Shear Wall Design Guide

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NORTH AMERICAN STEEL FRAMING ALLIANCE

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The following publication was developed by R.L. Brockenbrough & Associates for the American Iron and Steel Institute (AISI), In the production of this publication, due diligence has been exercised in consulting a wide range of pertinent authorities and experiences. Efforts have been made to present accurate, reliable and useful information. AISI acknowledges the principal author of this publication, Roger Brockenbrough and reviewers.

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1. Overview

In residential construction, steel studs and track are generally covered with cladding to form a wall assembly with significant shear strength. It is common design practice to use this wall shear strength to resist lateral loads, such as those caused by wind and earthquake.

This document includes information on walls constructed with (1.) plywood and oriented strand board (OSB) on the exterior wall surface, with or without gypsum wall board (GWB) on the interior wall surface, (2.) GWB on both surfaces, (3.) steel sheathing on one side, and (4.) steel X-bracing on one side. Most of this information is based on 3-1/2 x 1-5/8 in. studs, and attachment to the studs and track with self drilling screws. Limited information is included on walls with 6 x 1-5/8 in. studs sheathed with plywood, OSB, GWB, and with steel X-bracing; and on walls with sheathing attached by pneumatically driven pins. Additional information on sheathing attached by pneumatically driven pins is available from suppliers.

The strength of a wall system depends on the interaction of many factors including the strength of the sheathing; the type, size, and spacing of the fasteners used to attach the sheathing; the panel aspect ratio (ratio of long to short dimension of shear panel); and the strength of the studs. Because of these variables, the design strength of shear walls is usually based on tests of full height specimens. Thus, this document provides a summary of the results obtained in wall tests conducted by Serrette (1997, 1996, and 1994) and Tissell (1993). Of course, to develop the shear strength values, walls must be provided with anchors designed to resist the shear and uplift forces that are developed.

It has been common practice to base shear wall design values on the results of static tests. However it is well known that earthquakes can cause severe cyclic loadings. Wind also causes repeated load applications, although usually not at peak load levels. Static test results have been used because it was not considered practical to conduct large scale cyclic testing. However, tests conducted by Serrette (1996 and 1997) involved a significant number of cyclic tests. Consequently it is now possible to more rationally address shear wall design in high seismic regions.

2. Shear Wall Design Data

Tables 1, 2, and 3 give nominal (ultimate) strengths for the design of shear walls with cold-formed steel framing. As indicated, some of the values have been approved by national codes while more recent values are proposed for inclusion. The approved values have been accepted in the following codes: SBC, 1997; UBC, 1997; BOCA, 1999; IBC, current draft. Appendix Tables A1, A2, and A3 give test references for the values in Tables 1, 2, and 3.

The values in Tables 1 through 3 must be divided by a safety factor Ω (for Allowable Stress Design) or multiplied by a reduction factor ϕ (for Load and Resistance Factor Design). See the pertinent building codes for complete requirements. In the absence of other requirements, consider the following: Seismic, $\Omega = 2.5$ or $\phi = 0.60$; Wind, $\Omega = 2.0$ or $\phi = 0.65$. These values correspond to those given by AISI for steel diaphragm construction with mechanical fasteners (see *Specification for the Design of Cold-Formed Steel Structural Members*, American Iron and Steel Institute, 1996).

Table 1 is for wind loads and Table 3 is for seismic loads. Generally, for similar wall construction, the test values used to derive the wind load table are higher than the test values used to derive the table for seismic loads (Table 3). Thus, for cases that are not covered for wind loads (Table 1) but are covered for seismic loads (Table 3), it is conservative to use Table 3 for wind loads. Table 2 is for walls sheathed with GWB on both sides and is applicable to wind loads only. Maximum aspect ratios are as indicated. It is important to note that, as the aspect ratio increases, it is essential to properly tighten hold-downs and remove slack to minimize deflections.

Table 1 includes walls sheathed with plywood or OSB on one side; the OSB values are conservative where plywood values are not shown. For the 6/12 in. spacing, the strength can be increased by 30 percent if GWB is added to the opposite side of the wall. Table 1 also includes walls sheathed with steel sheet on one side. Table 3 is for seismic loads resisted by walls sheathed with plywood, OSB, or steel sheet, as indicated, on one side only.

Tables 1 through 3 are for walls with steel studs spaced at no more than 24 in. on centers. The studs must be doubled at the shear wall ends. Except where indicated otherwise, minimum stud size is 3-1/2 x 1-5/8 x 0.033 in. and minimum track size is 3-1/2 x 1-1/4 x 0.033 in. (minimum metal base thicknesses). In Table 3, thicknesses of 0.0433 are indicated for certain cases. In all cases, for seismic design in Zones 3 and 4, the stud and track thickness should not exceed 0.0433 in.

All panel edges must be fully blocked. Horizontal steel straps used as blocking must be a minimum of 1-1/2 in. wide and of the same material and thickness as the studs and track. Boundary members and anchorage details for uplift must have adequate strength to resist the forces resulting from the load combinations imposed by the building code. Panels must be at least 12 in. wide, such as when needed to complete a wall.

No code values are proposed for steel X-bracing because, as confirmed by the most recent tests (Serrette, 1997), it can be designed directly for the imposed loads. However, the design must address two important considerations. First, because the material yield strength is typically greater than the specified minimum value, end connections must be designed to withstand a brace force greater than that corresponding to the minimum specified material yield strength. Second, flat strap bracing on one side of a wall causes an eccentric loading on tracks and chord (end) studs; this eccentricity must be considered in design, particularly in high seismic zones.

3.0 Shear Wall Tests

3.1 Tests by Serrette (1997) on Walls with 3-1/2 x 1-5/8 in. Studs

Both static and cyclic load tests were conducted on walls with 3-1/2 x 1-5/8 studs spaced at 24 in. Double studs (back-to-back) were used at the ends of the walls. Tests included panels with APA rated sheathing (OSB or plywood, vertical), steel X-bracing, and steel sheet sheathing. The sheathing or bracing was placed on only one side of the panels. The tests were planned to answer remaining questions on OSB and plywood sheathed walls, to obtain design data for panels with high aspect ratios, and to obtain design data for walls with steel X-bracing or steel sheathing.

