Journal of Constructional Steel Research 70 (2012) 226–235

Contents lists available at SciVerse ScienceDirect

Journal of Constructional Steel Research

Strengthening of reinforced concrete structures with external steel shear walls

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ARTICLE INFO

Article history:
Received 23 November 2010
Accepted 8 August 2011
Available online 25 September 2011

Keywords:
Earthquake
External steel shear wall
Strengthening
Reinforced concrete structures

ABSTRACT

The strengthening of reinforced concrete (RC) structures with external steel shear walls was investigated in this study. The proposed technique allows the strengthening of in-service RC structures in parallel to reducing the construction costs and leading to faster and more workable solutions. The experimental program includes three-dimensional RC models, which exhibited some of the structural deficiencies commonly encountered in existing RC structures. The related tests were conducted under the imposed reversed cyclic lateral sway. Accordingly, performance of the proposed strengthening technique is found to be adequate for improving the seismic capacity of existing RC structures. Additionally, base shear capacity and stiffness of the strengthened model were significantly improved.

1. Introduction

Reinforced concrete (RC) buildings built before the adoption of modern codes have either collapsed or sustained various levels of damage during the past earthquakes. Many structural deficiencies were reported such as low-quality concrete, poor confinement of the end regions of columns and beams, weak column–strong beam behavior, short column behavior, inadequate splice lengths and improper hooks of the stirrups [1,2]. In order to prevent the ensuing loss of lives and property, a significant amount of research was carried out and several techniques were developed for strengthening of the existing buildings [3,4]. Seismic strengthening of the structures is mainly based on two strengthening schemes. Firstly, seismic retrofitting contributes to the structure's seismic performance by limiting the lateral drifts or improving the lateral drift capacity of the building. The former scheme is implemented by the addition of new structural elements which improve the strength and stiffness of the system. Alternatively, local strengthening of the low-ductility structural elements, which deteriorate the stability of the structure, may be an economical solution for buildings with limited number of deficient elements. However, local strengthening methods create a negligible improvement in base shear capacity and lateral stiffness of the system. For most of the cases, element based techniques may not be sufficient by themselves to adequately enhance the earthquake safety of strengthened structures [3]. In this case, it is better to implement the more comprehensive system-based strengthening methods, which improve both base shear capacity and lateral stiffness. Besides, such techniques might compensate for the local deficiencies by limiting the displacement demand [5].

The use of RC infill walls has a wide application area for the strengthening of vulnerable structures. In this context, the efficiency of infill RC walls is verified by many experimental studies [5,6]. Accordingly, structural properties of reinforced concrete frames (column reinforcement ratio, column and beam transverse reinforcement and column compressive strength) and the quality of connection between the frame and infill walls were influential in strengthened frame behavior. The utilization of external RC shear walls was also tested on RC specimens. Researchers tested both of the external wall schemes implemented in perpendicular [6] or parallel [7] to the side of the building and found that external RC walls behaved like monolithic walls. Only some minor cracks were observed between the wall and connecting elements beyond drift ratios of 2%. Hence, it was inferred that the external RC shear walls improve the stiffness and base shear capacity of the structural system.

Additionally, many theoretical and experimental studies [8–11] were carried out on the employment of steel shear walls as an alternative method. Most of the experimental studies on the use of steel braced shear walls for strengthening were performed on single-story and single-span frame models. The researchers recorded that strengthening the structures with steel shear walls increased the strength of the structure and a higher seismic performance was achieved considering the changes in ductility and energy dissipation

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doi:10.1016/j.jcsr.2011.08.010