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ABSTRACT

A full-scale experimental study on the structural performance of load-bearing wall panels made of cold-formed steel frames and boards is presented. Six different types of C-channel stud, a total of 20 panels with one middle stud and 10 panels with two middle studs were tested under vertical compression until failure. For panels, the main variables considered are screw spacing (300 mm, 400 mm, or 600 mm) in the middle stud, board type (oriented strand board – OSB, cement particle board – CPB, or calcium silicate board – CSB), board number (no sheathing, one-side sheathing, or two-side sheathing), and loading type (1, 3, or 4-point loading).

The measured load capacity of studs and panels agrees well with analytical prediction. Due to the restraint by rivet connections between stud and track, the effective length factor for the middle stud and the side stud in a frame (unsheathed panel) is reduced to 0.90 and 0.84, respectively. The load carrying capacity of a stud increases significantly whenever one- or two-side sheathing is used, although the latter is significantly more effective. It is also dependent upon the type of board used. Whereas panels with either OSB or CPB boards have nearly identical load carrying capacity, panels with CSB boards are considerably weaker. Screw spacing affects the load carrying capacity of a stud. When the screw spacing on the middle stud in panels with one-side sheathing is reduced from 600 mm to 300 mm, its load carrying capacity increases by 14.5 %, 20.6% and 94.2% for OSB, CPB and CSB, respectively.

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1. Introduction

Cold-formed steel sections are being increasingly used in building construction: roof, floor and wall panels, window reinforcements, mezzanine flooring, and so on. Because of its high strength and yet good forming properties, the material generally used is galvanized mild steel supplied initially in large coils and later slit to appropriate strip widths. Steel track and stud is seen as an environmentally friendly, recyclable alternative to timber traditionally used for studding and roofing trusses. The replacement of timber with steel becomes more prevalent in areas where timber resources are scarce, and also in commercial or community applications where other advantages such as speed of assembly and fire retardance are more important.

One of the major growth areas for cold-formed steel sections has been in the structural sector, particularly track and stud for plasterboard partitioning support. Panels consisting of a steel frame with one- or two-side sheathing have been widely used to construct external as well as internal walls of a building. For external walls, the panels support the structural load according to building regulations. For internal walls, some are load bearing whereas others are only for partitioning purposes and hence are only required to offer secondary structural support. Previous test results on gypsum-sheathed partition walls subjected to vertical compression reveal that the load carrying capacity of a C-channel stud is greatly enhanced by the boards (Miller and Pekoz, 1993, 1994; Lee and Miller, 2001; Telue and Mahendran, 2001). The American Standard (AISI, 1996) provides a few empirical formulas for calculating the failure load of a stud with two-side sheathing. There is no existing formula to account for the board contribution to the load capacity of a stud with one-side sheathing. The British Standard (BSI, 1998) offers no guidance on how to include the influence of board when calculating the load capacity of a sheathed frame.

This paper presents full-scale test results on the load carrying capacities of individual studs, frames, and panels (frames with either one- or two-side sheathing). Focus has been placed on one-side sheathing panels, as previous studies were mainly carried out for frames or panels with two-side sheathing. The effects of board type, screw spacing, stud dimensions, and loading type are explored. Although two-side sheathing panels are used in the final products, one of the boards often needs to be taken out for maintenance or other purposes. Consequently, in practical panel design, the load carrying capacity of a panel with one-side sheathing should be taken as the load carrying capacity of a panel having either one- or two-side sheathing.

2. Test program

2.1 Stud and panel configurations

Six different types of C-channel stud, designated here as CS9015 (90×39/42×8.4×1.5 mm), CDS9015 (90×60×12×1.5 mm), CDS9012 (90×60×12×1.2 mm), CDS9009 (90×60×12×0.9 mm), CDS9007 (90×60×12×0.7 mm) and side stud (93×67×1.2 mm), were tested. For each type, at least 2 nominally identical studs were tested. All of these except CDS9012 were used as panel studs.

CS9015, CDS9015, CDS9012, CDS9009 and CDS9007 are C-channel sections with lips, whilst the side stud (track) is a C-channel section without lips. Geometrical dimensions of the above studs are shown in Fig 1.