Static Tests

The test setup was essentially the same as that used for earlier tests as described below under 3.2 except that the loading rate was decreased to approximately 0.10 in./min. Studs were 0.033 in. thick except for one case where 0.043 in. thick studs were used as noted. The following assemblies were tested (see Table 4):

- OSB sheathing at aspect ratio of 4:1 with screw spacings along the edges of 2, 4, and 6 in. (Tests 5 - 10.)

- Steel X-bracing, 4-1/2 x 0.033 in. and 7-1/2 x 0.033 in., with aspect ratio of 2:1 (Tests 1- 4).

- Steel sheathing, 0.018 and 0.027 in. thick, with aspect ratios of 4:1 and 2:1 and screw spacings along the edges of 4 and 6 in. (Tests 11 - 16).

Table 4 lists the average value of maximum load obtained in the tests. Duplicate specimens were tested and the results of the two were within 10 percent except as noted in the table. Salient points are as follows.

OSB Sheathing with High Aspect Ratio. The displacement at maximum load was 2 in. or more for all specimens. With a 2 in. edge screw spacing, the end studs buckled just above the track. With a 6-in. screw spacing failure was initiated by buckling of the end studs at the hold-down, and with a 4-in. spacing displacements became excessive. Based on the 1996 and 1997 tests by Serrette, Figure 1 shows graphically how the static shear strength varies with the screw spacing, and how it compares with that of panels with an aspect ratio of 1 or 2. Previous tests had established that the shear strength per unit length was essentially the same for 8 x 8 ft and 8 x 4 ft panels and that results for 7/16 in. OSB could be used conservatively for 15/32 in. plywood (see 3.2). Figure 1 illustrates that, on a force per unit length

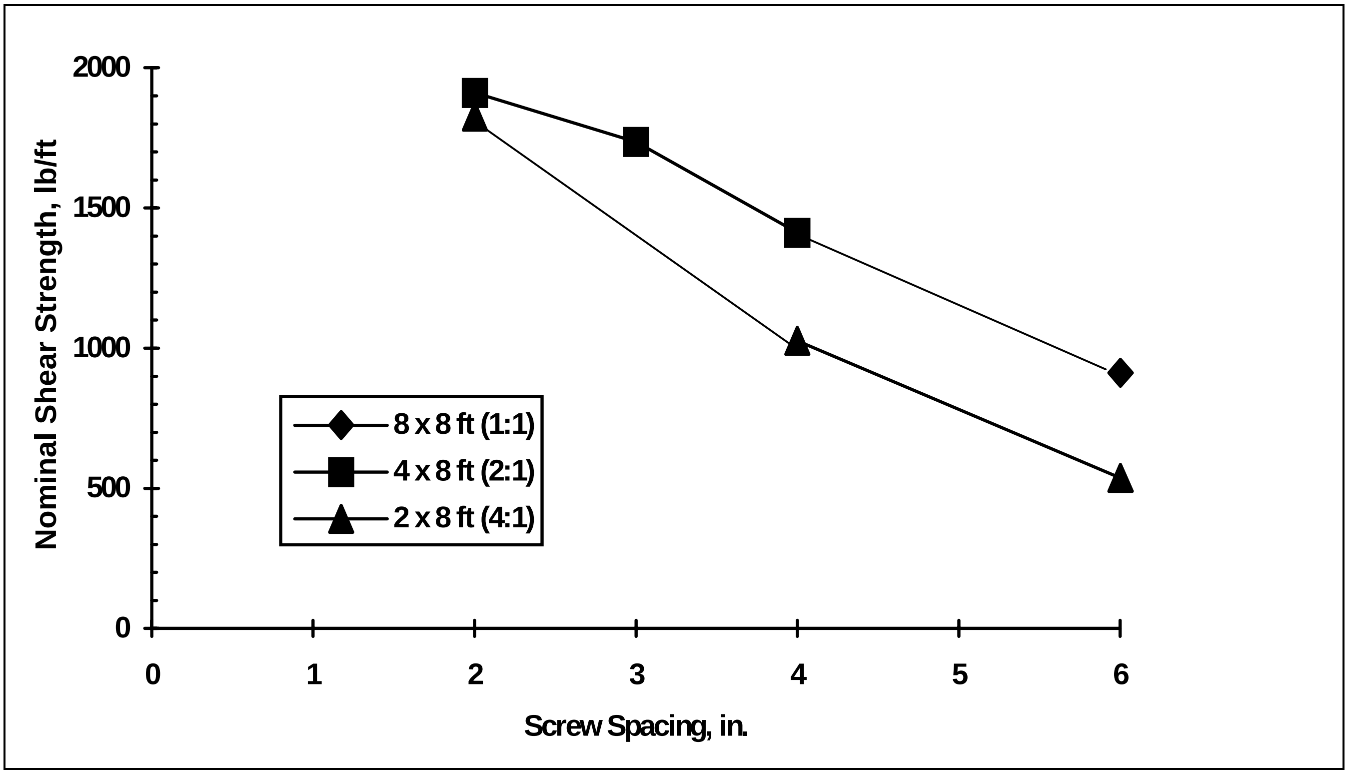

Figure 1. Nominal Static Shear Strength with OSB Sheathing as a Function of Screw Spacing and Aspect Ratio

basis, the shear strength of panels with an aspect ratio of 4:1 varies from 95 to 59 percent (depending on screw spacing) of that of panels with an aspect ratio of 2:1 or 1:1. The lower shear strength percentages occurred in those cases where the wall deflection became relatively large, long before the wall was able to develop its maximum strength.

Steel X-Bracing. With the 4-1/2 in. strap, failure resulted from local buckling of the end studs. With the 7-1/2 in. strap, failure resulted from local buckling in the top track and end stud, aggravated by bending due to the eccentricity of the strap force. Thus, although the strap area was increased by a factor of 1.67, the load increased by a factor of only 1.30. The maximum load for the wide strap, 877 lb/ft, was close to that for OSB sheathing with 6/12 in. screw spacing, 911 lb/ft. The effect of strap eccentricity should be considered when designing wall systems. Also, the force in the strap may be larger than that corresponding to the specified minimum yield strength because the actual yield strength is likely to be higher. Designers should consider that fact when calculating connection requirements. Average displacement at maximum load was 0.70 in. for the 4-1/2 in. straps and 0.82 in. for the 7-1/2 in. straps.

