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P21 Racking Tests on Customwood Clad Timber Framing

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P21 Racking Tests on Customwood Clad Timber Framing

1. CLIENT

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2. OBJECTIVE

To derive bracing ratings to be used with NZS 3604:1999 for bracing walls constructed on both timber and concrete floors, P21 racking tests were conducted on specimens which consisted timber framed walls clad on one side with 9 mm Customwood MDF sheets. Wall lengths tested were nominal 0.6 m and 2.4 m.

3. DESCRIPTION OF SPECIMENS

3.1 Product Description

The sheet material is known as 9 m thick Customwood MDF. The sheets come in size 2.44 m high by 1.22 m wide. These were cut to 2.40 m high and either 1.2 m wide or 0.6 m wide and were fixed to one side of the wall framing only. The sheets had a mean thickness of 9.2 mm and density of 6.83 kg/m^2. This report pertains to the samples provided only.

3.2 Construction of the Specimens

Four specimens were constructed for each of the two specimen lengths. For reasons discussed in Section 4.2, three of the 0.6 m long walls were used for simulated timber floor construction and one for simulated concrete floor construction. One of the 2.4 m long walls were used for simulated timber floor construction and three for simulated concrete floor construction.

All timber frames were constructed from 90 x 45 mm machine stress graded F5 kiln dried radiata pine. Figures 1 and 2 show the framing for the nominal 0.6 m and 2.4 m long walls respectively. (Note: These drawings do not show the 'P21 end restraint' described in Section 4.1.) The 'dummy' end stub studs shown in Figure 1 were omitted for the construction on the simulated concrete floor. The frames were 2.420 m high and either 0.645 m long or 2.445 m long for the nominal 0.6 m and 2.4 m long walls respectively. A single nog was used at wall mid-height. Two 90 x 3.33 mm gun nails were used to connect studs to the top and bottom plates and the nogs to the studs. Three 90 x 3.33 mm gun nails were used to connect the 'dummy' end stub studs to the studs.

Sheets were fastened to the timber framing using Hurricane nominal 30 x 2.5 mm flat head galvanised steel clouts as shown in Figures 3 and 4 for the nominal 0.6 m and 2.4 m long walls respectively. Around the perimeter of each sheet clouts were used at a maximum spacing of 150 mm with these fasteners being placed using a 10 mm edge distance. Fasteners along the top and bottom plate commenced at 25 mm from the vertical edge. For the 2.4 m wide wall, clouts were used at 300 mm centres to the intermediate studs. The sheets were not directly fixed to the nogs.

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3.2.1 Simulated Timber Floors

The wall base construction is shown in Figures 5 for nominal 0.6 m wide walls. The nominal 2.4 m wide walls did not used end straps or 'dummy' end stub studs.

The bottom plates of the frames were nailed through a strip of 20 mm thick particle board floor to the 150 x 100 mm timber foundation beam using pairs of 100 x 4 mm nails at nominal 600 mm centres. For the nominal 2.4 m wide walls these commenced at 50 mm from the inside face of end studs and were thereafter at nominal 600 mm centres. For the nominal 0.6 m wide walls these were at 50 mm from the inside face of the 'dummy' end stub studs.

At each end of the 0.6 m long walls, a 300 mm length of 25 mm x 1 mm galvanised mild steel strap was fixed between the studs and the foundation beam and also between the 'dummy' end stub studs and foundation beam as shown in Figure 5. Each strap was fixed to both the foundation beam and studs with six 30 mm x 2.5 mm diameter flat head galvanised clouts to each. The steel straps were installed before the cladding was fixed in place. No straps were used for construction of the nominal 2.4 m wide walls.

3.2.2 Simulated Concrete Floors

The wall base construction is shown in Figure 6. The nominal 2.4 m wide walls did not use end straps.

The bottom plate was fixed to the foundation beam with a 200 x 12 mm coach screw located 50 mm from the inside face of the end studs to simulate a concrete hold-down bolt. A 50 x 50 x 3 mm washer was used beneath the head of the coach screw. For the nominal 2.4 m wide walls there was also a bolt and washer 50 mm one side of the face of the stud at mid-wall length.

(a) Nominal 0.6 m wide wall

At each end of the bracing element, a 25 mm (wide) x 1 mm mild steel strap was wrapped under the bottom plate and fixed to the studs with six 30 mm x 2.5 mm diameter flat head galvanised clouts on each side.

(b) Nominal 2.4 m wide wall

No end straps were used on the 2.4 m wide wall.

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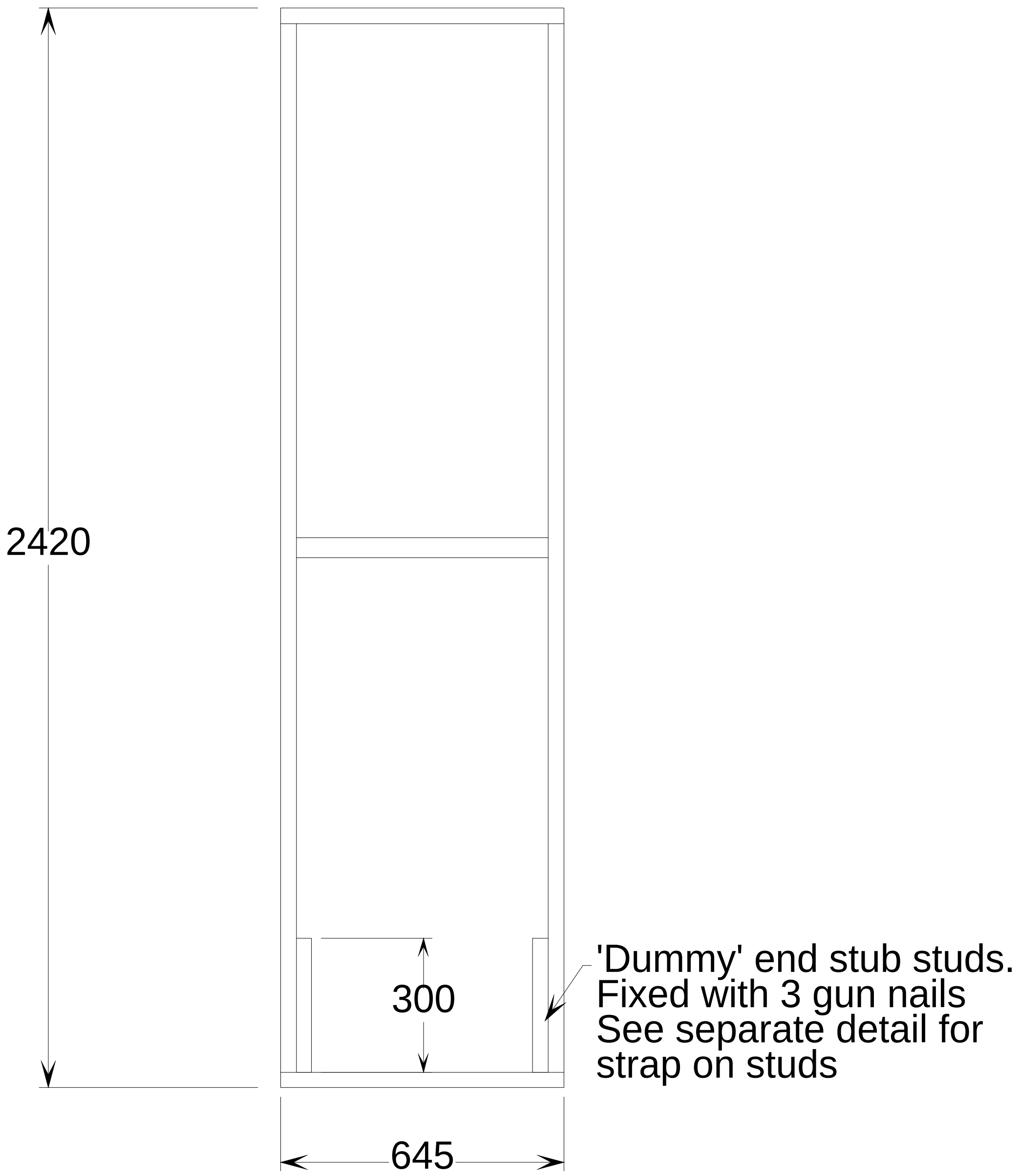

