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Finite Element Analysis of Hollow Structural Shape (HSS) Steel Brace with Infill Reinforcement under Cyclic Loading

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Abstract : Special concentrically braced frames is one of the seismic load resisting systems, which dissipates seismic energy when bracing members within the frames undergo yielding and buckling while sustaining their axial tension and compression load capacities. Most of the inelastic deformation of a buckling bracing member concentrates in the mid-length region. While experiencing cyclic loading, the region dissipates most of the seismic energy being input into the frame. Such a concentration makes the braces vulnerable to failure modes associated with low-cycle fatigue. In this research, a strategy to improve the cyclic behavior of the conventional steel bracing member is proposed by filling the Hollow Structural Shape (HSS) member with reinforcement. It prevents the local section from concentrating large plastic deformation caused by cyclic loading. The infill helps spread over the plastic hinge region into a wider area hence postpone the initiation of local buckling or even the rupture of the braces. The finite element method is introduced to simulate the complicated bracing member behavior and member-versus-infill interaction under cyclic loading. Fifteen 3-D-element-based models are built by ABAQUS software. The verification of the FEM model is done with unreinforced (UR) HSS bracing members' cyclic test data and aluminum honeycomb plates' bending test data. Numerical models include UR and filled HSS bracing members with various compactness ratios based on the specification of AISC-2016 and AISC-1989. The primary variables to be investigated include the relative bending stiffness and the material of the filling reinforcement. The distributions of von Mises stress and equivalent plastic strain (PEEQ) are used as indices to tell the strengths and shortcomings of each model. The result indicates that the change of relative bending stiffness of the infill is much more influential than the change of material in use to increase the energy dissipation capacity. Strengthen the relative bending stiffness of the reinforcement results in additional energy dissipation capacity to the extent of 24% and 46% in model based on AISC-2016 (16-series) and AISC-1989 (89-series), respectively. HSS members with infill show growth in Local Buckling, normalized energy cumulated until the happening of local buckling, comparing to UR bracing members. The 89-series infill-reinforced members have more energy dissipation capacity than unreinforced 16-series members by 117% to 166%. The flexural rigidity of infills should be less than 29% and 13% of the member section itself for 16-series and 89-series bracing members accordingly, thereby guaranteeing the spread over of the plastic hinge and the happening of it within the reinforced section. If the parameters are properly configured, the ductility, energy dissipation capacity, and fatigue-life of HSS SCBF bracing members can be improved prominently by the infill-reinforced method.

Keywords : special concentrically braced frames, HSS, cyclic loading, infill reinforcement, finite element analysis, PEEQ
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