Steel Sheathing. Failure of these panels resulted from rupture of the steel sheet along the line of screws at the edges. Diagonal "tension field" patterns were not observed. Decreasing the fastener spacing and increasing the steel sheathing thickness were effective in increasing the maximum load. The maximum loads for panels with an aspect ratio of 4:1 were similar (within 10 percent) to those for OSB panels with the same aspect ratio and fastener spacings. Displacement at maximum load was 2 in. or more for panels with an aspect ratio of 4:1, and averaged 1.30 in. for the panel with a ratio of 2:1.

Cyclic Tests

The test setup was essentially the same as that used for earlier tests as described below under 3.2 except that the loading rate was increased to 1 second per cycle (1.0 Hz). Studs were 0.033 in. thick except as noted. The following assemblies were tested (see Table 5):

- OSB and plywood sheathing at aspect ratio of 2:1 with screw spacings along the edges of 2 and 3 in. (Tests A1 - A8). These tests were conducted on panels with 0.033 in. thick framing but with thicker end studs (0.043 in.) because the shear strength in prior (1996) tests with these spacings had been limited by the strength of the end studs.

- Plywood sheathing at aspect ratio of 2:1 attached to thicker framing with screw spacings along the edges of 6 in. (Tests B1 - B4). These tests were conducted on panels with 0.043 in. and 0.054 in. thick framing to evaluate the behavior of fasteners in thicker studs.

- OSB sheathing at aspect ratio of 4:1 with screw spacings along the edges of 2, 4, and 6 in. (Tests E1 - E6).

- Steel X-bracing, 4-1/2 x 0.033 in. and 7-1/2 x 0.033 in., with aspect ratio of 2:1 (Tests C1 - C4).

- Steel sheathing, 0.018 and 0.027 in. thick, with aspect ratios of 2:1 and 4:1 and screw spacings along the edges of 4 and 6 in. (Tests D1 - D2, and F1 - F4).

Table 5 lists the average value of maximum load obtained in the tests. Duplicate specimens were tested and the results of the two were within 10 percent except as noted in the table. Salient points are as follows.

OSB and Plywood Sheathing at Aspect Ratio of 2. The back-to-back 0.043 in. thick studs provided increased strength so that failure was initiated by screw heads pulling through the sheathing. The plywood panels were 6 to 16 percent stronger than the OSB panels. Based on the 1996 and 1997 tests by Serrette, Figure 2 illustrates how the cyclic shear strength varies with screw spacing, aspect ratio, and thickness of end studs.

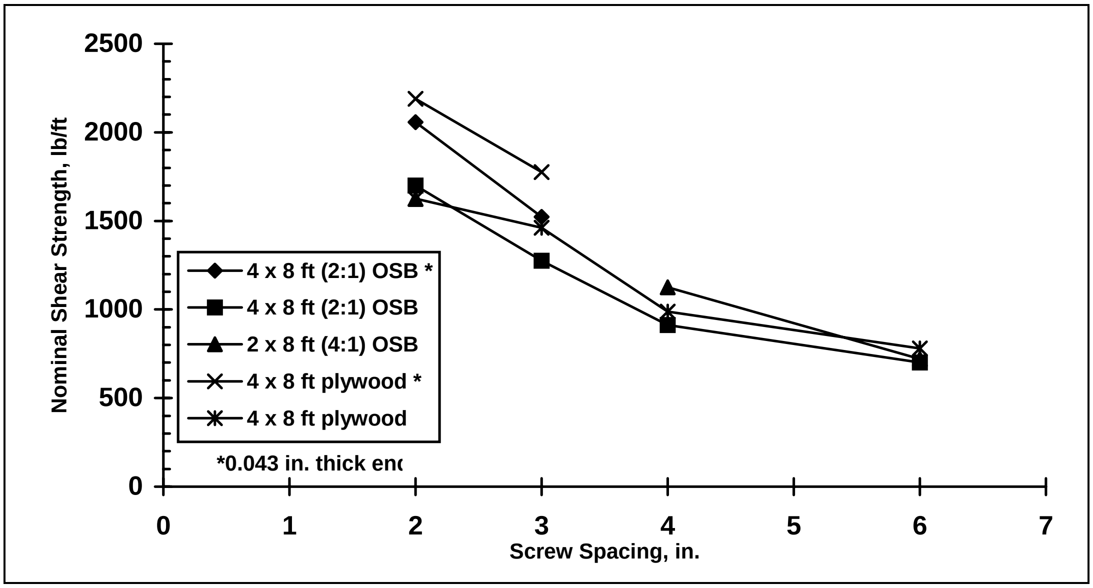

Figure 2. Nominal Cyclic Shear Strength with OSB and Plywood Sheathing as a Function of Screw Spacing, Aspect Ratio, and Thickness of End Studs

Plywood Sheathing Attached to Thicker Framing. In 0.043 in. thick framing, failure initiated by screw heads pulling through the sheathing or screws pilling out of the framing, but in 0.054 in. thick framing some of the screws failed in shear. These tests confirmed that No. 8 sharp point screws should be limited to 0.043 in. thick framing. The maximum loads were about 15 percent more than those previously obtained (1996) with 0.033 in. thick framing with the same screw spacing.

OSB and Plywood Sheathing with High Aspect Ratio. Failure modes were similar to those observed in static tests of similar specimens. Reduced edge screw spacings were effective in increasing strength. On a force per unit length basis, the shear strength of panels with an aspect ratio of 4:1 was generally similar to that of panels with an aspect ratio of 2:1.

Steel X-Bracing. Failure modes were similar to those observed in static tests of similar specimens. Because of the effects of eccentricity, the maximum load with the 7-1/2 in. wide strap was nearly the same as that with the 4-1/2 in. wide strap.

Steel Sheathing. Failure resulted from a combination of screws pulling out of the framing, rupture of the steel sheet along the line of screws at the edges, and in some cases local buckling of the end studs. Decreasing the fastener spacing result in increased maximum load.

3.2 Tests by Serrette (1996) on Walls with 3-5/8 x 1-5/8 in. Studs

Both static and cyclic load tests were conducted on walls with 3-1/2 x 1-5/8 x 0.033 in. studs spaced at 24 in. Double studs (back-to-back) were used at the ends of the walls. The plywood and OSB used in the tests were APA rated sheathing. The tests were planned to generate design data for specific wall constructions and to also answer certain fundamental design questions.

