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CALTRANS DIVISION OF RESEARCH, INNOVATION AND SYSTEM INFORMATION

TRANSFORMING IDEAS INTO SOLUTIONS

Research Results

Evaluation of Seismic Design for Temporary Structures

Bridge research to develop guidelines for seismic loading on the design of temporary bridges.

Geotechnical/ Structures

June 2025

Project Title: Evaluation of Seismic Design for Temporary Structures

Task Number: 3945

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WHAT WAS THE NEED?

Caltrans commonly constructs temporary bridges that have an expected lifespan of less than 5 years. Currently, seismic loading for temporary structures is based on a uniform hazard spectrum consistent with a 10% probability of exceedance in 10 years (100 years return period). This criterion was established to correspond to an approximate 0.2 PGA load level, the minimum design level before Caltrans adopted probabilistic-based specification of seismic demand. While the approximate 0.2g PGA target seems reasonable, it is rather arbitrary. In recent years, the ability to quantitatively assess bridge performance risk has advanced. Reassessment of our current seismic loading policy for temporary bridges is needed to advance Caltrans reliability and cost efficiency goals. There is a clear need to evaluate the relative risks and costs associated with alternative design hazard levels and provide recommendations for relevant seismic hazard levels for temporary bridge design.

WHAT WAS OUR GOAL?

The primary goal of this project is to evaluate the performance of temporary bridge design under different seismic hazard levels using nonlinear time-history (NLTH) simulations of prototype bridge models. Develop quantitative bridge performance for risk assessment and provide recommendations on future temporary bridge design.

WHAT DID WE DO?

Through the PEER-Bridge Program, Caltrans contracted with Professor Floriana Petrone at University of Nevada, Reno and Professor Sashi Kunnath at University of California, Davis to evaluate temporary bridge performance levels and the

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corresponding risk for selected representative prototype bridges under the study. The project aimed to provide recommendation on hazard level for future design. Representative prototype bridges were selected for study on 4 locations (Sacramento, San Francisco Bay Area, San Luis Obispo, and Los Angeles). The project developed nonlinear numerical modeling procedures and systematic probabilistic-based analysis to assess bridge seismic performance. This project also investigated the selection of alternative hazard levels for design.

WHAT WAS THE OUTCOME?

This study carried out fragility and risk analyses across a range of hazard levels, bridge life spans, and locations of different seismicity in California to provide recommendations to achieve a performance-based and hazard-consistent design for temporary bridges.

Bridges systems with lightweight superstructures are first designed for three hazard levels corresponding to 50, 100, and 200-year return periods at four sites in California based on the site-specific seismic demands obtained from the U.S. Geological Survey maps and the Caltrans Seismic Design Criteria without meeting the AASHTO minimum reinforcement requirements. The sites include San Francisco, Los Angeles, San Luis Obispo, and Sacramento. Fragility and risk calculations are carried out to assess the attainment of a set of damage states currently adopted by Caltrans. Results demonstrate that a hazard-based design can ensure satisfactory performance with damage limited to minor concrete cover spalling to large concrete cover spalling and extensive flexural cracks, even when the design minimum requirements for ordinary bridges are not met.

In addition, a baseline bridge model meeting the AASHTO (2020) and Caltrans (2019) minimum reinforcement requirements was used to identify the level of hazard resulting in Life Safety performance level, herein defined as the initiation of concrete core damage and longitudinal bar bucking. It was established that if a 200-year return period is targeted as the design return period for temporary bridges, the performance of the 'minimum design' bridge across the considered locations is satisfactory, with a probability of exceeding extensive flexural cracks and relatively large concrete cover spalling that substantially decreases for the locations with lower seismic hazard. Finally, an explicit comparison of the seismic risk for the bridges designed for 100 and 200-year return periods was carried out, showing that the risk is slightly affected by the change in the design return period from 100 to 200 years, thereby confirming the adequacy of the current recommendation of 100 years as the target return period when minimum design requirements are relaxed.

WHAT IS THE BENEFIT?

Bridges play a critical role in our transportation system in enhancing California mobility and economy. While the expected lifespan of temporary bridge is no more than five (5) years, with California's high seismic demands in many areas, the significance of temporary bridge performance cannot be overlooked. Although Caltrans' current design guidelines proposed simplified method on the design of temporary bridge, a more in-depth assessment is warranted to quantitatively measure the potential damages and associated risk on existing design methodology. Evaluating different hazard levels and corresponding performance will ultimately ensure reliability in the performance-based design of temporary bridge. The recommendations developed from this project will allow Caltrans to achieve consistency in design-basis performance assessment and also provide economically feasible options to our stakeholders on temporary bridge design.

IMAGES

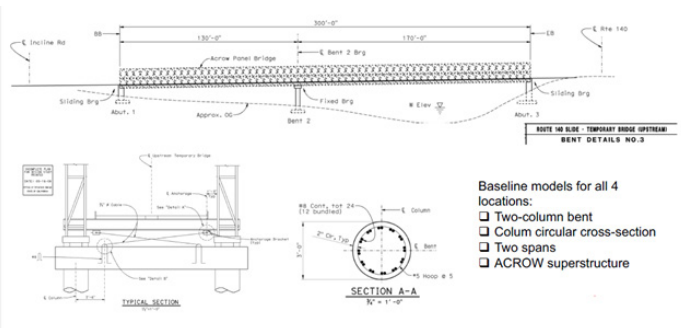

Image 1: Baseline model with ACROW superstructure (Curtesy of UNR/UCD research team)

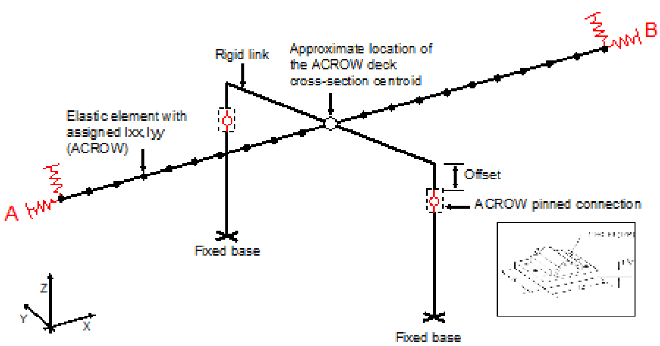

Image 2: Modeling approach in OpenSees (Curtesy of UNR/UCD research team)

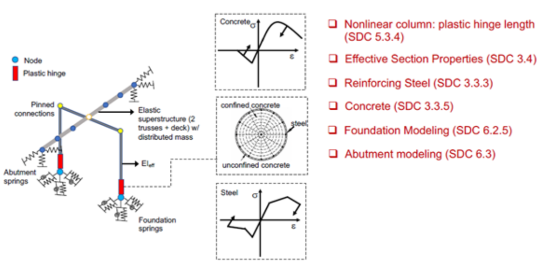

Image 3: Modeling approach in OpenSees (Curtesy of UNR/UCD research team)