Thin-Walled Structures 75 (2014) 76–86

Contents lists available at ScienceDirect

Thin-Walled Structures

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

Design of steel sheathed cold-formed steel framed shear walls

N. Balh [a], J. DaBreo [a], C. Ong-Tone [a], K. El-Saloussy [a], C. Yu [b], C.A. Rogers [a,*]

[a] Department of Civil Engineering, McGill University, Montreal, Canada
[b] Department of Engineering Technology, University of North Texas, Denton, USA

ARTICLE INFO

Article history:
Received 1 August 2013
Received in revised form
26 October 2013
Accepted 28 October 2013
Available online 27 November 2013

Keywords:
Shear wall
Design
Cold-formed steel
Lateral loading
Panel
Connections

ABSTRACT

A method for the design of steel sheathed cold-formed steel framed shear walls has been developed for inclusion in the American Iron and Steel Institute's North American standards for lateral design using a comprehensive database of single-storey shear wall tests carried out in Canada and in the United States. The wall configurations differed in terms of wall aspect ratio, framing and sheathing thickness, screw fastener schedule and framing reinforcement. The Equivalent Energy Elastic–Plastic (EEEP) analysis approach was used to derive key design information from the test data, including: nominal shear resistance, a resistance factor, an over-strength factor for capacity based seismic design and 'test-based' seismic force modification factors for ductility and over-strength.

1. Introduction

At present, the design in North America of light framed shear walls constructed of cold-formed steel (CFS) components falls under the jurisdiction of the American Iron and Steel Institute's (AISI) S213 Standard [1]. However, to improve on the usability and clarity of this existing standard its contents are to be reassigned to two new AISI standards that are currently in development. The AISI S240 North American standard for cold-formed steel structural framing [2] will include, among other aspects, the design of lateral load carrying systems for wind and low seismic loading, while the AISI S400 North American standard for seismic design of cold-formed steel structural systems [3] will address high seismic concerns. Moreover, the two new standards are to be established to improve on the efficiency and the practicality of incorporating upgraded design provisions for cold-formed steel systems and new lateral framing systems into a codified format available to practicing engineers. A lateral framing system for which improvement to the design process is warranted is the screw connected steel sheathed CFS framed shear wall. The existing AISI S213 design provisions for the USA and Mexico are limited to a few wall configurations (combinations of member thickness, sheathing thickness and sheathing connection pattern), while no design provisions are available for Canada. This limitation in design information severely restricts the capability of engineers to specify and design these all-steel shear walls. As such, there is a need to develop design provisions for a greater range of steel sheathed shear walls, with the intent of including the resulting design method in the new AISI S240 and S400 standards.

A design method for wood sheathed CFS framed shear walls was developed [4] and incorporated into AISI S213; the approach taken in the development of this existing design method, which is reliant on information gained from the testing of representative shear wall assemblies [5,6], can also be used to establish a design method for steel sheathed shear walls (Fig. 1(a)). In earthquake resistant design of light framed shear walls, the sheathing-to-framing screw connections act as the fuse device that dissipates seismic energy through inelastic deformations. The use of thin steel sheathing in-place of wood structural sheathing is expected to modify the behaviour of a shear wall due to the difference in material and thickness properties of the sheathing and the behaviour of the sheathing screw fasteners under load; thus, separate design information is required. A database of CFS framed steel sheathed shear wall tests was first generated by combining the results of laboratory based research programs in Canada [7–11] and in the United States [12–14]. The test programs comprised wall specimens that varied in aspect ratio, framing and sheathing thickness and screw fastener schedule/spacing. Additionally, included in the database were shear walls with special frame blocking reinforcement that were subjected to combined gravity and lateral loading.

The objective of the research described herein was to use this database of shear wall tests to develop a design method for steel

* Correspondence to: Department of Civil Engineering, McGill University, Macdonald Engineering Building, 817 Sherbrooke Street West, Montreal, QC, Canada H3A 0C3. Tel.: +1 514 398 6449; fax: +1 514 398 7361.
E-mail address: colin.rogers@mcgill.ca (C.A. Rogers).

