Parametric Evaluation of Seismic Damage on Curved Highway Viaducts under Near-fault Earthquakes

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Summary

This paper investigates the effectiveness of the use of seismic isolation devices on the overall 3D seismic response of curved highway viaducts with an emphasis on expansion joints. Furthermore, an evaluation of the effectiveness of the use of cable restrainers is presented. For this purpose, the bridge seismic performance has been evaluated on four different radii of curvature, considering two cases: restrained and unrestrained curved viaducts. Depending on the radius of curvature, three-dimensional non-linear dynamic analysis shows the vulnerability of curved viaducts to deck unseating and joint residual damage. In this study, the efficiency of using LRB supports combined with cable restrainers on curved viaducts is demonstrated, not only by reducing in all cases the possible damage, but also by providing a similar behavior in the viaducts despite of curvature radius.

Keywords: Nonlinear dynamic response, seismic damage, unseating prevention, curved viaducts.

1. Introduction

In recent years, horizontally curved steel viaducts have become an important component in modern highway systems as the most viable option at complicated interchanges or river crossings where geometric restrictions and constraints of limited site space make extremely complicated the adoption of standard straight superstructures. Curved alignments offer, in addition, the benefits of aesthetically pleasing, traffic sight distance increase, as well as economically competitive construction costs with regard to straight bridges. On the contrary, steel viaducts with curved configurations may sustain severe seismic damage owing to rotation of the superstructure or displacement toward the outside of the curve line due to complex vibrations occurring during strong earthquake ground motions [1]. During history, severe strong earthquakes have repeatedly demonstrated that during an earthquake, adjacent spans often vibrate out-of-phase, causing two different types of displacement problems. The first type is a localized damage caused by the spans pounding together at the joints. The second type occurs when the expansion joint separates, possibly allowing the deck superstructure to become unseated from the supporting substructure if the seismically induced displacements are excessively large. Additionally, bridges with curved configurations may sustain severe damage owing to rotation of the superstructure or displacement toward the outside of the curve line during an earthquake [1]. For this reason, curved bridges have suffered severe damage in past earthquakes. The implementation of modern seismic protection technologies has permitted the seismic modernization of bridges through the installation of cable restrainers that provide connection between adjacent spans. The purpose is to prevent the unseating of decks from top of the piers at expansion joints by limiting the relative movements of adjacent bridge superstructures. Moreover, cable restrainers provide a fail-safe function by supporting a fallen girder unseated in the event of a severe earthquake [1]. In addition, another commonly adopted earthquake protection strategy consists of replacing the vulnerable steel bearing supports with seismic isolation devices. Among the great variety of seismic isolation systems, lead-rubber bearing (LRB) has found wide application in bridge structures. This is due to its simplicity and the combined isolation-energy dissipation function in a single compact unit. Even though the application of the mentioned earthquake protection techniques, the considerable complexity associated with the analysis of curved viaducts requires a realistic prediction of the structural

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