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Nonlinear behavior of composite shear walls with vertical steel encased profiles

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ABSTRACT

Research on seismic engineering of buildings using composite steel–concrete structural systems has increased in the past decade. One horizontal resisting system for buildings, placed in seismic areas, is the composite steel–concrete structural shear wall with steel encased profiles (CSRCW). The benefits of this structural system, relative to more common systems, include the performance characteristics when subjected to service or ultimate loads. The present paper summarizes the experimental results of recent research made on six experimental steel–concrete composite elements 1:3 scale, tested in laboratory under cyclic lateral loads. The experimental elements differ by the arrangement of the steel shapes embedded in the cross section of the wall and by the cross section type of the steel encased profiles. All specimens were tested under constant vertical load and cyclically increasing horizontal (lateral) loads. The tests were performed until failure. Using the recorded data during the tests, the following parameters are presented and discussed: maximum load capacity, stress and strain distribution in structural components (reinforcements, structural steel and on concrete surface), interstory drifts, cracking patterns, deformation and degradation capacity.

1. Introduction

For many years, the reinforced concrete shear walls have been used as lateral resisting systems for earthquake loading. The researchers have studied many ways to provide ductile behavior to the walls, by providing high shear capacity in comparison with the flexural capacity. New concepts for the RC shear wall calculus are based on the deformation and the degradation capacity performance. The dissipated energy during earthquake is mostly provided by yielding of the longitudinal reinforcements located in the boundary regions. The design of the shear walls for buildings in seismic regions is made by using the design codes of the composite steel and concrete structures and the design guides of buildings for earthquake resistance. Severe technological complications occur, especially in the lower stories of the frame buildings with large bays, where shear walls must be provided to limit the lateral displacement of the structure. Due to the limits of the axial force ratio and the requirements on the transverse reinforcement at the confined boundary elements, imposed by the seismic codes, rather often a high percentage of steel results. The limited dimensions of the elements and the high percentage of the steel needed at the extremities of the walls can make impossible the use of rebars only. Then the designers may think of using special details like reinforcement by means of structural steel profiles.

Different types of composite shear wall systems have been studied for the purpose of improving the ductility of the conventional reinforced concrete shear walls. Recent research on composite shear walls were conducted by Liao et al. [1], Saari [2], Ji et al. [3], Hossain and Wright [4], Tong et al. [5], Belmouden and Lestuzzi [6], Greifenhagen and Lestuzzi [7], Su and Wong [8], Kim and Foutch [9]. The research and the specifications for the composite steel–concrete shear walls show a rather poor level of knowledge related to the nonlinear behavior, the maximum load, the stress and the strain distribution in structural components (reinforcements, structural steel and concrete), the interstory drifts, the cracking patterns, the deformation and the degradation capacity and the failure modes. In this paper, five possible solutions of shear walls with steel encased profiles, called composite steel reinforced concrete walls (CSRCW1 to 5) and one reinforced concrete typical shear wall (CSRCW6), are proposed and tested. A typical CSRCW experimental element scaled 1:3, simulating the lower three story of one composite wall from a multistory building is presented in Fig. 1. The steel profiles embedded in concrete offer a higher strength and deformation capacity than the structural steel itself, due to the presence of the confined concrete by stirrups, which prevents the buckling of the steel elements. In a common RC wall stiffness decreases rapidly after concrete cracking. This deficiency could be reduced or suppressed by the steel encased boundary elements, and due to this fact a higher ductility is obtained in comparison with common RC walls. The connection between the structural steel and the concrete is accomplished with steel headed shear studs welded to the steel profiles, thus reducing the possibility of sliding between the two materials. The

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