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Reversed cyclic performance of cold-formed steel shear walls with reinforced end studs

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ABSTRACT

To improve the shear performance of cold-formed steel (CFS) shear walls and to prevent a structure from collapsing due to compression buckling of the end studs, shear walls with concrete-filled rectangular steel tube columns as end studs were proposed. Cyclic loading tests on nine full-scale CFS shear walls with reinforced end studs were conducted concerning the influence of stud type, sheathing material and openings. The results showed that: (1) the walls' shear strength will be improved because the screws will be less able to tilt due to the concrete core in the reinforced end studs; (2) the walls' ductility may be improved by increasing stud thickness, but no meaningful difference in shear strength was observed when the interior stud section's type was replaced with a coupled C section; (3) compared to a wall that was individually sheathed with autoclaved lightweight concrete slabs on the external side, the shear strength could be increased by approximately 58.1% due to the addition of supplementary bolivian magnesium boards, which would be installed under the condition of an identical sheathing setup on the inner side; (4) the wall's shear capacity would be decreased due to an increase in the opening's size, and this shear capacity would also be impacted by the opening's position. Based on the experimental results and a bearing mechanism analysis of CFS shear walls with reinforced end studs, a simplified method for predicting the perforated walls' shear capacity was proposed, and the differences between the calculated and experimental results were within 8%.

1. Introduction

Over the years, cold-formed steel (CFS) shear walls have been widely used in residential and small commercial buildings in the USA, Japan, Australia, and Europe. Because of their light weight, ease of installation, and other advantages including their environmental characteristics and recyclability, CFS shear wall systems are increasingly used in China. However, these types of systems are still in the primary development phase.

To promote the development of mid-rise CFS buildings, a primary goal of this study was to improve the shear strength of CFS shear walls. Numerous experimental studies on the shear performance of CFS shear walls have shown that a failure of the fastener connections between the CFS framing members and the sheathings is the main reason that these walls fail in terms of shear. This type of failure is especially common near the edges of the walls and at the seams [1–5], and the failure of fastener connections is often expressed as a bearing failure of the wallboards [6–8]. However, a failure in the fastener connections has always been caused by tilting of the screws. After a screw head tilts, it will sink into the wallboard, resulting in an acceleration in the bearing failure of the wallboard. Consequently, limiting the ability of the screws to tilt is an effective way to improve the shear performance of fastener connections. Sheathing strength is also a key factor that influences the shear performance of fastener connections. Compared with gypsum wallboards and oriented strand boards, the shear strength of fastener connections and shear walls have significantly improved, especially when calcium silicate boards are used as wallboards due to their higher strength [4,8–10]. Nevertheless, experiments performed by Chen et al. [11] have confirmed that calcium silicate boards may cause severe safety issues for mid-rise CFS structures due to their explosive spalling at high temperatures, while bolivian magnesium boards and autoclaved lightweight concrete slabs exhibit excellent fire resistance.

In contrast, compression buckling of the end studs is an adverse failure mode for walls that resist lateral loads, and this type of buckling is frequently observed in CFS shear wall damage [1–5]. After compression buckling begins in the end studs, a wall can lose its bearing capacity, resulting in a construction collapse.

According to Cheng et al. [12], recent attention has been focused on the shear performance of walls that are sheathed with structural composite panels; these panels may improve the ease of construction, shear strength, and non-combustibility of the walls. However, compression buckling of the end studs is a recurring problem. Ye et al. [13] proposed a mid-rise CFS steel residential structure, in which concrete-filled

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Table 1
Test specimen details.

Specimen number	Section type of CFS studs (mm)		Specimen size (B × H)	Opening size (b × h)	Sheathing setups			
	Interior studs	End studs			Base layer		Face layer	
					1	2	3	4
WA1	C89	□89 × 100 × 0.9[a]	3.6 m × 3.0 m	–	GWB			
WA2	C89				BMB		GWB	
WA3	Coupled C89[b]				BMB		GWB	
WB1	Coupled C140[c]	□140 × 140 × 1.5[d]			BMB	–	GWB	ALC
WB2	C140				BMB		GWB	ALC
WB3	C140		2.1 m × 3.0 m		BMB		GWB	–
WC1	C140	□140 × 140 × 1.5[d]	3.6 m × 3.0 m	1.5 m × 1.5 m	BMB		GWB	ALC
WC2	C140			1.5 m × 2.4 m	BMB		GWB	ALC
WC3	C140				BMB		GWB	–

Note: a, d; concrete-filled rectangular steel tube (CFRST) columns (see Fig. 3); b, c; the coupled C sections (see Fig. 4).

rectangular steel tube (CFRST) columns were recommended to improve the stability of the walls.