Figure 1 - Framing Used for Nominal 0.6 m long walls

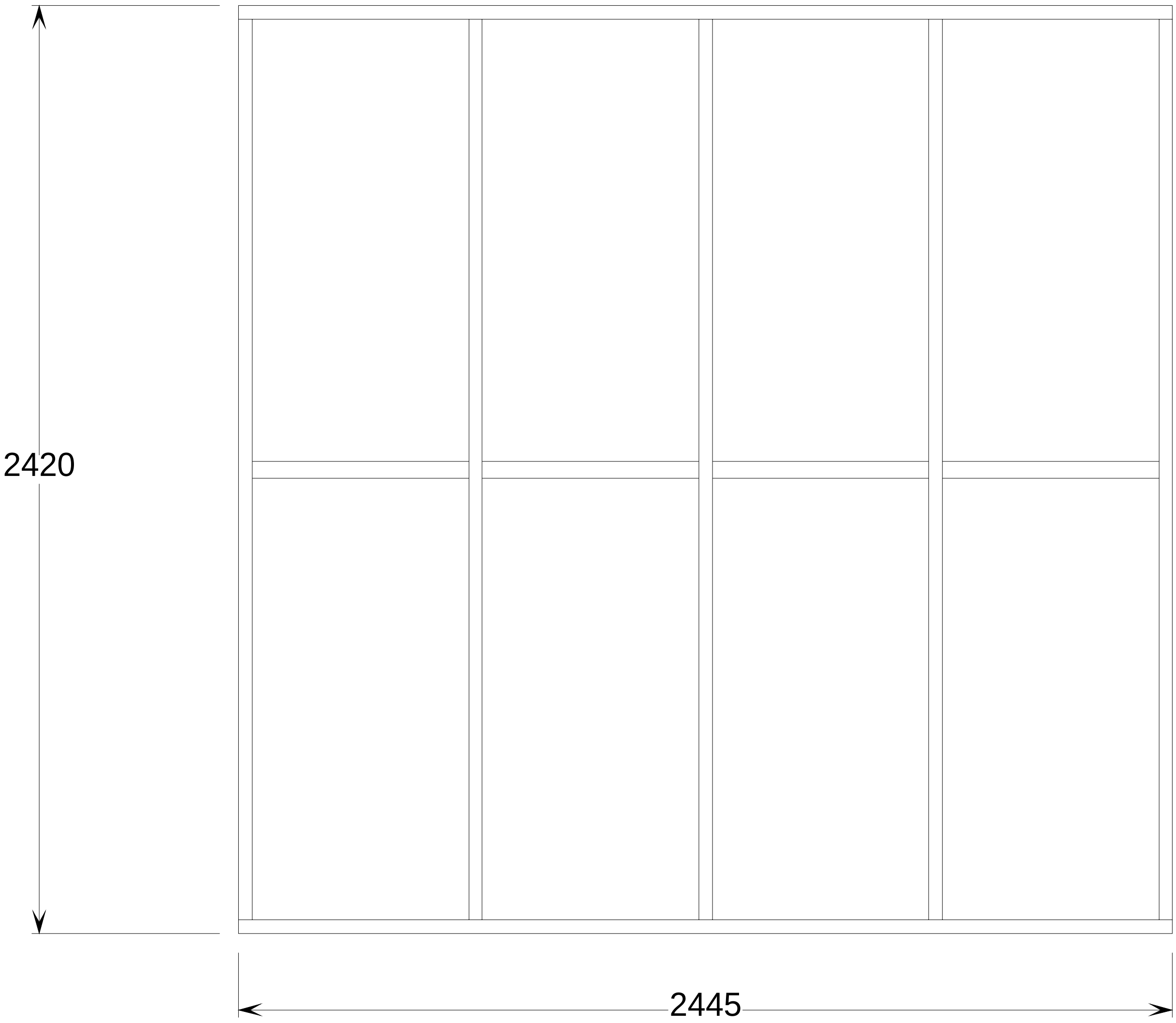

Figure 2 - Framing Used for Nominal 2.4 m long walls

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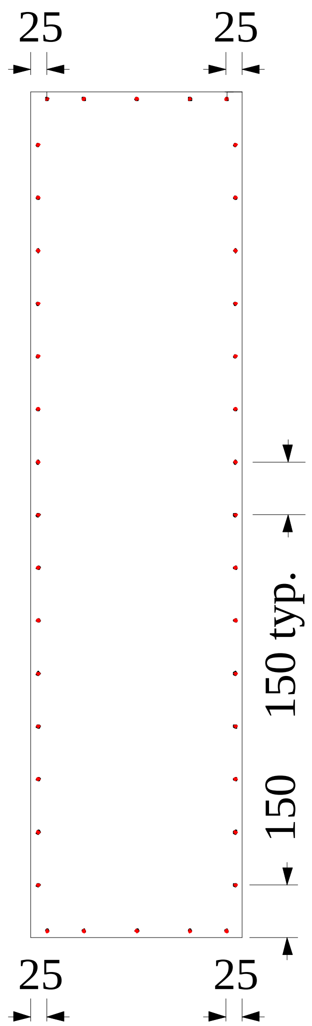
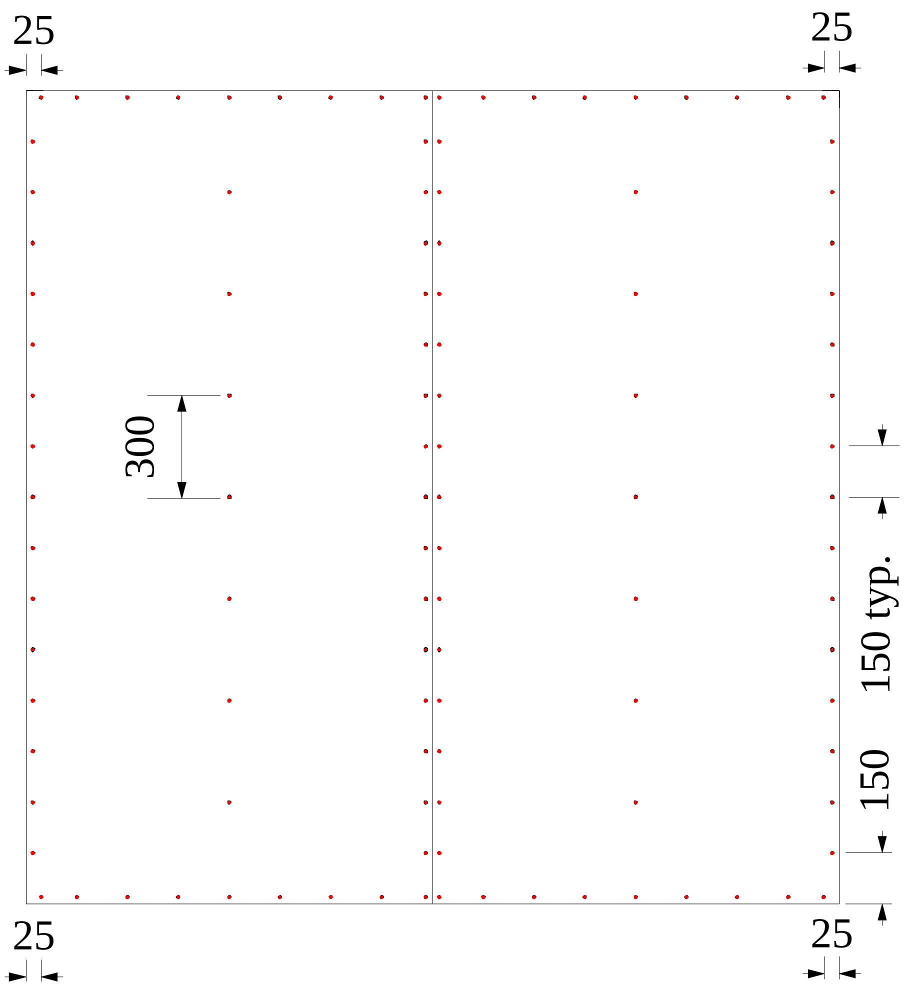


