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Experiments on seismic behaviour of steel sheathed cold-formed steel shear walls cladded by gypsum and fiber cement boards

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ABSTRACT

In this paper experiments are presented to investigate the seismic response of steel sheathed cold-formed steel (CFS) shear walls using gypsum and fiber cement board claddings. Six steel sheathed wall specimens of various cladding configurations were tested under cyclic loading. The use of claddings at either or both sides of the walls results in an increase of their lateral stiffness, shear strength and energy dissipation capacity by up to 67, 80% and 76%, respectively. On the use of claddings connected to the CFS walls their effects on the shear strength must be incorporated into the current design specifications for an efficient and safe design.

1. Introduction

Steel sheathed cold-formed steel (CFS) shear walls are identified amongst the lateral load resistant systems in ASCE7-10 [1]. AISI S213-07/S[1]-09 [2] and recently AISI-S240-16 [3,4] and AISI-S400-16 [5,6] present the nominal shear strength of steel sheathed CFS shear walls of 0.457 and 0.686 mm sheathing thicknesses with aspect ratios (i.e. height-to-width ratios) of up to 2:1 and 4:1, respectively. The use of single and double sided steel sheathing on CFS shear walls increases their shear strength and energy dissipation capacity [7,8]. The state-of-the-art of the steel sheathed CFS shear walls has been extensively reviewed by the authors elsewhere [7]. To protect the structural elements of the walls against fire and for the finishing purposes, claddings of different types are being used, which are commonly assumed as non-structural components in design. While several research have been conducted on the structural effect of claddings on various configurations of CFS shear walls [9–17], lack of research is evident for that of the steel sheathed CFS shear walls. Adham et al. [9] performed six cyclic loading tests on one-sided X-strap-braced, 2.44 m × 2.44 m CFS shear walls, most of which were cladded by 16 mm gypsum board on both sides. Serrette and Ogunfunmi [10] conducted a comparative experimental work on 2.44 m × 2.44 m strap-braced CFS walls with and without gypsum board cladding. Gad et al. [11,12], based on their experimental and numerical work, concluded that the overall stiffness and strength of the cladded strap-braced shear walls were the sum of the contributions from gypsum boards and strap-braces. Moghimi and Ronagh [13] showed improvements in the racking resistance of shear walls and the distortional buckling resistance of studs and chord members when cladded with gypsum boards. Research have also conducted [14–17] on various configurations of sheathing on the walls using oriented strand board (OSB), corrugated steel sheet and gypsum board led to conclusions highlighting their effects on the shear strength of the walls.

The reported increase of the shear strength of the walls due to the cladding engagement imposes additional forces on the members in the load path towards the foundation. This effect could eventually change the type of failure of the wall elements from a ductile failure (e.g. in sheathing-to-wall fasteners) to a brittle failure (e.g. chord stud buckling). This is particularly important when considering a significant reduction in the energy dissipation capacity of the steel sheathed shear walls caused by the latter failure as recently reported by the authors [7].

Further, shortage of design specification [2–6] on the structural effects of claddings limits the efficient design of such structures.

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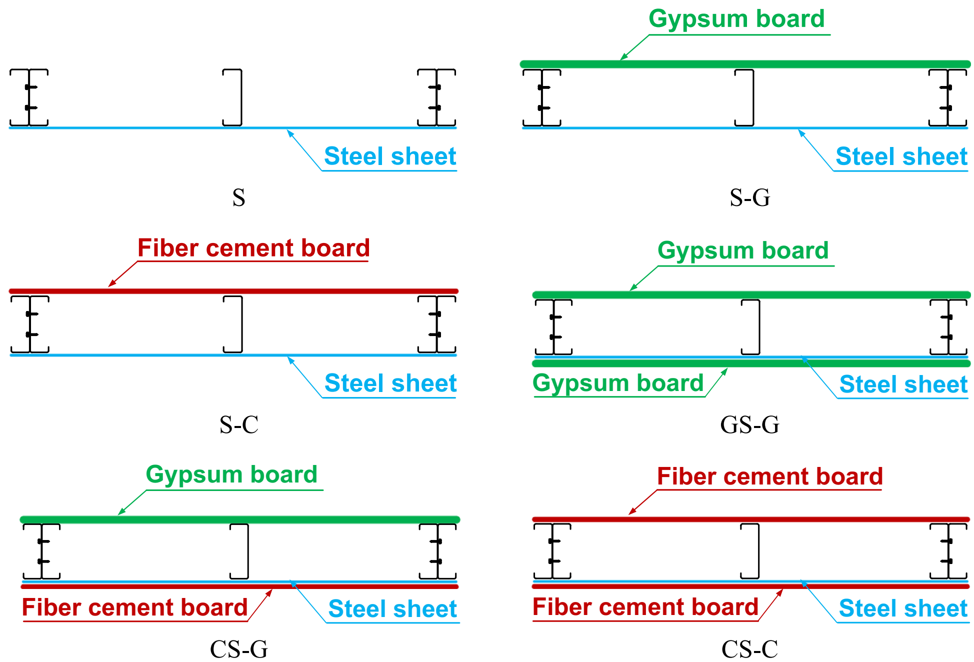

