Seismic Retrofit of Bridge Steel Truss Piers Using a Controlled Rocking Approach
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ABSTRACT

The steel-concrete connection at the foundation interface of steel truss bridge piers has been shown through simple analysis to be inadequate to resist seismic demands. This connection, having little to no ductility, may potentially be the weak link in the seismic load path. A picture of a typical anchorage connection is shown in Figure 1. While strengthening the existing connection to resist seismic demands economically is an option, this could also increase the demand on other, possibly vulnerable, members. Allowing failure or releasing the anchorage connection may allow a rocking bridge pier system to develop that can effectively isolate the superstructure. The proposed retrofit solution presented here uses a rocking system with added passive energy dissipation devices to control the rocking response while forcing damage into easily replaceable, ductile structural "fuses". The system has an inherent restoring force with a possible re-centering capability to limit or prevent residual displacements after an earthquake. A sketch of a retrofitted tower is shown in Figure 2. The retrofit strategy attempts to capacity protect all existing structural elements thus allowing the bridge to remain in service after a seismic event.

BACKGROUND

The performance of existing steel bridges in past earthquakes has found certain details to be potentially vulnerable. These include the steel columns, joints and connections, steel tower bents, and steel superstructures. From an ultimate design standpoint steel bridges have performed well but significant damage in members and especially connections has been seen, leaving structures out of service until costly repairing can be done. This is unacceptable performance especially for bridges deemed critical for the response and recovery efforts following an earthquake.

A literature review revealed that the rocking bridge pier concept has been implemented into a few bridges including the Lions Gate Bridge (north approach) in Vancouver and the South Rangitikei Rail Bridge in New Zealand. Both use a steel yielding device at the foundation interface to dissipate energy.

OBJECTIVES

- To assess performance of existing steel/concrete anchorage details
- To produce a retrofit strategy that protects existing bridge elements and limits or requires no strengthening of the foundation
- To verify that the retrofitted structure meets the performance objectives

METHODS

This research investigates the dynamic characteristics of the above proposed rocking/energy dissipation system including development of a design method for the energy dissipation devices. An axial tension/compression yielding brace (often called an "buckling-restrained brace") is selected as the energy dissipating "fuse" in this application. Testing has shown the brace able to withstand repeated cycling at high levels of axial strain (2.5-3.0%) (Iwata et. al., 2000). A capacity design procedure is used and constraints are identified to protect all other elements. The constraints include limiting forces, impact energy to the foundation, and displacement ductility on the "fuse" elements. The re-centering capability is also included as a design constraint, however optional.

The design procedure uses a graphical approach by which a pair of design parameters ($A_{ub}$ and $L_{ub}$) are varied and solutions found that satisfy the design constraints. A sample design plot is shown with the solution area shaded in Figure 3.

RESULTS

The retrofit solution creates ductile response with limited retrofit effort. The design procedure appears to reasonably predict the response of the rocking/energy dissipation system described while satisfying the performance objectives. Various response parameters are shown in Figure 6.

CONCLUSIONS

Results (including many not presented here) suggest that the proposed retrofit strategy is a promising method to achieve ductile seismic response of bridge steel truss pier anchorage connections.

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Publications