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Experimental study on slotted RC wall with steel energy dissipation links for seismic protection of buildings

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ABSTRACT

In this paper a novel RC (Reinforced Concrete) shear wall named the slotted RC wall is presented. The main feature of the novel wall is the vertical slots along the wall, equipped with steel energy dissipation links. The slotted wall is designed to improve the deformation capacity and control the damage for the conventional shear wall. To deeply investigate the seismic performance of the proposed slotted wall, five wall specimens were designed, including a conventional shear wall and four slotted walls with different slot widths and shear link sizes. Quasi-static cyclic test was conducted. The test results presented much improved energy dissipation capacity in the slotted walls compared with the conventional wall. The slotted configuration decreases the stiffness and bearing capacity of the wall compared with the conventional RC shear walls, and slightly enhances the deformation capacity of the wall. This enhanced deformation capacity is most evident in the slotted wall with the weakest energy dissipation links, which did not sustain damage to the RC components under a drift ratio of 1/100, and failed under a drift ratio of 1/36. A numerical model of the slotted wall was constructed and the results are compared with the experimental results, showing good agreement and confirming the effectiveness of the slotted wall configuration.

1. Introduction

Earthquake resilient structures are expected to maintain their functions or recover their functions rapidly after an earthquake [1,2]; therefore, earthquake damage to the structures should be limited to an acceptable level [3,4]. However, RC (Reinforced Concrete) shear walls may sustain significant damage in an earthquake, requiring large-scale repairs or even demolition [5]. As significant compression strain can be developed in RC shear walls, the concrete on the lateral side of the wall can be crushed. Several solutions are proposed to enhance the deformation capacity of the concrete. Ji et al. proposed a concrete-filled steel tubular boundary element for a steel double-skinned plate-concrete composite wall. The steel double-skinned plate restrains the concrete, and when tested under compressional loads the yield and final drift ratios reached 1/200 and 1/30, respectively [6]. However, for large-scale applications the cost of a steel double-skinned plate wall is too high. Furthermore, access to the in-site cast RC slab and the double skinned wall is difficult for construction.

In recent years, the structure control approach has been suggested as a good solution for achieving earthquake resilient structures [7]. Based on the concept of structure control, a pin-supported wall is constructed to prevent story-collapse in the frame structure [8,9]. Special energy dissipators were installed between the pin-supported wall and main structure. According to the analysis, the pin-supported wall can help maintain a uniform overall deformation mode, and enhance the deformation and energy dissipation capacities of the frame structures, preventing story collapse.

As shown above, the functional division, deformation mode, and failure mode of the concrete structure can be controlled by various configurations of the concrete and steel components. This paper focuses mainly on improving the seismic performance of the RC shear walls. Five wall specimens (one conventional shear wall and four slotted walls) were designed to investigate the performance of the proposed design. Quasi-static tests were conducted and the performance of the slotted walls was compared with that of conventional shear walls, demonstrating the advantages of the slotted wall in terms of damage control and deformation capacity. Some important design parameters of the slotted wall were investigated.

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2. Experiments on slotted RC walls

2.1. Specimen design

Five specimens were designed in the test as shown in Fig. 1a. S1 is the standard specimen. The height, width and thickness of the wall are 4000 mm, 1500 mm and 200 mm, respectively. The overall cross-section of S1 is $1500 \times 200\ \text{mm}^2$, with two slots ($150 \times 200\ \text{mm}^2$) and three RC components ($400 \times 200\ \text{mm}^2$). The width-to-thickness ratio of each RC component is 2.0. The wall can be seen as three parallel RC components connected by six steel shear links with M-size. Different to S1, S2 has only four M-sized steel shear links, installed 1300 mm and 2700 mm from the lower end of the slot. In S3, the upper steel shear links are S-sized links, the middle steel shear links are L-sized, and the lower steel shear links are M-sized. In S4, the slot width is only 100 mm. S5 is the conventional shear wall specimen. All the specimens have the same loading and base beams, with the cross-sections of $400 \times 400\ \text{mm}^2$ and $800 \times 800\ \text{mm}^2$, respectively. Note that in the building structures using the slotted walls, the slots don't run through along the height of the entire structure, but arranged separately in each story. Therefore, there is a short wall segment without slots in each story, connected with the RC slab. The non-slotted wall segments were considered to be infinitely rigid. In the test, the loading beam and the base beam are used to simulate the non-slotted wall segments.