In this paper, a panel refers to a cold-formed steel frame sheathed on one or both sides with boards. Two types of panel frame were used, one with one middle stud (Fig2a) and the other with two middle studs (Fig 2b). In total 20 panels with one middle stud were tested, including 3 frames (with no sheathing), 14 one-side sheathed panels, and 3 two-side sheathed panels. The main variables in these tests are sheathing type (no sheathing, one-side sheathing, two-side sheathing), board type (calcium silicate board, cement particle board, oriented strand board), and screw spacing on the middle stud. All panels are 2.45 m high and 1.25 m wide, and the circumference of each panel is made of the 93×67×1.2 mm track. The stud is connected to the track by 3 rivets on each flange, and the top and bottom tracks are connected with the side stud (track) by 2 rivets on each flange. The boards are attached to the frame by diameter 5 mm self-drilling screws. For all panels, screw spacing on each track (top, bottom, left and right) is fixed at 300 mm, whereas screw spacing on the middle stud is varied from 300mm, 400mm to 600mm, respectively. Fabrication details of panels with one middle stud are given in Table 1.

Table 1. Test panels with one middle stud (CS 9015)

Panel No	Board	Sheathing	Screw spacing on middle stud
1		No	
2		No	
3	CPB	One side	400
4	CPB	One side	400
5	CPB	One side	600
6	OSB	One side	400
7	OSB	One side	600
8	CSB	One side	400
9	OSB	One side	600
10	OSB	One side	400
11	CPB	One side	300
12	CPB	One side	600
13	OSB	One side	300
14	CSB	One side	300
15	CSB	One side	600
16	OSB	Two side	300
17	CPB	Two side	300
18	CSB	Two side	300
19	CSB	One side	400
20		No	

In total 10 panels with two middle studs (Fig 2b) were tested. For these panels the tracks are identical to those used in constructing the 20 panels with one middle stud. However, four different middle studs, CS9015, CDS9015, CDS9009 and CDS 9007, are used in the panels. All panels with two middle studs have one-side sheathing, with one oriented strand board (OSB) attached to the frame by self-drilling screws (Table 2).

Table 2. Test panels with two middle studs

Panel No	Board type	Sheathing	Screw spacing on middle stud	Middle stud type
1	OSB	One side	400	CS9015
2	OSB	One side	600	CS9015
3	OSB	One side	300	CS9015
4	OSB	One side	300	CS9015
5	OSB	One side	600	CDS9015
6	OSB	One side	600	CDS9007
7	OSB	One side	600	CDS9009
8	OSB	One side	600	CDS9015
9	OSB	One side	300	CDS9009
10	OSB	One side	300	CDS9007

2.2 Material properties

Two steel grades were used for the cold-formed studs. The tensile yield strength for CS9015, CDS9015, CDS9012 and track is 350 N/mm^2, whereas the yield strength for CDS9009 and CDS9007 is 200 N/mm^2. For both steel grades, the Young's modulus is 205 GPa and Poisson's ratio is 0.3.

Three different boards, cement particle board(CPB), orient strand board(OSB) and calcium silicate board(CSB), were used in the panel. CPB is the stiffest and densest among the all of boards. OSB is like a wood chipped board and it is the lightest one. CSB is slightly brittle. The exact board material properties will be tested further.

2.3 Test procedures and instrumentation

All tests were carried out on a 500-ton Amsler hydraulic machine, with a wood beam fixed to the bottom of the machine to support the frames and panels. For the 20 panels with one middle stud, vertical compressive loads were applied in two different ways. For the first 15 panels, concentrated loads were applied via three loading blocks (3-point loading), each connected with a calibrated load cell placed separately on the top of the middle stud and the top of each side track (Fig. 3). For the remaining 5 panels, a single concentrated load was applied to the top of the middle stud. Installation of load cells and position transducers is shown in Fig 3 for 3-point loading.

For the 10 panels with two middle studs, concentrated loads were applied via four calibrated load cells (4-point loading), through four loading blocks placed separately on the top of each middle stud and side track.

For each individual stud, concentrated load was applied to the top of the stud via a loading block connected to a calibrated load cell with a ball head. The bottom of the stud is placed on a second loading block with a ball joint to simulate simple support conditions.

