P21 WALL TESTING
ON TIMBERCRETE WALL PANELS

FOR

TIMBERCRETE NZ LTD

REPORT NO: TE06-001

by
Doug Gaunt

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A report prepared for
Timbercrete NZ Ltd – Steve Watts

by

Doug Gaunt

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Correspondence to:

Unit Leader
Ensis Wood Processing and Products
Private Bag 3020
Leader
ROTORUA

Phone: (07) 343-5777
Fax: (07) 343-5507

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Unit 

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P21 Testing of Timbercrete Wall Panels

Objective

- To evaluate the P21 wall bracing performance of 2400mm high Timbercrete solid timber/masonry unlined walls of 880mm and 1800mm lengths.

Material

Timbercrete NZ Ltd constructed the 2400mm high walls in the Timber Engineering Pole-barn. The walls were left for at least 28 days to cure and were carried down to the laboratory for testing by forklift.

The 880mm long walls were constructed as follows:

- From 430mm long x 150mm high x 150mm wide Timbercrete masonry blocks.
- The walls were built on top of three nail laminated 140x45 timber joists.
- The walls comprised of 14 courses with every second bed-joint having a strip of 25x0.9mm steel strapping.
- A 140x45 timber top plate
- Each end of the walls had continuous M12 tie rod (100mm approx in from the wall ends) between from the timber joists and the top plate. A 50x50x3mm washer was used over the top plate with an 80x80x5mm washer used at the underside of the joists.

The 1800 long walls were constructed as follows:

- From 430mm long x 150mm high x 150mm wide Timbercrete masonry blocks.
- The walls were built on top of three nail laminated 140x45 timber joists.
- The walls comprised of 14 courses with every second bed-joint having a strip of 25x0.9mm steel strapping.
- A 140x45 timber top plate
- Each end of the walls had continuous M12 tie rod (120mm approx in from the wall ends) between from the timber joists and the top plate. A 50x50x3mm washer was used over the top plate with an 80x80x5mm washer used at the underside of the joists.

Test Methods

1. The testing was carried out on the 1st and 14th August 2006 in the Timber Engineering laboratory at Ensis, Rotorua.
2. All the walls were tested for their P21 wall racking performance in the Timber Engineering wall racking test rig as shown in Figure 1.

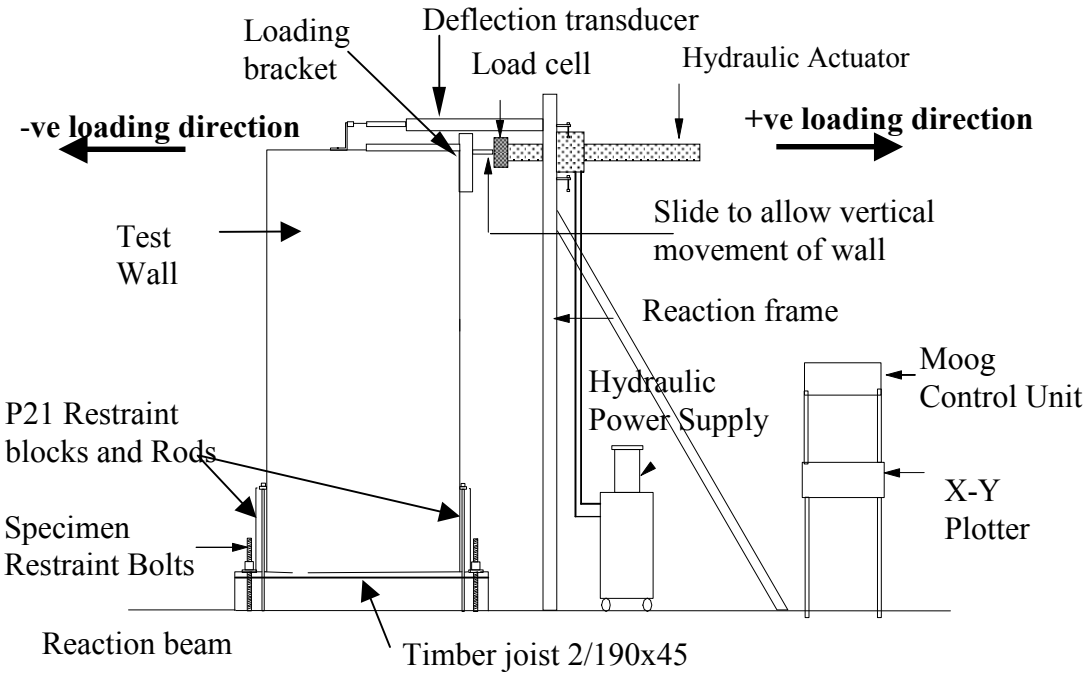

Figure 1: *Timber Engineering P21 Wall Racking Test Setup*

The test procedure was to rack the walls as follows:

- From start (zero deflection, zero load)
- Three cycles +8mm deflection to –8mm deflection
- Followed by Three cycles +15mm deflection to –15mm deflection
- Followed by Three cycles +20mm deflection to –20mm deflection
- Followed by Three cycles +25mm deflection to –25mm deflection
- Followed by Three cycles +30mm deflection to –30mm deflection
- Followed by Three cycles +35mm deflection to –35mm deflection
- Followed by Three cycles +40mm deflection to –40mm deflection
- Followed by Three cycles +45mm deflection to –45mm deflection
- Return to (zero deflection, zero load), finish test.