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http://dx.doi.org/10.1016/j.tws.2013.10.023

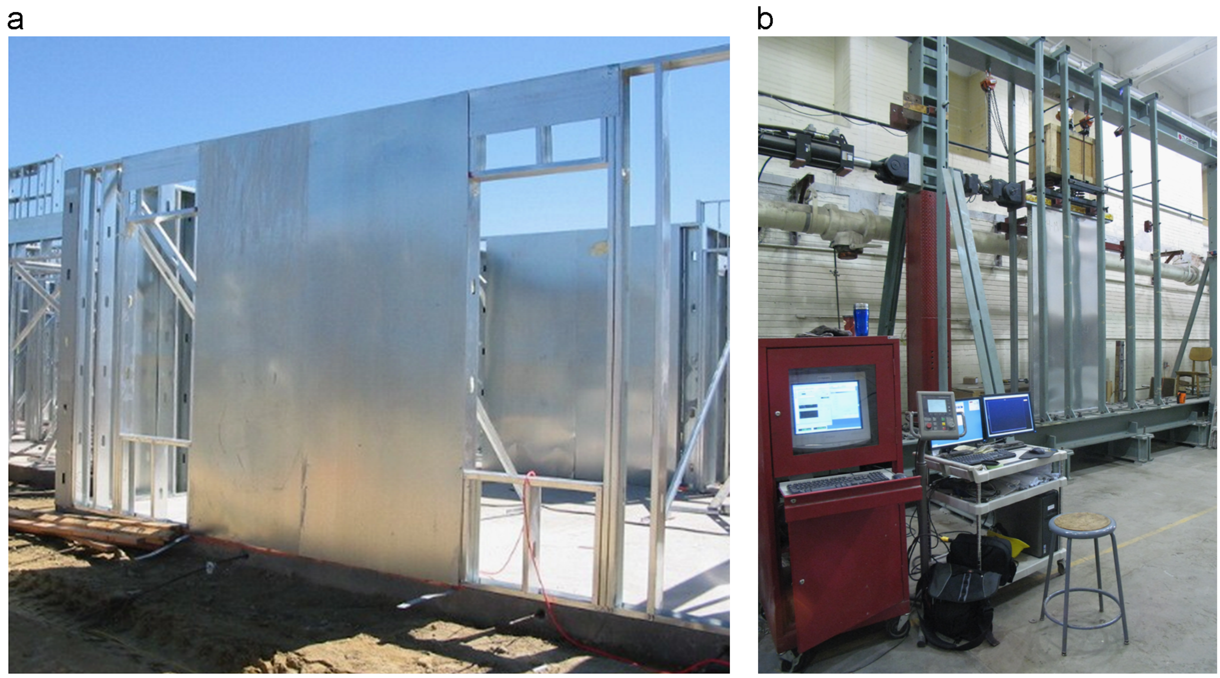

Fig. 1. (a) Typical steel sheathed CFS framed shear wall during construction (photo courtesy of K. Bell, Simpson Strong-Tie Co. Inc.), and (b) single-storey shear wall test setup at McGill University.

sheathed CFS framed walls. The scope of research involved the application of the Equivalent Energy Elastic–Plastic (EEEP) method [15–17] to analyse the test data and to derive key design information [7–9,18].

2. Shear wall test programs

Data obtained from the test programs of single-storey steel sheathed shear wall assemblies carried out in Canada (Table 1) [7–10] and in the United States (Table 2) [12,13] were combined to establish a database of information. The Canadian test program comprised two phases [10]; the first phase authored by Balh and Rogers [8] and Ong-Tone and Rogers [7] contained 54 test walls (18 configurations) subjected to displacement based monotonic and reversed cyclic lateral loading protocols, while the second phase included 14 shear walls (8 configurations) tested by DaBreo and Rogers [9] under combined lateral and gravity loading, as depicted in Fig. 1(b). The US test program also comprised two phases; the first was composed of 58 test walls (15 configurations) by Yu et al. [12] and the second phase included 35 test walls (13 configurations) by Yu and Chen [13], all of which were tested under lateral displacement based monotonic and reversed cyclic loading. A brief summary of these two test programs is provided herein.