Output from the load cells and displacement transducers was fed into a data logger, and subsequently transferred to a computer for further analysis. Load-displacement curves were recorded automatically during the tests. In addition to load and displacement recordings, strain distribution in the panel was measured with strain gauges attached to the stud, track and board at various locations, and the results are reported in a companion paper by Wang et al. (2002).

3. Results and discussion

The test results are summarized in Tables 3, 4 and 5.

Table 3. Failure stress of individual studs

Stud type	Test failure load (kN)	Average failure load (kN)	Predicted failure load (kN)	Test failure load/predicted failure load*	Test failure stress (N/mm^2)
CS9015	18.7, 19.2, 17.5	18.5	17.5	1.06	67.8
CDS9015	43.0, 42.9, 40.9	42.3	44.6	0.95	123.7
CDS9012	29.4, 29.5, 29.7	29.5	33.2	0.89	103.0
CDS9009	17.4, 17.9	17.7	18.0	0.98	85.3
CDS9007	11.0, 11.2	11.1	11.6	0.96	69.2
Track	10.0, 9.7, 9.5	9.7	10.3	0.94	36.0

*Predicted failure are calculated according to BS5950:5, with effective length factor K=1. It is assumed that the stud fails due to overall flexural buckling and the effect of neutral axis shift is accounted for.

Table 4. Tests results for panels with one middle stud

Panel No	Panel type	Loading position	Maximum load (kN)				Failure mode (Middle/Side)
			Left	Middle	Right	Total	
1[1]	Frame	3	n.a.	n.a.	n.a.	46.8	FB[2]/FB
2	Frame	1	n.a.	30.4	n.a.	n.a.	FB/FB
3	CPB400	3	28.8	56.1	29.5	111.4	TFB[3]/FB
4	CPB400	1	n.a.	54.9	n.a.	n.a.	TFB/FB
5	CPB600	1	n.a.	53.4	n.a.	n.a.	TFB/FB
6	OSB400	1	n.a.	58.2	n.a.	n.a.	TFB/FB

7	OSB600	1	n.a.	53.2	n.a.	n.a.	TFB/FB
8	CSB400	3	20.8	35.6	20.4	67.1	TFB/FB
9	OSB600	3	21.4	43.2	20.7	77.4	TFB/FB
10	OSB400	3	25.8	44.3	23.9	83.9	TFB/FB
11	CPB300	3	24.7	58.5	25.0	98.0	TFB/FB
12	CPB600	3	23.9	48.5	22.2	78.4	TFB/FB
13	OSB300	3	21.4	49.5	19.9	85.0	TFB/FB
14	CSB300	3	18.5	56.2	18.4	89.5	TFB/FB
15	CSB600	3	22.2	28.9	20.7	62.6	TFB/FB
16	OSB300	3	33.0	86.7	32.2	141.7	Crushed
17	CPB300	3	29.9	81.1	27.4	138.4	Crushed
18	CSB300	3	30.0	71.0	27.6	128.6	Crushed
19	CSB400	3	25.3	28.4	23.3	60.4	TFB/FB
20	Frame	3	14.2	23.0	13.2	47.5	FB/FB

[1]Only the total load of three columns measured

[2]FB: (Overall) flexural buckling

[3]TFB: Torsional-flexural buckling

Table 5. Test results for panels with 2 middle studs

Panel No	Screw spacing (mm)	Rivet number	Maximum load (kN)					Failure mode (Middle/Side)
			Left	Middle Left	Middle Right	Right	Total	
1	400	1	21.4	42.3	48.2	21.2	132.0	TFB/FB
2	600	1	24.5	41.9	44.2	24.1	128.4	TFB/FB
3	300	1	20.4	46.6	33.7	26.4	120.2	TFB/FB
4	300	1	23.8	13.0	11.9	23.9	68.9	NF[1]/FB
5	600	2	20.6	60.9	53.4	20.4	150.1	TFB/FB
6	600	2	14.6	14.0	11.8	13.3	50.5	LB[2]/NF
7	600	2	14.9	21.9	19.0	15.4	67.0	LB/NF
8	600	2	25.7	59.0	57.7	19.6	150.1	TFB/FB
9	300	2	15.7	28.0	21.5	15.5	70.7	LB/NF
10	300	2	15.9	15.8	11.90	17.0	51.8	LB/NF

[1]NF: No failure.

