

Performance of Cold-Formed Steel-Framed Shear Walls: Alternative Configurations

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PREFACE

This report presents the results of twenty shear wall tests that were conducted to evaluate the performance of wall configurations not permitted in the building codes in 2002. In this test program, four areas of performance were addressed, as follows:

- Reversed cyclic performance of 7/16-in. OSB shear walls sheathed one side and framed with 54- and 68-mil steel.
- Reversed cyclic performance of 7/16-in. OSB shear walls sheathed each side and framed with 54- and 68-mil steel.
- Reversed cyclic performance of 27-mil sheet steel shear walls (sheathed one side) with simple lap shear connections at the adjoining edges of the sheet steel panels (adjoining edge perpendicular to framing).
- Monotonic performance of ½-in. gypsum sheathed shear walls (sheathed one side) with alternative (to the current codes) blocking configurations and fastener schedules.

The findings provided a basis for the AISI Committee on Framing Standards to establish design options for shear walls in the AISI *Standard for Cold-Formed Steel Framing – Lateral Design*.

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An Applied Research Project

ABSTRACT

This report presents the results of twenty shear wall tests that were conducted to evaluate the performance of wall configurations not currently (2002) permitted in the building codes. Ten (10) walls were evaluated under reversed cyclic loading and the other ten (10) under monotonic loading. Brief descriptions of the test program and results are presented in the following paragraphs.

The reversed cyclic load tests comprised 4 ft. x 8 ft. 54- and 68-mil framed walls with 7/16-in. OSB rated sheathing on one or both sides of the wall and 33-mil framed walls with 27-mil sheet steel. The sheet steel wall incorporated a horizontal lap shear joint at the wall mid-height. The monotonic tests focused exclusively on 8 ft. x 8 ft. gypsum sheathed shear walls with an unblocked configuration, except for two tests.

Overall, the OSB tests showed that the No. 8 screws in 54-mil framing and No. 10 screws on 68-mil framing permitted a ductile mode of failure at the connection. In the doubled-sided (sheathing each side) wall tests, the load demands on the 54-mil chord studs exceeded the capacity of studs and the load demands at the holdown attachment to the 68-mil chords studs exceeded the capacity of the screws. As a result, the capacity of the double-sided wall was less than twice the capacity of the single-sided wall. In the sheet steel walls, shear buckling accompanied by diagonal tension resulted in high demands on a few screws at the mid-height joint which caused the panel to unzip prematurely along the joint. Failure in the GWB monotonic tests was characterized by breaking of the wallboard at the location of the fasteners along the “un-papered” edges and screw pull-through along the “papered” edges of the wallboard.

Keywords: Shear, walls, OSB, sheet, steel, cyclic, monotonic, cold-formed, gypsum, wallboard, sheathing.

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BACKGROUND

The 1997 UBC provisions for cold-formed (light-gauge) steel-framed braced walls limits the lateral force resisting system to 15/32-in. Structural I plywood, 7/16-in. OSB rated sheathing, ½-in. gypsum wallboard/sheathing or diagonal bracing (tension and/or compression members). Testing for development of the UBC design values for sheathed walls included both monotonic (“static”) and reversed cyclic loadings for wind and seismic conditions, respectively. Subsequent to publication of the 1997 UBC, additional wall testing was completed (including sheet steel shear walls) and the results of this latter work were used to update and expand the design data in the 1997 UBC. The current state-of-the-art for cold-formed steel-framed lateral force design is contained in the 2000 International Building Code (IBC).

In both the 1997 UBC and 2000 IBC, limitations were justifiably imposed on the range of applicability of the published design data for the simple reason that the data is based on physical testing. The primary code limitations are summarized below:

- For seismic design, the maximum uncoated framing thickness is 0.043 in. or 0.048 in. (depending on whether the UBC or IBC, respectively, is referenced), and the minimum uncoated framing thickness is 0.033 in.
- Studs are a minimum 1-5/8 in. (flange) x 3-1/2 in. (web) with a 3/8 in. flange return (lip).
- Tracks are a minimum 1-1/4 in. (flange) x 3-1/2 in. (web).
- A minimum of two back-to-back studs are required at the ends (boundaries) of a shear wall.
- Minimum of No. 8 screws are required for attachment of plywood and OSB sheathing.

