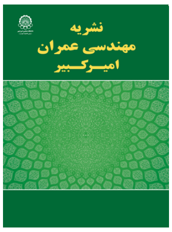

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Feasibility Study on Utilizing Self-centering Structural System for Typical Highway Bridges in Iran

A. Vasseghi*, B. Mansouri, S. Rointan

International Institute of Earthquake Engineering and Seismology, Tehran, Iran

ABSTRACT: Recently, in developed countries, a variety of self-centering structural systems have been developed using precast concrete bends and the Accelerated Bridge Construction (ABC) method to reduce construction time, increase safety, reduce seismic damage, reduce repair and reconstruction costs, and increase seismic resiliency. In this system, bridge bents are constructed by precast elements tied together with post-tensioned tendons such that under the effect of lateral seismic forces, they are able to rock and self-center back to their original configuration. The use of this system greatly reduces the residual displacements and the seismic damage. Also, due to the use of prefabricated elements, the construction speed of the bridge is significantly increased. This paper compares the seismic performance of one type of self-centering structural system with the conventional structural system for three typical highway bridges constructed in Iran. An analytical model for simulating nonlinear behavior due to the rocking motion in the self-centering system is first developed and verified by comparing the analytical response with the experimental results. Then, the concrete bends of the three typical bridges in Iran are modeled and analyzed once as a conventional system and once as a self-centering system, and the seismic performance of these two systems is compared with each other. The results of this study indicate that despite the modest increase in maximum lateral drifts, the residual drifts are substantially reduced when the conventional system is replaced by the self-centering system.

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1. INTRODUCTION

In seismic regions, highway bridges are usually designed using capacity design principles by enforcing the formation of plastic hinges in the columns. The columns are expected to undergo major inelastic deformations during severe earthquakes, leading to significant residual drift. The residual drift is one of the decisive seismic serviceability parameters, and it defines whether a bridge can be used after the earthquake or not. For example, after the Kobe earthquake in 1995, more than 100 bridges with residual drift of more than 1.75% had to be demolished, although most of these bridges were sufficiently stable [1]. The residual drift is also an important parameter for estimating the post-earthquake resistance and the stability of the bridge structure against aftershocks [2]. The effects of residual drift on post-earthquake performance have led the scientific communities to develop self-centering structural systems with low residual drift and limited potential damage. In this system, the bridge bends are constructed using precast cap-beams and columns. The precast members are connected to each other and to the foundation by unbounded tendons, as shown in Fig. 1. The tendons and the superstructure weight provide the self-centering forces for the bridge bend. Internal or external energy dissipation devices are also commonly used at the joints to absorb seismic energy.

In this paper, the seismic performance of a self-centering system proposed by Guerrini et al. [3, 4] is compared with the conventional system for three typical bridges in Iran. An analytical model that simulates the rocking motion of a self-centering system is first developed and validated by test results. Then, typical bends of the three bridges are analyzed as a conventional system and a self-centering system, and the seismic performance of these two systems is compared with each other.

2. MODELING OF THE SELF-CENTERING SYSTEM

An analytical model is developed for simulation of rocking motion and the self-centering column tested by Guerrini et al. (Figure 2) is selected to verify the model. The rocking motion is simulated by using a combination of gap and nonlinear spring elements to model the mortar bed underneath the column (Figure 3). The hysteresis response of the test specimen is compared with the results of the analysis in Figure 4. This figure shows that the hysteresis curves of the analytical model are in good agreement with the test results.

*Corresponding author's email: vasseghi@iiees.ac.ir

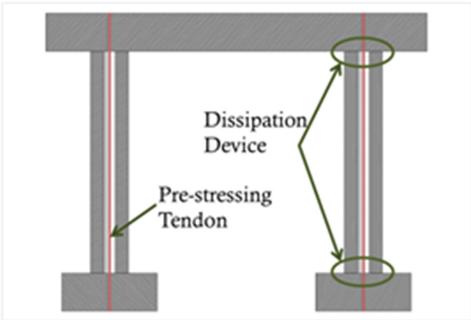


Fig. 1. Self-centering system for bridge bend

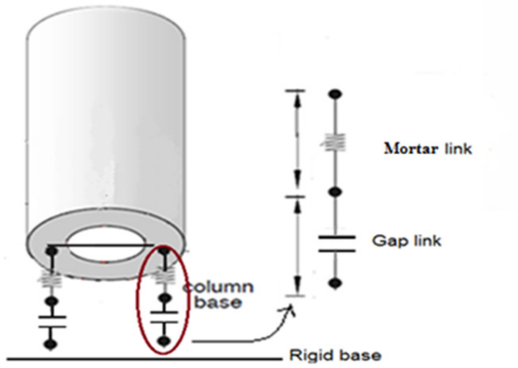
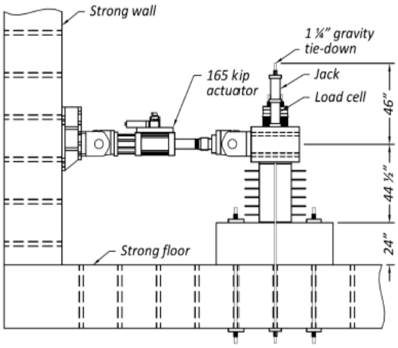
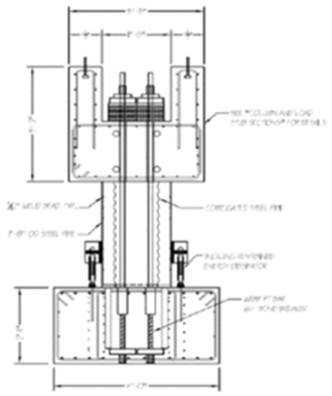