Static Tests

In these tests the bottom track of the wall assembly was attached to a fixed base. The top track was bolted to a loading plate that was displaced laterally at a rate of 0.30 in./min. with unloading and reloading at 1/2 in. and 1-1/2 in. lateral displacement. Spacers (1/2 in. thick) were used below or above the tracks so that the panels were relatively free to displace vertically before failure. Adequate hold-downs were used to prevent premature failure in the wall.

Static tests of wall panels with sheathing on one side only addressed the following fundamental questions:

- How does the strength of walls with plywood and OSB sheathing compare?

- What is the effect of orienting sheathing perpendicular to the framing instead of parallel?

- On a force per unit length basis, how does the strength of 8 x 8 ft and 8 x 4 ft wall panels compare?

- What is the effect of dense fastener schedules?

Tests with sheathing on both sides addressed the following questions:

- What is the behavior of walls with OSB on one side and GWB on the other?

- What is the behavior of walls with GWB on both sides?

Table 6 gives the test results and the various design questions are addressed below. Duplicate specimens were tested and the results of the two were generally within 10 percent. However the variation was greater for specimens with GWB both sides (12 percent for specimens 2Al/2A3 and 17 percent for specimens 2A2/2A4.)

Plywood Versus OSB Sheathing. A comparison of tests 1A6/7 and 1A2/3 shows that the shear strength of the wall with 15/32 in. plywood sheathing is about 17 percent stronger than the wall with 7/16 in. OSB sheathing. Consequently, all of the results shown for OSB sheathing can be used conservatively for plywood sheathing.

Sheathing Orientation. A comparison of tests lA2/3 and 1A5/6 shows that the shear strength of the wall with the sheathing oriented perpendicular to the framing (horizontal) is about 11 percent higher than the wall with parallel sheathing (vertical). Thus the results shown for parallel orientation can be used for either orientation.

Test Panel Size. A comparison of tests 1E1/2 and 1A5/6 shows that the shear strength per unit length is essentially the same for 8 x 8 ft and 8 x 4 ft wall panels. Therefore, either size can be used for test purposes.

Effect of Fastener Spacing. In one series of tests, the screw spacing was held at 12 in. along intermediate members and decreased from 6 in. to 2 in. along the panel edges. The results showed that the wall shear strength can be significantly increased by decreasing the edge fastener spacing as shown by the comparison below. Even though double studs were used at the ends of the wall (back-to-back with the sheathing attached only to the outer studs), for the 2 in. and 3 in. spacings ultimate failure was triggered by crippling of the end studs.

Test Ref. No.	Fastener Spacing (in.)	Nominal Shear (lb/ft)	Static Shear Strength Ratio
1A2/3	6/12	911	1.00
1D3/4	4/12	1412	1.55
1D5/6	3/12	1736	1.91
1D7/8	2/12	1912	2.10

Effect of Interior GWB. Walls were tested using 1/2 in. GWB on the interior with a 7 in. fastener spacing (edge and intermediate), and 7/16 in. OSB on the exterior with a 6/12, 4/12, and 2/12 spacing. A comparison of tests 1Fl/2 and 1A2/3 shows that, for an OSB fastener spacing of 6/12, the GWB increases the shear strength of the wall by 1/3. A comparison of the tests for the closer spacings shows that the addition of the GWB has little effect.

GWB on Both Sides. Walls with GWB on both sides had much lower shear strengths than walls with OSB sheathing, but may still be satisfactory for regions with relative low loads. Panels were tested with a 7/7 in. fastener spacing (both sides) and with a 4/4 fastener spacing. A comparison of tests 2A2/4 and 2A1/3 shows that the closer spacing increased the shear strength by 46 percent.

Cyclic Tests

The setup for these tests was similar to that described for the static tests. A time-displacement loading sequence was used in accordance with the sequential phase displacement protocol recommended by an ad hoc committee of the Structural

Engineers Association of Southern California. The cyclic rate was 1.5 seconds per cycle (0.67 Hz). The loading consisted of repeated sequences in which three fully reversed cycles are applied at a given displacement, one cycle at an increased displacement followed by three cycles at decreasing displacements, then three cycles at the increased displacement.

The cyclic tests all involved wall panels with OSB or plywood on one side. They were planned to generate design data and also to determine (1.) the relative strength of walls with OSB and with plywood, (2.) the effect of dense fastener schedules, and (3.) the relative strength of walls in cyclic and in static tests. The results are shown in Table 7 and discussed below.

Plywood Versus OSB Sheathing. A comparison of tests with similar fastening schedules shows that there was little difference in the cyclic shear strength of walls with 15/32 in. plywood and walls with 7/16 in. OSB sheathing. For screw spacings of 6/12, 4/12, and 3/12 in., OSB sheathing resulted in about 5 percent greater strength. For the 2/12 in. spacing, where failure was triggered by crippling of the end studs, the OSB value was 5 percent less than the plywood value.

Effect of Fastener Spacing. As in the static tests, the cyclic tests showed that the wall shear strength can be significantly increased by decreasing the edge fastener spacing as shown by the following comparison:

Fastener Spacing (in)	OSB Shear Strength Ratio	Plywood Shear Strength Ratio	Average Cyclic Shear Strength Ratio
6/12	1.00	1.00	1.00
4/12	1.30	1.27	1.28
3/12	1.82	1.87	1.84
2/12	2.42	2.08	2.25

The shear strength ratios did not differ greatly from those in the static tests.

Cyclic Versus Static Tests. As expected, the cyclic test results were somewhat lower than static test results for walls of similar construction. For walls with OSB sheathing on one side, the ratio of cyclic strength to static strength varied somewhat with the fastener spacing as shown by the following:

Screw Spacing (in)	Ratio of Cyclic Strength to Static Strength
6/12	0.77
4/12	0.65

3/12	0.89
2/12	0.73

The overall average was 0.76.

