

# Effect of Bilateral Excitation on the Seismic Performance of Reinforced Concrete Bridge Columns

Hidenori Ogimoto

Graduate Student, Department of Civil Engineering, Tokyo Institute of Technology

ogimoto@cv.titech.ac.jp

The combination of two lateral components of seismic effect has been a major concern in seismic design of bridges. It is obvious that during an earthquake a bridge is subjected to a set of three components of ground motions. In practice, it is general to size bridge columns assuming that they are subjected to two lateral components of a ground motion in the weak and strong axes independently. Flexural strength and ductility capacity of a column are generally determined based on the experimental data of cyclic loading test under unilateral excitation. Since it has been revealed that flexural strength and ductility capacity under bilateral excitation are less than those under unilateral excitation (Zahn et al 1983, Kawashima et al 1992, Stathis et al 1995), it is likely that the current design flexural strength and ductility capacities are overestimated.

This paper presents cyclic and hybrid loading tests on eleven reinforced concrete specimens with the same structural properties to clarify the effect of bilateral excitation. Accuracy of a fiber element analysis which includes a new empirical stress vs. strain relation of confined concrete is verified based on the test data.

Eleven cantilevered reinforced concrete columns with the same structural properties were constructed. They have a 400 mm x 400 mm square section, and are 1,750 mm tall with an effective column height of 1,350 mm. They were designed in accordance with the 1996 Japanese Design Specifications of Highway Bridges. Hybrid and cyclic loading tests were conducted for eleven cantilevered reinforced concrete bridge columns. Fiber element analysis was conducted to correlate the experimental response. Based on the experimental and analytical results presented herein, the following conclusions may be deduced.

- 1) Flexural strength and ductility capacity of reinforced concrete bridge columns with a square section significantly deteriorate under the bilateral excitation than unilateral excitation in both cyclic and hybrid loading tests.
- 2) Failure of the columns under the cyclic loading test in which loading displacement was stepwisely increased with three loading excursions at each loading step is much extensive than the failure developed in the hybrid loading test using the JMA Kobe Observatory ground motion in the 1995 Kobe, Japan earthquake and the Sylmar Parking Lots ground motion in the 1994 Northridge, USA earthquake. Loading protocol is important, and it has to be carefully determined in the cyclic loading tests.
- 3) The 40% Kobe record and 50% Sylmar record result in similar peak response displacements in the bilateral hybrid loading tests. However, residual drift is much larger in both NS and EW directions under the 50% Sylmar than the 40% Kobe records. The residual drift highly depends on ground motions.
- 4) Analytical model provides quite accurate lateral force vs. lateral displacement hystereses of the columns in the cyclic loading tests. Overall response of the columns in the hybrid loading tests can be correlated by analysis. However evaluation of residual drifts requires more experience in the analysis because it is sensitive to the post-yield stiffness.