- Minimum of No. 6 screws for attachment of gypsum wallboard/gypsum sheathing.
- Aspects ratios per the code (2:1 maximum in the UBC; up to 4:1 in the IBC for some applications).
- No increase in strength is permitted for walls sheathed both sides with the same material (except as provided for gypsum wallboard/sheathing).
- Gypsum wallboard/sheathing must be applied perpendicular to framing with minimum prescribed strapping at abutting joints.

Given the nature of the residential market today, designers/engineers are finding that the limitations imposed by the codes can potentially impede their ability to provide designs that are responsive to market needs and competitive with alternative light framing materials. Knowing that the code limitations are based strictly on a limited scope of testing, designers/engineers have extrapolated the existing design data based on their interpretation of basic engineering principles. In some instances, demonstrating that these extrapolations comply with the intent of the building code may be difficult.

OBJECTIVE

The objective of the research reported in this document was to develop performance data for cold-formed steel-framed shear wall systems not directly addressed or permitted in current building codes. An ancillary objective was to help focus the efforts of the industry on possible new design needs. In the following section, the scope of the test program is described.

SCOPE

In this test program, four areas of performance were addressed. These four areas included:

- Reversed cyclic performance of 7/16-in. OSB shear walls sheathed one side and framed with 54- and 68-mil steel.
- Reversed cyclic performance of 7/16-in. OSB shear walls sheathed each side and framed with 54- and 68-mil steel.
- Reversed cyclic performance of 27-mil sheet steel shear walls (sheathed one side) with simple lap shear connections at the adjoining edges of the sheet steel panels (adjoining edge perpendicular to framing).
- Monotonic performance of ½-in. gypsum sheathed shear walls (sheathed one side) with alternative (to the current codes) blocking configurations and fastener schedules.

Additional details of the test program are provided in the following section.

TEST PROGRAM

For each of the four performance areas identified in the previous section, a series of tests, as indicated in Tables 1 through 4, were conducted. As shown in the tables, for each wall configuration, two identical tests were completed.

The overall dimensions (out-to-out) of the walls for the reversed cyclic load tests were 4 ft. (wide) x 8 ft. (tall) while the wall dimensions for the monotonic tests (GWB) were 8 ft. x 8 ft. Stud spacing in all tests was 24 in. on center and all boundary members were back-to-back studs (same thickness at track and interior studs). Other wall details are given in Tables 1 through 4.

Table 1. Reversed cyclic performance of 7/16-in. OSB single-sided shear walls
(**sheathed one side**) framed with 54- and 68-mil steel

Test No.	Framing ¹	Sheathing and Attachment			Test protocol ⁴	Comments ⁵
		Type ²	Screw spacing ³	Screw size		
1 and 2	350S162-54 studs 350T125-54 track	7/16-in. OSB rated sheathing	2"/12"	No. 8 self-drilling screws	Reversed cyclic load	- Sheathing one face of the wall 4 ft. x 8 ft. wall (1) 4 ft x 8 ft. sheet
3 and 4	350S162-68 studs 350T125-68 track	7/16-in. OSB rated sheathing	2"/12"	No. 10 self-drilling screws	Reversed cyclic load	- Sheathing one face of the wall 4 ft. x 8 ft. wall (1) 4 ft x 8 ft. sheet

¹ Stud and track Grade 50 steel ASTM A653 or A792 or A875. Framing fasteners: No. 10 pancake head self-drilling screws.
² Per DOC PS1 or PS 2 exterior use.
³ a" / b"—a inches at the supported panel edges and b inches in the panel field. Fastener panel edge distance = 3/8 in.
⁴ See "TEST PROCEDURE" in main text
⁵ Simpson S/HD15 used at each chord (attached with 48 No. 10 screws)

Table 2. Reversed cyclic performance of 7/16-in. OSB double-sided shear walls
(**sheathed each side**) framed with 54-mil and 68-mil steel

Test No.	Framing ¹	Sheathing			Test protocol ⁴	Comments ⁵
		Type ²	Screw spacing ³	Screw size		
6 and 7	350S162-54 studs 350T125-54 track	7/16-in. OSB rated sheathing	2"/12"	No. 8 self-drilling screws	Reversed cyclic load	- Sheathing both faces of the wall 4 ft. x 8ft. wall (2) 4 ft. x 8 ft. sheets
8 and 9	350S162-68 studs 350T125-68 track	7/16-in. OSB rated sheathing	2"/12"	No. 10 self-drilling screws	Reversed cyclic load	- Sheathing both faces of the wall 4 ft. x 8ft. wall (2) 4 ft. x 8 ft. sheets

