0-6916: Seismic Vulnerability and Post-Event Actions

Background

Historically, seismic hazards have not been a major concern in the design and maintenance of bridges in the State of Texas due to the infrequency and low magnitudes of seismic events experienced in the state. A recent increase in the number earthquakes across Texas and the larger magnitude earthquakes that have occurred recently in nearby states has raised concerns over the seismic vulnerability of the Texas's bridge inventory and the need for a plan of action for immediate post-earthquake response by TxDOT officials. To address these concerns, the research team developed tools to better quantify (1) the seismic hazards in the State of Texas and (2) the seismic vulnerability, or fragility, of the Texas bridge inventory. From the bridge fragility functions developed in this project, a post-earthquake action plan was proposed to identify bridges requiring inspection based on their likelihood of experiencing damage in a certain earthquake event.

What the Researchers Did

The research team, comprising civil engineers with specializations in geotechnical and structural engineering, as well as seismologists and geologists, conducted a literature review; conducted in-situ field measurements of V_{s30} at 29 sites in Texas, mostly in the Dallas-Fort Worth region; validated proxy methods to estimate V_{s30} values across the state; developed deterministic hazard maps for earthquake scenarios in Texas; compiled a suite of ground motions representative of Texas seismicity; characterized TxDOT's bridge inventory to develop a series of statistically representative bridge samples for various types of bridges; created nonlinear computational models of bridge samples for use in seismic analyses; developed fragility curves to predict the probability of exceeding various levels of damage at a given level of ground shaking intensity. This work was used to propose a plan of action for TxDOT officials to identify the bridges requiring inspection or some other action after an earthquake event.

What They Found

From this project, the researchers found that:

- P-wave seismogram and geology-based proxy methods can be used with a certain degree of confidence to estimate values of V_{s30} where in-situ measurements are not available.
- Ground motion prediction models, updated to be representative of ground motions in the Texas region, along with updated V_{s30} maps were be used to generate deterministic seismic hazard maps for earthquake scenarios Texas. For Magnitude 5 scenarios in the Dallas-Fort Worth and El Paso regions, peak ground accelerations (PGAs) in the vicinity of the epicenter were between 0.42 g and 0.50 g; whereas

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PGAs for Magnitude 6 events in the same areas ranged from 0.54 g to 0.63 g.

- Analysis of the TxDOT bridge inventory indicated that steel bearings are typical for steel girder bridges in Texas based on the age of construction of this bridge type, whereas prestressed girder bridges are expected to have elastomeric bearings. Multi-column bridge bents with drilled shaft or concrete piling foundations are most common for the bridge classes considered in this study. This information, along with detailed analysis of the bridge inventory and as-built drawings from TxDOT bridges, provided the basis for the bridge modeling assumptions made in the study.
- Bearings are generally the component of a bridge most vulnerable to damage during a seismic event, followed by reinforced concrete columns. Abutments are significantly less likely to experience damage than the aforementioned bridge components.
- Based on the fragility curves developed in this project, multi-span simply-supported and continuous steel girder bridges are the most vulnerable bridge types considered in this study. Prestressed concrete girder bridges are expected to have slightly better seismic performance compared to steel girder bridges. This observation is attributed to the fact that the elastomeric bearings used in prestressed girder bridges are believed to exhibit better seismic performance compared to the steel bearings common in steel girder bridges.

What This Means

The fragility curves produced in this project can be used to determine the level of ground shaking intensity that requires some action to be taken. For example, TxDOT officials can decide that inspection is required when a bridge has a certain likelihood of experiencing "slight" damage. This likelihood of damage can be correlated to a ground shaking intensity (e.g., peak ground acceleration) threshold for each bridge class via the developed fragility curves. Following a seismic event, TxDOT officials can use ShakeMaps produced by USGS to identify the areas with ground shaking exceeding this threshold, and ultimately the bridges that require inspection or some other action. An example implementation of this post-earthquake response plan was provided in the project report for one earthquake scenario and two different assumed "thresholds for action." To facilitate implementation of the proposed action plan, the research team recommends that the results of this project be integrated into an application such as the USGS ShakeCast. Once the results are implemented, this software can automate the post-event action plan process of identifying bridges requiring action, using the refined V_{s30} maps and the Texas-specific bridge fragility curves to better estimate levels of shaking and the likelihood of damage across the state.

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