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SUMMARY REPORT: RESULTS OF APRI WALL BRACING TESTS

TO: AUSTRALIAN PARTICLEBOARD RESEARCH INSTITUTE

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SUMMARY

This report presents racking results obtained for 29 tests performed on 2.4 m high x 3.0 m long, timber framed, particleboard sheathed wall panels. Complete test results, as being typical for the whole range of panels, are given for six panels, one of which was tested in bending, racking and uplift, another in uplift and racking, and the remaining four in racking alone. Studs for all frames were at 600 mm centres, particleboard sheathing was 6 mm thick, and nailing patterns either the standard 150/300 or close 75/150. Timber framing was 70 x 45 mm and 90 x 45 mm, F8 Radiata pine, 70 x 38 mm and 70 x 50 mm, F11 hardwood and 70 x 40 mm, F17 hardwood. A total of four of the panels were tested incorporating a cyclone rod. Design racking loads (kN/m) have been evaluated and racking resistances grouped on the basis of species, nailing pattern, and whether or not a rod has been fitted. Compatible reports to the information contained herein are TWP Reports 105, 114, 116, 122 and 124.

NOTE:

The Particleboard suppled by Pyneboard was a High Moisture Resistant (HMR) board initially tradenamed Fineline HMR and subsequently re-named Hydroline. The board supplied by Softwood Holdings was identified as Texpan HMR. Throughout the text of this report the HMR suffix has been excluded from the particleboard name.

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SECTION 1

1.1 INTRODUCTION

The testing programme described herein was carried out for the Australian Particleboard Research Institute on particleboard sheathed, timber framed wall panels constructed at CIAE. The work is a direct result of a pilot programme performed on model wall panels and reported separately by the writer in TWP Report No. 105. The particleboard, 6 mm Fineline and 6 mm Hydroline was supplied by Pyneboard, Oberon, NSW and 6 mm Texpan supplied by Softwood Holdings, Mt. Gambier, South Australia. The timber framing material, 70 x 45 mm and 90 x 45 mm, F8 Radiata pine, and 70 x 38 mm, 70 x 50 mm, F11, 70 x 40 mm, F17 studs and plates and 100 x 50 mm, F14 joists and rafters were supplied by J.B. Hinz & Sons, The Caves via Rockhampton.

Panels tested to failure in racking, including sheathing type and thickness, nailing pattern, timber framing stress grade and dimensions, and whether or not a cyclone rod was fitted are listed in Table 1.1. All panels were 2.4m high x 3.0m long and studs were at 600mm centres.

PANEL IDENT.		SHEATHING TYPE & THICK. (mm)		NAILING PATTERN (mm)	TIMBER FRAMING (DIMS & GRADE)	CYCLONE ROD
TP	1	6 Fineline	HMR	150/300	70x45xF8 Radiata	No
	2	6 Fineline	HMR	150/300	70x45xF8 Radiata	No
	15	6 Fineline	HMR	150/300	70x45xF8 Radiata	No
	16	6 Texpan	HMR	150/300	70x40xF8 Radiata	No
	3	6 Fineline	HMR	75/150	70x45xF8 Radita	No
	35	6 Hydroline		75/150	70x45xF8 Radiata	No
	37	6 Hydroline		75/150	70x45xF8 Radiata	No
E1	(F)	6 Fineline	HMR	150/300	90x45xF8 Radiata	No
E1	(T)	6 Texpan	HMR	150/300	90x45xF8 Radiata	No
	5	6 Fineline	HMR	150/300	90x45xF8 Radiata	No
	17	6 Texpan	HMR	150/300	90x45xF8 Radiata	No
	18	6 Texpan	HMR	150/300	90x45xF8 Radiata	No
	19	6 Texpan	HMR	150/300	90x45xF8 Radiata	No
	7	6 Fineline	HMR	75/150	90x45xF8 Radiata	No
	33	6 Hydroline		75/150	90x45xF8 Radiata	No
	6	6 Fineline	HMR	150/300	90x45xF8 Radiata	Yes
	31	6 Hydroline		150/300	90x45xF8 Radiata	Yes
	8	6 Fineline	HMR	75/150	90x45xF8 Radiata	Yes
	32	6 Hydroline		75/150	90x45xF8 Radiata	Yes
	38	6 Hydroline		150/300	70x38xF11 hardwood	No
	39	6 Hydroline		150/300	70x38xF11 hardwood	No
	25	6 Hydroline		150/300	70x50xF11 hardwood	No
	36	6 Hydroline		150/300	70x50xF11 hardwood	No
	12	6 Fineline	HMR	75/150	70x50xF11 hardwood	No
	27	6 Hydroline		75/150	70x50xF11 hardwood	No
	29	6 Hydroline		150/300	70x50xF11 hardwood	Yes
	30	6 Hydroline		150/300	70x50xF11 hardwood	Yes
	28	6 Hydroline		150/300	70x40xF17 hardwood	No
	34	6 Hydroline		150/300	70x40xF17 hardwood	No