Fig. 1b shows the all the cross-sections of the specimens. In the slotted RC walls, the diameter of the longitudinal rebar and stirrup are 12 mm and 8 mm, respectively. The spacing of the stirrup is 80 mm in the anchoring region for shear links and 100 mm in other regions. For the conventional shear wall specimen S5, eight 12-mm rebars are arranged in the boundary element. 8-mm rebars with a spacing of 150 mm are adopted as the distributed rebars in both vertical and horizontal directions. The rebar used in the shear wall is denoted HRB400 (Hot-rolled Ribbed Bar), and has a nominal yield stress of 400 MPa. The concrete used in the specimens has a strength grade of C40 (nominal cubic compressive strength $f_{cu,d} = 40\,\text{MPa}$, and the design value of the axial compressive strength is $f_{c,d} = 19.1\,\text{MPa}$).

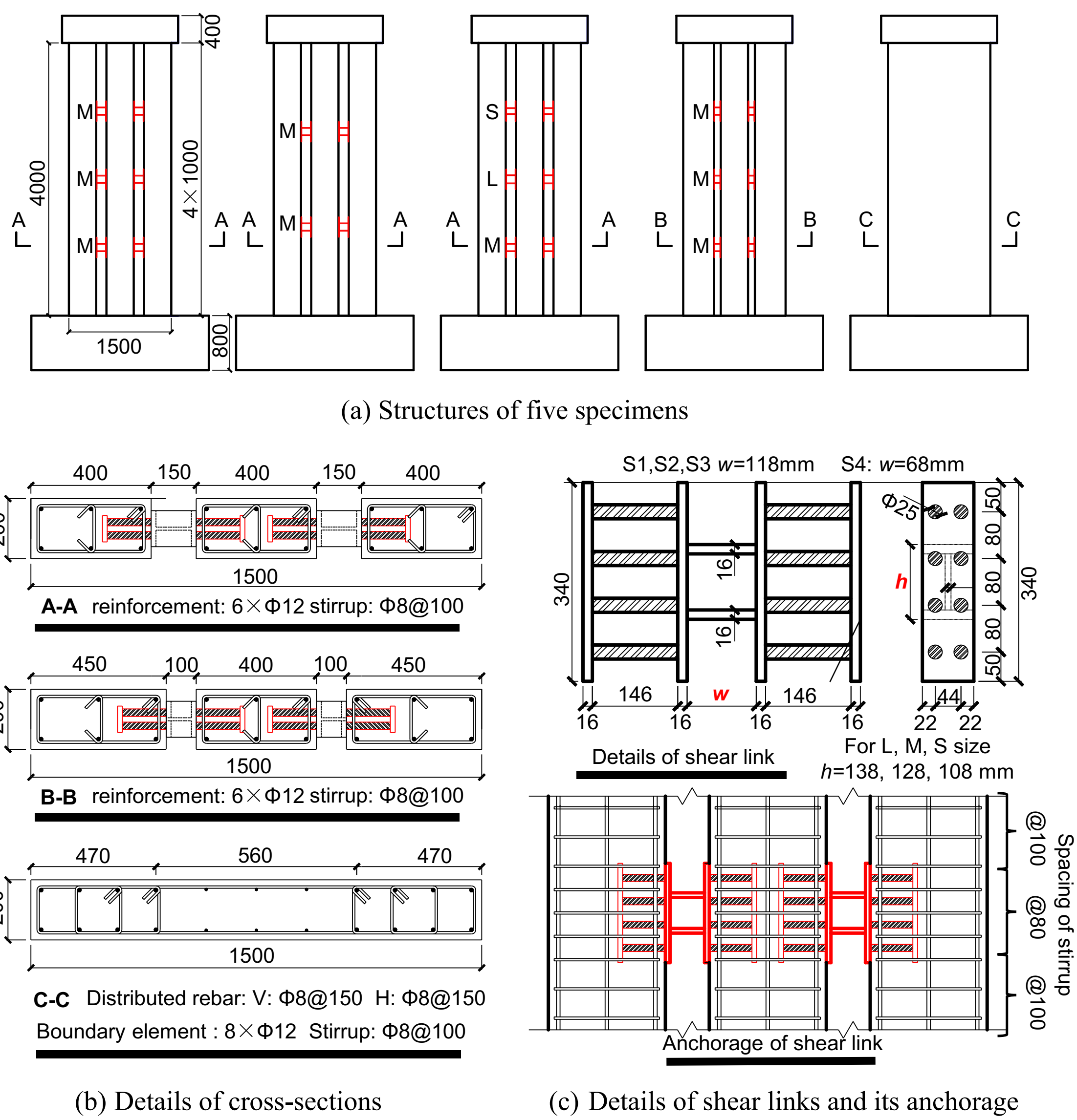

Fig. 1. Design of all the specimens; steel shear links are shown in red.