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Monotonic and cyclic loading tests for cold-formed steel wall frames sheathed with calcium silicate board

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ABSTRACT

This research is concentrated on the structural strength and behavior of cold-formed steel wall frame sheathed with calcium silicate board under shear load. Test specimens with two different thicknesses of sheathing were assembled, 9 mm and 12 mm, with one-side or two-side of attachment. Monotonic shear and cyclic loading tests are conducted on wall specimens utilizing two C sections connected back-to-back to be as chord studs and calcium silicate board sheathing on the exterior. Based on the test results, detailed discussions on the strength, stiffness, energy absorption, ductility ratio, and failure mode of cold-formed steel wall specimens are given. It is noted that the failure mostly occurred at the bottom track of wall specimens due to the large deformation or tearing failure of track. The wall strength is not affected by the change of sheathing's thickness significantly, but wall frames attached with two-side calcium silicate board sheathing provide higher resisting strength and stiffness than those attached with one-side sheathing. In this study, test results are also used to compare with the previous study that single chord stud was used in the assembly of wall frame. In addition, the suggested response modification factor of the wall sheathed with calcium silicate board is proposed for design purpose.
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1. Introduction

Cold-formed steel (CFS) structure has been widely used in the building construction industry due to its ease of assembly, high strength, and low cost. Many researches were conducted to study the behaviors of CFS wall frame, and these walls are mainly attached with Oriented-Strand Board (OSB) and gypsum board sheathing. Because of higher shear resistance capacity character, using steel sheet as a sheathed material for CFS wall frame becomes more popular in the building construction. The lateral design of CFS wall framing using plywood, OSB, gypsum board, and steel sheet can be found in the AISI S213 standard [1]. Because there is not much supporting information about the design of CFS wall frame using calcium silicate board (CSB) as a cladding, this research focused on the structural strength and behavior of cold-formed steel wall frame sheathed with calcium silicate board under shear load. Two different thicknesses of sheathing, 9 mm and 12 mm, with one-side or two-side of attachment were utilized in the assembly of test specimens. Both monotonic and cyclic loading tests were conducted in the test program. The strength, stiffness, energy absorption, ductility ratio, and failure mode of each test specimen are discussed and presented in this paper. To obtain the seismic design parameter for the CFS wall frame sheathed with CSB, the response modification factor is also investigated and proposed in this study.

Pan and Shan [2] studied the structural strength of cold-formed steel wall frames with sheathing under monotonic shear loading. Two aspect ratios, 1.0 and 2.0 were utilized in the design of wall specimens. Three different kinds of sheathing material, gypsum board, calcium silicate board, and oriented-strand board, with two different thicknesses (9 mm and 12 mm) were adopted in the test specimens. It was found that the ultimate strengths of specimens with one-side sheathing are about 50% less than those of specimens with two-side sheathing for the wall frames having the same aspect ratio. And the ultimate strengths of specimens having aspect ratio of 2.0 are about 35% less than those of specimens having aspect ratio of 1.0 for the wall frames with the same sheathing configuration. From the test results, it can be seen that the mechanical properties of sheathing material influence not just the specimen's loading capacity, but also the structural behavior. The specimens with gypsum sheathed have the lower values of ultimate load and energy absorption as compared with the specimens with either calcium silicate board or oriented-strand board. However, the specimens with gypsum sheathed have the higher values of ductility ratio.

Xu and Maritinez [3] investigated an analytical method to determine the ultimate lateral strength of the shear wall panel and its associated displacement. The method takes into account the factors that primarily affect the behavior and the strength of

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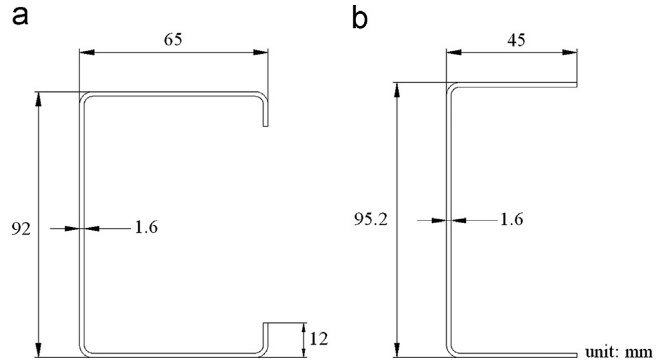

Fig. 1. Dimensions of cold-formed steel sections. (a) C-shaped section and (b) track.