TABLE 1.1

A nailing pattern defined 150/300 means nail centres around a sheet edge were 150 mm and on internal studs 300 mm. For all panels other than TP 36 the nails used were 2.8 mm diameter x 40 mm long galvanised clouts. For TP 36 nails were the same except they were 30 mm long. The non-sequential numbering of panels results from tests being performed on a particular panel to evaluate response, then if satisfactorily performed, replicas being tested.

Panels tested to failure in uplift, including sheathing type and thickness, nailing pattern, timber framing stress grade and dimensions and whether or not a cyclone rod was fitted are listed in Table 1.2. All panels were 2.4m high x 3.0m long and studs were at 600m centres.

PANEL IDENT.	**SHEATHING TYPE & THICK.**	**NAILING PATTERN**	**TIMBER FRAMING**	**CYCLONE ROD**
TP 4	6 Fineline HMR	150/300	70x45xF8 Radiata	No
9	6 Fineline HMR	150/300	90x45xF8 Radiata	No
10	6 Fineline HMR	75/150	90x45xF8 Radiata	No

TABLE 1.2

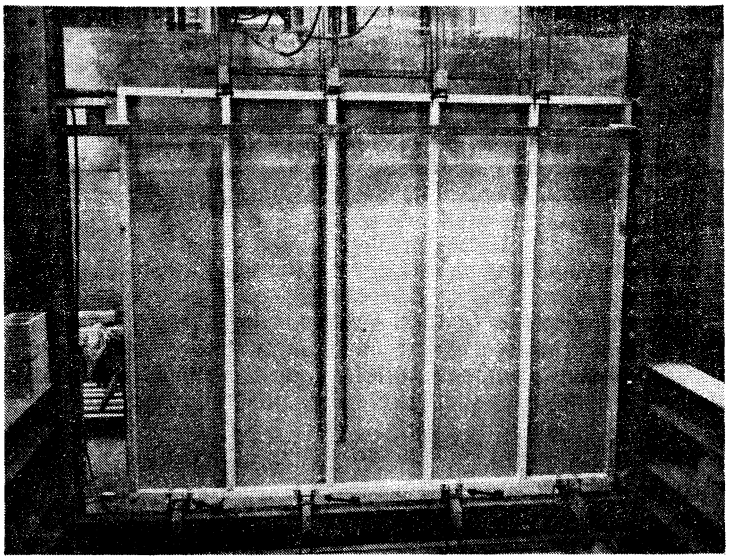
1.2 LOADING RIG

1.2.1 General

Loading of all panels was carried out in the Three Dimensional Loading Frame located in the Heavy Structures Laboratory of the Civil Engineering Department, CIAE. Plate 1.1 shows a typical panel located in the loading frame prior to testing. Since both racking and uplift loads occur in the plane of a panel it was necessary to use only the rigid, end portal frame of the three dimensional system for these loading cases. Plate 1.2 shows a typical "material tear-out behind nail" failure under racking load.

