Thin-Walled Structures 94 (2015) 280–292

Contents lists available at ScienceDirect

Thin-Walled Structures

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

Testing of steel sheathed cold-formed steel trussed shear walls

Hui-Wen Tian [a], Yuan-Qi Li [a,b,*], Cheng Yu [c]

[a] Department of Structural Engineering, Tongji University, Shanghai 200092, China
[b] State Key Laboratory of Disaster Reduction in Civil Engineering, Shanghai 200092, China
[c] Department of Engineering Technology, University of North Texas, Denton, TX 76207, USA

ARTICLE INFO

Article history:
Received 27 October 2014
Received in revised form
24 March 2015
Accepted 10 April 2015
Available online 14 May 2015

Keywords:
Cold-formed steel
Shear wall
Truss
Corrugated steel sheathing
Lateral loading
Connection

ABSTRACT

This research is focused on the behavior of a novel cold-formed steel (CFS) shear wall system- steel sheathed cold-formed steel trussed shear wall (SSCFSTSW), which is different in skeleton configuration compared to conventional steel sheathed CFS framed shear wall. A test program was conducted on shear walls of various configurations. The walls differed in sheathing, chord studs and skeleton configurations. The results indicated that SSCFSTSW gave a significantly higher ultimate strength than that obtained from conventional shear walls. Based on the results, detailed discussion of the influence of different configurations on the performance of shear walls is given.

1. Introduction

Cold-formed steel (CFS) structures have been widely used in the building construction industry due to their unique advantages such as being cost-effective, high strength and easy to work with. CFS wall frames are used to bear the vertical loads and to resist the horizontal loads such as earthquake loads and wind loads. These conventional walls are mainly attached with Oriented-Strand Board (OSB), gypsum board or cement board sheathing. In recent years, using steel sheets as a sheathed material for CFS wall frames has also gained popularity in the building construction due to its high shear resistance, high ductility and good construction feasibility. The system mentioned above has already been approved as a lateral force resisting system and its design has been addressed through the American Iron and Steel Institute (AISI) North American Standard for Cold-Formed Steel framing–Lateral Design S213 [1]. In this research, a new type of cold-formed steel shear wall system referred to as steel sheathed cold-formed steel trussed shear wall (SSCFSTSW) for use in mid-rise residential and commercial buildings was developed. As shown in Fig. 1, the new shear wall system is different in skeleton configuration from the conventional steel sheathed CFS framed shear wall. SSCFSTSW uses a truss as the structural skeleton instead of CFS frames in conventional shear walls. This research is focused on the structural strength and behavior of SSCFSTSW under in-plane shear loading. Compared to conventional steel sheathed CFS framed shear wall, SSCFSTSW gave a significantly higher ultimate strength and a greater unit elastic stiffness, and dissipated more energy. The sheathing-to-framing connection failure mode and the brace-to-track connection failure mode observed in the tests allowed the shear walls to dissipate more energy in the lateral load path, and are consistent with the seismic design philosophy. As such, in earthquake design, the two connections probably act as the fuse devices that dissipate seismic energy through inelastic deformation. However, the new shear wall system may have some shortcomings, too, such as the complexity in terms of construction due to many different members to be installed, difficulty in guaranteeing the construction quality, and poor performance in thermal insulation and corrosion resistance.

In recent years, a series of experimental researches has been carried on steel sheathed CFS framed shear walls in order to achieve some purposes including adding new design parameters to the codes and verifying strength values presented in the codes. Some researchers also investigated the influence of different details on the structural performance. These researches are briefly reviewed as follows.

Serrette et al. [2,3] conducted a research program consisted of 14 test walls with dimensions of $610 \times 2440\ \text{mm}^2$ and $1220 \times 2440\ \text{mm}^2$, and the results have been included in the U.S. codes. The nominal thickness of frame members was 0.84 mm, and the nominal thickness of steel sheathing was 0.46 mm and 0.68 mm. Yu et al. [4,5] carried out a research project of shear wall tests with the aim of adding new values to the codes. These walls were constructed of 0.84 mm or

* Corresponding author at: Department of Structural Engineering, Tongji University, Shanghai 200092, China. Tel.: +86 21 65980586.
E-mail addresses: crazythw2008@126.com (H.-W. Tian), liyq@tongji.edu.cn (Y.-Q. Li), cyu@unt.edu (C. Yu).

http://dx.doi.org/10.1016/j.tws.2015.04.009
0263-8231/

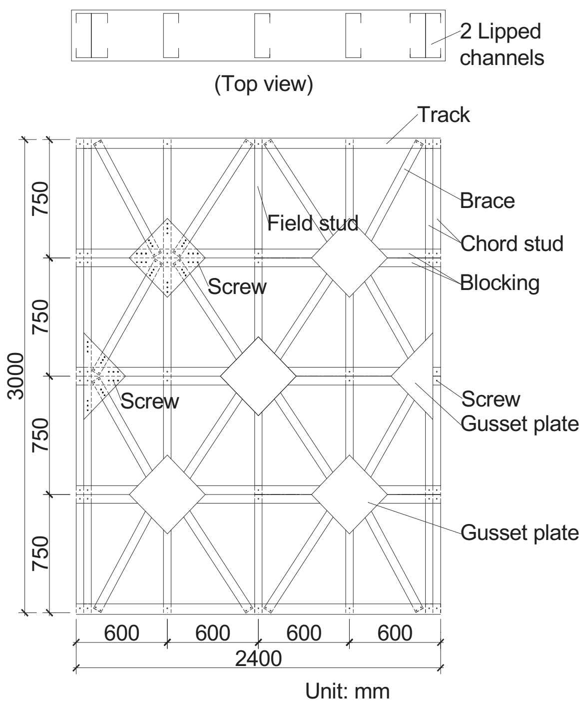

Fig. 1. Detail of truss (Configuration 4).

