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Experimental study on the rotation capacity of cold-formed steel beams

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ABSTRACT

The rotation capacity of cold-formed steel (CFS) beams has been evaluated through experimental investigation. Studies on different structural levels have been performed. At the element level, different profile slenderness ratios have been considered, and different section shapes have been investigated by increasing the number of flange bends: C-section and curved-section, which represents an infinite number of flange bends. At the connection level, a web bolted moment resistant type of connection using through plate has been adopted. In web bolted connections without out-of-plane stiffeners, premature web buckling results in early loss of strength. Hence, out-of-plane stiffeners have been examined to delay web and flange buckling and to produce relatively high moment strength and ductility. The experimental results have been compared with numerical results obtained by the authors in another paper work. The results revealed that increasing the number of flange bends will not in all cases enhance the behavior. Meanwhile, the use of out-of-plane stiffeners can increase the seismic energy dissipation, the moment strength and the ductility, when compared with the case without stiffeners.

1. Introduction

The use of CFS sections as main structural elements in building constructions is mainly limited to roof and side purlins, mezzanine floors, storage racks and stud-wall frames with low seismic energy dissipation capacity [1–6]. Generally, moment-resisting frames with CFS sections cannot create plastic hinges in CFS beams; and in turn, cannot produce adequate ductility for high seismic resistance [7–10]. The previous studies on behavior of CFS elements and associated beam-column connections in moment-resisting frames under monotonic and cyclic loading are relatively limited [11–15]. It has been reported that the ductility is mainly provided by the connection (yielding the material around the bolt holes) while the beams and columns remain elastic [4–6]. Keerthan and Mahendran [16] performed experimental study for the effect of flange straps on the shear capacity and shear behavior of lipped C-section. It has been reported that the use of flange straps enhances the specimens shear and bending strength with 9 to 20% of its original value. Chen et al. [17] measured the specimen capacity, modes of failure, and local deformation for CFS lipped C-sections under web crippling load. It has been reported that the section capacity increases with the increase of bearing plate stiffness. Bending tests have been performed to simply supported CFS beams with C-section, lapped Z-section, and coupled back-to-back channel section, under four-point and three-point loadings [18–20]. Yang et al. [14] investigated the energy dissipation and failure mechanism of CFS hollow rectangular columns and reported an effective range for the wall length-to-width ratio. Padilla et al. [21] studied the energy dissipation of CFS beams with C-section under both monotonic and cyclic loading conditions. It has been reported that the amount of energy dissipation is dependent on buckling modes. Wang and Zhang [22] investigated the effect of edge stiffeners on the flexural behavior of CFS beams with C-section. The experimental results revealed that the edge stiffeners greatly increase the flexural strength and affect the buckling mode. In addition, the beam flexural resistance in case of non-pure bending is higher than that of pure bending case. Bagheri et al. [12,23] performed full-scale experimental tests for CFS structures under gravity and cyclic loading. Particular details for the beam-to-column connection have been investigated to resist seismic loads. It has been reported that the specimens could achieve a flexural strength of 60% the plastic moment in association with a rotation angle of 0.04 rad. Mirghaderi et al. [24] presented a new I-beam to box-column connection by a vertical plate passing through the column. It has been reported that the through plate connection can effectively transfer the moment from the beam to the column with a rotation angle of 0.04 rad. Experimental investigations have been performed for specimens with different connection configurations, to evaluate the strength and stiffness of bolted connections between CFS elements [25,26]. Four modes of failure have been reported. Two modes have been observed in the CFS section: due to bearing around the bolt hole; and due to flexure. The former mode of failure could achieve a bending strength up to 50% of the plastic moment. The other two modes of failure have been observed in the gusset plate: due to lateral torsion buckling; and due to flexure. The later mode could achieve a bending strength up to 75% of the plastic moment. Apparently, the bearing failure mode should be avoided as it reduces the strength of the connection. Chung and Lau [27] studied the behavior of CFS in moment connections

