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# Different slit configuration in corrugated sheathing of cold-formed steel shear wall

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ABSTRACT

Recent research showed that shear walls with corrugated steel sheathing demonstrated high strength, high initial stiffness but low ductility under cyclic loading and thus were not favorable for seismic applications. A possible solution by creating openings in the field of the corrugated sheets in order to improve the ductility was newly proposed by the authors. This paper presents an experimental study on the seismic behavior of the cold-formed steel shear walls using corrugated steel sheathings with different slits configurations. A total of 14 full scale shear wall specimens, including seven different slit configurations and one unperforated wall configuration, were tested under lateral cyclic loading. The test results indicate that with proper slit configurations on the sheathing, the corrugated steel sheathed shear wall shows an improved high ductility without significant reduction in shear strength and stiffness. Details of the test program and general results are presented in this paper.


## 1. Introduction

In recent years, cold formed steel (CFS) has become increasingly popular for low- and mid-rise residential and commercial buildings due to its favorable properties of light weight, high strength-weight ratio, non-combustibility, quick construction process, and less labor requirement. High-performance CFS shear walls with different innovative sheathing material were investigated by worldwide researchers. Discoveries from previous research (Fülöp and Dubina [1], Stojadinovic and Tipping [2], Yu et al. [3]) have proven that shear walls with corrugated steel sheathing are promising solutions due to its high strength and high stiffness. However, previous research also found that shear walls with corrugated steel sheathing demonstrated lower ductility under cyclic loading than the conventional flat steel sheet shear walls and shear walls sheathed by wood based panels. The low ductility was primarily caused by the screw connection failures on the corrugated sheathing.

In order to improve the ductility of the CFS shear walls sheathed with corrugated steel sheets, series of full-scale shear wall tests were recently conducted at the University of North Texas to investigate the behavior and strength of CFS shear walls using corrugated steel sheathing with various openings [4,5]. The idea of creating openings in corrugated steel sheathing is to utilize the openings to weaken the stiffness of the sheathing locally and enable material yielding, out-of-plane deformation, and sheet tearing around the opening areas to be the failure modes and energy dissipation mechanism and meanwhile the screw failures can be avoided or mitigated. It is expected that the local failures in the sheathing will avoid instant loss of shear wall strength after peak and increase the energy dissipation capacity of the wall under cyclic loading. Shear walls with various diameters of circular holes in the sheathing were tested by Yu et al. [4]. The results revealed that shear walls with circular holes did improve the shear wall's ductility but the shear strength and the stiffness were significantly reduced. It was therefore not recommended by Yu et al. to use circular holes in the corrugated steel sheathings as a method of improving shear wall's ductility. Yu et al. [5] continued the research by introducing slit openings in the corrugated sheathing. Shear walls with various lengths of horizontal or vertical slits in the sheathing were tested. It was found that with proper slit opening in the corrugated sheathing, the shear wall could give desirable ductility while maintaining relatively high shear strength and initial stiffness. Besides, nonlinear dynamic analyses on building systems were also performed in Yu et al. [5] and the results showed that the new shear wall system could greatly reduce the collapse probability of cold-formed steel buildings.

Shear wall specimens in Yu et al. [5] used low-profile Vulcraft 0.6C corrugated sheets as the only sheathing material. On the west coast of the United States where the seismic loads control the structural design for most mid-rise buildings, Verco decks are the commonly used low-profile corrugated sheathing. Therefore there is a need to analyze the seismic performance of Verco sheathed shear walls in addition to

