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Experimental study on seismic behaviour of an innovative composite shear wall

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ABSTRACT

To improve the strength and ductility of the core walls in high-rise buildings which would be subjected to combined high axial compressive force and bending moment during the earthquake, an innovative concrete filled double-skin steel-plate composite (CFDSC) wall is proposed. The CFDSC wall is composed of the concrete filled double-skin steel-plate wall body with transverse stiffeners, vertical diaphragms and distributed batten plates welding on the internal surface of the double steel plates, and the concrete filled steel tube (CFST) columns including a pair of CFST columns positioned at the end of the cross section as boundary elements and an additional one located in the central section of the wall. Five CFDSC wall specimens were tested under constant axial compressive force and lateral reversed cyclic loading to investigate the seismic behaviour of the wall considering the effect of axial force ratio and shear span ratio. The favourable seismic performance of the CFDSC walls was demonstrated in the test. No serious pinching effect was observed on the hysteresis curves of all the specimens. The drift ratios corresponding to the ultimate stage were recorded as being in the range from 1/67 to 1/30 and the ductility coefficients were varied from 4.50 to 8.22. The experimental results manifest that the CFDSC walls have great energy dissipation capacity. Formulae for calculating the lateral load-carrying capacity of the CFDSC wall, taking the confinement effects from steel plates into account, were proposed. The results calculated by the proposed method show good agreement with the experimental results.

1. Introduction

The reinforced concrete (RC) shear walls are critical structural components to resist the lateral force in high-rise buildings. In recent years, constructions of high-rise buildings are increasing rapidly in China, while the conventional RC shear wall might not be able to provide sufficient resistance to the seismic loading combinations, particularly for the walls located at the lower stories which are usually subjected to substantial axial compressive force and bending moment. To satisfy the seismic design requirement of high-rise buildings in earthquake zone, the concrete filled double-skin steel-plate composite (CFDSC) wall, which consists of two steel faceplates on the exterior surfaces and the infill concrete, is becoming increasingly attractive as the main lateral resistance component. The CFDSC wall takes advantages of both RC wall and steel plate wall [1]. The infill concrete could prevent the concave local buckling of the steel plates, and thus improves the anti-local buckling capacity of the steel faceplates, while the strength and ductility of the inner concrete are enhanced due to the confinement from the outer steel plates. By the reason of its excellent mechanics performance, the thickness of CFDSC wall could be much smaller than that of the conventional RC wall, which could reduce the weight of building and increase the usable floor area [2]. Furthermore, the construction process of the CFDSC shear wall is also quite efficient since the steel faceplates could act as permanent formwork. It has been proved that the CFDSC wall performed high lateral resistance and excellent energy-dissipating capacity, and thus has been adopted in several high-rise buildings to replace the traditional RC shear wall [3,4].

Various types of CFDSC wall and the corresponding design recommendations have been proposed and reported in the existing literatures. A CFDSC wall comprising of vertically aligned profiled steel sheeting and infill concrete was firstly conceived by Wright et al. [5], and its axial compressive, flexural and shear behaviour were further investigated [1,6–8]. To strengthen the combination between the steel plates and the infill concrete, tie bars, tie bolts, stiffeners or vertical diaphragm were adopted in the CFDSC system. Eom et al. [2] tested

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three isolated and two coupled CFDSC walls connected by tie bars with rectangular and T-shaped cross sections under in-plane cyclic loading. The use of tie bars was also introduced by Ji et al. [9] and Chen et al. [10]. However, the construction of tie bars or tie bolts requires complex welding process. Moreover, Nie et al. [11–13] studied the cyclic behaviour of the CFDSC walls using high-strength concrete with vertical diaphragms. Zhang et al. [14] developed the bundled lipped channel-concrete T-shaped composite wall, which is comprised of a cold-formed square hollow section in the centre and two cold-formed lipped channels at each side to form the flange of the wall. Generally, the experimental results of the CFDSC wall with the aforementioned configurations exhibited great mechanical properties with high ductility and energy dissipation capacity. Compared with the ones with tie bar or tie bolts, the CFDSC walls with vertical diaphragms, stiffener or distributed batten plates showed better seismic performance [11,15,16].

Recently, an innovative CFDSC wall was presented and adopted in the China Southern Airlines Building in Guangzhou, China, as Fig. 1 shows. The total height of the China Southern Airlines Building was 150 m, and the thickness of the innovative CFDSC wall was only 220–500 mm. This innovative CFDSC wall was composed of the concrete filled double-steel-plate wall body and the CFST columns, as shown in Fig. 2. A pair of CFST columns was positioned at the end of the cross section to perform as boundary elements, while an additional one was in the central section of the wall to segment the wall into appropriate parts. The CFST columns were connected by the double steel faceplates. In order to enhance the contact between the steel faceplates and the infill concrete and reduce the effective width of the steel faceplate for alleviating the local buckling effects, the transverse stiffeners and vertical diaphragms were welded on the internal surface of the steel plate and the steel plates were divided into several compartments. At the centre of each steel compartment, a batten plate was attached between the double steel plates for further strengthening the connection between the inner concrete and the steel plate. The proposed configuration is expected to not only augment the seismic performance of the CFDSC wall but also simplify the construction process, which consequently reduces the cost. The deformation capacity of the CFDSC wall could be enhanced significantly by the employment of CFST boundary elements [16,17] and the reinforcements which combine the double steel plates and the inner concrete into integration. The CFST column located in the middle of the section separates the whole steel plate into small part, which leads to more convenient welding of the inner reinforcements and easier achievement of modular production. The avoidance of serried tie bars or tie bolts welding in the steel plate could also simplify the construction procedure.

(a) Architectural rendering

(b) Photo of building site

(c) Installation of composite shear wall

(d) Hoisting of composite shear wall

Fig. 1. China Southern Airlines Building.