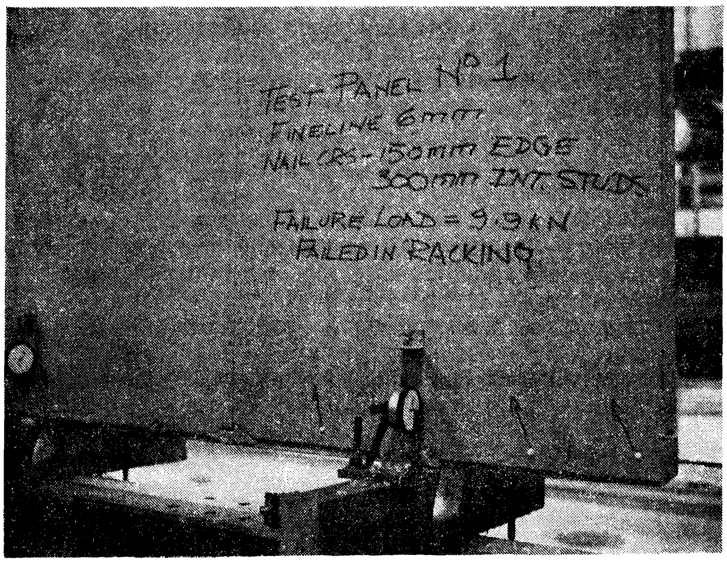
For the application of simulated bending loads, Plate 1.3 shows how transverse beams were arranged in one bay to provide continuous support to the top and bottom plates of the panels. Flexure loads were applied via discrete concrete blocks as shown in Plate 1.4.

Racking loads were applied by means of a 120 kN Ritch hydraulic jack reacting against the rigid portal through a 50 kN load cell. The load was applied by a hand operated pump and measured by a digital voltmeter connected to the load cell.