[2]LB: Local buckling

3.1 Individual stud tests

The test results are summarized in Table 3. Failure stress for each stud was obtained by dividing the failure load with the stud cross-sectional area. The results of Table 3 reveal that CDS9015 has the highest load capacity, with a failure stress approximately 2 and 4 times higher than that of CS9015 and track, respectively. The track has the worst performance. In a previous study (Tian and Lu, 2002), an optimization method based on sequential quadratic programming (SQP) was used to find the minimum weight C-section and the corresponding dimensions, subjected to the constraints of yielding and local/global (flexural and torsional) buckling. The weight and section dimensions of CDS9015 are selected according to this optimal design, and hence the high structural performance of CDS9015 is expected. All four deep flange studs, CDS9015, CDS9012, CDS9009 and CDS9007, have identical geometrical dimensions except their wall thickness t (Fig. 1b). It is seen from Table 3 that the load capacity of a stud is sensitive to wall thickness, with the stud failure stress decreasing significantly as t is decreased. In other words, the section dimensions as shown in Fig. 1b are optimal for CDS9015 but not for CDS9012, CDS9009 and CDS9007. Also, it should be pointed out that the yield strength of steel for CDS9009 and CDS9007 is 200 N/mm^2, much smaller than that (350 N/mm^2) for CDS9015 and CDS9012, which may also have contributed to the low structural efficiency of CDS9009 and CDS9007.

No significant torsion of the stud was observed during testing: all individual studs failed due to overall flexural buckling. The ratio of measured failure load to predicted failure load calculated according to BS5950:5 (with effective length factor, K=1) is given in Table 3. Except for CDS9012, the difference between experimental measurement and theoretical prediction is less than 6%.

3.2 Frame with one middle stud

Three frames (panels with no sheathing, see Tables 1 and 4) were tested. Of these, two frames (No. 1 and No. 20) were subjected to 3-point loading and one frame (No. 2) to 1-point loading. The measured stud load capacity for the first two frames are presented in Table 6. For frame No. 1, only the total frame failure load was measured and hence is not included in Table 6.

Table 6. Stud failure load in frames

Loading position	Failure load (kN)		Frame failure load/individual stud load	
	Middle stud	side stud	Middle stud	side stud
1	30.4	n.a.	1.64	n.a.
3	23.0	13.7	1.24*	1.41**

*Effective length factor, K=0.90 for overall buckling

**Effective length factor, K=0.84 for overall buckling

Local buckling on the side tracks was observed to occur in the early stage of loading, because the track wall is thin (1.2 mm) and is not stiffened by lips as in the case of middle studs. In sequel, local buckling also occurred on the top and bottom tracks. As the load is further increased, local buckling occurred in the connection area between the middle stud and track, with the end of the middle stud eventually touching the track web. When the load reached its maximum, overall buckling was observed on the middle stud. The load then decreased significantly as the frame softened. Upon complete unloading, the frame sustained permanent deformation due to extensive failure in the middle and side studs (tracks). Fig 4 shows one of the frames after failure.

Compared with the failure loads obtained in individual stud tests as presented in Table 3, the results of Table 6 show that the stud in a frame can carry more load than the corresponding individual stud with simple supports. This is expected, as the rivet connections in a frame provide more constraints than simple supports. In accordance with elastic overall buckling theory, the effective length factor K is found to be 0.90 for the middle stud and 0.84 for the side stud. This is compared with K=1.0 for simple supports and K=0.75 for clamped ends.

3.3 Sheathed panels with one middle stud

For panels with one-side sheathing, the behavior of the middle and side studs can be directly observed during testing. A typical failed panel is shown in Fig 5. In all panels, the middle stud failed due to overall torsional-flexural buckling, whereas side studs (tracks) failed due to overall flexural buckling and heavy folding due to local buckling.

1) Effect of screw spacing

Tables 7 and 8 present the ratio of stud-in-panel failure load to failure load of the corresponding individual stud for selected values of screw spacing: 300, 400 and 600 mm. In general, a stud-in-panel can carry more than twice the load carried by an individual stud. For the middle stud, screw spacing has some influence on its load capacity, especially for panels sheathed with CSB board. When screw spacing on the middle stud (CS9015) is decreased from 600 mm to 300 mm, its load capacity is increased by 14.5 %, 20.6% and 94.2% for OSB, CPB and CSB board, respectively. For the side studs, screw spacing for all panels is fixed at 300 mm. The effect of screw spacing on middle stud load capacity is plotted in Fig. 6.