The first phase Canadian walls were of dimensions (aspect ratios) of 610 mm × 2440 mm (4:1), 1220 mm × 2440 mm (2:1), 1830 mm × 2440 mm (1.33:1) and 2440 mm × 2440 mm (1:1). The framing members and sheathing were of ASTM A653 [21] Grade 230 MPa steel. The studs (92.1 mm web, 41.3 mm flange and 12.7 mm lip) and tracks (92.1 mm web, 38.1 mm flange) were 0.84 mm or 1.09 mm thick, and were connected using No. 8 × 12.7 mm wafer head self-drilling/self-tapping screws. Built-up back-to-back chord studs were used at the wall ends, while single field studs were spaced at 610 mm on-centre along the wall length where applicable. Simpson Strong-Tie S/HD10S hold-down devices were attached to both ends of each chord stud. The sheathing panels were either 0.46 mm or 0.76 mm nominal thickness and were attached to one side of the wall using No. 8 × 19 mm self-drilling/self-tapping pan head screws. The sheathing screws were placed 9.5 mm from the panel edge and spaced at 50 mm, 75 mm, 100 mm or 150 mm on-centre over the perimeter and at 300 mm on-centre along the field stud(s). A typical 1220 mm × 2440 mm wall, sheathed with a single steel panel, is illustrated in Fig. 2(a). The longer walls required two sheathing

Table 1
Matrix of shear wall test configurations from McGill University studies [7–10].

Configuration	Number of tests and protocol[a]	Wall length (mm)	Wall height (mm)	Framing thickness (mm)	Sheathing thickness (mm)	Fastener schedule (mm)[b]
1[c]	3M and 2C	1220	2440	1.09	0.46	150/300
2[c]	2M and 2C	1220	2440	1.09	0.46	50/300
3[c]	2M and 3C	1220	2440	0.84	0.46	150/300
4[d]	2M and 2C	1220	2440	1.09	0.76	150/300
5[d]	2M and 2C	1220	2440	1.09	0.76	100/300
6[d]	2M and 2C	1220	2440	1.09	0.76	50/300
8[c]	2M and 2C	610	2440	1.09	0.76	100
9[c]	2M and 2C	610	2440	1.09	0.76	50
11[c]	2M and 2C	2440	2440	1.09	0.76	100/300
12[d]	1M	1830	2440	1.09	0.76	100/300
13[d]	1M	1830	2440	1.09	0.76	50/300
B1[e]	1M and 1R	1220	2440	1.37	0.76	50/300
B2[e]	1M and 1R	1220	2440	1.09	0.46	50/300
B3[e]	1M and 1R	1220	2440	1.09	0.76	100/300
B4[e]	1M and 1R	1220	2440	1.09	0.76	150/300
B5[e]	1M and 1R	1220	2440	1.09	0.46	100/300
B6[e]	1M and 1R	1220	2440	1.09	0.46	150/300
B7[e]	1M	1220	2440	1.37	0.76	75/300
B8[e]	1M	1220	2440	1.37	0.46	75/300

[a] M-Monotonic, C/R-CUREE reserved cyclic protocol for ordinary ground motions [17,19].
[b] Fastener schedule (*e.g.* 75/300) refers to the approx. spacing in mm between the sheathing to framing screws on the panel perimeter and along the intermediate studs (field spacing).
[c] Balh and Rogers [8].
[d] Ong-Tone and Rogers [7].
[e] DaBreo and Rogers [9]; frames reinforced with quarter-point blocking (same size as track members).