DRISI
Caltrans Division of Research, Innovation and System Information

Research Results

Seismic

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Project Title:
Development of a Rational Design Method for Shear Keys at In-Span Hinges in Multi-Frame Highway Bridges

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Improving Shear Key Performance in Multi-Frame Bridges

Proposed method lowers construction costs of multi-frame bridges while increasing their seismic safety

WHAT IS THE NEED?

Long, concrete box-girder highway bridges are often constructed as multiple frames that are separated by in-span hinges in their superstructure. This multi-frame bridge system, widely used for long bridges in California, simplifies construction by facilitating post-tensioning of the bridge superstructure and lowering the effects of creep deformation in long bridges. It also allows for longitudinal thermal expansion and contraction. When designing multi-frame bridges, the adjacent frames are connected with shear key members placed in in-span hinges to preserve the integrity of the entire bridge during a seismic event. Caltrans has standardized a shear key detail—a pipe/cable shear key—that performs both as a transverse shear key and longitudinal restrainer. However, the capacity and stiffness of this detail had not been fully investigated. A method to ensure a safe and cost-effective design of shear key elements in multi-frame bridges was needed.

WHAT WAS OUR GOAL?

The goal was to better understand the seismic response of multi-frame bridges in the transverse direction and develop a rational, data-driven, and simple design method for in-span shear keys.

WHAT DID WE DO?

Caltrans, in partnership with the University of Connecticut Department of Civil and Environmental Engineering, conducted approximately 7,700 nonlinear response history analyses on high-fidelity models of a large set of prototype bridges using OpenSees simulation software. The team reviewed 52 two-, three-, four-, and five-frame bridges with single, extended pile-shaft and two-column bents. The researchers designed the prototype bridges in accordance to the Caltrans Seismic Design Criteria v1.7. They generated a suite of ground motions representing the design acceleration response spectrums used for nonlinear time history analyses. The large dataset from these analyses was processed, summarized, and interpreted to identify trends and correlations. To study the force-deformation relationship of the pipe/cable shear key detail, the researchers developed a refined 3D finite-element model and validated it using the data from experiments previously performed at the University of Nevada, Reno.

WHAT WAS THE OUTCOME?

The results provide a better understanding of the complex seismic response of multi-frame bridges and proposed a methodology for estimating seismic demands on shear keys. The study also produced reference values for the capacity of steel pipe shear keys. The analyses demonstrated that the pipe shear key detail is very ductile under lateral loading and maintains resistance under large transverse displacements. The lateral capacity and stiffness of the pipe shear key varies with the size of the longitudinal gap. Cyclic loading can significantly reduce the element's lateral stiffness. The effect of variation of tensile forces in cable restrainers on the lateral resistance is negligible.

WHAT IS THE BENEFIT?

Because of a lack of data, bridge designers have taken a conservative approach when designing in-span shear keys, adding to construction costs and construction complexities, and in many cases, limiting the application of the multi-frame bridge system despite its major benefits. The study enhances the current design practice for bridge columns, superstructures, and in-span hinges of multi-frame bridges. The proposed method lowers the overall cost of construction by eliminating some design uncertainties while increasing the seismic safety of multi-frame bridges.

LEARN MORE

To view the reports for the entire study:
www.dot.ca.gov/newtech/researchreports/reports/2014/CA15-2424_FinalReport_Part_1.pdf

www.dot.ca.gov/newtech/researchreports/reports/2014/CA14-2424_FinalReport_Part_2.pdf

IMAGES

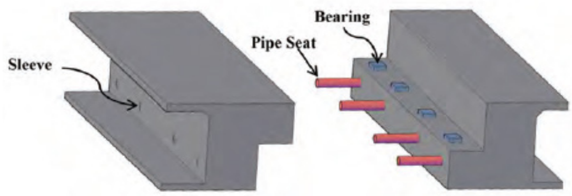

Figure 1: Pipe seat extenders in a typical in-span hinge

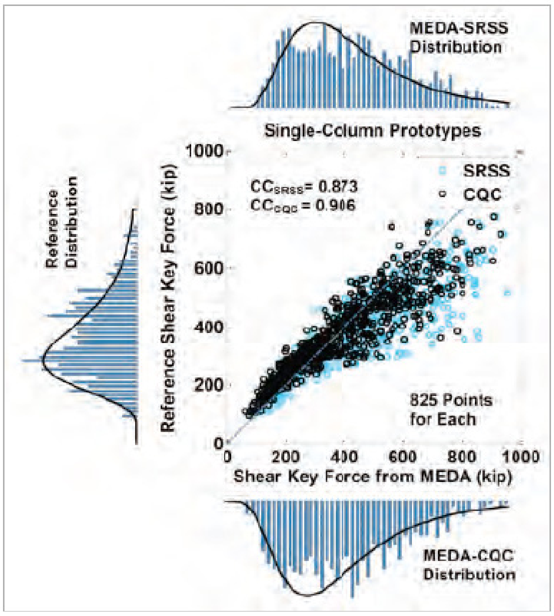

Figure 2: Comparison of the estimated shear key forces from the proposed method with reference forces from analyses (left, single-column bridges; right, two-column bridges)