Analytical and laboratory study of prefabricated concrete frame system with steel shear wall

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Abstract

This study investigates the structural performance of steel shear walls in precast concrete frames, focusing on their ability to control damages caused by earthquakes through experimental and numerical methods. First, two full-scale laboratory samples of steel shear walls with precast concrete frames and beam-to-semi-rigid column connections were examined under cyclic load following the ACI-374 loading protocol. The steel panels in these samples were made of black and galvanized sheets. Also, a laboratory sample of a precast concrete frame was tested alone under cyclic load to analyze the interaction between a steel shear wall and the concrete frame. In the design and construction of laboratory samples, steel sheets were connected using rivets due to the limitation of the steel sheet width. In this structural system, all components, except for the steel panel, function as control forces. In contrast, the steel panel is controlled based on deformation. When subjected to lateral loading, the steel panel experiences a distribution of forces including tensile, compressive, and shear stresses. The tensile force is distributed diagonally across the steel panel. Also, the creation of compressive forces occurs as diagonal lines of force form but opposite to tensile forces. Finally, shear forces are distributed parallel to the wall surface. The beam and column remained undamaged in the laboratory samples, yielding satisfactory results. Subsequently, a numerical method was employed to analyze the laboratory samples, and the findings exhibited an acceptable level of accordance with the initial laboratory results. A parametric study was undertaken, wherein the investigated variables encompassed the type of beam-tocolumn connection, materials, and the geometric configuration of the beam and column within the surrounding frame. The steel panel acts as a fuse for energy absorption, as indicated by the research results. Upon comparison of the seismic parameters of both the experimental and numerical samples, it is evident that the samples featuring galvanized steel sheets exhibit superior performance when contrasted with their counterparts utilizing black steel sheets. Finally, the comprehensive analysis of the results showed that in the laboratory samples of steel shear walls with precast concrete frames, the average behavior coefficient, over-strength, and displacement amplification factor are equal to 5.4, 2.2, and 8, respectively. Upon comparing these coefficients with the standard recommended coefficients in ASCE/SEI 7-22 for special concrete shear walls (5, 2.5, and 5) and intermediate concrete moment frames (5, 2.5, and 4.5), it becomes evident that the proposed system demonstrates better seismic performance. The findings demonstrate that the utilization of steel shear walls in combination with precast concrete frames presents a viable solution for the design of earthquake-resistant structures.

Keywords: Steel shear walls, Semi-rigid connection, Energy absorption, Galvanized sheet, Precast concrete frame.