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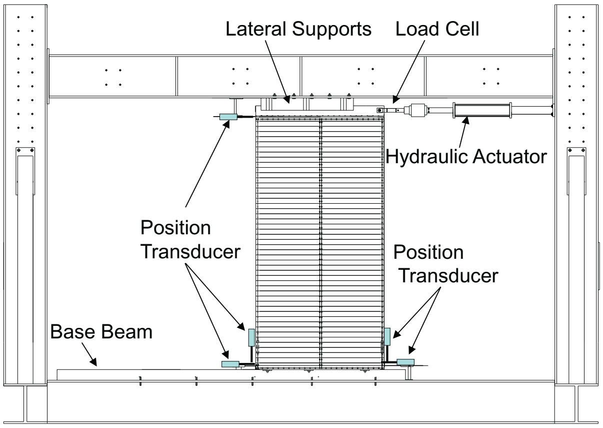


**Fig. 1.** Test setup.

analysis done on the Vulcraft low profile sheathing in Yu et al. [5]. This paper follows the previous research and tries to find a suitable slit configuration for shear walls using another low-profile Verco Decking SV36 corrugated sheathing. Shear walls using Verco corrugated steel sheathing with different slits configurations were tested under cyclic loading. The test program encoMPassed a total of 8 different wall configurations including the unperforated shear walls. The experimental results, including the measured wall performance and failure mechanism, are presented in this paper. It is worth mentioning that there has been a number of experimental and analytical research on the hot-rolled steel framed shear wall using corrugated plates [6–8]. However the hot-rolled steel framed shear walls used structural steel members as the boundary elements and the corrugated plate was welded to the frame. The failure mechanism of the hot-rolled steel framed shear wall was different from that of the CFS framed shear walls. The numerical model for the hot-rolled steel framed shear walls are not suitable for CFS shear walls.

## 2. Test program

### 2.1. Test setup

All shear wall tests reported in this paper were conducted on a 4.88 m span, 3.66 m high self-equilibrating steel testing frame which was equipped with one 156 kN hydraulic actuator. Specimens were secured to the test bed and a lateral force was applied to the top of the wall horizontally through a loading beam. The applied force was measured using an 89 kN load cell placing between the actuator shaft and the loading beam. The loading beam was connected to the top track of the wall by No. 12 hex washer head (HWH) self-drilling screws. The out-of-plane movement of the wall was restricted by the lateral supports installed at both sides of the loading beam. Test setup of the loading system is shown in Fig. 1. More test setup details can be found in Yu et al. [4,5].

### 2.2. Test procedure

All the shear wall specimens were tested under cyclic loading. The lateral load was applied to the top of wall using a displacement based protocol - CUREE protocol with 0.2 Hz (5 s) loading frequency, which was in accordance with method C in ASTM E2126 Standard Test Methods for Cyclic (Reversed) Load Test for Shear Resistance of Vertical Elements of the Lateral Force Resisting Systems for Buildings [9]. The specified displacement amplitudes were determined based on the ultimate displacement capacity obtained from the monotonic test results. In this test program, the displacement capacity of walls without sheathing opening in Yu et al. [4] was used for all cyclic tests, i.e. the ultimate displacement capacity $\Delta = 114.3$ mm.

### 2.3. Test specimens

A total of 14 shear wall specimens including 8 different wall configurations were tested in this research. The framing members used ASTM A1003 Grade 50 (345 MPa) or Grade 33 (225 MPa) steel structural studs and tracks from the Steel Framing Industry Association (SFIA). The boundary studs were back-to-back studs fastened together with No. 12 × 31.8 mm HWH self-drilling screws with 152.4 mm distance on center. The interior stud used one single C-shaped member. Two Simpson Strong-Tie S/HD15S hold-downs were used in each specimen, one on each chord stud. The hold-downs were attached to the inside of the chord studs by No. 14 × 25.4 mm HWH self-drilling screws. For each wall specimen, two ASTM 307 [10] bolts with a diameter of 19.1 mm were used to fix the hold-downs to the test bed and two additional