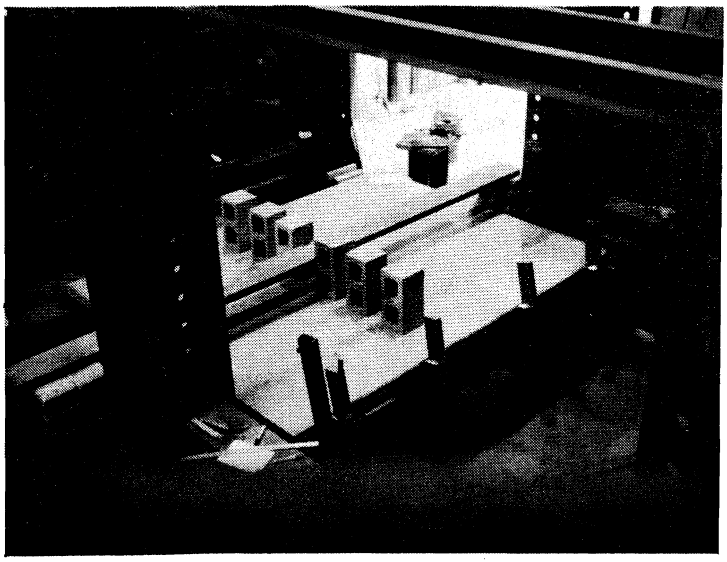
TYPICAL PANEL ARRANGEMENT

PLATE 1.1



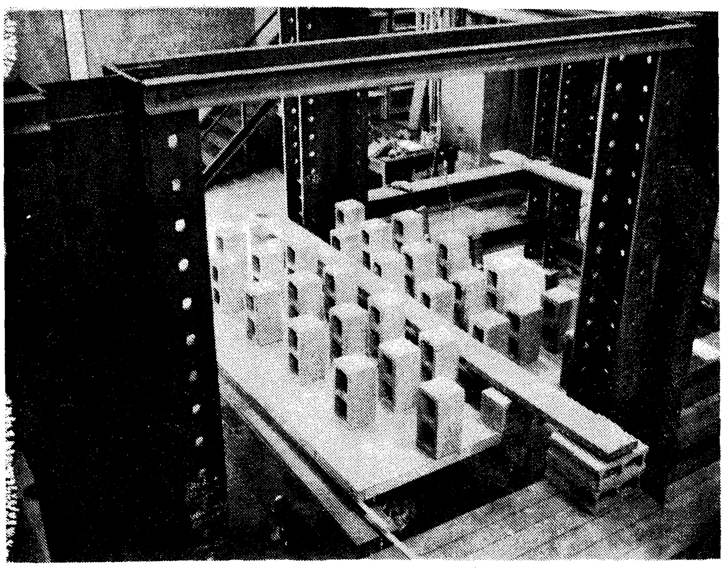
FAILURE MODE OF TEST PANEL NO. 1

PLATE 1.2



TYPICAL INTERNAL STUD UNDER DESIGN LOAD

PLATE 1.3



TYPICAL PANEL SUBJECTED TO DESIGN LOAD

PLATE 1.4

Uplift loads were applied through a series of up to four, 120 kN capacity, Ritch hydraulic jacks, reacting against the horizontal beam member of the portal frame. The load was applied by a hand operated pump and measured by a pressure gauge previously calibrated against a standard proving ring.

Accuracy of load measurements is estimated to be within 5% in all cases.

1.2.2 Racking Test Arrangement

Test panels 1 through 4 were tested in racking by positioning in the loading frame as shown in Plate 1.1. Steel hangers were arranged as illustrated to restrain the joists. A horizontal restraint was located at bottom plate level to minimise translation. 75 x 50 mm x F14 timber members were positioned at the top, one either side of the panel, to restrain the top plates against lateral buckling.

Dial gauges 1 and 2 were positioned as shown in Figure 1.1 to measure horizontal panel and portal frame deflection. Total racking deflection is therefore, the sum of these two readings and also includes any rigid body movement the panel may inherit. Dial gauge 3 was attached to monitor panel rigid body movement. Hence, the panel horizontal deflection becomes:

$$\Delta = DG2 + DG1 - DG3$$

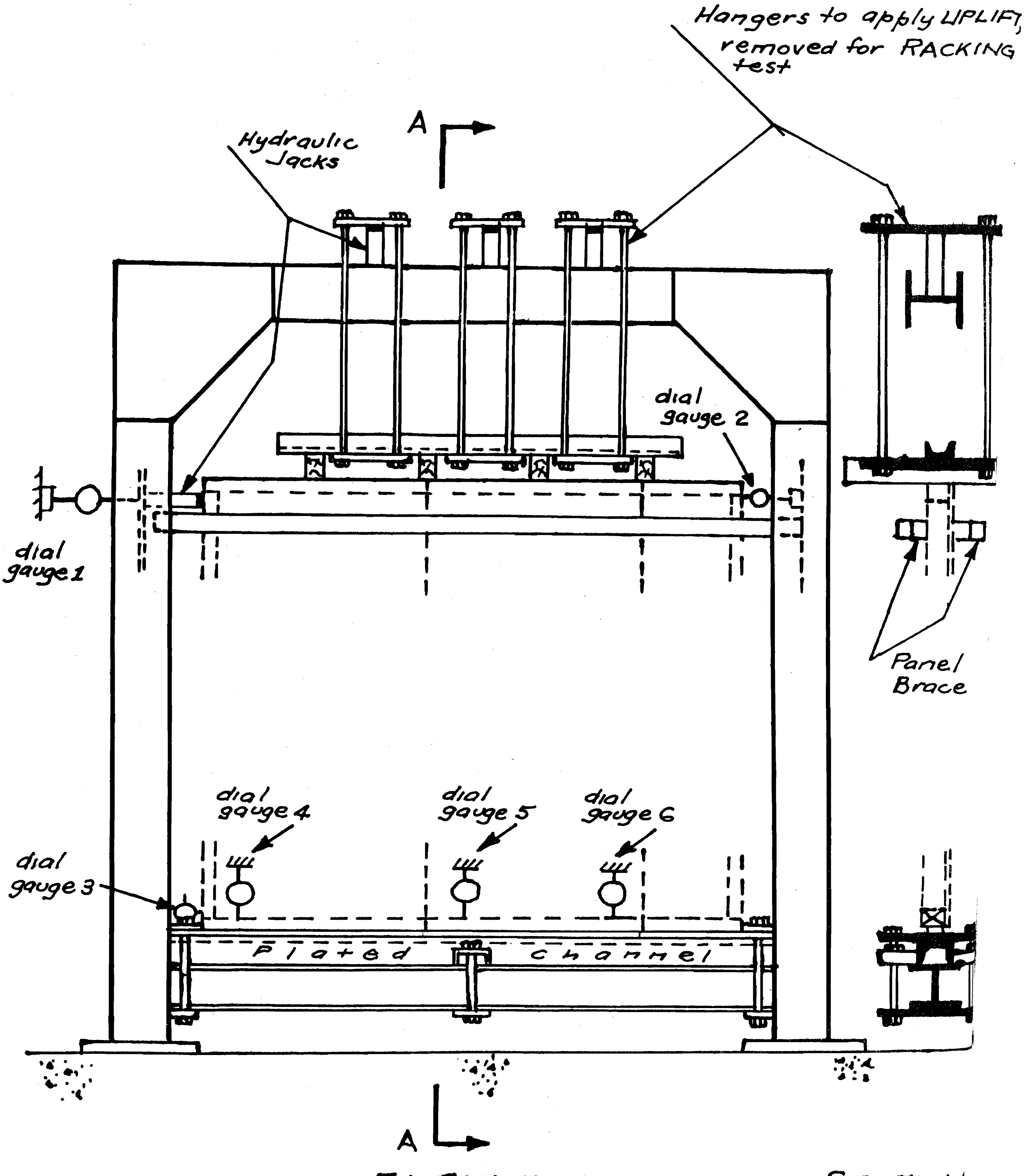
The deflection Δ still contains the horizontal component movement due to panel rotation. Therefore, the true racking deflection Δ_R is:

$$\Delta_R = \Delta - \Delta_{ROT}$$

Dial gauges 4, 5 and 6 shown in Figure 1.1 monitored vertical panel movement thus enabling the centre of rotation to be conservatively estimated as being at mid-length of the panel. Hence, horizontal deflection due to panel rotation is given by:

$$\Delta_{ROT} = \left(\frac{2.4 \times DG4}{1.5}\right) \text{ mm}$$

For subsequent racking tests the loading rig was modified to that shown in Figure 1.1. This arrangement minimised both rigid body translation and rotation, and in a number of ways, e.g. slab on ground, more realistically modelled the actual dwelling situation. A further modification eliminated the necessity to measure frame sway.



TEST RIG ARRANGEMENT

FIGURE 1·1

1.2.3 Uplift Test Arrangement

For uplift tests the rafter to top plate connection was effected through a continuous 32 x 1.6mm thick galvanised steel strap bent to fit around one side of the rafter, under the top plate and around the other side of the rafter. The strap was connected to the rafter by means of five hand driven 40x2.8mm diameter galvanised clouts on either side of the top plate.

Wall panels 1 through 4 when tested in uplift, were positioned in the loading frame as shown in Plate 1.1. Joist restraint was effected in the same manner as described for the initial racking tests. The uplift forces on the rafters were applied by hydraulic jacks suitably positioned on the horizontal beam of the portal frame and reacting against the hangers. Test panels 9 and 10 were tested in uplift in the modified test rig shown in Figure 1.1

Four gauges were attached to panels to measure the following:

(i) top plate movement
(ii) bottom plate movement
(iii) relative movement between the top and bottom plate
(iv) sheathing deformation

Information obtained from the above measurements was not used quantitatively.