3. Continuous plots of load and deflection were made using an XY recorder.

4. The load/deflection plots were anaylsed in accordance with the Supplement to P21: An Evaluation Method of P21 Test Results for use with NZS3604:1990. This evaluation method uses a 0.9 multiplier to calculate the ultimate wind bracing units. Discussing this 0.9 factor with Stuart Thurston of BRANZ, the factor exists to take account of the effects of wind turbulence. If the walls were only tested at +/-8mm and then +/-35mm without building up to the larger deflection with a series of three loading cycles at 5mm increments the 0.9 factor should be used. However as we built up to the maximum deflection cycles in a series of steps the

0.9 factor does not apply. This was first suggested by Andrew King of BRANZ and has since been adopted by BRANZ. On this basis we have deleted the 0.9 factor from our calculations.

Results

The following Table 1 summarises the P21 results for the wall lengths tested.
Table 1 shows:

- The different wall lengths,
- The earthquake bracing unit per metre, in brackets is the limiting state (U) = Ultimate or (S) = Serviceability,
- The wind bracing unit per metre, in brackets is the limiting state (U) = Ultimate or (S) = Serviceability.

Definitions: From NZS4203:1993
Ultimate Limit State – This condition is reached when the building ruptures, becomes unstable or loses equilibrium.
Serviceability Limit State – This condition is reached when the building becomes unfit for its intended use through deformation, vibratory response, degradation or other physical aspects.

Table 1: *Summary of Timbercrete P21 wall test results.*

Laboratory Test Numbers	Wall Length (mm)	Earthquake Bracing units / metre	Wind Bracing units / metre
237410 237412 237413	880	**195 (U)**	**178 (S)**
237411	1800	**Not tested**	**278 (U)**

Figures 2, & 3 show the calculations used in deriving the bracing ratings in Table 1.

The maximum load capacity of the hydraulic actuator in 25kN and this limited the testing of the 1800mm long walls to the +/- 15mm cycle. It thus was decided not to test the remaining 1800mm long walls.

General Comments on the Wall Performance.

880mm long walls
At the +/-45mm cycle the load was still increasing after each cycle stage.
At these extreme deflections (Photo 3) the vertical component of racking was being taken by the M12 tie rods with sufficiently high forces to deform the bottom 80x80x5mm washers (Photo 2) into the underside of the timber joists. Some cracking (Photo 1) occurred in the horizontal bed joints as expected under these high racking uplift forces.
The lateral component of the racking force appeared to be resisted by a combination dowel action with M12 tie rods and the bed joint strength. Under loading there did not appear to be any signs of sliding at the base or at the bed-joints.

1800mm long wall
Up to the level at which the test was stopped the wall appeared to be behaving as per the 880mm long walls.

Photo 1: *Shows cracking at 40mm top plate deflection, these cracks close up when top plate deflection returns to 0mm*

Photo 3: *Shows 880mm wall at 55mm top plate deflection*

Photo 2: *Shows 80x80 washers after racking to 55mm*

Figure 2: Calculations for the 880mm long walls 237410, 237412 & 237413

P21 RACKING TEST RESULTS EVALUATION
Timbercrete 150mm blocks
2 - M12 tie downs at each end 80x80x6 bottom washers
3 - 100x4.0 P21 hold downs each end
Calculated to BRANZ TR No. 10. NZS 3604 1990
Forest Research Institute, PB 3020 Rotorua. TE Lab

Summary		
Earthquake	**195**	**BU/m**
Wind	**178**	**BU/m**

Date of test:-	**14-Aug-06**	Ship No. **2352**	Tested by	Doug Gaunt
Date of calcn:-	**14-Aug-06**	Job No. **TE06-001**	Data Analysed by	Doug Gaunt

	Serviceability Cycles		Ultimate Cycles				
	Cycle to H/300 or DLQ or DLW 8.00 X mm		Cycle to Displacement y=(mm)			Wall dimensions L(mm) 880	H(mm) 2400
Lab Number	Loads	Residual	Maximum				
Plus direction	S	Defln, C	Load	def @ P		d at P/2	4th,R
Minus direction	kN	mm	P(kN)	y (mm)	P/2 (kN)	d mm	kN
237412 plus	**4.90**	**1.00**	**12.30**	**40.0**	6.15	**13.0**	**11.90**
minus	**4.60**	**1.00**	**12.20**	**40.0**			**11.70**
237413 plus	**4.20**	**1.50**	**11.00**	**40.0**	5.50	**12.0**	**10.00**
minus	**4.40**	**1.60**	**11.20**	**40.0**			**9.80**
237410 plus	**4.00**	**0.50**	**11.00**	**40.0**	5.50	**13.5**	**10.40**
minus	**4.40**	**0.50**	**11.20**	**40.0**			**10.80**
	(S)	(C)	(P)	(y)		(d)	(R)
Avgs	4.42	1.02	11.48	40.00	5.72	12.83	10.77
CoV %	6.46	42.27	4.78	0.00	5.36	4.86	7.40

y = average failure deflection or peak deflection of the three tests.
d= average first cycle displacement at half peak, (the very first cycle wall reaches the load)
R = Residual load, P = Peak Load, S = Serviceability load