Table 7. Ratio of middle stud failure load in panel to failure load of individual stud[1]

Board	One-side sheathing			Two-side sheathing
	Screw spacing 300 mm	Screw spacing 400 mm	Screw spacing 600 mm	Screw spacing 300 mm
OSB	2.68	2.39	2.34	4.68
CPB	3.16	3.03	2.62	4.38
CSB	3.03	1.92	1.56	3.83

[1]Middle stud section: CS9015; 3-point load applied to all panels.

Table 8. Ratio of side stud failure load in panel to failure load of individual side stud[1]

Board	One-side sheathing	Two-side sheathing
	Screw spacing 300 mm	Screw spacing 300 mm
OSB	2.29	3.36
CPB	2.64	2.98
CSB	2.08	2.97

[1]Side stud section: track 93×67×1.2; 3-point loading applied to all panels.

2) Effect of board type

The type of board used to sheath the steel frame affects the stud load capacity (Tables 7 and 8). Whereas panels sheathed with OSB or CPB boards have similar load capacities (the latter is in general better), the load capacity of panels sheathed with CSB boards is substantially lower, especially for large screw spacing as shown in Fig 6. In tests, it was observed that screws were very easily to be pulled out of CSB boards.

3) One-side versus two-side sheathing

Three panels sheathed on both sides were tested, with screw spacing fixed at 300 mm. The results are summarized in Tables 7 and 8, and further in Table 9 where a comparison with panels with one-side sheathing is made. Compared with the corresponding stud failure load in panels with one-side sheathing, the middle stud failure load in panels with two-side sheathing is increased by 75%, 39%, and 26% for OSB, CPB and CSB board, respectively, whereas the side stud failure load is increased by 46%, 13% and 43%, respectively (Table 9). The failure modes of studs in 2-side sheathed panels can be examined by removing one of the boards after the test, and are found to be considerably different from those in 1-side sheathed panels. Due to the effect of sheathing from both sides, the middle as and side studs remain straight, with no visible overall buckling. The top and bottom ends of the studs are locally crushed as a result of high stress level in the rivet connection region.

Table 9. Ratio of stud failure load in 2-side sheathed panel to stud failure load in 1-side sheathed panel[1]

Board	Middle stud	Side stud
OSB	1.75	1.46
CPB	1.39	1.13
CSB	1.26	1.43

[1]Screw spacing on middle and side studs is fixed at 300 mm.

4) Effect of loading position

One frame and four panels with 1-side sheathing were subjected to 1-point loading (via the middle stud), the rest being subjected to 3-point loading. A comparison of the middle stud load capacity attained under these two different loading conditions is presented in Table 10. The stud load capacity for panels subjected to 1-point loading is approximately 10-30% higher, except in the case of CPB board with 400 mm screw spacing, than that for identical panels subjected to 3-point loading. The reason is that, under 3-point loading, through the top and bottom tracks, the boards and side studs are more efficient in sharing the load sustained by the middle stud. The total load capacity of a panel with 1-point loading is only about 70% of that corresponding to 3-point loading. For practical design, the former is somewhat conservative but fail-safe.

Table 10. Ratio of failure load with 1-point loading to failure load with 3-point loading[1]

Board	Screw spacing	Middle stud load	Total load
CPB	400	54.9/56.1=0.98	54.9/111.4=0.49
CPB	600	53.4/48.5=1.10	54.9/78.4=0.70
OSB	400	58.2/44.3=1.31	58.2/83.9=0.69
OSB	600	53.2/43.2=1.23	53.2/77.4=0.69
Frame		30.4/23.0=1.32	30.4/47.5=0.64

[1]For panel test with 1-point loading, failure load of middle stud was equal to the total failure load.