3.3 Tests by Serrette (1994) On Walls with 6 x 2 in. Studs

A series of static load tests were conducted by Serrette (1994) on walls with studs 6 x 1-5/8 x 0.033 in. These tests included flat strap tension X-bracing (one side), gypsum wall board (GWB) on one side and gypsum sheathing board (GSB) on the other, GWB and GSB in combination with flat strap X-bracing, plywood (one side), OSB (one side), and FiberBond™ wallboard (one side). Double studs (back-to-back) were used at the ends of the walls. The plywood and OSB used in the tests were APA rated sheathing. Fasteners were screws in most cases, and pneumatically driven pins in two cases. The tests were performed according to ASTM E72 with unloading and reloading at 1/2 in. lateral displacement. The results of these tests are shown in Table 8.

3.4 Tests by Tissell (1993)

A series of static load tests were conducted by Tissell (1993) for the American Plywood Association on walls with studs in thicknesses of 0.047, 0.059, and 0.074 in. These tests included plywood and OSB sheathing on one side only. They were fastened with screws in most cases, but with pneumatically driven pins in two cases. The end studs were only single studs. Testing was in accordance with ASTM E72 except for the use of higher test loads and the deflection reference point. In most cases failure occurred due to buckling of the single end studs or tearing around the anchor bolts. The premature stud buckling was likely affected by the lack of bracing on the unsheathed side. The test results are given in Table 7.

References

Serrette, R., G. Hall, and J. Ngyen (1997), "Additional Shear Wall Values for Light Weight Steel Framing," American Iron and Steel Institute, Washington, DC, March 1997.

Serrette, R., G. Hall, and J. Ngyen (1996), "Shear Wall Values for Light Weight Steel Framing," American Iron and Steel Institute, Washington, DC, January 1996.

Serrette, R. (1994), "Light Gauge Steel Shear Wall Tests," Department of Civil Engineering, Santa Clara University, Santa Clara, CA, 1994.

Tissell, J. R. (1993), "Structural Panel Shear Walls," Research Report No. 154, American Plywood Association, Tacoma, WA, May 1993.

Table 1

Nominal (Ultimate) Shear Values to Resist Wind Forces for Walls with Cold-Formed Steel Framing and Indicated Sheathing

Wall Construction[1,2]	Code Status	Max. Aspect Ratio	Wall Shear[4], lb/ft, for Fastener Spacing at Panel Edges (in.)			
			6	4	3	2
15/32" structural 1 sheathing 4-ply, one side	Approved	2:1	1065[3]	-	-	-
7/16" rated sheathing, OSB, one side	Approved	2:1	910[3]	1410	1735	1910
7/16" rated sheathing, OSB, one side, oriented perpendicular to framing	Proposed	2:1	1020[3]			
7/16" rated sheathing, OSB, one side	Proposed	4:1	-	1025	1425	1825
0.018" steel sheet, one side	Proposed	2:1	485	-	-	-
0.027" steel sheet, one side	Proposed	4:1	-	1000	-	-

Notes:

1. Maximum stud spacing is 24 in. c.c.
   Minimum stud size is 3-1/2 x 1-5/8 x 0.033 in. (min. base metal thickness).
   Minimum track size is 3-1/2 x 1-1/4 x 0.033 in. (min. base metal thickness).
   Steel per ASTM A653 Grade 33.
2. Minimum framing screws are No. 8 x 5/8 in. wafer head self-drilling.
   Minimum screws for OSB and plywood sheathing are No. 8 x 1 in. flat head, sharp point, self drilling.
   Minimum screws for steel sheathing are No. 8 x 1/2 in. modified truss head, self drilling.
   Maximum spacing of sheathing fasteners other than at edges is 12 in.
   Sheathing can be oriented either parallel or perpendicular to framing, except as noted.
3. Where fully blocked gypsum board is added to the opposite side of the wall assembly per Table 2, increase values by 30 percent.
4. For design, divide by a safety factor (ASD) or multiply by a reduction factor (LRFD).

Table 2

Nominal (Ultimate) Shear Values to Resist Wind Forces for Walls with Cold-Formed Steel Framing and Faced with Gypsum Wall Board Both Sides

Wall Construction[1,2,3]	Code Status	Max. Aspect Ratio	Wall Shear[4], lb/ft, for Fastener Spacing Shown (edge/field, in.)	
			7/7	4/4
1/2" gypsum board both sides	Approved	2:1	585	850

Notes:

1. Apply gypsum board perpendicular to framing with strap blocking behind the horizontal joint and with solid blocking between the first two end studs.
2. Maximum stud spacing is 24 in. c.c.
   Minimum stud size is 3-1/2 x 1-5/8 x 0.033 in. (min. base metal thickness).
   Minimum track size is 3-1/2 x 1-1/4 x 0.033 in. (min. base metal thickness).
   Steel per ASTM A653 Grade 33.
3. Minimum framing screws are No. 8 x 5/8 in. wafer head self-drilling.
   Minimum screws for gypsum wall board are No. 6 x 1 in.
4. For design, divide by a safety factor (ASD) or multiply by a reduction factor (LRFD).

Table 3

Nominal (Ultimate) Shear Values to Resist Seismic Forces for Walls with Cold-Formed Steel Framing and Indicated Sheathing

Wall Construction[1,2]	Code Status	Max. Aspect Ratio	Wall Shear[4], lb/ft, for Fastener Spacing at Panel Edges (in.)			
			6	4	3	2
15/32" structural 1 sheathing 4-ply, one side	Approved	4:1	780	990	1465	1625
15/32" structural 1 sheathing 4-ply, one side; end studs, 0.043" min. thickness	Proposed	2:1	-	-	1775	2190
15/32" structural 1 sheathing 4-ply, one side; all studs and track, 0.043" min. thickness	Proposed	2:1	890	1330	1775	2190
7/16" rated sheathing, OSB, one side	Approved for 2:1, Proposed for 4:1	4:1	700	915	1275	1700
7/16" rated sheathing, OSB, one side; end studs, 0.043" min. thickness	Proposed	2:1	-	-	1520	2060
0.018" steel sheet, one side	Proposed	2:1	390	-	-	-
0.027" steel sheet, one side	Proposed	4:1	-	1000	1085	1170

Notes:

1. Maximum stud spacing is 24 in. c.c.
   Minimum stud/track thickness is 0.033 in. (min. base metal thick.) except as noted.
   Minimum stud size is 3-1/2 x 1-5/8.
   Minimum track size is 3-1/2 x 1-1/4.
   Steel per ASTM A653 Grade 33.
2. Minimum framing screws are No. 8 x 5/8 in. wafer head self-drilling.
   Minimum screws for OSB and plywood sheathing are No. 8 x 1 in. flat head, sharp point, self drilling.
   Minimum screws for steel sheathing are No. 8 x 1/2 in. modified truss head, self drilling.
   Maximum spacing of sheathing fasteners other than at edges is 12 in.
   Sheathing can be oriented either parallel or perpendicular to framing.
4. For design, divide by a safety factor (ASD) or multiply by a reduction factor (LRFD).