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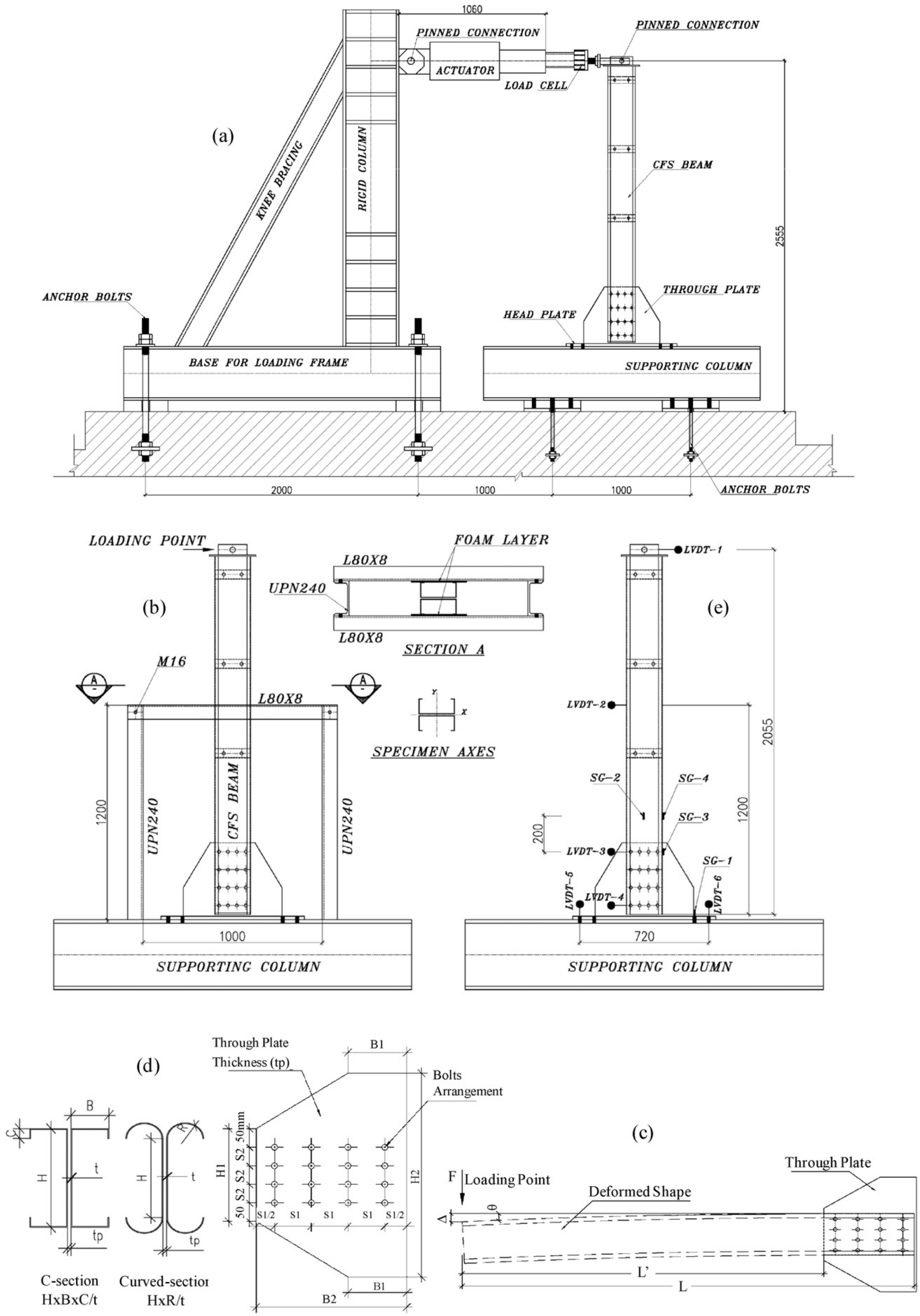

Fig. 1. Experiment setup — support system, loading system, specimen components and instrumentation.