulate the bridge responses under the generated ground motions. Key EDPs, such as peak pier drift and isolation displacement, were recorded,

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allowing for comparisons between the average EDPs produced by each suite and the established damage states defined by Caltrans. This data provided insights into the effectiveness of the different scaling methodologies.

In the later stages, the project assessed the uncertainties involved in seismic design, evaluating how uncertainties transfer from seismic hazard analysis through structural modeling. By comparing current practices with a more integrated approach that maintains the full distribution of uncertainty, predominant sources of variance were identified.

WHAT WAS THE OUTCOME?

The results demonstrate that the spectral matching methodology consistently yields lower bias and variability in EDP predictions compared to amplitude scaling for both bridge models and at both sites. Specifically, spectral matching produced means closer to the CSS benchmark and more consistent predictions of peak drift ratios across suites. This reduced variability across suites is especially important for practical applications, where engineers typically rely on a single suite of motions. The analysis shows that amplitude-scaled suites lead to more variable results, making final predictions more sensitive to the subjective selection of time series. In contrast, spectral matching shows much less dependence on the individual motions selected, offering more reproducible and reliable EDP estimates across users. These findings suggest that modern spectral matching techniques may offer an effective alternative in bridge design without the limitations traditionally associated with spectral matching.

WHAT IS THE BENEFIT?

This research will provide supports to Caltrans current Seismic Design Criteria practices for bridges, particularly in optimizing ground motion scaling methods. By comparing amplitude scaling and spectral matching techniques, this study will clarify their impacts on seismic response predictions, helping Caltrans make bridges safer and more resilient against earthquakes.

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