All fixings are 30 x 2.5 mm galvanised flat head clouts
Edge distance is 10 mm except 25 mm at corners as shown.
Clouts around the perimeter are at 150 mm centres
No clouts to mid-height nogs.

Figure 3 – Nailing Pattern for the nominal 0.6 m long walls



All fixings are 30 x 2.5 mm galvanised flat head clouts
Edge distance is 10 mm except 25 mm at corners as shown.
Clouts around the perimeter continue at 150 mm centres
Clouts on studs at middle of sheets are at 300 mm centres starting 300 m
from sheet edge.
No clouts to mid-height nogs.

Figure 4 - Nailing Pattern for the nominal 2.4 m long walls

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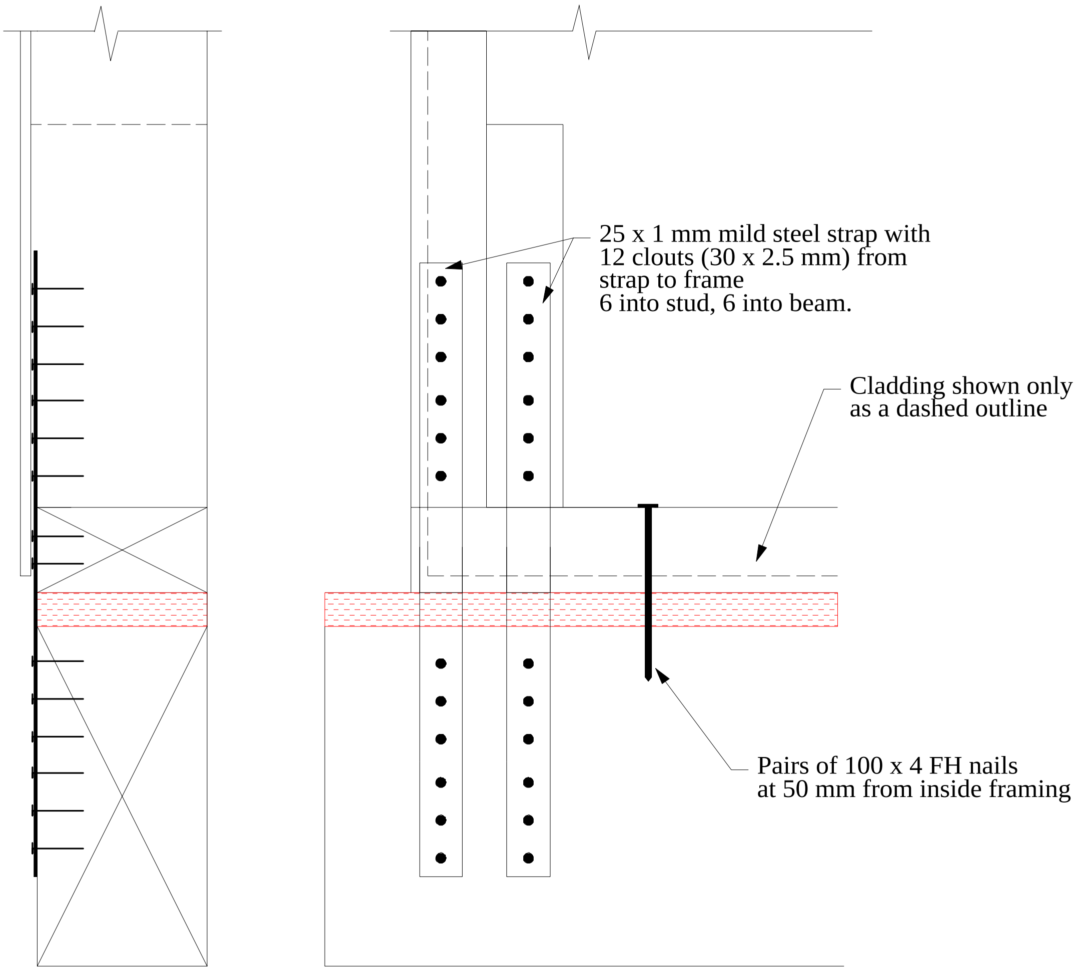

Figure 5 Connection of 0.6 m Long Wall to Timber Foundation

(Fixing 2.4 m long walls to timber foundations was similar but omitted the steel straps and 'dummy' end stub studs.)