3.4 One-side sheathed panels with two middle studs

1) Observation

For the 10 panels with one-side sheathing and two middle studs, the test results are presented in Table 5. The type of middle stud used in each panel has been given in Table 2. For panels 1 to 4, one rivet was used for stud-to-track connection, whereas for panels 5 to 10, two rivets were used. For panel No 3, the failure load of the middle right stud was found to be uncharacteristically low, which is believed to be caused by the relatively large gap between its ends and the web of top as well as bottom track as a result of poor assembly. To verify this assertion, another panel (No. 4) was fabricated and tested for which the gap between stud and track was separately 15 mm and 6 mm at the top and bottom of the middle left stud, and 18 mm and 30 mm at the top and bottom of the middle right stud. The test result (Table 5) shows that the middle left and right studs in panel No 4 can only support 13 and 12 kN load, respectively, only a quarter of their normal load capacity.

The failure mode of stud CS9015 in 1-side sheathed panels with two middle studs is similar to that in 1-side sheathed panels with one middle stud. The optimized middle stud CDS9015, on the other hand, failed due to overall torsional-flexural buckling. Middle studs, CDS9009 and CDS9007, failed due to heavy local buckling as shown in Fig 7, due mainly to their thin wall thickness; no overall buckling was observed. However, even after middle studs CDS9009 or CDS9007 had failed, the side studs were still intact (Fig. 7) and could continue to carry load.

2) Comparison of stud failure loads for panels with one and two middle studs

For panels 1 to 4 having two CS9015 middle studs, the stud failure load is nearly identical to that in 1-side sheathed panels with one middle stud (Table 11). These tests show that the distance between studs has negligible influence on stud failure load, which is consistent with the findings of Telue et al. (2001).

Table 11. Ratio of middle stud failure load for panels with one middle stud to middle stud failure load in panels with two middle studs

Board	Middle stud Screw spacing	Ratio of middle stud failure load[1]

OSB	300	49.5/46.6=1.06
OSB	400	44.3/45.3=0.98
OSB	600	43.2/43.1=1.00

[1]For panels with two middle stud, middle stud failure load is average value. All middle studs are CS9015.

3) Comparison of failure loads for different middle studs

Four different middle studs, CS9015, CDS9015, CDS9009 and CDS9007 were used in test panels with 1-side sheathing and two middle studs (Table 2). For each stud, its load capacity is compared in Table 12 with that of individual stud for two values of screw spacing: 300 and 600 mm.

Whilst the load capacity of CS9015 in the 1-side sheathed panel (either with one or two middle studs) is more than twice that of CS9015 tested individually, the increase in the failure load for the long flange CDS studs is less than 40%. For the light gage studs, CDS9009 and CDS9007, the failure load is only increased by 16% for screw spacing 600 mm. When screw spacing is reduced from 600 mm to 300 mm, the failure load for CSD9009 and CDS 9007 is increased by 40% and 25%, respectively (Table 12). Fig 8 compares the failure stress of the four middle studs in panel with that of individual studs for 600 mm screw spacing. Each stud performs differently. When tested individually, the failure stress of CS9015 is only half that of optimized CDS9015. However, when both are used as the middle studs of a panel, the failure stress of CDS9015 is only 7% larger than that of CS9015. Consequently, the optimal stud for panel construction will in general be different from that obtained by excluding the constraining effects of boards, screws and rivets.

Table 12. Ratio of middle stud failure load in panels with two middle studs to failure load of individual stud

Stud	Screw spacing 300 mm	Screw spacing 600 mm
CS9015	46.6/18.5=2.52	43.1/18.5=2.33
CDS9015	n.a.	57.8/42.3=1.37
CDS9009	24.8/17.7=1.40	20.5/17.7=1.16
CDS9007	13.9/11.1=1.25	12.9/11.1=1.16

4. Conclusions

Nearly all individual studs compressed under simple conditions failed due to overall flexural buckling (FB), with insignificant torsional buckling. For panels with one-side sheathing, all of the middle studs except the light gauge CDS9009 and CDS9007 failed as a result of torsional-flexural buckling (TFB), CDS9009 and CDS9007 failed due to heavy local buckling (LB) with visible permanent deformation, and side studs (tracks) failed due to flexural buckling (FB) and heavy local buckling (folding flanges). For panels with two-side sheathing, the studs failed by overall torsional-flexural buckling and local crushing near their ends.

