POST-TENSIONED ENERGY DISSIPATING (PTED) STEEL FRAMES FOR SEISMIC REGIONS

The innovation is a new post-tensioned steel moment-resisting connection that is designed to eliminate welding from beams to columns and to significantly enhance the seismic response of steel framed structures. This system incorporates high strength post-tensioned steel bars that clamp the beams to the columns through pre-stressing along with energy dissipating (ED) bars. These ED bars, when inserted in steel cylinders to limit buckling, are able to develop stable inelastic axial deformations in both tension and compression. The pre-stressing elements are designed to remain elastic even when the system undergoes large lateral deformations. These tensioning elements create a positive restoring spring force that re-centers the structure to its original position at every cycle of loading during the earthquake. This property also assures a fully re-centered structure after a major earthquake.

This is innovative as it changes current practice in moment-resisting steel frames that consists of rigidly connecting beams to columns through full penetration welds. Following the unexpected failures of beam-to-column connections in more than one hundred steel moment-resisting frames (MRFs) during the 1994 Northridge, California earthquake, an extensive research program in the U.S. lead to a better understanding of the cyclic behavior of welded and bolted steel moment connections and to the development of more stringent welding practices. These new guidelines, however, have raised the fabrication and erection costs of MRFs. Furthermore, even with these enhanced requirements, inelastic deformations as well as residual drifts are expected to occur under seismic loading. Inspection and repair of these structures is very difficult following an earthquake.

The research leading to the development of PTED steel frames originated at the University of California at San Diego in 1998 where the first of the inventors was a doctoral student and where the second of the inventors was a faculty member. The Herrick Corporation and Dywidag International were partners in the development of this system.

The concept was validated through full-scale connection tests and half-scale shake table simulations. Numerical and experimental results showed that this connection is capable of achieving stiffness and strength characteristics comparable to a traditional welded moment-resisting connection. In addition, the connection can be designed to provide a sufficient amount of energy dissipation per cycle to control the maximum response of the building during an earthquake. Construction is time efficient as the connection gains more than 60% of its strength immediately after post-tensioning. This allows construction of subsequent floors to continue while the ED bars are installed in the previous floor of a building.

This structural behavior is achieved without introducing inelastic deformations in the beam or column and without residual drifts. Rapid inspection following an earthquake and replacement of the yielding elements is also possible for this system allowing for rapid and cost effective full upgrade of such a structure after a major earthquake.

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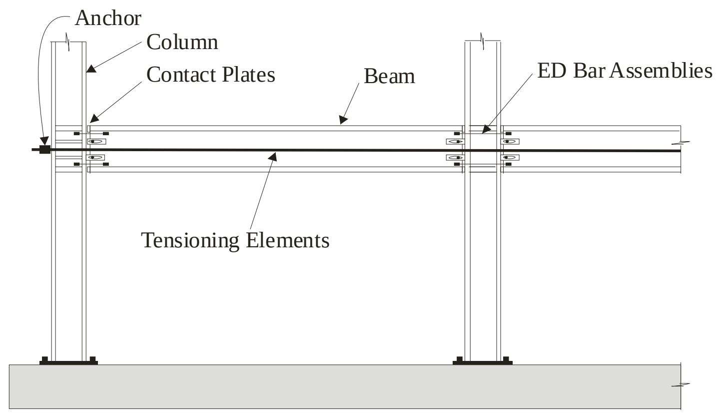

Figure 1: Schematic of PTED Steel Frames

a) b)

Figure 2: Moment Resisting Connections: a) Traditional welded connection after undergoing deformations up to 3% drift, b) PTED Exterior Connection at 3% drift

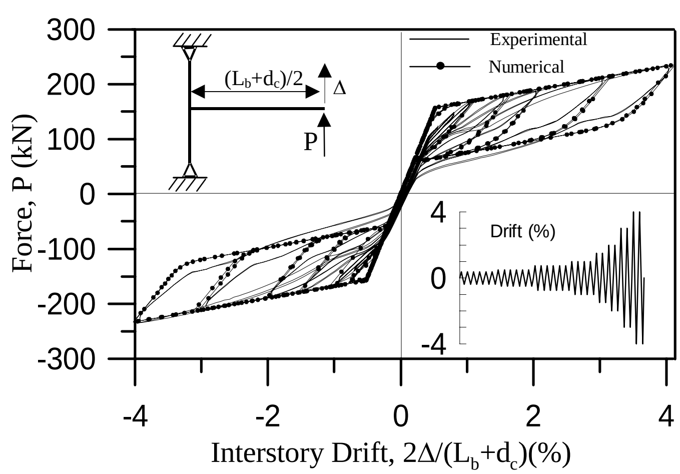

Figure 3: Force Deflection Response of PTED Exterior Connection (returns to zero force-zero displacement after seismic loading – no residual deformations)