Table 4

Nominal (Ultimate) Shear Strength of Walls With 3-1/2 x 1-5/8 in. Steel Studs on 24 in. Centers based on Static Tests by Serrette (1997)

A. Tests with OSB Sheathing

Ref. No.	Sheathing Thickness/Type	Screw Spacing* (in)	Wall Size (ft)	Nominal Shear (lb/ft)
9, 10	7/16" OSB	6/12	2 x 8	537**
5, 6	7/16" OSB	4/12	2 x 8	1026
7, 8	7/16" OSB	2/12	2 x 8	1825

* Screws for OSB were No. 8-18 x 1 in. self drilling, flat head, zinc plated.
** Ratio of maximum load for these two specimens was 0.66.

B. Tests With Steel X-Bracing

Ref. No.	Bracing Width/ Thickness (in)	No. of Screws, Strap to Gusset*	Wall Size (ft)	Nominal Shear (lb/ft)
1, 2	4-1/2 x 0.033	20	4 x 8	673**
3, 4***	7-1/2 x 0.033	30	4 x 8	877

* Screws for X-bracing were No. 8-18 x 1/2 in. self drilling, modified truss head, zinc plated.
** Ratio of maximum load for these two specimens was 0.87.
*** Studs for tests 3 - 4 were 3-1/2 x 1-5/8 x 0.043 in. spaced at 24 in., A653 Grade 33 steel.

C. Tests with Steel Sheathing

Ref. No.	Sheathing Thickness/Type	Screw Spacing* (in)	Wall Size (ft)	Nominal Shear (lb/ft)
11, 12	0.018" Steel	6/12	2 x 8	491
13, 14	0.027" Steel	4/12	2 x 8	990**
15, 16	0.018" Steel	6/12	4 x 8	483

* Screws for sheathing were No. 8-18 x 1/2 in. self drilling, modified truss head, zinc plated.
** Ratio of maximum load for these two specimens was 0.88.

D. Notes

1. See Serrette (1997) for further details.
2. Nominal (ultimate) shears listed are average of two tests.
3. Sheathing (or bracing) on one side only.
4. Screw spacing 6/12 indicates 6 in. on panel edges, 12 in. on intermediate members.
5. Screws for framing were No. 8-18 x 1/2 in. self drilling, modified truss head, zinc plated.
6. Studs were 3-1/2 x 1-5/8 x 0.033 in. spaced at 24 in., A653 Grade 33 steel, except as noted.
   Track was 3-1/2 x 1-1/4 x 0.033 in., top and bottom, A653 Grade 33 steel.
   Thicknesses refer to minimum base metal thickness.
7. For design, divide by a safety factor (ASD) or multiply by a reduction factor (LRFD).

Table 5

Nominal (Ultimate) Shear Strength of Walls With 3-1/2 x 1-5/8 in. Steel Studs on 24 in. Centers based on Cyclic Tests by Serrette (1997)

A. Tests with OSB and Plywood Sheathing

Ref. No.	Sheathing Thickness and Type	Screw Spacing* (in)	Framing Thickness (in.)	Wall Size (ft)	Nominal Shear (lb/ft)
A1, A2	15/32" plywood	3/12	0.033**	4 x 8	1775
A3, A4	15/32" plywood	2/12	0.033**	4 x 8	2190
A5, A6	7/16" OSB	3/12	0.033**	4 x 8	1523
A7, A8	7/16" OSB	2/12	0.033**	4 x 8	2058
B1, B2	15/32 plywood	6/12	0.043	4 x 8	892***
B3, B4	15/32 plywood	6/12	0.054	4 x 8	904***
E1, E2	7/16" OSB	6/12	0.033	2 x 8	721
E3, E4	7/16" OSB	4/12	0.033	2 x 8	1126
E5, E6	7/16" OSB	2/12	0.033	2 x 8	1624***

* Screws for OSB were No. 8-18 x 1 in. self drilling, flat head, zinc plated.
** End studs were 0.043 in.
*** Ratio of maximum load was 0.85 for B1-B2, 0.88 for B3-B4, and 0.84 for E5-E6.

B. Tests With Steel X-Bracing

Ref. No.	Bracing Width and Thickness (in)	No. of Screws, Strap to Gusset*	Framing Thickness (in.)	Wall Size (ft)	Nominal Shear (lb/ft)
C1, C2	4-1/2 x 0.033	20	0.033	4 x 8	821
C3, C4	7-1/2 x 0.033	30	0.033	4 x 8	839

* Screws for X-bracing were No. 8-18 x 1/2 in. self drilling, modified truss head, zinc plated.

C. Tests With Steel Sheathing

Ref. No.	Sheathing Thickness and Type	Screw Spacing* (in)	Framing Thickness (in.)	Wall Size (ft)	Nominal Shear (lb/ft)
D1, D2	0.018" Steel	6/12	0.033	4 x 8	392
F1, F2	0.027" Steel	4/12	0.033	2 x 8	1003
F3, F4	0.027" Steel	2/12	0.033	2 x 8	1171

* Screws for sheathing were No. 8-18 x 1/2 in. self drilling, modified truss head, zinc plated.

D. Notes

1. See Serrette (1997) for further details.
2. Nominal (ultimate) shears listed are average of two tests. Each is based on average values for last stable hysteretic loop.
3. Sheathing (or bracing) on one side only. Horizontal strap. 0.033 x 1.5 in. at stud midheight.
4. Screw spacing 6/12 indicates 6 in. on panel edges, 12 in. on intermediate members.
5. Screws for framing were No. 8-18 x 1/2 in. self drilling, modified truss head, zinc plated.
6. Studs were 3-1/2 x 1-5/8 spaced at 24 in., A653 Grade 33 steel.
   Track was 3-1/2 x 1-1/4, top and bottom, A653 Grade 33 steel.
   Thicknesses refer to minimum base metal thickness.
7. For design, divide by a safety factor (ASD) or multiply by a reduction factor (LRFD).

