PEAK AND RESIDUAL DISPLACEMENT-BASED DESIGN METHOD FOR ENHANCING SEISMIC PERFORMANCE OF BRIDGE BENTS RETROFITTED WITH BRBS

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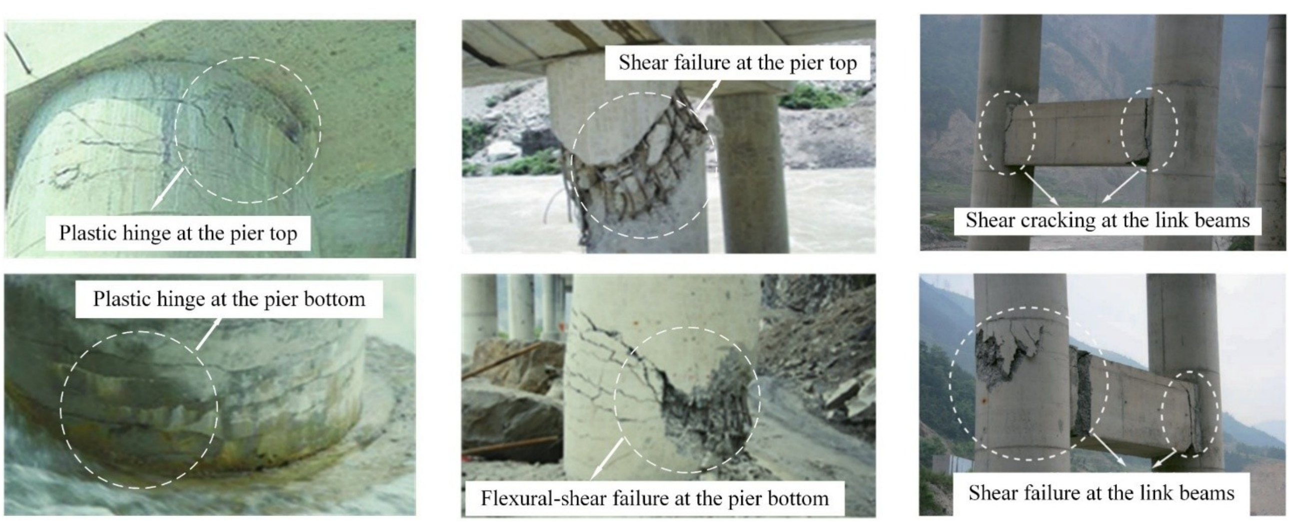
Extended Abstract

Bridge bents are widely used in highway bridges and urban viaducts. They are important load-bearing components that support the superstructure and transfer loads to the foundations. However, past earthquakes have shown that bridge bents have high seismic vulnerability. Common damage modes include flexural failure of pier columns, shear failure or flexural-shear failure of pier columns, and shear failure of link beams, as shown in Fig. 1. These damage modes may reduce the stiffness, integrity, and seismic performance of bridge bents. They may also reduce post-earthquake trafficability and delay functional recovery. Therefore, damage control of both pier columns and link beams should be considered in the seismic design of bridge bents.



(a) Flexural failure of piers (b) Shear or flexural-shear failure of piers (c) Shear failure of link

Figure 1- Common failure modes of bridge piers

To improve the seismic performance of bridge bents, this study uses buckling-restrained braces, or BRBs, as structural fuses. The structural fuse is designed to yield first and dissipate seismic energy. In this way, the primary structure can be protected from severe damage. This concept is useful for bridge bents because it can improve energy dissipation and post-earthquake recoverability.

The presentation is about a peak and residual displacement-based design method for bridge bents retrofitted with BRBs. In this method, the ductility factor and residual displacement factor are used as performance metrics. The ductility factor is used to control the inelastic deformation demand. The residual displacement factor is used to control the post-earthquake residual deformation. Single-degree-of-freedom systems with and without structural fuses are first studied. Prediction formulas are then developed for the ductility factor and residual displacement factor. These formulas are combined with a traditional displacement-based design framework.

The proposed method can consider different design performance objectives, including no damage, minor damage, and moderate damage. It can also consider bridge bents with and without link beams. If the bare bridge bent cannot meet the target performance, seismic performance enhancement is needed. Then BRBs are designed as structural fuses to improve the seismic response of the bridge bent.

Three BRB configurations are considered in this study. They are diagonal BRBs, inverted-V BRBs, and toggle BRB systems. Different configurations lead to different axial deformations in the BRBs. They also affect the energy dissipation efficiency of the system. Among these configurations, the toggle BRB system has a displacement amplification effect. This effect helps the BRBs make better use of their seismic performance.

Two bridge bent cases are used to verify the proposed design method. Case 1 is a bridge bent without a link beam and with rectangular columns. Case 2 is a bridge bent with a link beam and with circular columns. The proposed design method is applied to these two bridge bents. Nonlinear time-history analyses are then carried out in OpenSees to check the design results.

The analysis results show that BRBs can effectively reduce the peak displacement of bridge bents. Before retrofitting, the peak displacements of the bare bridge bents exceed the design displacements under several ground motions. This means that the damage state may be greater than minor damage. After retrofitting with BRBs, the peak displacements are significantly reduced. Most of them are smaller than the

design displacements. This means that the structures can recover their function with no repair or minor repair.

The results also show that the proposed design method is reliable. The error between the design displacement and the average peak displacement from nonlinear time-history analysis can be controlled within 5%. Compared with diagonal and inverted-V BRBs, the toggle BRB system provides better control of peak displacement and damage state. It can make better use of the seismic performance of BRBs. The highlights of the design concept, prediction formulas, design procedure, BRB configurations, nonlinear time-history analysis results, and main conclusions will be presented.

Keywords*: Damage control; Seismic performance enhancement; Structural fuse; Displacement-based design; Inelastic response spectra.*