¹ Stud and track Grade 50 steel ASTM A653 or A792 or A875. Framing fasteners: No. 10 pancake head self-drilling screws.
² Per DOC PS1 or PS 2 exterior use.
³ a" / b"—a inches at the supported panel edges and b inches in the panel field. Fastener panel edge distance = 3/8 in.
⁴ See "TEST PROCEDURE" in main text.
⁵ Simpson S/HD15 used at each chord (attached with 48 No. 10 screws)

Table 3. Reversed cyclic performance of 27-mil sheet steel shear walls with simple lap shear connections at the adjoining panel edges

Test No.	Framing ¹	Sheathing			Test protocol ⁴	Comments ⁵
		Type ²	Screw spacing ³	Screw size		
10 and 11	350S162-33 studs 350T125-33 track	27-mil 33 ksi sheet steel	2"/12"	No. 8 self-drilling screws	Reversed cyclic load	- Sheathing one face of the wall 4 ft. x 8ft. wall (2) 4 ft. x 4 ft.-3/4 in. sheets 1.5 in. lap joint at wall mid-height w/single line of fasteners

¹ Stud and track Grade 33 steel ASTM A653 or A792 or A875. Framing fasteners: No. 8 modified truss head self-drilling screws.
² Grade 33 ASTM A653 or A792 or A875.
³ a" / b"—a inches at the supported panel edges and b inches in the panel field. Fastener panel edge distance = 3/8 in.
⁴ See "TEST PROCEDURE" in main text.
⁵ Simpson S/HD10 used at each chord (attached with 33 No. 10 screws)

Table 4. Monotonic performance of ½-in. gypsum wallboard (GWB) single-sided shear walls

Test No.	Framing ¹	Sheathing			Test protocol ⁴	Comments ^{5, 6}
		Type ²	Screw spacing ³	Screw size		
12 and 13	350S162-33 studs 350T125-33 track	½-in. GWB	4"/4"	No. 6 self-drilling	Monotonic	• Sheathing one face of the wall • 8 ft. x 8 ft. wall • (2) 4 ft. x 8 ft. sheets (perpendicular to framing) • no blocking/strapping @ horizontal joint
14 and 15	350S162-33 studs 350T125-33 track	½-in. GWB	7"/7"	No. 6 self-drilling	Monotonic	• Sheathing one face of the wall • 8 ft. x 8 ft. wall • (2) 4 ft. x 8 ft. sheets (perpendicular to framing) • no blocking/strapping @ horizontal joint
16 and 17	350S162-33 studs 350T125-33 track	½-in. GWB	8"/12"	No. 6 self-drilling	Monotonic	• Sheathing one face of the wall • 8 ft. x 8 ft. wall • (2) 4 ft. x 8 ft. sheets (perpendicular to framing) • no blocking/strapping @ horizontal joint
18 and 19	350S162-33 studs 350T125-33 track	½-in. GWB	4"/12"	No. 6 self-drilling	Monotonic	• Sheathing one face of the wall • 8 ft. x 8 ft. wall • (2) 4 ft. x 8 ft. sheets (perpendicular to framing) • 2-in. 33 mil strap @ horizontal joint
20 and 21	350S162-33 studs 350T125-33 track	½-in. GWB	4"/12"	No. 6 self-drilling	Monotonic	• Sheathing one face of the wall • 8 ft. x 8 ft. wall • (2) 4 ft. x 8 ft. sheets (perpendicular to framing) • no blocking/strapping @ horizontal joint

¹ Stud and track Grade 33 steel ASTM A 653 or A 792 or A 875. Framing fasteners: No. 8 modified truss head self-drilling screws.
² Type X ASTM C 36
³ a" / b"—a inches at the supported panel edges and b inches in the panel field. Fastener panel edge distance = 3/8 in.
⁴ See "TEST PROCEDURE" in main text.
⁵ Simpson S/HD10 used at each chord (attached with 33 No. 10 screws)
⁶ Horizontal joint not taped and mudded.

TEST PROCEDURE

Each wall was tested in a horizontal position. Installation of the 4 ft. x 8 ft. walls was accomplished by attaching the bottom of the wall to a reaction beam. Between the bottom track and the reaction beam a 3-1/2 in. wide by ¾-in. thick plate was used to