Table 6

Nominal (Ultimate) Shear Strength of Walls With 3-1/2 x 1-5/8 in. Steel Studs on 24 in. Centers Based on Static Tests by Serrette (1996)

Ref. No.	Sheathing Thickness and Type	Sheathing Orientation	Screw Spacing (in)	Wall Size (ft)	Nominal Shear (lb/ft)
1A6, 1A7	15/32" 4-ply plywood	V	6/12	8 x 8	1062
1A2, 1A3	7/16" OSB	V	6/12	8 x 8	911
1A5, 1A6	7/16" OSB	H	6/12	8 x 8	1022
1E1, 1E2	7/16" OSB	H	6/12	4 x 8	1025
1D3, 1D4	7/16" OSB	V	4/12	4 x 8	1412
1D5, 1D6	7/16" OSB	V	3/12	4 x 8	1736
1D7, 1D8	7/16" OSB	V	2/12	4 x 8	1912
1F1, 1F2	7/16" OSB 1/2" GWB	V	6/12 7/7	4 x 8	1216
1F3, 1F4	7/16" OSB 1/2" GWB	V	4/12 7/7	4 x 8	1560
1F5, 1F6	7/16" OSB 1/2" GWB	V	2/12 7/7	4 x 8	1884
2A1, 1A3	7/16" OSB 1/2" GWB	H	7/7 7/7	8 x 8	583
2A2, 2A4	7/16" OSB 1/2" GWB	H	4/4 4/4	8 x 8	849

Notes:

1. See Serrette (1996) for further details.
2. Nominal (ultimate) shears listed are average of two tests.
3. Sheathing on one side only except for tests with GWB.
   Horizontal strap, 0.033 x 1.5 in., at midheight of studs.
   V indicates sheathing parallel to framing, H indicates sheathing perpendicular.
4. Screw spacing 6/12 indicates 6 in. on panel edges, 12 in. on intermediate members.
   Screws for plywood and OSB were No. 8 x 1in. self drilling, flat head with counter-sinking nibs under the head, type 17 point, coarse high thread, zinc plated.
   Screws for GWB were No. 6 x 1-1/4 in. self drilling, bugle head, type S point.
5. Studs were 3-1/2 x 1-5/8 x 0.033 in. spaced at 24 in., A653 Grade 33 steel.
   Double studs (back-to-back) were used at the ends of the wall.
   Track was 3-1/2 x 1-1/4 x 0.033 in., top and bottom, A653 Grade 33 steel.
   Thicknesses refer to minimum metal base thickness.
6. For design, divide by a safety factor (ASD) or multiply by a reduction factor (LRFD).

Table 7

Nominal (Ultimate) Shear Strength of Walls With 3-1/2 x 1-5/8 in. Steel Studs on 24 in. Centers Based on Cyclic Tests by Serrette (1996)

Ref. No.	Sheathing Thickness and Type	Sheathing Orientatio n	Screw Spacing (in)	Wall Size (ft)	Nominal Shear (lb/ft)
OSB1,OSB 2	7/16" OSB	V	6/12	4 x 8	700
OSB3,OSB 4	7/16" OSB	V	4/12	4x8	912
OSB5,OSB 6	7/16" OSB	V	3/12	4x8	1275
OSB7,OSB 8	7/16" OSB	V	2/12	4x8	1700
PLY1,PLY 2	15/32" 4-ply plywood	V	6/12	4x8	780
PLY3,PLY 4	15/32" 4-ply plywood	V	4/12	4x8	988
PLY5,PLY 6	15/32" 4-ply plywood	V	3/12	4 x 8	1462
PLY7,PLY 8	15/32" 4-ply plywood	V	2/12	4 x 8	1625

Notes:

1. See Serrette (1996) for further details.
2. Nominal (ultimate) shears listed are average of two tests. Each is based on average values for last stable hysterectic loop.
3. Sheathing on one side only.
   Horizontal strap, 0.033 x 1.5 in., at midheight of studs.
   V indicates sheathing parallel to framing.
4. Screw spacing 6/12 indicates 6 in. on panel edges, 12 in. on intermediate members.
   Screws for plywood and OSB were No. 8 x 1 in. self drilling, flat head with counter-sinking nibs under the head, type 17 point, coarse high thread, zinc plated.
   Screws for GWB were No. 6 x 1-1/4 in. self drilling, bugle head, type S point.
5. Studs were 3-1/2 x 1-5/8 x 0.033 in. spaced at 24 in., A653 Grade 33 steel.
   Double studs (back-to-back) were used at the ends of the wall.
   Track was 3-1/2 x 1-1/4 x 0.033 in., top and bottom, A653 Grade 33 steel.
   Thicknesses refer to minimum metal base thickness.
6. For design, divide by a safety factor (ASD) or multiply by a reduction factor (LRFD).

Table 8

Nominal (Ultimate) Shear Strength of Walls With 6 x 1-5/8 in. Steel Studs on 24 in. Centers and 6/12 in. Sheathing Fastener Spacings Based on Static Tests by Serrette (1994)

Ref. No.	Wall Sheathing	Sheathing Orientation	Screw Type	Wall Size (ft)	Nominal Shear (lb/ft)
1	2 x 0.033 in. strap X-bracing, with one No. 8 screw each stud and anchored at gussets	–	–	8 x 8	303 (3 tests)
2	1/2 in. GWB (both sides)	V	No. 6	8 x 8	748 (4 tests)
3	side a: 1/2 in. GWB side b: 1/2 in. GSB +2 x 0.033 in. X-straps per test 1	V	–	8 x 8	929 (4 tests)
4	15/32" 4-ply plywood	V	No. 6	8 x 8	1049 (2 tests)
5	15/32" 4-ply plywood	V	0.114-in. dia. pins	8 x 8	621 (1 test)
6	15/32" 4-ply plywood	V	No. 8	8 x 8	976 (2 tests)
7	15/3'-'" 4-ply plywood	H (no blocking)	No. 8	8 x 8	421 (1 test)
8	15/32" 4-ply plywood	H (with blocking)	No. 8	8 x 8	980 (1 test)
9	7/16" OSB	V	0.114-in. dia. pins	8 x 8	600 (1 test)
10	7/16" OSB	V	No. 8	8 x 8	788 (3 tests)
11	7/16" OSB	H (with blocking)	No. 8	8 x 8	828 (11 test)
12	7/16" OSB	V	No. 6	8 x 8	317 (3 tests)

