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Research Notes

A Comprehensive Set of Testing Protocols for Buckling-Restrained Braces Applied to Bridges

Development of a set of prequalifying buckling-retrained braces loading protocols for conventional bridge structures at risk to both near and far-field earthquakes.

Geotechnical/ Structures

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Development of test protocols and design guidance for for buckling-restrained braces

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WHAT IS THE NEED?

Buckling-restrained braces (BRBs) have recently become popular as a ductile seismic force-resisting element in building structure. Their rise in use is due in part to a comprehensive guide to the design of BRB frames and a substantiated set of prequalifying testing criteria for BRBs, provided in the AISC Seismic Provisions for Structural Steel Buildings (AISC 2010). The testing criteria includes physical testing of BRBs to a loading protocol that was developed using brace demands obtained from various braced frame buildings. Even though BRB have been utilized on a few long-span bridges in Japan and one in the U.S., there is no established design procedure for use on bridge.

The upcoming 2nd edition of the Caltrans Seismic Design Specifications for Steel Bridges (Caltrans SDS) contains the first set of guidelines on the use of BRBs on bridges in the U.S. However, this protocol is conservative since it represent the 84th percentile demand from a suite of near-fault ground motions scaled to one design spectrum applied to only one long span suspension bridge. Therefore, it represents a narrow range of earthquake intensities and is most likely unreasonably conservative for other types of less flexible bridges (i.e., having less displacement demands) and certainly too conservative for any which are not located near a major fault line. Therefore, an expanded effort is required to develop a set of bridge-BRB prequalifying loading protocols that more appropriately cover a number of different bridge structures, brace schemes, and seismic demands (i.e., design-level and maximum considered events).

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WHAT ARE WE DOING?

In order for the protocols to be relevant, several bridge structures that represent a majority of "typical" or conventional bridges must be identified. The intent is to include both steel and reinforced concrete bridge construction types. Various potentially advantageous buckling-restrained brace (BRB) configurations will be identified for all considered bridge structures. These bridges will be designed and parameterized so as to cover a wide variety of structures for statistical relevance. Finite element models of these bridges will then be developed. All bridge models will be modified accordingly to facilitate the proposed BRB configurations.

A basic parametric study for each bridge type will identify the BRB specifications that provide a satisfactory seismic response. This substitutes a non-existent established design procedure. A range of near- and far-field ground motions will be selected and scaled to the appropriate response spectra to represent design-level and maximum-considered intensities. Models will be subjected to simulated shaking and BRB demands will be collected and organized to formulate statistically representative component loading protocols for prequalification testing purposes.

WHAT IS OUR GOAL?

Working together with Caltrans engineers, the Caltrans Guide Specifications for Seismic Design of Steel Bridges will be updated to reflect the requirements of the new BRB loading protocols for their corresponding steel bridge types. If pursed, the corresponding Caltrans concrete bridge specifications will also be updated. These specifications will then reflect the developed protocols and required testing for BRB implementation on bridges.

WHAT IS THE BENEFIT?

Most bridges in California are of a conventional structure, unlike a suspension bridge for which the previous protocol was developed. Therefore, this work will provide a detailed study of the requirements and specific seismic response benefits of BRB on conventional bridge structures (such as steel truss or plate girder). The ductile energy dissipation and force fuse properties of BRB, either through retrofit or new construction practices, will provide increased protection to the surrounding bridge elements decreasing seismic damage. Reduced longitudinal bridge span displacements, provided by BRB, will also be considered which will decrease the likelihood of span unseating during large seismic shaking.

Finally, this study represents the type of groundwork necessary to advance bridge design practice towards the increased use of energy dissipation elements on standard bridges. In the absence of standardized and statistically relevant demand information, implementation of these devices and components is difficult without undergoing a relatively extensive nonlinear time history study for each bridge project. This is a large impediment for typical bridge structures designed and built within tight budget constraints. Therefore, a comprehensive set of BRB loading protocols will facilitate their use and increase the safety of the state's bridges.

WHAT IS THE PROGRESS TO DATE?

None, pending start of this task

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