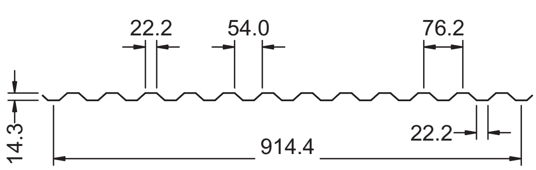


**Fig. 2.** Corrugated sheet steel profile- Verco Decking SV36 (unit mm).

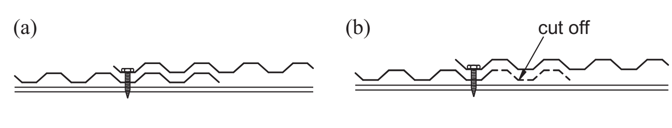


**Fig. 3.** Sheathing overlapping configurations. (a) Two overlapped ribs. (b) One overlapped ribs.

**Table 1**
Test specimens.

| Label | | Width × height (m) | Stud | Track | Sheathing thickness | Screw | Slits configuration |
|---|---|---|---|---|---|---|---|
| Config.1 | No.1 | 2.44 × 1.22 | 350S200-68, 345 MPa | 350 T125–68, 345 MPa | 0.686 mm, 550 MPa | #12 × 32 mm | No opening |
| | No.2 | 2.44 × 1.22 | 350S200-68, 345 MPa | 350 T125–68, 345 MPa | 0.686 mm, 550 MPa | #12 × 32 mm | No opening |
| Config.2 | No.3 | 2.44 × 1.22 | 350S162-68, 345 MPa | 350 T150–68, 345 MPa | 0.686 mm), 550 MPa | #12 × 32 mm | 24 × 51 mm (6 rows) |
| | No.4 | 2.44 × 1.22 | 350S162-68, 345 MPa | 350 T150–68, 345 MPa | 0.686 mm), 550 MPa | #12 × 32 mm | 24 × 51 mm (6 rows) |
| | No.5 | 2.44 × 1.22 | 350S162-68, 345 MPa | 350 T150–68, 345 MPa | 0.686 mm, 550 MPa | #12 × 32 mm | 24 × 51 mm (6 rows) |
| Config.3 | No.6 | 2.44 × 1.22 | 350S162-68, 345 MPa | 350 T150–68, 345 MPa | 0.686 mm, 550 MPa | #12 × 32 mm | 24 × 25 mm (6 rows) |
| Config.4 | No.7 | 2.44 × 1.22 | 350S162-68, 345 MPa | 350 T150–68, 345 MPa | 0.686 mm, 550 MPa | #12 × 32 mm | 12 × 51 mm (staggered) |
| Config.5 | No.8 | 2.44 × 1.22 | 362S162-68, 345 MPa | 362 T150–68, 345 MPa | 0.686 mm, 550 MPa | #12 × 32 mm | 12 × 51 mm (3 rows) |
| Config.6 | No.9 | 2.44 × 1.22 | 350S162-68, 345 MPa | 350 T150–68, 345 MPa | 0.686 mm, 550 MPa | #12 × 32 mm | 12 × 51 mm (6 rows) |
| | No.10 | 2.44 × 1.22 | 350S162-68, 345 MPa | 350 T150–68, 345 MPa | 0.686 mm, 550 MPa | #12 × 32 mm | 12 × 51 mm (6 rows) |
| Config.7 | No.11 | 2.44 × 1.22 | 350S162-54, 225 MPa | 350 T125–54, 345 MPa | 0.457 mm, 550 MPa | #10 × 19 mm | 12 × 51 mm (6 rows) |
| | No.12 | 2.44 × 1.22 | 350S162-54, 225 MPa | 350 T125–54, 345 MPa | 0.457 mm, 550 MPa | #10 × 19 mm | 12 × 51 mm (6 rows) |
| | No.13 | 2.44 × 1.22 | 350S162-54, 225 MPa | 350 T125–54, 345 MPa | 0.457 mm, 550 MPa | #10 × 32 mm | 12 × 51 mm (6 rows) |
| Config.8 | No.14 | 2.44 × 0.61 | 350S162-68, 345 MPa | 350 T150–68, 345 MPa | 0.686 mm, 550 MPa | #12 × 32 mm | 6 × 51 mm (6 rows) |