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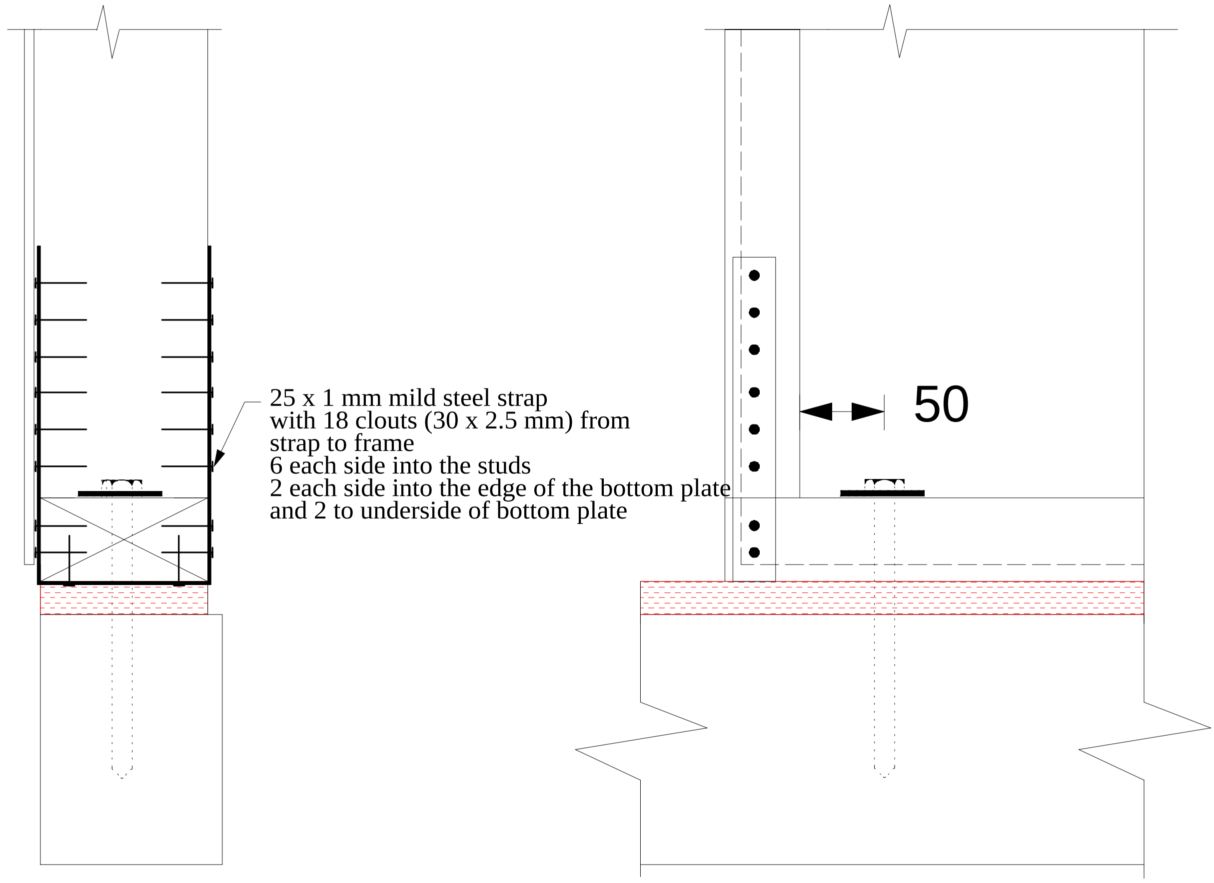

Figure 6 Fixing 0.6 m Long Walls to Simulated Concrete Foundations
(Fixing 2.4 m long walls to simulated concrete foundations was similar but omitted the steel straps.)

4. DESCRIPTION OF TESTS

4.1 Test Arrangement and Equipment

The racking test specimens were installed in a rigid steel loading frame. P21 end restraints were installed in accordance with the recommendations of BRANZ P21:1988. "A Wall Bracing Test and Evaluation Procedure".

Horizontal load was applied to the centre of the specimen top plate with a 30 kN closed loop electro-hydraulic ram and measured with a 25 kN load cell.

Nylon rollers were used to prevent out-of-plane movement of the top plate.

Linear potentiometers were used to measure the horizontal displacement of the top plate, vertical uplift of the studs at either end of the specimen, and horizontal displacement of the bottom plate.

The test load and displacement measurements were recorded using a PC running a software program to record the data. The load cell was calibrated to International Standard EN ISO 7500-1 1999 Grade 1 accuracy and the linear potentiometers were calibrated to an accuracy of ±0.2 mm.

4.2 Test Procedure

The first two specimens of each test length were representative of a timber foundation and a concrete foundation respectively. The foundation condition that yielded the lowest indicative bracing result was then used for the remaining two specimens. After analysis of data after the first two tests it was concluded that the timber foundation case gave the lowest bracing ratings for the nominal 0.6 m long wall length and the concrete foundation gave the lowest bracing ratings for the nominal 2.4 m long wall length, although the difference between the concrete and timber foundation evaluated bracing ratings was small. Therefore, two more timber foundation cases were tested for the 0.6 m wall length and two more concrete foundation cases were tested for the 2.4 m wall length.

The loading sequence consisted of 3 displacement controlled cycles of the top plate to displacements of ±8, ±15, ±20, ±25, ±30, ±35, ±45 and ±55 mm except in some tests the cycling stopped after the cycles to ±35. In these instances the end restraint was then changed to an 'EM3' end restraint and the full test regime repeated. This was to facilitate possible future reduction of test results to the new proposed EM3 test and evaluation procedure. The results of this portion of the testing have been retained by BRANZ and are not reported herein. The actual top plate displacement regime used can also be seen in the hysteresis plots given in the appendix.

4.3 Date and Location of Tests

The tests were carried out in February 2004 at the Structural Engineering Laboratory of BRANZ Ltd, Judgeford, New Zealand.

5. OBSERVATIONS AND RESULTS

5.1 Observations

All timber floor simulation tests deformed in the same manner. Approximately 50% of the top plate movement was attributed to 'rocking' action of the whole specimen and 50% due to slip between sheet and framing. Sheet damage at clout locations was almost undetectable with the naked eye. The 'rocking action' was due to two mechanisms, both of which required 'slip' between the P21 end restraint and end studs and (for the 0.6 m long walls) 'give' in the nailed joint between end straps and timber. These were:

- vertical movement of the end studs; and
- nail pullout between bottom plate and foundation beam and hence upwards movement of the bottom plate.

The concrete floor simulation test specimens deformed in a similar manner except that the bottom plate only had small uplift at the bolt locations and curved upwards between bolt and end studs.

5.2 Results

Calculation sheets and typical test hysteresis loops are given in the appendix. P21 results based on three replicate test specimens are summarised in Table 1.

Table 1 –Bracing ratings for 2.4 m high walls lined with nominal 9 mm thick Customwood based on three replicate specimens

Foundation Type	Nominal Wall Length	Earthquake		Wind	
		Specimen Rating (BU)	Rating per metre (BU)	Specimen rating (BU)	Rating per metre (BU)
Timber	**0.6 m**	63	105	66	110
Concrete	**2.4 m**	209	87	234	97

Indicative bracing ratings on construction for which only a the single specimen was tested are summarised in Table 2. Thus, Table 2 gives indicative bracing ratings for 0.6 m long walls on concrete foundations whereas Table 1 gives bracing ratings for 0.6 m long walls on timber foundation. The P21 test procedure requires that bracing ratings be determined from three replicates and thus the values in Table 2 are indicative ratings only.

Table 2 –Indicative bracing ratings for 2.4 m high walls lined with nominal 9 mm thick Customwood based on a single test specimen only

Foundation Type	Nominal Wall Length	Earthquake		Wind	
		Specimen Rating (BU)	Rating per metre (BU)	Specimen rating (BU)	Rating per metre (BU)
Concrete	**0.6 m**	67	112	65	108
Timber	**2.4 m**	210	87	237	99

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6. ASSESSMENT OF BRACING RATING OF CUSTOMWOOD WALLS.

Note that (with the exception of the wind bracing rating for the 0.6 m long walls) for each wall length that the average results for the full three specimen test series given in Table 1 is less than or equal to the indicative result for the corresponding wall length for the other floor simulation case in Table 2. The exception is expected to be due to the variability in the results for replicate construction. The closeness of the derived bracing values for the two foundation cases in corresponding construction indicates that the results from Table 1 can be applied to both construction lengths.

Thus, based on the results given in Section 5 of this report, and the previously published P21 test results for 1.2 m long bracing panels with a single end strap given in BRANZ Report No. STR 227/2, BRANZ considers that the wall bracing ratings given in Table 3 may be used for lateral load resistance determination of buildings using the design procedures of Section 5 of NZS 3604:1999. The results are applicable for walls on either timber or concrete foundations. Sheathing fixing, bottom plate fixing and end straps must be as per the figure numbers noted in Table 4.