Displacement Recovery Factor (k1)	k1 = 1.4 - C/X	1.00	(.8 <= K1 <= 1.0)
Resistance (earthquake - servicabilibity limit state	F = k1xS	4.42	
Average Structural Displacement Ductility factor	u = y/d	3.12	
Ductility Modification factor	K4 =	0.80	
DLW = Selected deflection limit for wind forces	DLQ = Selected deflection limit for earthquake forces		

P21 TR 10 Supplement Calculations

Branz Technical Recommendation No. 10. NZS 3604 1990
Limit States Values — Timbercrete 150mm blocks
2 - M12 tie downs at each end 80x80x6 bottom washers
3 - 100x4.0 P21 hold downs each end

Earthquake Rating	***Ultimate***	***Serviceability***
EQ Ultimate	20 x K4 x R = 171.92	20/0.48 x F/k4 = 230.50
	195.4 BU/m	
Wind Rating	***Ultimate***	***Serviceability***
Wind Ultimate	20* P = 229.67	20 / 0.563 x F = 156.90
	178.3 BU/m	

Figure 3: *Calculations for 1800mm long wall 237411*

Timbercrete 150mm blocks
2 - M12 tie downs at each end 90x90x6 bottom washers
3 - 100x4.0 P21 hold downs each end
Calculated to BRANZ TR No. 10. NZS 3604 1990
Forest Research Institute, PB 3020 Rotorua. TE Lab

Summary		
Earthquake	**#DIV/0!**	**BU/m**
Wind	**278**	**BU/m**

Date of test:-	**1-Aug-06**	Ship No. **2352**	Tested by Doug Gaunt
Date of calcn:-	**1-Aug-06**	Job No. **TE06-001**	Data Analysed by Doug Gaunt

	Serviceability Cycles		Ultimate Cycles				
	Cycle to H/300 or DLQ or DLW 8.00 X mm		Cycle to Displacement y=(mm)			Wall dimensions L(mm) 1800	H(mm) 2400
Lab Number	Loads	Residual	Maximum				
Plus direction	S	Defln, C	Load	def @ P		d at P/2	4th,R
Minus direction	kN	mm	P(kN)	y (mm)	P/2 (kN)	d mm	kN
237411 plus	**16.00**	**2.00**	**25.00**	**15.0**	12.50	**5.0**	
minus	**21.20**	**2.00**	**25.00**	**15.0**			
plus					0.00		
minus							
plus					0.00		
minus	**Test machine maximum capacity = 25kN**						
	(S)	(C)	(P)	(y)		(d)	(R)
Avgs	18.60	2.00	25.00	15.00	4.17	5.00	#DIV/0!
CoV %	13.98	0.00	0.00	0.00	141.42	0.00	#DIV/0!

y = average failure deflection or peak deflection of the three tests.
d= average first cycle displacement at half peak, (the very first cycle wall reaches the load)
R = Residual load, P = Peak Load, S = Serviceability load

Displacement Recovery Factor (k1)	k1 = 1.4 - C/X	1.00	(.8 <= K1 <= 1.0)
Resistance (earthquake - servicabilibity limit state	F = k1xS	18.60	
Average Structural Displacement Ductility factor	u = y/d	3.00	
Ductility Modification factor	K4 =	0.77	
DLW = Selected deflection limit for wind forces	DLQ = Selected deflection limit for earthquake forces		

P21 TR 10 Supplement Calculations

Branz Technical Recommendation No. 10. NZS 3604 1990
Limit States Values
Timbercrete 150mm blocks
2 - M12 tie downs at each end 90x90x6 bottom washers
3 - 100x4.0 P21 hold downs each end

Earthquake Rating		***Ultimate***		***Serviceability***
EQ Ultimate	20 x K4 x R =	#DIV/0!	20/0.48 x F/k4 =	1001.11
	#DIV/0!	**BU/m**		
Wind Rating		***Ultimate***		***Serviceability***
Wind Ultimate	20* P =	500.00	20 / 0.563 x F =	660.75
	277.8	**BU/m**		

References

1. R.C Cooney, M.J Collins: A Wall Bracing Test and Evaluation Procedure, BRANZ Technical paper P21, 1979, revised 1982, 1987, 1988.
2. A.B King, K.Y.S Lim: Supplement to P21: An Evaluation Method of P21 Test Results for use with NZS3604:1990, BRANZ Technical Recommendation No:10., December 1991.