DRISI
Caltrans Division of Research, Innovation and System Information

Research Results

Analytical Investigation of Replaceable Structural Fuses for Bridges

Structural fuses dissipate seismic energy while maintaining the integrity of other key bridge elements

Seismic

JANUARY 2014

Project Title:
Resilient Bridges: Replaceable Structural Fuses for Post-Earthquake Accelerated Service, Phase I: Analytical Investigation

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WHAT IS THE NEED?

Existing seismic bridge design procedures for columns focus on maintaining sufficient ductile response to provide lateral load resistance and prevent bridge collapse in the event of an earthquake. However, even when the bridge remains standing after an earthquake, damage due to inelastic deformation sustained during the earthquake can be severe enough to compromise the structural integrity of the columns. While well-detailed, ductile-reinforced concrete columns are expected to perform well, when there is damage, repairs are labor intensive, expensive, and time consuming, sometimes requiring lengthy bridge closures. Developing a structural fuse system that uses accelerated bridge construction pier concepts can expedite bridge repairs, reduce closures, and limit the disturbance to local residents.

WHAT WAS OUR GOAL?

The goal was to investigate the feasibility of using replaceable structural fuses as part of the bridge substructure to dissipate the seismic energy without compromising column safety.

WHAT DID WE DO?

To study the feasibility of using structural fuses, Caltrans, in partnership with researchers at the University of Buffalo, compared various types of structural fuses, including buckling-restrained braces (BRB), steel plate shear walls, and triangular-added damping and stiffness devices. They found that the BRB provided the most practical and economical solution as a structural fuse. The BRB can effectively dissipate seismic energy while keeping bridge columns intact. A typical BRB consists of a slender steel core supported by a concrete casing to prevent buckling under axial compression.

Initially, the researchers conducted simple static pushover analyses using fundamental capacity design principles to investigate seismic demands on the columns for two proposed bridge bent (pier) configurations: a two-concrete-filled tube column and a box-pier column. Comparison of theoretical and actual pushover curves in both cases showed good results, indicating that bridge bent behavior was consistent with the data predicted by the structural fuse concept.

To further validate this concept analytically, the research team conducted more complicated nonlinear time history analyses to verify the behavior of the bridge bents, comparing those results to the response predicted by the design procedure, elastic response spectrum, and pushover analysis. They sized the BRBs to meet the structural fuse objectives for managing seismic lateral loads for the proposed bridges, formulated design installation procedures, and developed proposed design specifications for connecting the BRBs to other structural members of the concrete bridge bents.

WHAT WAS THE OUTCOME?

Structural fuses that use BRBs offered the most practical solution with the widest range of applications. Structural fuse systems effectively dissipate energy in select structural elements, separate from the gravity-load-resisting columns, so damage is limited to the sacrificial structural fuses, and the columns remain elastic and intact.

WHAT IS THE BENEFIT?

Recent earthquakes have shown the vulnerability of bridges to seismic events and the price of bridge failures as a function of costly repairs, traffic delays, and public safety. The analytical results show that installing structural fuses with BRBs in bridge bents add a protective element to bridge columns experiencing seismic events. Because structural fuses are disposable and easily replaced, they provide an economical, low-maintenance solution to protect bridge substructures.

LEARN MORE

To view the complete report:
www.dot.ca.gov/research/researchreports/reports/2013/final_report_task_2296.pdf

IMAGES

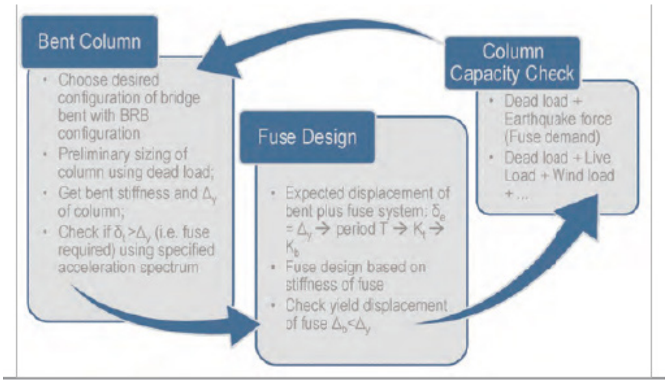

Figure 1: Design flowchart of bridge bent with buckling-restrained braces

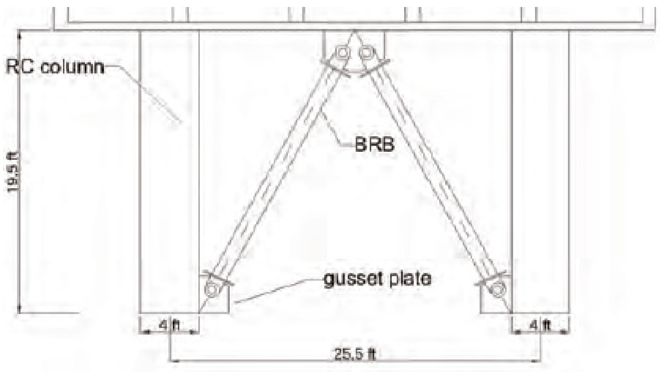

Figure 2: Transverse bridge bent with inverted-V BRBs