Table 3 –Bracing ratings for 2.4 m high walls lined with nominal 9 mm thick Customwood

Bracing Element Type	Bracing Element Length	Bracing Rating BU's/m		Hold-down at each end
		Earthquake	Wind	
A	0.6 m to 1.2 m	105	110	2 straps
B	Longer than 1.2 m	121	128	1 strap
C	Longer than 2.4 m	87	97	No strap

Table 4 –Figure numbers for construction details

Part	Bracing Element Type	Timber Foundations	Concrete Foundations
Sheathing Fixing	A	Figure 3	Figure 3
Sheathing Fixing	B and C	Figure 4	Figure 4
Bottom Plate	A, B and C	Figure 5	Figure 6
End Straps	A	Figure 5	Figure 6
End Straps	B*	Figure 5	Figure 6
End Straps	C	No end straps or dummy studs required.	

Legend

* the 'dummy' end stud and associated steel strap is omitted.

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Appendix

- **Load-displacement plots**
- **P21 Calculation Sheets**

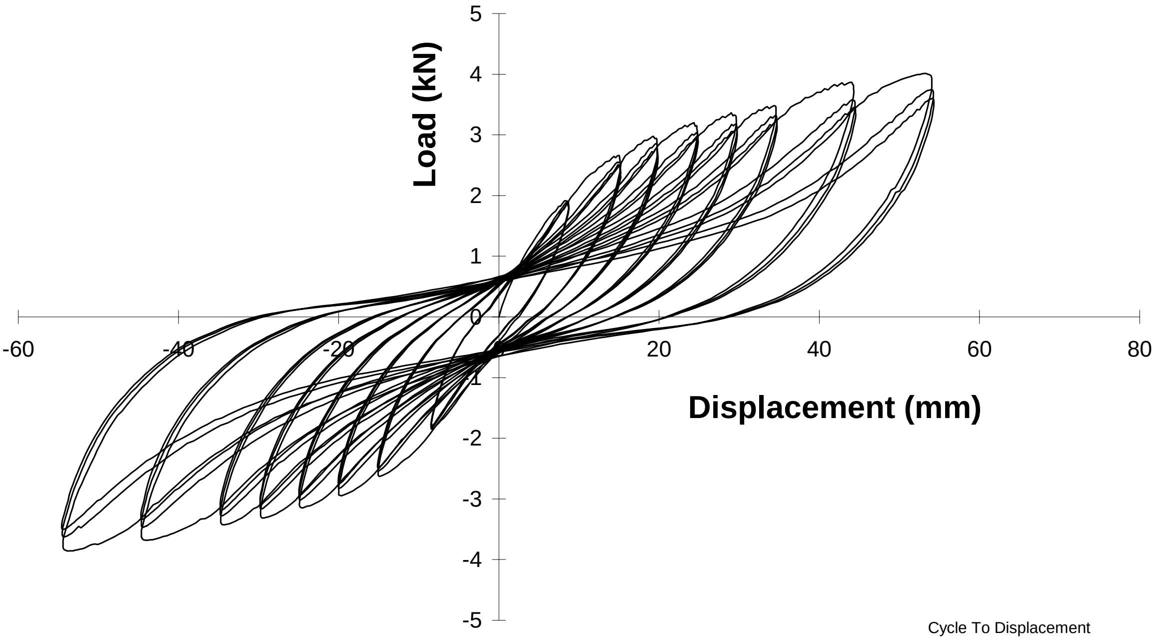
Data is in the following order:

1. Load-displacement plot for Specimen 2 (0.6 m long wall on timber foundation)
2. Load-displacement plot for Specimen 3 (0.6 m long wall on timber foundation)
3. Load-displacement plot for Specimen 4 (0.6 m long wall on timber foundation)
4. Analysis spreadsheet of results from Specimens 2, 3 and 4.

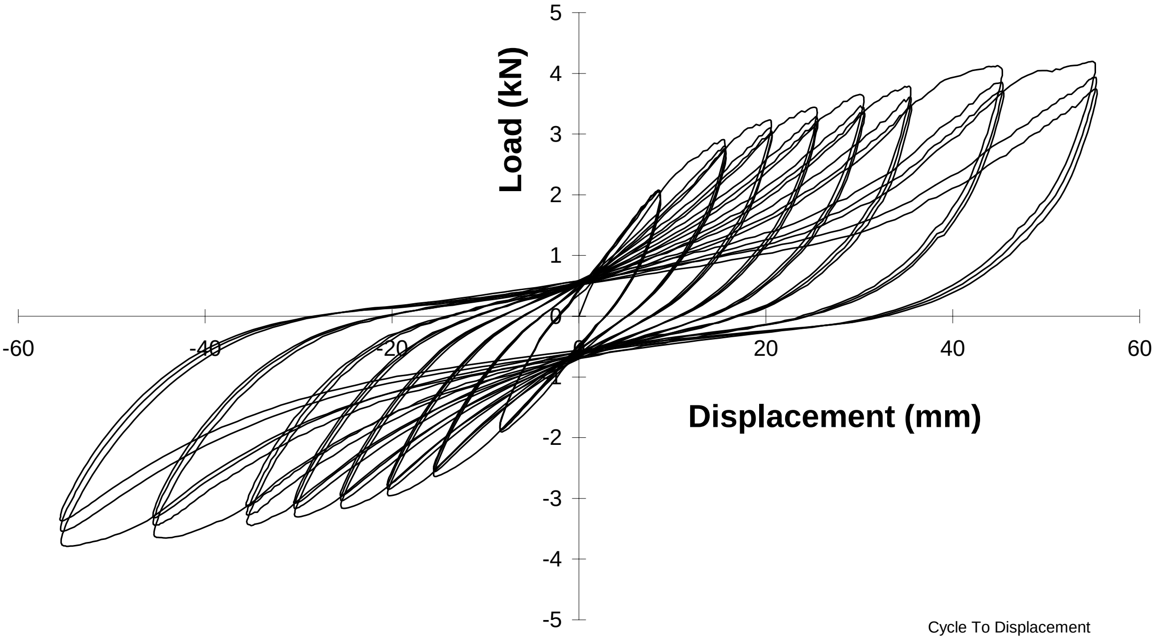
5. Load-displacement plot for Specimen 5 (2.4 m long wall on concrete foundation)
6. Load-displacement plot for Specimen 7 (2.4 m long wall on concrete foundation)
7. Load-displacement plot for Specimen 8 (2.4 m long wall on concrete foundation)
8. Analysis spreadsheet of results from Specimens 5, 7 and 8.

9. Load-displacement plot for Specimen 1 (0.6 m long wall on concrete foundation)
10. Indicative analysis spreadsheet of results from Specimen 1.

11. Load-displacement plot for Specimen 6 (2.4 m long wall on timber foundation)
12. Indicative analysis spreadsheet of results from Specimen 6.