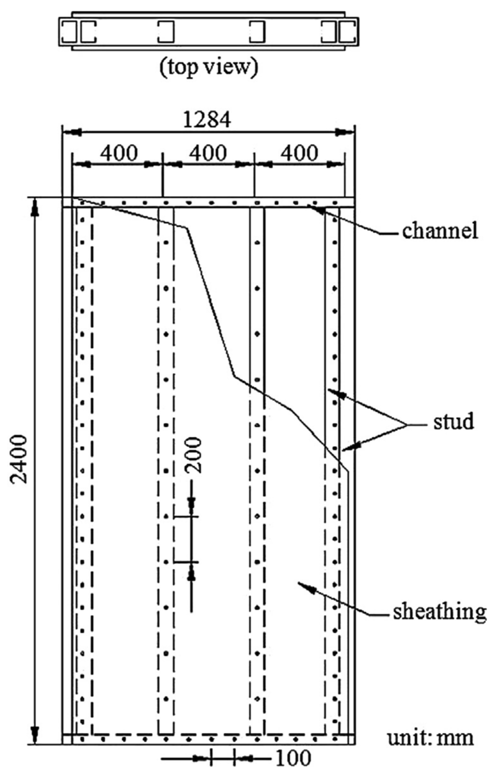

Fig. 2. Configuration of wall frame specimen.

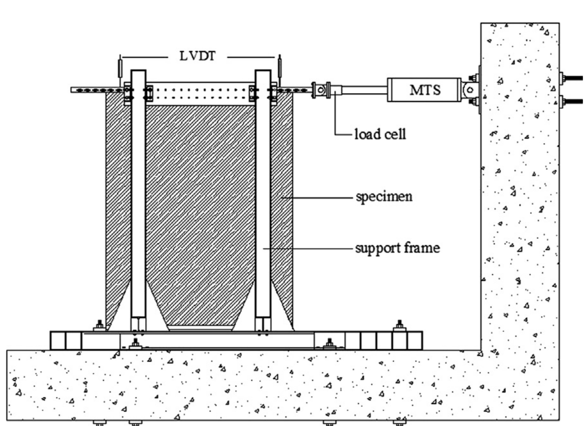

Fig. 3. Setup of wall test specimen.

the shear wall panel, such as material properties, geometrical dimensions and construction details. The comparisons made on the results obtained from the proposed method and extensive experimental tests. They found that the proposed method yields a better accuracy in the lateral strength than the displacements.

Fulop and Dubina [4] studied a 12 ft × 8 ft cold-formed stud frame. The experimental shear walls included frame without sheathing, frames two-side sheathed with gypsum board and corrugated sheet, frames one-side sheathed with OSB and corrugated sheet, frames one-side sheathed with opening on OSB and corrugated sheet, and frames braced with steel strap. Each series consisted of identical wall panels tested statically, both monotonic and cyclic. Results showed that the shear-resistance of wall panels is significant both in terms of rigidity and load bearing capacity, and can effectively resist lateral loads. Failure started at the bottom track in the anchor bolt region, therefore strengthening of the corner detail is crucial.

Moghimi and Ronagh [5] investigated wall frame assemblies having diagonal bracing, bracket, gusset plates and base anchors under lateral cyclic loads. It was found that the CFS wall frames provided better shear resistance when the diagonal strap bracing or the bracket at four corners was used.

Yu [6] conducted a research aimed to add shear strength values for 0.686 mm, 0.762 mm, and 0.838 mm steel sheet sheathed CFS shear walls with aspect ratios of 2:1 or 4:1. The test program consisted of monotonic tests for determining the nominal shear strength for wind loads, as well as the cyclic tests using the CUREE protocol to obtain the shear strength for seismic loads. The test results indicate that the reduction factor provided in the AISI standard is a simple reduction factor that represents fairly well the

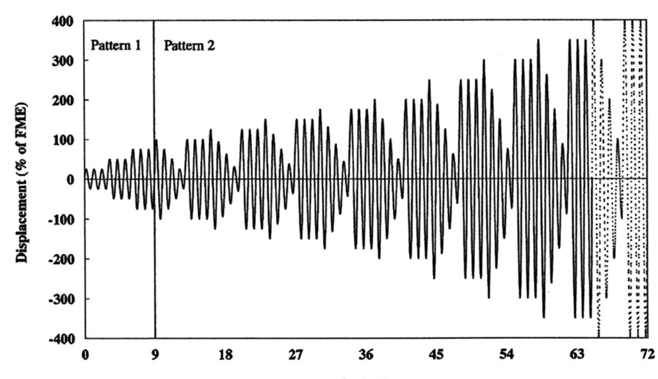

Fig. 4. Displacement and cycles relationship [10].

Fig. 5. Tearing failure of bottom track (FC-C09-HT-2).

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