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Bridge Seismic Performance Due to Near-Fault Ground Motion Effects

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Abstract

Most of the bridge seismic design specifications do not consider the detail effects caused by the near-fault effects, including direct activities and fling effects. Some near-fault ground motions combine with severe vertical accelerations and could cause severe damage or failure of bridges. Design strategies for a bridge across an active fault is needed to ensure the safety of bridge structure and the feasibility of the bridge constructions. In the US highway agency, two studies were performed to investigate the bridge seismic performance with near-fault ground motions:
(1) The seismic performance of the Bolu Viaduct in the Duzce, Turkey, earthquake of November 1999 was studied via a non-linear, time-history analysis of a multi-degree of freedom model. The viaduct had a seismic isolation system consisting of yielding-steel energy dissipation units and sliding pot bearings. The Duzce earthquake caused a surface rupture across the viaduct, which resulted in excessive superstructure movement and widespread failure of the seismic isolation system. The effect of the rupture was modeled by a static, differential ground displacement in the fault-parallel direction across the rupture. The ground motions used in the analysis contain common near-fault features including a directivity pulse in the fault-normal direction and a fling step in the fault-parallel direction. The analysis used a finite element package capable of modeling the mechanical behavior of the seismic isolation system and focused on the structural response of a 10-span module of the viaduct. This analysis showed that the displacement of the superstructure relative to the piers exceeded the capacity of the bearings at an early stage of the earthquake, causing damage to the bearings as well as to the energy dissipation units. The analysis also indicated that shear keys, both longitudinal and transverse, played a critical role in preventing collapse of the deck spans.

(2) Near-Fault Ground Motion Effects on Substandard Bridge Columns and Bents. Under this study, several large-scale reinforced concrete models were constructed and tested on a shake table using near and far-field ground motion records. The first set of testing consisted of two identical substandard bridge bents. One of the bents had been tested under the Sylmar far-field record and the other one was tested under the Rinaldi near-fault record. The second set of testing consisted of two substandard circular bridge column models. Through the experimental and analytical studies, it was observed that regardless of the measure of input or response, the near-fault record generally led to larger strains, curvatures, and drift ratios than those of the far-field motion. It was also found that the residual displacements were small compared to those for columns meeting current seismic code requirements.

This presentation will briefly discussed the simulation and shake-table test results.

Dr. Phil Yen is serving as the chair of International Bridge Seismic Committee (IBSC) and the conference General-chair of the 5th, 6th and 7th National Seismic Conference for Bridges and Highways (NSC) in the US. He is the Principal Bridge Engineer in Structural Dynamics of a highway agency. He is responsible to enhance and implement bridge technology in extreme events related to structural dynamics, and has the technical responsibility to conduct the earthquake engineering research in the highway constructions. He was a voting committee member of the new AASHTO's new seismic design code development. Dr. Yen has published many technical papers in the area of modal identification of bridges structures, non-destructive evaluation and testing, seismic design, shake-table test of bridge columns and bridge vibration tests, cable stress assessment of cable–stayed bridges. Dr. Yen has been invited as a keynote speaker and presenter in many national and international earthquake engineering conferences and technical committee meetings, including International Earthquake Engineering Conference and US National Seismic Conferences for Bridges and Highways, US-Japan Bridge Engineering Workshops. The recent two major seismic engineering products with his direct involvement are (1) the new Seismic Retrofitting Manual for Highway Bridges and other Structures; and (2) the newly adopted AASHTO Seismic Design Guide-Specifications for Highway Bridges.