Specimen 2. Load-displacement plot. Nominal 0.6 m long wall on a timber foundation



Specimen 3. Load-displacement plot. Nominal 0.6 m long wall on a timber foundation

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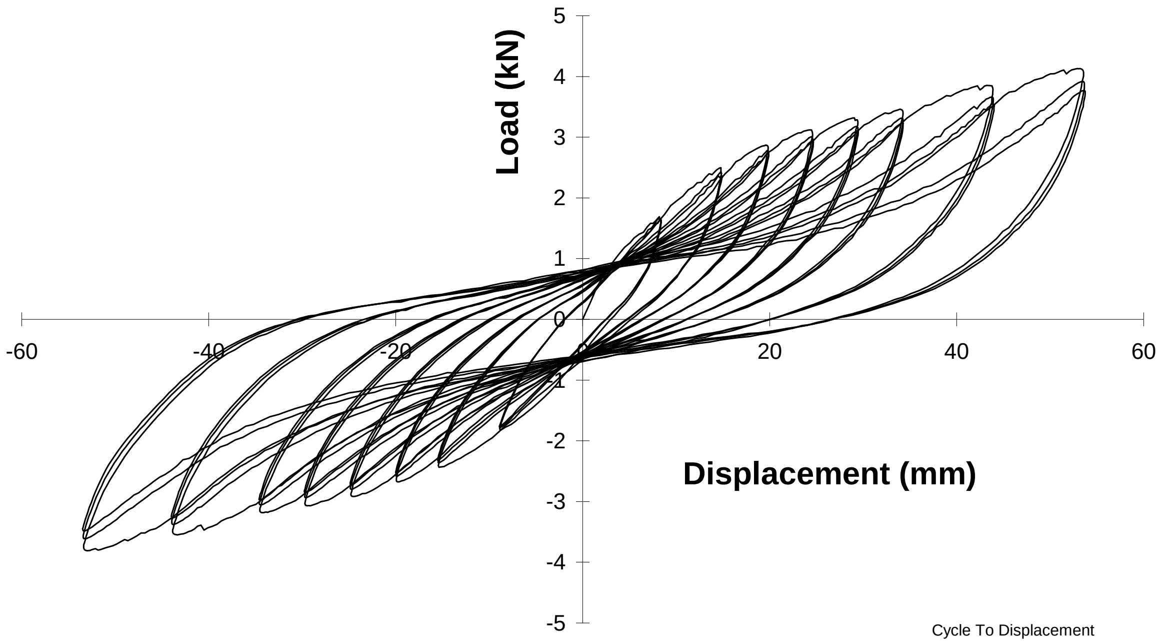

Specimen 4. Load-displacement plot. Nominal 0.6 m long wall on a timber foundation

	Servicability Cycles Cycle To Displacement x = 8 (mm)		Ultimate Cycles Cycle To Displacement y = 36 (mm)			
Specimen No.	Load S (kN)	Residual Displacement C (mm)	Maximum Load P(kN)	Calculated P/2(kN)	Displacement @P/2=d (mm)	4th Cycle Load at y mm R (KN)
1	+ 1.84	+ 2.30	+ 3.43	+ 1.72	+ 6.70	+ 3.11
	- 1.88	- 2.30	- 3.50			- 3.18
2	+ 1.88	+ 2.20	+ 3.46	+ 1.73	+ 7.10	+ 3.11
	- 2.05	- 2.80	- 3.78			- 3.46
3	+ 1.79	+ 1.80	+ 3.20	+ 1.60	+ 8.50	+ 2.69
	- 1.70	- 2.70	- 3.48			- 3.23
Averages	S= 1.86	C= 2.35	P= 3.48		d= 7.43	R= 3.13

K1 = 1.4 - C/X = 1.00

F = K1 x S = 1.86

The "Asymmetry Of Performance" criterion in the last paragraph of Section 6.5 shall be followed.

u = y/d = 4.84

u	1.00	2.00	2.50	3.00	3.50	4.00
K4	0.35	0.60	0.67	0.74	0.87	1.00

For other values of u, linear interpolation is used to determine K4

Therefore K4 = 1.00

EVALUATION : EARTHQUAKE PERFORMANCE

BU(EQ) = 20 x the lesser of K4R or 2.1 x F/K4

K4 x R = 3.13 2.1 x F/K4 = 3.9

Therefore BU(EQ) = 20 x 3.13 **BU(EQ) = 63** **Bracing Units**

EVALUATION : WIND PERFORMANCE

BU(wind) = 20 x the lesser of P or 1.78 x F

P = 3.48 1.78 x F = 3.3

Therefore BU(WIND) = 20 x 3.30 **BU(WIND) = 66** **Bracing Units**

600 mm long Customwood sheathed wall on a timber foundation.