Fig. 3. Mortar bed modeling



a) Test setup



b) Test specimen

Fig. 2. Self-centering column tested by Guerrini et al. [4]

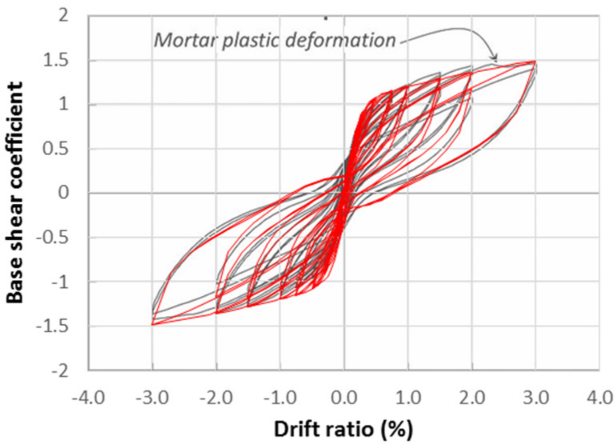
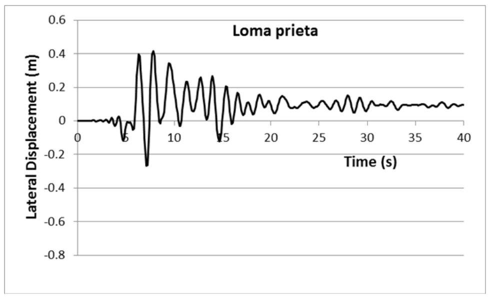
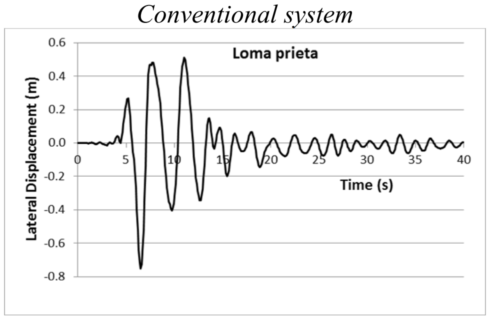


Fig. 4. Comparison of hysteresis curves



Conventional system



Self-centering system

Fig. 5. Lateral displacement response of a typical bridge bend

3. RESULTS AND DISCUSSION

Three different bridges with various span lengths constructed in Iran are selected for this study. Typical concrete bends of the three bridges are modeled and analyzed once as a conventional system and once as a self-centering system, and the seismic performance of these two systems is compared with each other. Nonlinear response history analyses are conducted for each bridge bend using seven earthquake records. Fig. 5 shows the typical displacement responses of the two systems. As shown in this figure, the residual displacement of the self-centering system is very small, but the peak displacement is higher compared to the

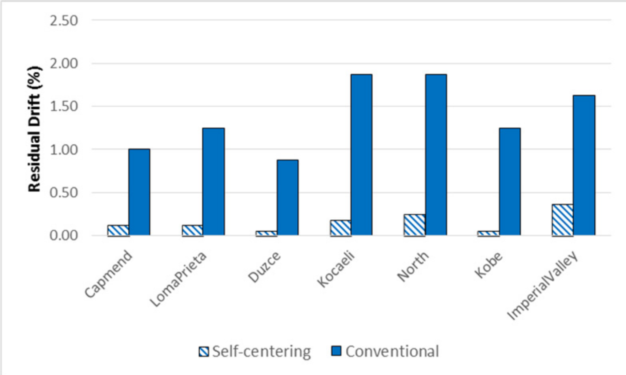


Fig. 6. Residual drift ratio

conventional system. The residual drift ratios in one of the bridges are shown in Fig. 6. In the conventional system, the residual drift ratio is between 0.9% and 1.9% and the potential seismic damage would be severe. The residual drift in the self-centering system is less than 0.4%, and thus the potential damage would be negligible.

4. CONCLUSION

In this paper, typical bends of three bridges in Iran were modeled with the conventional system and the self-centering system, and the seismic performance of these two systems was compared. The seismic response of each system was evaluated by nonlinear time history analyses using seven earthquake records. The results of this study show that the peak lateral drift in the self-centering system increases significantly. However, due to the lack of displacement-sensitive non-structural items on highway bridges, the increase in the peak drift is not expected to cause serious problems. In this system, despite the increase in the peak drift, the residual drift is greatly reduced. In some cases, the residual drift ratios of the conventional system are more than the critical level of 1.75%. In these cases, the potential damage will be severe and based on previous experience, the bridges need to be demolished. The residual displacement of the self-centering system in all cases is less than 0.4 percent and the potential damage is negligible. The significant reduction of the residual displacement in the self-centering system drastically reduces the repair costs and allows for the operation of the bridge immediately after the earthquake.

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