Notes:
1. See Serrette (1994) for further details.
2. Nominal (ultimate) shears listed are average of indicated no. of tests.
3. Sheathing on one side only except for tests with GWB.
   V indicates sheathing parallel to framing, H indicates sheathing perpendicular.
4. Screw spacing 6/12 indicates 6 in. on panel edges, 12 in. on intermediate members.
5. Studs were 6 x 1-5/8 x 0.033 in. spaced at 24 in., A653 Grade 33 steel.
   Double studs (back-to-back) were used at the ends of the wall.
   Track was 6 x 1-1/4 x 0.033 in., top and bottom, A653 Grade 33 steel.
   Thicknesses refer to minimum metal base thickness.
6. For design, divide by a safety factor (ASD) or multiply by a reduction factor (LRFD).

Table 9

Nominal (Ultimate) Shear Strength of Walls With Steel Studs on 24 in. Centers Based on Static Tests by Tissell (1993)

Stud Thicknes s (in.)	Sheathing Thickness and Type	Fastener Size	Screw Spacing (in)	Wall Size (ft)	Nominal Shear (lb/ft)
0.074	3/8" plywood*	No. 10-24	4/12	8 x 8	1666
0.059	3/8" plywood*	No. 10-24	4/12	8 x 8	1093
0.059	7/16" OSB*	No. 10-24	4/12	8 x 8	1248
0.047	3/8" plywood*	No. 8-18	6/12	8 x 8	748
0.047	3/8" plywood*	No. 8-18	4/12	8 x 8	960
0.047	7/16" OSB*	No. 8-18	3/12	8 x 8	1095
0.074	19/32" OSB**	0.144" - dia. pin	6/12	8 x 8	1088
0.074	5/8" plywood**	0.144" - dia. pin	4/12	8 x 8	1865

Notes:

1. See Tissell (1993) for further details.
2. Sheathing on one side only. Orientation was vertical.
3. Screw spacing 6/12 indicates 6 in. on panel edges, 12 in. on intermediate members.
4. Single studs were used at the ends of the wall.
   Studs 0.059 and 0.047 in. thick were 3-1/2 x 1-5/8 in.
   Studs 0.074 in. thick were 2-1/2 x 1-5/8 in.
   Track was same width and thickness as studs.
   Thicknesses are nominal.
5. For design, divide by a safety factor (ASD) or multiply by a reduction factor (LRFD).

Footnotes:

*APA Structural 1.

**APA rated sheathing.

Appendix

Table A 1

Test Reference Numbers* for Nominal Shear Values for Wind Forces (Plywood, OSB, or Steel Sheathing - See Table 1)

Wall Construction	Code Status	Max. Aspect Ratio	Fastener Spacing at Panel Edges (in.)			
			6	4	3	2
15/32" structural 1 sheathing 4-ply, one side	Approved	2:1	1A6/7	-	-	-
7/16" rated sheathing, OSB, one side	Approved	2:1	1A2/3	1D3/4	1D5/6	1D7/8
7/16" rated sheathing, OSB, one side, oriented perpendicular to framing	Proposed	2:1	1A5/6 1E1/2			
7/16" rated sheathing, OSB, one side	Proposed	4:1	-	5/6	(I)	7/8
0.018" steel sheet, one side	Proposed	2:1	15/16	-	-	-
0.027" steel sheet, one side	Proposed	4:1	-	13/14	-	-

Notes:
* For underlined test numbers, see Serrette 1997; for others see Serrette 1996.
(I) indicates interpolated value.

Table A2

Test Reference Numbers* for Nominal Shear Values for Wind Forces (Gypsum Wall Board Both Sides - See Table 2)

Wall Construction	Code Status	Max. Aspect Ratio	Fastener Spacing (edge/field, in.)	
			7/7	4/4
1/2" gypsum board both sides	Approved	2:1	2A1, 1A3	2A2, 2A4

Notes:
* For test numbers, see Serrette 1996.

Table A3

Test Reference Numbers* for Nominal Shear Values for Seismic Forces (Plywood, OSB, or Steel Sheathing - See Table 3)

Wall Construction	Code Status	Max. Aspect Ratio	Fastener Spacing at Panel Edges (in.)			
			6	4	3	2
15/32" structural 1 sheathing 4-ply, one side[a]	Approved	4:1	PLY 1/2	PLY 3/4	PLY 5/6	PLY 7/8
15/32" structural 1 sheathing 4-ply, one side; end studs, 0.043" min. thickness	Proposed	2:1	-	-	A1/2	A3/4
15/32" structural 1 sheathing 4-ply, one side; all studs and track, 0.043" min. thickness[b]	Proposed	2:1	B1/2	(I)	A1/2	A3/4
7/16" rated sheathing, OSB, one side[c]	Approved for 2:1, Proposed for 4:1	2:1 4:1	OS B1/2 E1/2	OS B3/4 E3/4	OS B 5/6 -	OS B 7/8 E5/6
7/16" rated sheathing, OSB, one side; end studs, 0.043" min. thickness	Proposed	2:1	-	-	A5/6	A7/8
0.018" steel sheet, one side	Proposed	2:1	D1/2	-	-	-
0.027" steel sheet, one side	Proposed	4:1	-	F1/2	(I)	F3/4

Notes:

* For underlined test numbers, see Serrette 1997; for others see Serrette 1996.

(I) indicates interpolated value.

a. Tests PLY1 - PLY8 were conducted on assemblies with 2:1 aspect ratio. The results were extended to a 4:1 aspect ratio because tests on similar OSB assemblies established the validity of this approach. See note c.

b. For the case of all 0.043 in. thick studs with edge spacings of 3 and 2 in., the values from tests A1 - A4 (end studs 0.043 in., others 0.033 in.) were considered as lower bounds.

c. The approved values for a 2:1 aspect ratio were proposed also for a 4:1 aspect ratio because the values for tests E1 - E4 exceeded the values for tests OSB1 - OSB4, and the value for E5/6 was 95% of the value for OSB7/8.