Seismic Behavior and Performance of Steel Structures Equipped with Pure Bending Yielding Dissipater (PBYD)

Alireza Ahmadi, Farhad Behnamfar, Nov. 2021

One of the methods to reduce earthquake damage is to concentrate damage on pre-defined members. These members, which minimize damage to the structure by absorbing major part of the seismic force during an earthquake, are known as structural fuses. Structural fuses can be designed in a way that could be replaced or repaired after an earthquake. Using this method also optimizes design and makes seismic retrofit and construction cost-effective. In this research, the behavior and performance of steel structures with pure bending yielding damper system were studied and compared with a special concentrically braced frame system. This damper is composed of a number of steel plates which, by using a mechanism, creates pure bending yielding moment in major parts of the plates. The structures studied in this research have 4, 8 and 12 floors that have been designed by a common software. The structural system has been designed with the damper in two modes of brace stiffness-to-damper ratio equal to 1.5 and 2 and the modes have been evaluated. To perform nonlinear analysis, nonlinear modeling of structures was performed in OpenSEES software after the design and in both types of structural systems, beams and columns were modeled using fiber element with force-based formulation. To model the braces in the special concentrically braced frame system, 8 segments of a fiber element with displacement formulation have been used, that has an initial imperfection in the middle which is 0.001 of the brace effective length. Also, to model the damper, an axial spring to which the hysteresis damper behavior is assigned with a specific material has been applied. The proposed model was verified by results of 16 experimental specimens. Based on the comparison of the results, it was found that the model has a very good accuracy for modeling pure bending dampers. After modeling the structures, their behavior and performance were studied and evaluated using two types of nonlinear pushover analysis and nonlinear dynamic analysis. Pushover analysis results of the structures showed that the system with pure bending damper has a higher overstrength factor, ductility reduction factor and response modification factor than the special concentrically braced frame system. In addition, it was observed that in the system with the damper, by decreasing the ratio of the brace stiffness to the damper stiffness, overstrength factor, ductility reduction factor and response modification factor of the structure increase. From the results of dynamic analysis, it was also found that the values of the maximum interstory and residual drift ratios in structures with dampers due to softer and more ductile behavior, are higher than structures with the special concentrically braced frame system. However, in the system with dampers, the values of the maximum interstory drift ratio were about less than 1%, which indicates the appropriate stiffness of this type of structural system. Furthermore, by decreasing the ratio of the brace stiffness to the damper stiffness, it was observed that the maximum interstory and residual drift ratios decrease. The results of dynamic analysis also showed that in the system with the damper, all members including beams, columns and braces, remained in the elastic region and no damage was done to them. This shows that the damper acts as a structural fuse and prevents damage to other elements. In the concentrically braced frame system, however, only the beams and columns remain in the elastic region, but the braces have experienced significant plastic deformation.

Keywords:

Pure bending yielding damper, concentrically braced frame, response modification factor, nonlinear static analysis, nonlinear dynamic analysis, structural fuse, cyclic behavior.