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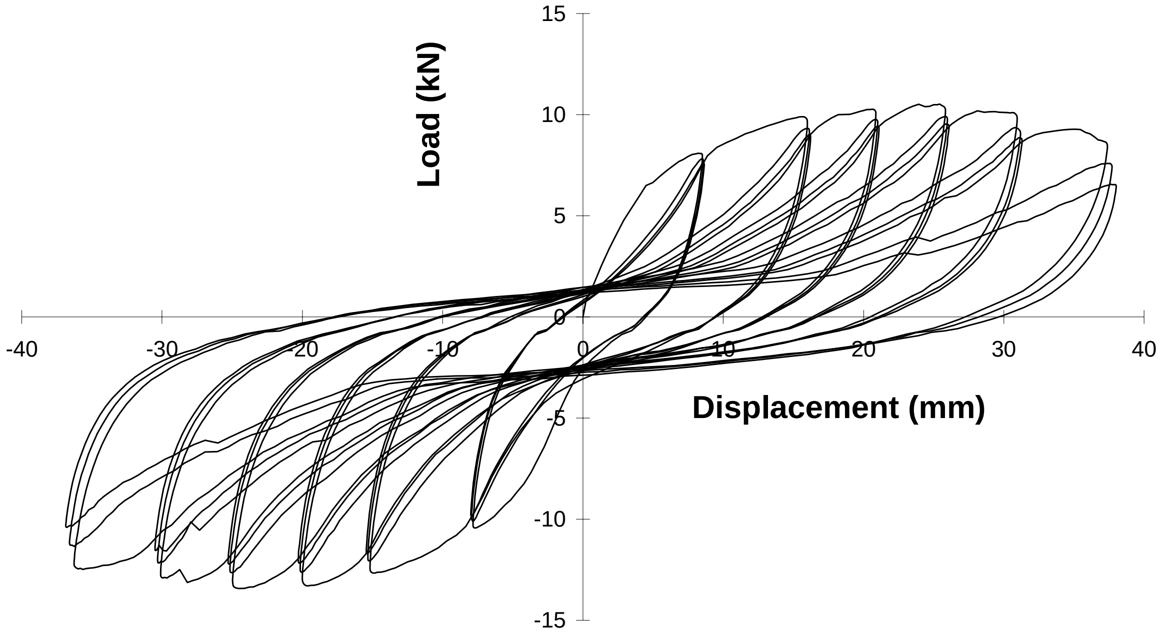
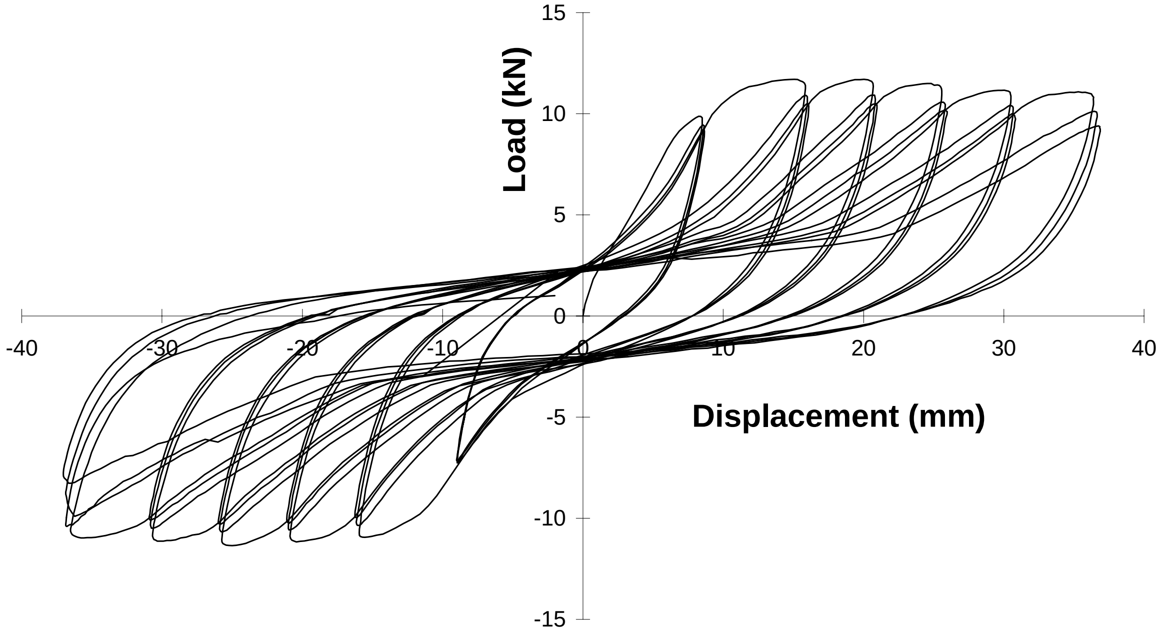
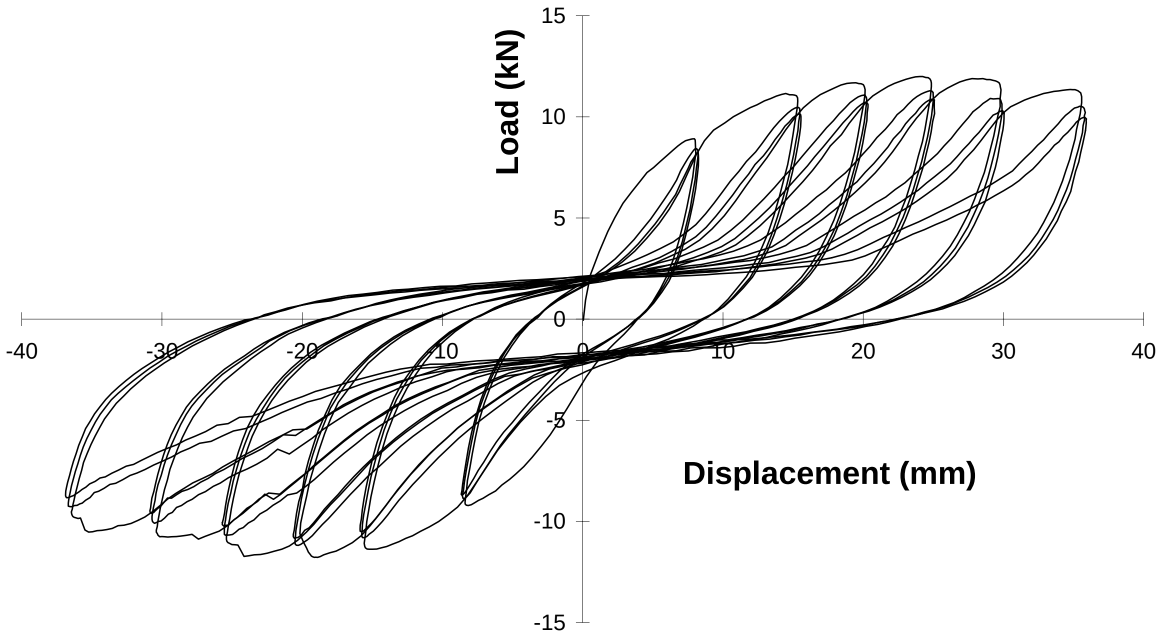


Specimen 5. Load-displacement plot. Nominal 2.4 m long wall on a concrete foundation



Specimen 7. Load-displacement plot. Nominal 2.4 m long wall on a concrete foundation



Specimen 8. Load-displacement plot. Nominal 2.4 m long wall on a concrete foundation

	Servicability Cycles Cycle To Displacement x = 8 (mm)		Ultimate Cycles Cycle To Displacement y = 36 (mm)			
Specimen No.	Load S (kN)	Residual Displacement C (mm)	Maximum Load P(kN)	Calculated P/2(kN)	Displacement @P/2=d (mm)	4th Cycle Load at y mm R (KN)
1	+ 9.74	+ 1.80	+ 12.66	+ 6.33	+ 3.40	+ 11.41
	- 8.12	- 4.20	- 10.55			- 9.51
2	+ 7.14	+ 4.80	+ 11.36	+ 5.68	+ 4.20	+ 10.26
	- 8.57	- 2.70	- 11.76			- 10.49
3	+ 9.22	+ 3.40	+ 11.76	+ 5.88	+ 3.30	+ 10.26
	- 8.93	- 3.90	- 12.05			- 10.90
Averages	S= 8.62	C= 3.47	P= 11.69		d= 3.63	R= 10.47

K1 = 1.4 - C/X = 0.97

F = K1 x S = 8.33

The "Asymmetry Of Performance" criterion in the last paragraph of Section 6.5 shall be followed.

u = y/d = 9.91

u	1.00	2.00	2.50	3.00	3.50	4.00
K4	0.35	0.60	0.67	0.74	0.87	1.00

For other values of u, linear interpolation is used to determine K4

Therefore K4 = 1.00

EVALUATION : EARTHQUAKE PERFORMANCE

BU(EQ) = 20 x the lesser of K4R or 2.1 x F/K4

K4 x R = 10.47 2.1 x F/K4 = 17.5

Therefore BU(EQ) = 20 x 10.47 **BU(EQ) = 209 Bracing Units**

EVALUATION : WIND PERFORMANCE

BU(wind) = 20 x the lesser of P or 1.78 x F

P = 11.69 1.78 x F = 14.83

Therefore BU(WIND) = 20 x 11.69 **BU(WIND) = 234 Bracing Units**

2400 mm long Customwood sheathed walls on a concrete foundation.

