Evaluation and Enhancement of Steel Beam-to-Column Moment Connections using Visco-Plastic Dampers (VPD)

Abstract

Today, steel structures are considered among the structures commonly used in most countries. That is why many researchers are working out the proper behavior of these structures in components such as beam-column connections. In addition to criterion of resistance to gravity loads, stability against earthquakes forces in seismically active areas is mandatory for all structures. Therefore, sufficient resistance of components and connections in steel structures is important and critical to securely transmit the applied forces. If a structure has a proper ductility, the input energy will properly be dissipated and as a result, the structural responses are reduced. The energy absorption capacity can be provided through plastic deformations of components called plastic hinges. However, given the nature of inelastic deformation behavior during an earthquake occurring in a structure designed according to the current codes, repairing the structural damages is expensive, time-consuming and sometimes impossible. Importance of rehabilitation of structures under damages in the event of severe earthquakes, the idea of using damage control systems in structures has been raised by many researchers during the past few decades. Many systems have been developed and suggested to date whose most appropriate ones in terms of low cost, speed in installation and repair are the passive control systems. This type of system passes its input energy through proper ways in certain components and has a quite stable and ductile hysteretic behavior and will act as a fuse in structures. In this study, a new system for steel beam-to-column connection is developed using a series of typically available materials for damage control at the floor level of steel moment connections. The developed damper is equipped with rubber- steel cores (*R-SCD*) that have a visco-plastic behavior. It enjoys viscoelastic material properties in elastic phase under small earthquakes as well as plastic properties of steel materials under severe earthquakes for energy dissipation. The proposed system can easily be repaired or replaced after severe earthquakes that inflict damage to steel cores without needing excess manpower. These steel moment connections are expected to impose no plastic deformation in the main structural components such as beams and columns which is considered as the main advantage of this system. After applying strong earthquakes on structures, the only sources of energy dissipation are the steel cores of the damper that concentrate all damage in themselves and the main parts of the structure remain undamaged. Then, easily and without predetermined arrangements, moment connections can be repaired or replaced. To verify the intended behavior in such dampers, several laboratory samples were prepared whose major differences were in the type of the main body system, viscoelastic layer thickness, material and shape of the steel cores. Samples were put under cyclic loading in accordance with the loading protocol *ATC-24* and as the result of which a very stable hysteretic behavior with good ductility was observed. To verify the behavior of laboratory samples, their analytical model was tested and validated using the finite element method. Eventually, the hysteresis curves obtained from experimental data matched very well with the analytical results. Finally, in order to evaluate the performance of the proposed damper in steel beam-to-column moment connections and confirm their behavioral model, a moment connection was designed. The design was made based on current regulations regarding two different approaches including the reduced beam section and a T-shaped connection. Finally, the nonlinear analyses were accomplished using the finite elements method. The results demonstrated superiority of the proposed damper system in terms of the damages to the main structural components.

Keywords: energy dissipation, visco-plastic damper, steel beam-to-column connection, rubber, steel cores, plastic deformations.