The load carrying capacity of stud CS9015 and track increases dramatically when they are used to construct panels with either one- or two-side sheathing. This is compared with the small to moderate increase in load capacity for studs with deep flanges (CDS9015, CDS9009 and CDS9007) when used as the middle studs of sheathed panels, especially for the light gage studs with low yielding strength (CDS9009 and CDS9007). A stud which fails at low stress levels when tested individually may not necessarily perform poorly when used as the middle stud of a sheathed panel; some of the failure mechanisms observed in the former may be suppressed by the use of board attachments and connections. How to obtain the minimum weight and geometrical dimensions of a middle stud in a sheathed panel remains a challenge task.

The selection of board type affects the panel load capacity. The failure load of panels sheathed with OSB boards is about 20% higher than that of panels sheathed with CPB boards, and about 70% higher than that of panels sheathed with CSB boards. Furthermore, by sheathing both sides of a frame the stud load capacity is significantly increased in comparison with 1-side sheathed panels.

The load carrying capacity of studs increases with decreasing screw spacing. When screw spacing is decreased from 600 mm to 300 mm, the load capacity of middle stud CS9015 in one-side sheathed panels with OSB, CPB and CSB board attachments is increased by 14.5 %, 20.6% and 94.2%, respectively. By comparing stud load capacities for 1-side sheathed panels with one and two middle studs, it is concluded that the separation distance between neighboring studs has negligible influence.

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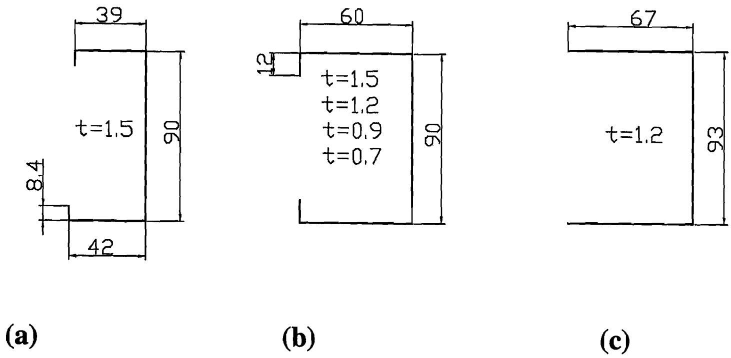

Fig. 1 Cross-sectional geometry of stud and track
(a) CS9015, (b) CDS9015, CDS9012, CDS9009, CDS9007, and (c) track.

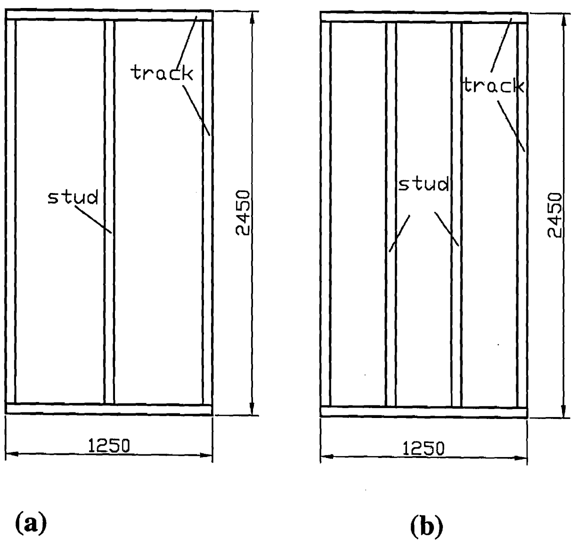

Fig. 2 Geometry of steel frame: (a) with one middle stud; (b) two middle studs.

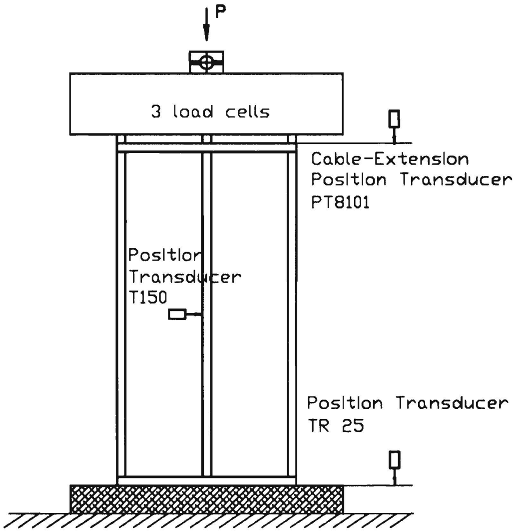

Fig. 3 Load cells and position transducers.