1.09 mm thick framing, with 0.69 mm, 0.76 mm or 0.84 mm thick sheathing. Three fastener spacing configurations on the panel edges were 152 mm, 102 mm and 51 mm. A discrepancy between the testing results obtained from Yu and Serrette's test results for 0.69 mm sheet steel walls was found. Ellis [6] conducted a series of shear wall tests to analyze the reason for this discrepancy. He studied the effects of using CUREE and SPD loading protocols and determined that the different reversed cyclic protocols likely resulted in the difference in measured responses. Yu and Chen [7,8] experimentally studied another research to verify the published nominal shear strength values for 0.46 mm and 0.69 mm steel sheets. Another goal in the tests was to investigate the effects of wall detailing such as framing thickness, sheathing screws size and screws pattern for 1.83 m wide CFS shear walls. The framing thickness was 0.84 mm, 1.09 mm and 1.37 mm, and the sheathing thickness was 0.46 mm, 0.69 mm, 0.76 mm and 0.84 mm. Ong-Tone, Rogers, Balh and DaBreo et al. [9–12] conducted a suite of shear wall tests with the aims of developing Canadian seismic design provisions for steel sheathed shear walls and of confirming the US values that are listed in the AISI S213 Lateral Design Standard. The shear wall configurations varied in framing thickness (studs, tracks and blockings), sheathing thickness and sheathing fastener spacing. These test walls were constructed of 0.84 mm, 1.09 mm or 1.37 mm thick framing, with 0.46 mm or 0.76 mm thick steel sheathing, using screw fastener schedules of 50 mm, 100 mm and 150 mm.

2. Shear wall test program

2.1. Test matrix and test specimen

The test program included 8 shear walls (Configurations1–5), in which the behavior of five walls (Configurations1–5) was investigated under the monotonic loading and three (Configurations 1, 2 and 5) under the reversed cyclic loading protocol (Table 1). Test specimens included SSCFSTSW (Configurations 1–3), steel sheathed CFS framed shear wall (Configuration 5) and truss (Configuration 4), shown in Figs. 1–3. All the wall specimens were with the same dimension of 2400 mm width and 3000 mm height. The walls differed in skeleton construction, sheathing configuration and chord studs detail. The matrix of wall specimens encompassed two skeleton constructions of frame and truss, two sheathing configurations of corrugated and plain steel sheets, and two chord studs types of built-up and back-to-back sections.

Table 1
Matrix of shear wall test specimens.

Configuration	Number of tests and protocol[a]	Skeleton construction	Sheathing configuration	Chord studs type
1	1M and 1C	Truss	Corrugated steel sheet	Built-up section
2	1M and 1C	Truss	Plain steel sheet	Built-up section
3	1M	Truss	Plain steel sheet	Back-to-back section
4	1M	Truss	No sheathing	Back-to-back section
5	1M and 1C	Frame	Corrugated steel sheet	Built-up section

[a] M-Monotonic loading, C-Cyclic loading.

The SSCFSTSWs (Configurations 1–3) were constructed of the truss skeleton and three steel sheathing (Figs. 1 and 2). The truss skeleton was assembled with tracks (142 mm web × 45 mm flange × 1.2 mm thickness), studs (140 mm web × 50 mm flange × 12 mm lip × 1.2 mm thickness), blockings (142 mm web × 45 mm flange × 1.0 mm thickness), braces (140 mm web × 50 mm flange × 12 mm lip × 1.0 mm thickness) and gusset plates (Fig. 1). The member sizes of the truss skeleton were chosen according to Eqs. (1)–(5) in the following prior to testing. For the reasons of simplicity in terms of construction and calculation, firstly, two thicknesses of the truss members were chosen, then further design calculations were made according to Eqs. (1)–(5) and some optimizations for the member sizes were conducted.

According to the analysis that have been carried out by finite element analysis software, the predominant failure modes of truss were the axial compression failure of brace, the shear failure of screw connections at the end of brace and the axial compression failure of chord studs. Therefore, the design of the truss skeleton included the determination of the shear strength of the truss associated with the failure of brace and the check of the axial strength for chord studs.

The shear strength of the truss can be expressed as

$$V = \min(V_1, V_2, \ldots, V_I, \ldots, V_L) \tag{1}$$

$$V_I = \alpha\beta mN \cos\theta \tag{2}$$

$$N = \min(P_n, n_1 P_{ss1}, n_2 P_{ss2}) \tag{3}$$

where V is the shear strength of the truss from the analysis; V_1, V_2, V_I, V_L are the shear strength of the truss on floor 1, floor 2, floor I and floor L from the bottom to the top; α is the correction coefficient due to the buckling of the brace-to-track connections, approximately taken as unit; β is the correction coefficient due to the difference of aspect ratio, approximately taken as unit; m is the number of the braces in floor I; N is the minimum value of the axial strength for the brace, the shear strength of screw connections at one end of the brace, the shear strength of screw connections at the other end of the brace; θ is the angle between the brace and the horizontal line; P_n is the axial strength for the brace determined by the procedure described in APPENDIX 1.2.1 according to the North American Specification for the Design of Cold-Formed Steel Structural Members (S100-2007) [13]; $n_1 P_{ss1}$ is the shear strength of screw connections at one end of the brace, n_1