The main purpose of this study is to investigate the shear performance of CFS shear walls with CFRST columns as end studs. Cyclic loading tests on nine full-scale walls with reinforced end studs were conducted. Three types of anti-fire wallboards (gypsum wallboard, bolivian magnesium boards and autoclaved lightweight concrete slabs) were used by different combinations to improve shear strength of the walls concerning the fire resistance requirement for mid-rise CFS structures. Details about the specimens, the test procedures, and the test results were presented. Furthermore, a quantitative study on the effect of an opening's size and position on the shear performance of a wall was also conducted, based on which a simplified method was proposed to predict the shear capacity of walls with an opening.

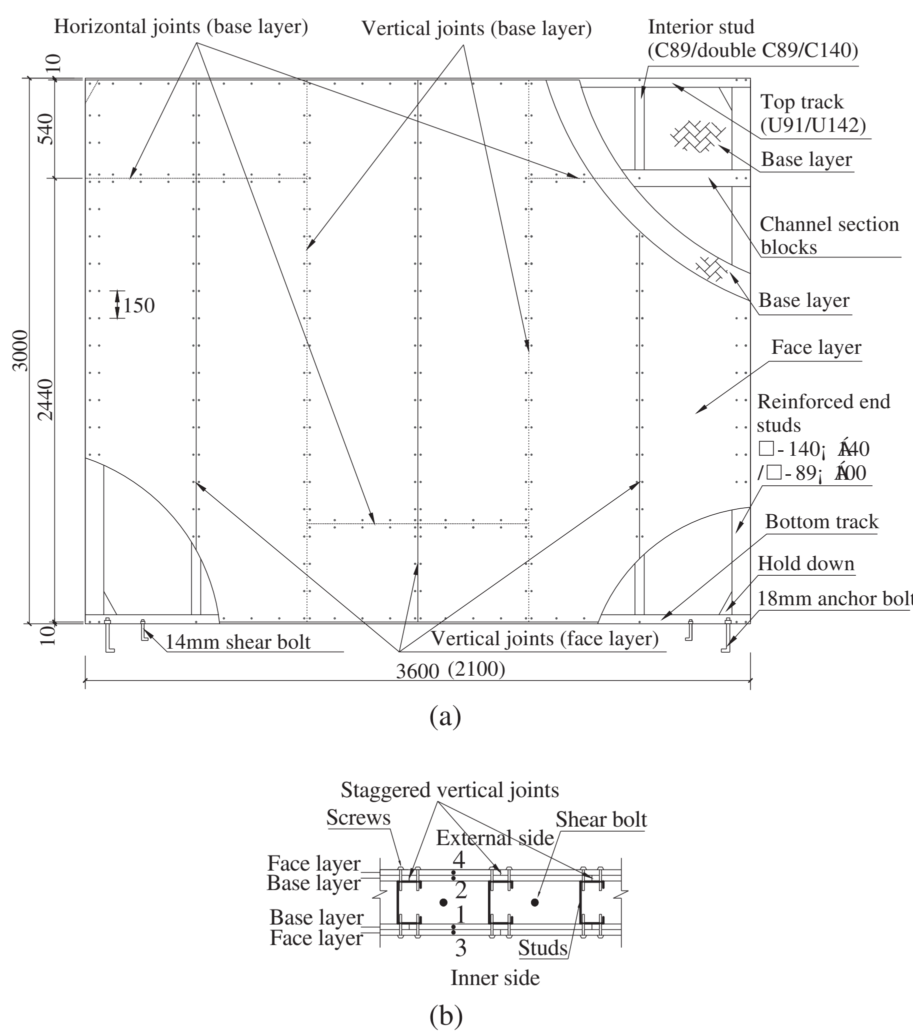

Fig. 1. Configuration of specimens WA1–WA3 and WB1–WB3. (a) Basic wall configuration. (b) Details of sheathing setups.