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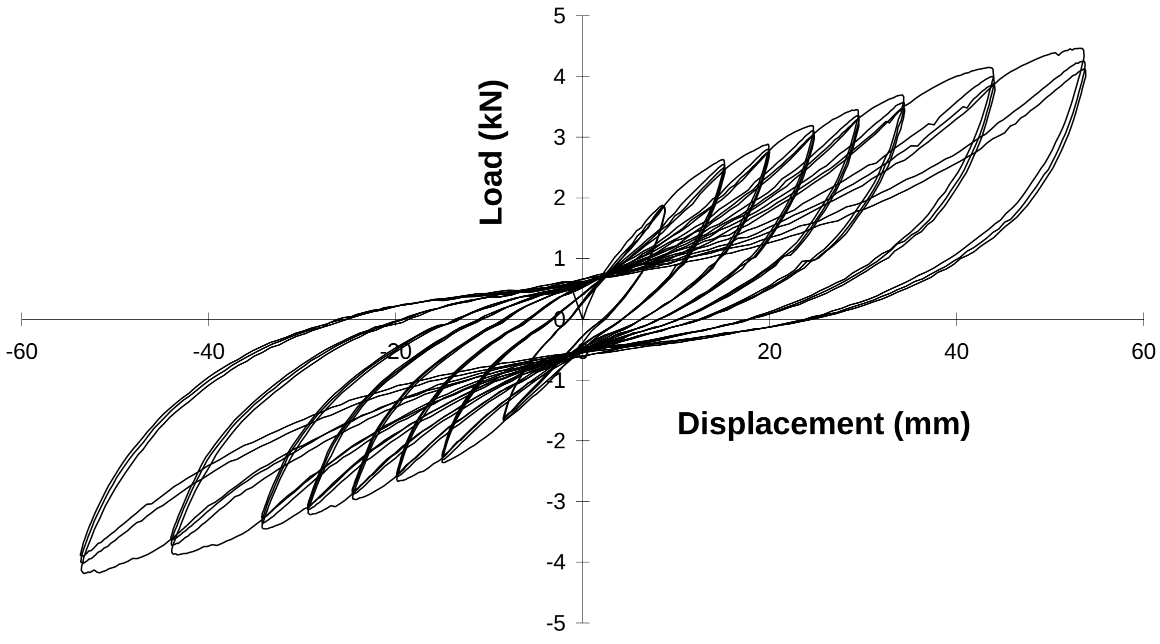

Specimen 1. Load-displacement plot. Nominal 0.6 m long wall on a concrete foundation

	Servicability Cycles Cycle To Displacement x = 8 (mm)		Ultimate Cycles Cycle To Displacement y = 36 (mm)			
Specimen No.	Load S (kN)	Residual Displacement C (mm)	Maximum Load P(kN)	Calculated P/2(kN)	Displacement @P/2=d (mm)	4th Cycle Load at y mm R (KN)
1	+ 1.72	+ 1.51	+ 3.46	+ 1.73	+ 8.10	+ 3.20
	- 1.91	- 2.40	- 3.71			- 3.50
Averages	S= 1.82	C= 1.96	P= 3.59		d= 8.10	R= 3.35

K1 = 1.4 - C/X = 1.00

F = K1 x S = 1.82

The "Asymmetry Of Performance" criterion in the last paragraph of Section 6.5 shall be followed.

u = y/d = 4.44

u	1.00	2.00	2.50	3.00	3.50	4.00
K4	0.35	0.60	0.67	0.74	0.87	1.00

For other values of u, linear interpolation is used to determine K4

Therefore K4 = 1.00

EVALUATION : EARTHQUAKE PERFORMANCE

BU(EQ) = 20 x the lesser of K4R or 2.1 x F/K4

K4 x R = 3.35 2.1 x F/K4 = 3.81

Therefore BU(EQ) = 20 x 3.35 **BU(EQ) = 67** **Bracing Units**

EVALUATION : WIND PERFORMANCE

BU(wind) = 20 x the lesser of P or 1.78 x F

P = 3.59 1.78 x F = 3.23

Therefore BU(WIND) = 20 x 3.23 **BU(WIND) = 65** **Bracing Units**

Indicative test only.

0.6 m long Customwood wall on a concrete foundation

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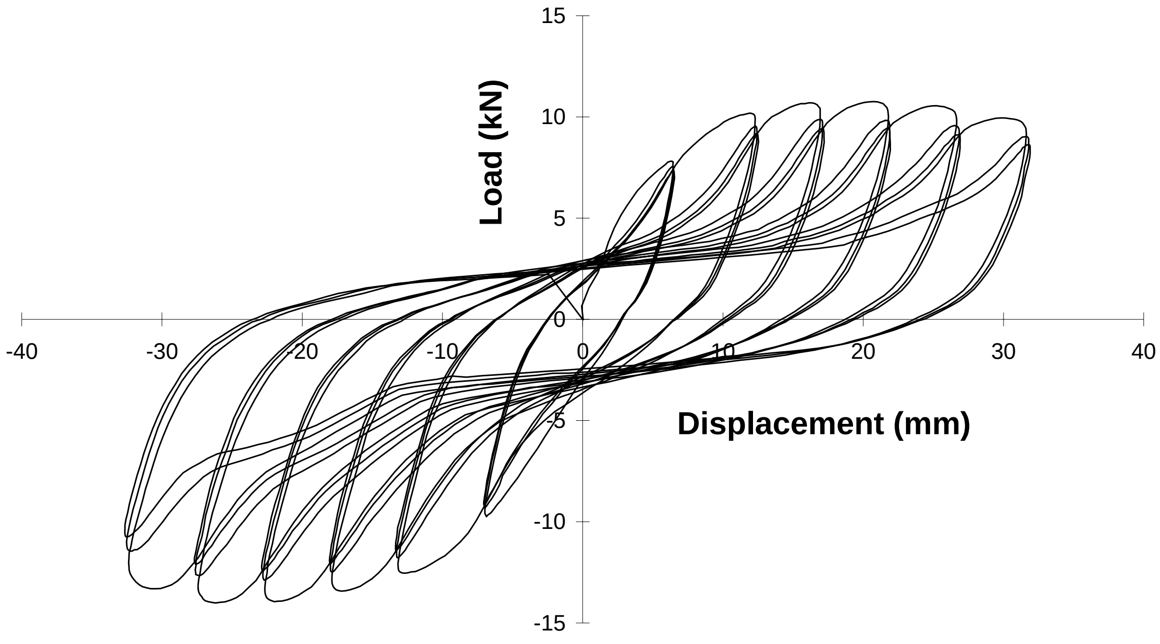

Specimen 6. Load-displacement plot. Nominal 2.4 m long wall on a timber foundation

	Servicability Cycles Cycle To Displacement x = 8 (mm)		Ultimate Cycles Cycle To Displacement y = 22 (mm)			
Specimen No.	Load S (kN)	Residual Displacement C (mm)	Maximum Load P(kN)	Calculated P/2(kN)	Displacement @P/2=d (mm)	4th Cycle Load at y mm R (KN)
1	+ 9.34	+ 2.40	+ 12.90	+ 6.45	+ 2.81	+ 11.45
	- 7.78	- 2.73	- 10.75			- 9.54
Averages	S= 8.56	C= 2.57	P= 11.83		d= 2.81	R= 10.49

K1 = 1.4 - C/X = 1.00

F = K1 x S = 8.56

The "Asymmetry Of Performance" criterion in the last paragraph of Section 6.5 shall be followed.

u = y/d = 7.83

u	1.00	2.00	2.50	3.00	3.50	4.00
K4	0.35	0.60	0.67	0.74	0.87	1.00

For other values of u, linear interpolation is used to determine K4

Therefore K4 = 1.00

EVALUATION : EARTHQUAKE PERFORMANCE

BU(EQ) = 20 x the lesser of K4R or 2.1 x F/K4

K4 x R = 10.49   2.1 x F/K4 = 18

Therefore BU(EQ) = 20 x 10.49   **BU(EQ) = 210**   **Bracing Units**

EVALUATION : WIND PERFORMANCE

BU(wind) = 20 x the lesser of P or 1.78 x F

P = 11.83   1.78 x F = 15.2

Therefore BU(WIND) = 20 x 11.83   **BU(WIND) = 237**   **Bracing Units**

Indicative test only.
2.4 m long Customwood wall on timber foundation

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