Thin-Walled Structures 98 (2016) 312–331

Contents lists available at ScienceDirect

Thin-Walled Structures

journal homepage: www.elsevier.com/locate/tws

Performance of cold-formed-steel-framed shear walls sprayed with lightweight mortar under reversed cyclic loading

Bin Liu [a,*], Ji-Ping Hao [a], Wei-Hui Zhong [a], Hao Wang [b]

[a] Department of Civil Engineering, Xi'an University of Architecture and Technology, Xi'an, PR China
[b] CRUPE Framing (UK) Ltd., Twickenham, Greater London, UK

ARTICLE INFO

Article history:
Received 17 July 2014
Received in revised form
20 April 2015
Accepted 24 September 2015
Available online 19 October 2015

Keywords:
Cold-formed steel
Shear wall
Sprayed lightweight mortar
Calcium silicate board
Reversed cyclic loading

ABSTRACT

Sheathing with sprayed lightweight mortar (SLM) is proposed to enhance the performance of shear walls framed with cold-formed steel (CFS). Full-scale specimens were tested to assess the failure mode, strength, stiffness, ductility, and energy absorption achieved. Slippage between the CFS framing and the SLM significantly increased the walls' strength and stiffness and restricted crack propagation. The failure mode typically involves local buckling of the end studs. Specimens with SLM on the front and calcium silicate boards (CSBs) on the back were weaker than specimens with SLM sheathing on both sides. Joint-strengthened knee elements or X-shaped steel-strap bracings increased the load-bearing capacity and reduced the ductility of the specimens.

© 2015 Elsevier Ltd. All rights reserved.

1. Introduction

As alternatives to timber structures, structures framed with cold-formed steel (CFS), consisting of CFS members and lightweight sheathing, are suitable for load-bearing and enclosure systems in low-rise residential and commercial buildings. Because of their many advantages, which include light weight, dimensional stability, cost effectiveness, full recyclability, and workability, such structures have been widely employed in recent years in North America, Europe, Australia, Japan, and China. CFS-framed shear walls constitute the main force-resisting members of such structural systems, which typically consist of steel frames (including studs, tracks, blocking members, and bracing members) and lightweight sheathing attached to the CFS members by self-drilling screw connections. The shear walls support the vertical loads transferred from the floors and roofs, as well as horizontal wind and seismic loads. The mechanical behaviour of such structures under horizontal loads is complex. The relevant standard of the American Iron and Steel Institute, AISI S213 [1], was based on the results of a series of monotonic and cyclic tests conducted on CFS-framed shear walls by Serrette et al. [2–4].

Fülöp and Dubina [5] also conducted a series of monotonic and cyclic loading tests on full-scale CFS-framed walls with different types of sheathing, including walls made of corrugated sheets, gypsum boards, and oriented strand boards (OSBs). The results showed that the shear resistance of the wall panels was significant in terms of both rigidity and load-bearing capacity and that the hysteretic behaviour was characterised by significant pinching. Failure was initiated in the bottom track around the anchor bolt, and this heightened the need for strengthening the corners. The damage gradually increased in the seam fasteners until overall failure of the wall panels occurred.

Pan and Shan [6] conducted an experimental study on the structural strength of CFS-framed shear walls sheathed with gypsum boards, calcium silicate boards (CSBs), and OSB panels. Two aspect ratios, 1.0 and 2.0, were used in the design of the test specimens. The CFS walls with the OSB panels were found to have the highest ultimate strength, followed by the CFS walls with CSB panels and the CFS walls with gypsum boards. For the same aspect ratio, the ultimate strengths of the wall specimens with one-sided sheathing were approximately 50% of those of the specimens with two-sided sheathing. Design ductility ratios of 6.6, 3.8, and 3.9 were suggested for CFS-framed walls sheathed with gypsum boards, CSB panels, and OSB panels, respectively.

Nithyadharan [7] tested eight different CFS-framed shear walls sheathed with CSB panels and observed that the failure process involved titling, bearing, and pull-through of the screws, followed by complete separation and rigid body rotation of the CSB panels. The ultimate strength and energy dissipation increased with

* Correspondence to: Department of Civil Engineering, Xi'an University of Architecture and Technology, No. 13, Yanta Road, Xi'an 710055, Shaanxi Province, PR China.
E-mail address: liubin881113@gmail.com (B. Liu).

http://dx.doi.org/10.1016/j.tws.2015.09.024
0263-8231/© 2015 Elsevier Ltd. All rights reserved.