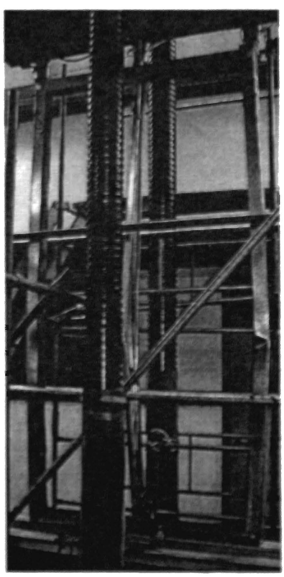

Fig. 4 Typical frame failure mechanisms.

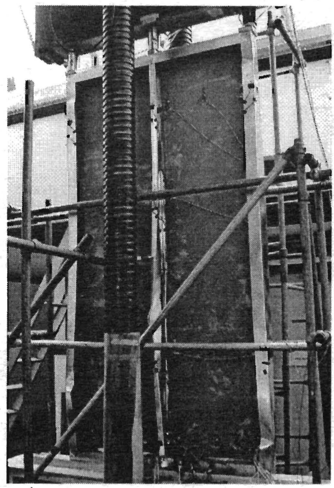

Fig. 5 Failure mechanisms of panel with one middle stud.

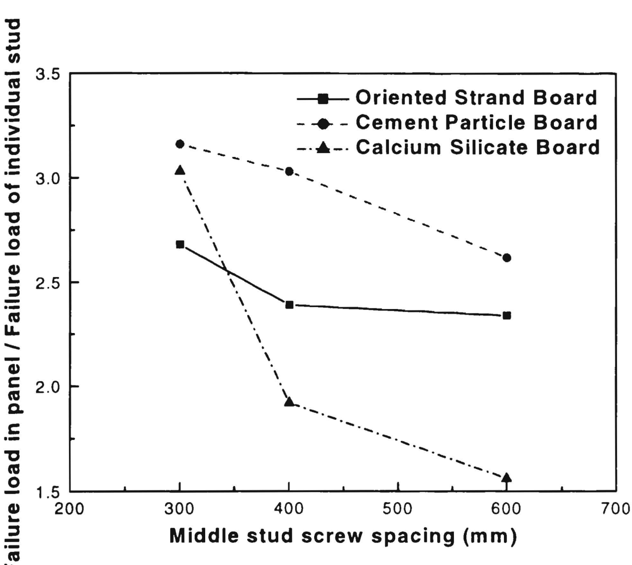

Fig. 6 Ratio of failure load for stud in 1-side sheathed panel with one middle stud (CS9015) to that of individual stud plotted as a function of screw spacing for three different selections of board type.

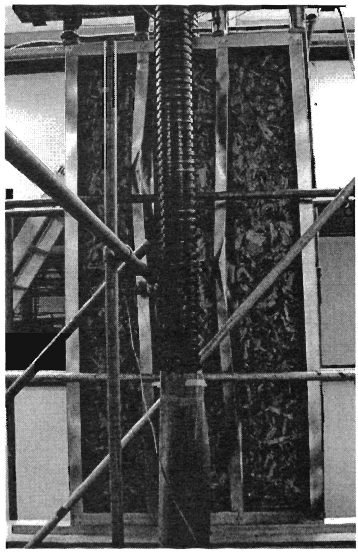

Fig. 7 Failure mechanisms of 1-side sheathed panel with two middle studs (CDS9007).

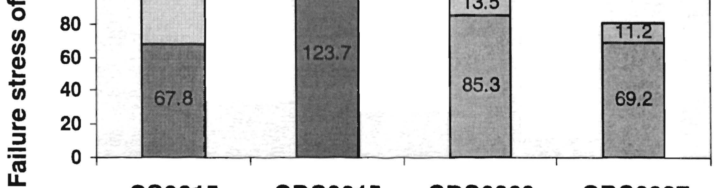

Fig. 8 Comparison between failure stress of individual stud and failure stress of stud in 1-side sheathed panel with two middle studs (screw spacing 600 mm).