1.2.4 Bending Test Set-up

Wall panels tested in bending were done so under the following load conditions:

(i) to design load, individual studs of unsheathed panel
(ii) to proof load, i.e. 0.6 x design load, panel fully sheathed
(iii) to design load, panel fully sheathed
(iv) to design load, individual internal studs of fully sheathed panel

Such a loading procedure provided a means of estimating the increase in flexural stiffness due to composite (T-beam) and two-way action.

1.3 PANEL CONSTRUCTION

No special care was taken during fabrication of the panels, construction techniques being representative of normal on site practice. Features of note concerning construction of panels include:

(i) stud centres were 600 mm in all cases

(ii) particleboard sheathing was fastened to only one side of a panel

(iii) secondary connection between top and bottom plates and studs was effected by means of two predrilled hand-driven 100 x 3.8 mm diameter nails driven into the end grain of each stud

(iv) primary connection between particleboard, top and bottom plates, and studs was effected by means of hand driven 40 mm long x 2.8 mm diameter galvanised clouts, except for TP 36.

(v) joist/bottom plate fixity for Test Panels 1 through 4 was obtained by 32 x 1.6 mm galvanised steel straps.

(vi) sheets were connected within 2 mm of the bottom edge of the bottom plate with clouts driven 22 mm from edges around the panel. Where sheet edges butted over internal studs, landing were approximately halved to effect connection.

1.4 LOADING PROCEDURE

All panels were preloaded to 0.6 x estimated design load and held at this load for five minutes. All dial gauge readings were monitored during this cycle. On load removal residual deformations were noted. Each panel was then loaded to its full design load in each of the three modes, i.e. bending, uplift, and racking. Prior to loading a panel to failure in a particular mode it was again loaded to the proof value, held for five minutes then unloaded. After giving sufficient time for panel recovery loading was then applied to failure.

Dial gauges positioned to measure panel rotation under racking load were rezeroed after proof loading whilst those gauges used to measure racking deformation were not touched. All gauges mounted on the uplift panel were rezeroed after proof loading as were those used in the monitoring of flexural deflections.

1.4.1 Evaluation of Allowable Racking Load

For a wall panel to be deemed adequate as a structural element capable of resisting applied racking loads it must be:

(i) stiff enough to resist the design loads without deflecting excessively

(ii) strong enough to resist the design loads and still provide an adequate safety margin on its ultimate load carrying capacity

(iii) remain stable, i.e. show no signs of buckling or the demonstration of any tendencies towards becoming dimensionally unstable under adverse environmental conditions

To evaluate the limiting load carrying capabilities of a wall panel it is necessary to consider the three factors mentioned above.

Where panel configurations were considered suitable for use as bracing walls a minimum of two systems were tested and their failure racking loads averaged. This average value of racking load is then converted to a "design racking load/metre" through application of Equation 2.1.

Invariably deflections at the design racking load were less than panel height/300, i.e. 8 mm and sheathing buckling was not considered significant at the design load.

Results of an exposure test programme conducted over a period of 24 weeks indicated panels left fully exposed for periods in excess of 12 weeks should be carefully inspected and resheathed, if necessary, prior to continuing construction.

SECTION 2

2.1 TEST RESULTS

In this section typical results from the various groups of test panels in Table 1.1 are presented. For complete results and discussion the reader is referred to TWP Reports Nos 105, 114, 116, 122, and 124.

Design racking loads for the 2.4 m high x 3.0 m long panels was estimated to be 4 kN (4.5 kN was also used) for a 33 m/s design wind velocity and 6.75 kN for a 42 m/s wind speed. Panels consisting of 70 x 45 mm, F5 and F8 pine studs are suitable only for use in 33 m/s wind areas due to their lack of sufficient flexural stiffness to resist higher wind forces. 70 x 38 mm x F8 hardwood panels are also included in this category for the same reason although such framing may be used with 450 mm centre stud spacing. 90 x 45 mm x F8 pine framing, 70 x 50 mm x F11, and 70 x 40 mm x F17 hardwood framing are suitable for use in terrain category 3, cyclonic areas.