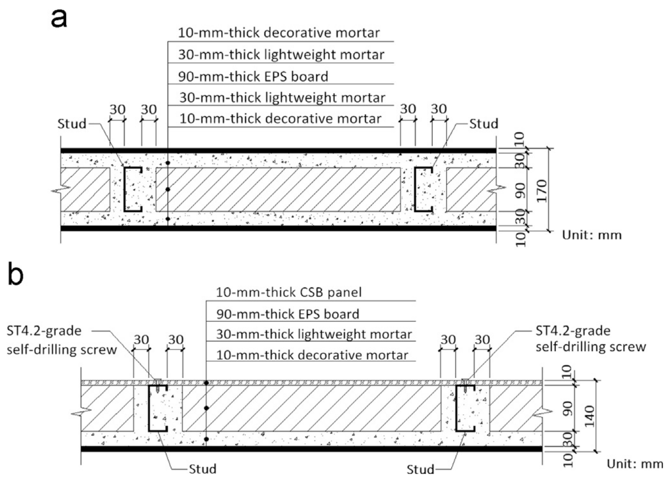

Fig. 1. Details of wall specimens: (a) wall specimen with SLM on both sides and (b) wall specimen with SLM on the front side and CSB panels on the back side.

increasing board thickness and screw edge distance. The wall panels with a Type B board arrangement (two boards with a discontinuity at the intermediate stud) underwent considerably larger deformations than those with a Type A board arrangement (a single board across which shear was transferred) because of the additional relative slippage at the screws in the interior studs of the former.

Liu [8] conducted a series of cyclic tests on full-scale CFS walls sheathed with OSB panels. The results indicated that the primary energy dissipation mechanism occurs at the fastener-to-sheathing connections and involves tilting, bearing, and pull-through. The use of interior gypsum boards was observed to increase the initial stiffness and modestly increase the strength, while the other behaviours were similar to those observed in cases with a ledger track and no interior gypsum board. Overall, the hysteretic behaviour of the CFS wall panels was found to include a severe pinching response. Equivalent energy elastic plastic (EEEP) and Pinching4 models fitted to the tested data were recommended for use in nonlinear history analysis.

Zeynalian [9] studied the structural behaviour of CFS-framed shear walls sheathed with fibre-cement boards (FCBs) under cyclic lateral loading and concluded that the lateral resistance of CFS walls sheathed with FCB panels under cyclic loading was satisfactory with regard to both the shear strength and ductility and that the design was thus usable in seismic regions. The removal of FCB panels from one side was observed to decrease both the strength and ductility of the wall, although this modification could be made efficiently when diagonal stud elements were used at the corners of the wall.

The US Army Corps of Engineers (USACOE) published TI 809-07 [10], which stipulates more stringent guidelines for the design of CFS-framed shear walls than the AISI Standard [1]. The USACOE standard suggests that in calculating the shear capacity of a CFS wall, it is reasonable to ignore the contribution of the sheathing on both sides and rely on only the strength of the CFS frame. Zeynalian [11–13] conducted experimental and numerical studies of CFS frames with knee elements and concluded that although CFS frames exhibit relatively high maximum drifts, their strengths are lower than those of X-shaped bracing systems. Knee-stud bracing systems can thus only be used in low-seismic-activity regions where the required lateral resistance capacity is low.

Moghimi [14,15] investigated the shear behaviour of CFS frames with steel-strap X-shaped bracing. The results showed that local and distortional buckling of the frame members occurred in stable modes and that strap-braced CFS frames could be used to provide a considerable amount of shear capacity after the appearance of the first signs of buckling. The addition of brackets to the four corners of a CFS frame could also be used to considerably improve the lateral performance of the frame assemblies. By choosing appropriate perforated straps, the strap alongside the distributed holes could be made to reach yielding, thus avoiding the tearing of the strap at the tension unit location or at the strap-to-frame connection.

Iuorio and Macillo [16,17] conducted experimental and theoretical studies to evaluate the seismic behaviour of CFS-strap-braced stud walls. Their results showed satisfactory agreement between the theoretically predicted and experimentally determined behaviour of the walls and connection systems in terms of shear capacity. The study results also highlighted the need for careful design of the wall corners because their behaviour might significantly affect the overall wall response. Moreover, the behaviour factor values provided by AISI S213 [1] were widely confirmed by the experimental tests, with the code values corresponding to the lower limits of the experimental results.

In recent years, some researchers have proposed new connecting and sheathing techniques to improve the shear resistance of CFS-framed shear walls. Serrette [18,19] used steel pins and structural adhesive to attach structural wood sheathing, and the

Table 1
Description of test specimens.

Number	Group	Specimen label[a]	Type of CFS frame	Type of sheathing	Wall thickness (mm)	Vertical loading (kN)
1	Type A	F-KB	Knee elements	No sheathing	90	30
2		F-XB	X-shaped bracing on both sides			
3	Type B	W-NB-1	No bracing	SLM on both sides	170	30
4		W-NB-2				60
5		W-KB-1	Knee elements			30
6		W-KB-2				60
7		W-KB-S-1	Knee elements with joint-strengthening			30
8		W-KB-S-2				60
9		W-XB-1	X-shaped bracing on both sides			30
10		W-XB-2				60
11	Type C	W-NB-CSB	No bracing	SLM on the front side and CSB panels on the back side	140	30
12		W-XB-CSB	X-shaped bracing on one side			

[a] The notations of the letters in the specimen labels are as follows: F: frame, W: wall, NB: no bracing, KB: knee-element bracing, XB: X-shaped bracing, CSB: calcium silicate board, S: joint-strengthening.

Download English Version:

https://daneshyari.com/en/article/308480

Download Persian Version:

https://daneshyari.com/article/308480

Daneshyari.com