Fig. 1. Plan cross-sections of the specimens.

American Iron and Steel Institute (AISI) Lateral Design standard [2] recommends a 30% increase of shear strength when using a wooden sheathing (or OSB) on one side and a fully blocked gypsum board on the other side of the walls subject to wind and other in-plane loading. Summation of the shear strengths of different sheathing material at both sides of the walls is not permitted [2].

A comparative experimental work was conducted at the Building and Housing Research Centre (BHRC) of Iran to study the structural effects (including lateral stiffness, shear strength, ductility and energy dissipation capacity) of cladding on the steel sheathed shear walls. Six full-scale wall specimens using different cladding configurations of gypsum and fiber cement boards were tested under lateral cyclic loading, the results from which are presented in the following sections. The experimental results are compared against the predictions of the most recent standards for estimating lateral strength of walls with multiple layers of the sheathing material and potentials for design improvements are discussed.

2. Testing arrangements

Presented in Fig. 1 are six steel sheathed shear-wall specimens cladded with various gypsum and fiber cement boards configurations. For ease of referencing S, G and C stand for steel sheathing, gypsum and cement boards, respectively as instructed in Table 1. The nominal thicknesses of the steel sheathing and the wall members were 0.5 mm and 1.25 mm, respectively. The gypsum and fiber cement boards were 15 mm and 10 mm thick, respectively. The specimen details, design considerations, test setup, instrumentation, loading protocol and material properties are presented in the following sub-sections.

Table 1
Shear wall test specimens.

Specimen	Front side sheathing/cladding	Back side cladding
S	Steel sheet (S)	–
S-G	Steel sheet (S)	Gypsum board (G)
S-C	Steel sheet (S)	Fiber cement board (C)
GS-G	Gypsum board + Steel sheet (GS)	Gypsum board (G)
CS-G	Fiber cement board + Steel sheet (CS)	Gypsum board (G)
CS-C	Fiber cement board + Steel sheet (CS)	Fiber cement board (C)

2.1. Specimen details

Fig. 2 shows typical details and screw spacing arrangements of the test specimens. The specimens were 1200 mm wide and 2400 mm high with the studs spaced at 600 m. Built-up back-to-back lipped channels were used for the chord studs, and a single stud placed in the middle. Single tracks were used at the top and bottom of the walls. The nominal depth of the studs and tracks was 150 mm. The studs were connected to the top and bottom tracks through their flanges by three No. 10 × 19 mm self-drilling – self-tapping pan head screws. The webs of the built-up studs were connected to each other by two lines of No. 14 × 32 mm hex washer head (HWH) self-drilling screws at the spacing of 300 mm between the screws in each line. No. 10 × 19 mm self-drilling – self-tapping pan head screws were used to connect the steel sheathing to the wall frame. The screws were positioned along a single line on the tracks and in a staggered pattern on the chord studs spaced at 50 mm. No. 6 × 32 mm and No. 8 × 41 mm self-drilling screws spaced at 200 mm connected gypsum and fiber cement boards, respectively.

Blocking members were placed at the mid-height of the walls, with the same section as the tracks, connected to the interior and chord studs (as seen in Fig. 3). The specific blocking connection detailed to provide higher degree of torsional restraining effect to the studs.

To resist shear forces four ASTM A325-M16 (with 16 mm-diameter bolts, two at each side) were used to connect the bottom track to the base beam. Two hold-downs (fabricated in the testing lab) connected the chord studs to the base beam via ASTM A490-M20 bolts (20 mm diameter) to resist the overturning forces. Fig. 4 shows the hold-down details and dimensions with relatively thick plates to avoid uplift deformations. Each hold-down was connected to the chord stud through three lines of No. 14 × 32 mm hex washer head (HWH) self-drilling screws at 40 mm intervals.