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Novel Method for Probabilistic Evaluation of the Post-Earthquake Functionality of a Bridge

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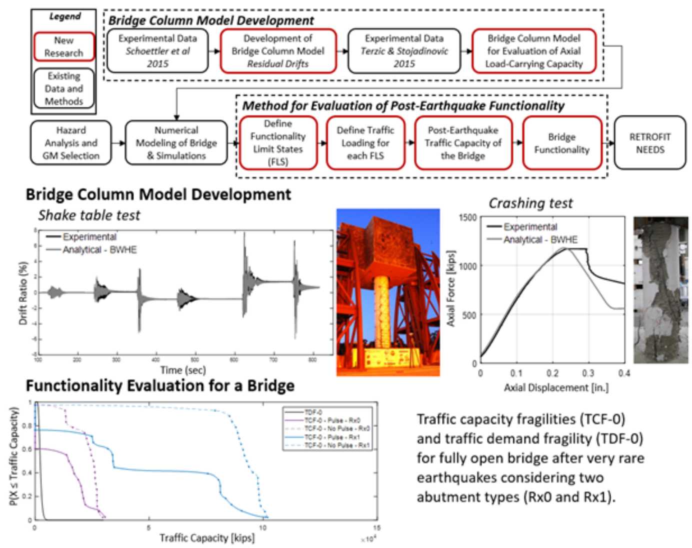
California has more than a 99% chance of having one or more earthquakes of magnitude 6.7 or larger within the next 30 years; such an event will generate significant economic losses and cause major societal disruptions. Furthermore, the likelihood of one or more mega-earthquakes of magnitude 8 or larger occurring within the next 30 years is 7%. A mega-earthquake will generate an economic loss of more than $200 billion, as well as about 1,800 deaths, and it will affect the lives of close to 38 million people. Damage to overpass bridges, which play a critical role within the highway network and overall transportation system, will contribute significantly to the economic losses and societal disruptions.

In California, modern highway bridges designed using the Caltrans Seismic Design Criteria are expected to maintain bridge integrity and provide safety in case of a design-level earthquake. However, their functionality will likely be compromised in case of a design-level (or beyond-design-level) earthquake that generates excessive residual drifts. There currently exists no validated, quantitative approach for estimating the functionality level of a bridge after an earthquake due to the difficulty of accurately simulating the residual drifts of the bridge columns. Given the lack of validated quantitative guidelines for estimating the post-earthquake functionality of the bridge, bridge inspectors and maintenance engineers can provide an estimate of the capacity of the bridge to function based on qualitative observations, with each judgment founded on personal experience. But an objective evaluation of the capacity of a bridge to carry self-weight and traffic loads after an earthquake is essential for a safe and timely bridge reopening. Hence, the goal of this research is to develop a novel method for probabilistic evaluation of the post-earthquake functionality of the bridge founded on an explicit evaluation of residual drifts and associated traffic capacity considering realistic traffic load scenarios.

Study Methods

To meet the goals of the research, the study first uses existing experimental data to develop and calibrate a finite-element model of a bridge column that accurately evaluates its post-earthquake residual drift and axial load-carrying capacity. Subsequently, the research proposes a method for direct evaluation of the post-earthquake functionality of a reinforced concrete highway overpass bridge through finite-element simulations. The method includes a definition of the functionality limit states for the bridge (full traffic, limited traffic, emergency vehicles only, no traffic), the recommendations for modeling a bridge structure by incorporating the proposed bridge column model, a definition of realistic traffic load scenarios that correspond to different traffic load restrictions, and finally, evaluation of post-earthquake functionality through comparison of traffic capacity with traffic demand.



Proposing a novel method for objectively evaluating the bridge's capacity to function after an earthquake, which is essential for a safe and timely reopening of the bridge.

Findings

The major findings of the research are the following: (1) nonlinear beam with hinge elements, implemented into the computational platform OpenSees, can be used to accurately predict a column's post-earthquake residual drift and axial load-carrying capacity; and (2) the objective evaluation of the post-earthquake bridge functionality (as proposed in this study) may be used in place of current practices to improve public safety and minimize economic impacts caused by unnecessary bridge closures.

Policy/Practice Recommendations

Information on the post-earthquake functionality of overpass bridges can be effectively used to support bridge maintenance decision-making process by enabling an identification of retrofit needs that will generate long-term benefits to transportation agencies through reduced business interruptions.

About the Principal Investigator

Vesna Terzic is an Associate Professor at the Department of Civil Engineering and Construction Engineering Management, California State University, Long Beach. Dr. Terzic's expertise includes the development of advanced models and tools for seismic performance assessment and resilience evaluation of civil infrastructure. She is a recipient of the prestigious ACI Chester Paul Siess Award for Excellence in Structural Research.

To Learn More

For more details about the study, download the full report at **transweb.sjsu.edu/research/1916**