Complete test results are presented for the following panels:

TP 16 - tested in bending, racking, and uplift.
70 x 45 x F8, Radiata pine framing, no bolt, standard nailing
Preload and proof load based on: 33 m/s design wind speed.

P 18 - tested in racking and uplift
90 x 45 x F8, Radiata pine framing, no bolt, standard nailing
Preload and proof load based on: 42 m/s design wind speed.

TP 31 - tested in racking,
90 x 45 x F8 Radiata pine framing, bolt included, standard nailing
Proof load based on: 42 m/s design wind speed.

TP 33 - tested in racking
90 x 45 x F8, Radiata pine, no bolt, close nailing.
Proof load based on: 42 m/s design wind speed.

TP 35 - tested in racking.
70 x 45 x F8, Radiata pine framing, no bolt, close nailing
Proof load based on: 42 m/s design wind speed.

TP 38 - tested in racking.
70 x 38 x F11, hardwood, no bolt, standard nailing
Proof load based on: 42 m/s design wind speed

2.2 TEST PANEL NO. 16

Test Panel 16 was constructed from 70 x 45 mm, F8 Radiata pine framing with studs at 600 mm centres and 6 mm Texpan nailed at 150 mm centres on edge studs and 300 mm on internal studs.

2.2.1 Bending - Test Results

Time-load-deflection results for flexure are given in Table 2.1. The average deflection for the six unsheathed studs was 8.52 mm which is less than span/240, i.e., 10 mm or a maximum of 12 mm for live load. The average deflection of the four internal sheathed studs, loaded individually, was 5.78 mm indicating an increase in stiffnesss due to composite and two-way action of 32%. The average mid-span deflection of the four internal studs, subjected to full panel design load, was 7.35 mm.

In this case the contribution to two-way action due to sheathing is 14% and that due to composite action 18%.

2.2.2 Racking - Test Results

Time-load-deflection results are given in Table 2.2 for the panel proof loaded to a total racking load of 2.7 kN, held for five minutes and released, then reloaded to a design value of 4.5 kN and again released. The panel was then tested to the proof and design load in uplift.

Figure 2.1 shows a load-deflection plot on proof loading, unloading and reloading to the full design value and again unloading. Residual deformations after attaining each of these load levels are also shown.

Table 2.3 shows the time-load-deflection data for the panel reloaded to the proof load, holding for five minutes, unloading then reloading to failure.

This panel displayed prominent buckles even at the proof load. The buckles did not disappear on removal of the load nor did they tend to get worse even at loads approaching the failure value.

Panel failure occurred at a load of 14.4 kN. The failure mode was that due to tearing out of the board from behind the nail, but only in a localised area, at the first nail in the bottom plate at the loaded end.

The load-deflection curve of Figure 2.2 shows a linear response to an estimated load of approximately 4.0 kN which corresponds to a racking deflection of less than 2 mm.

During initial loading it was noted that the sheathing at mid-height of the second stud from the loaded end buckled away from the stud by about 4 mm, halfway between the 300 mm spaced nails. This type of behaviour had not previously been observed.

2.2.3 Uplift - Test Results

Time-load-deflection results are set out in Table 2.4 for a proof load of 1.5 kN/rafter which was held for five minutes and released. Following proof loading the four dial gauges were rezeroed and the panel reloaded to its design value of 2 kN/rafter.

APRI WALL PANEL TESTS

DATE TESTED: **TEST PANEL No 16**

FLEXURE TEST DATA SHEET

SHEET 1 OF 2

Loaded Stud I.D.	Unsheathed Panel: Design Load/Stud: Time (min)			Fully Sheathed Panel: Proof Load: Time (min)			Full Design Load: Time (min)			Full Design Load/Stud: Time (min)		Mid-span stud deflections (mm)					
	Time (min)	Load (N)	Mid-span Defl'n. (mm)	Time (min)	Load (N)	Mid-span Defl'n (mm)	Time (min)	Load (N)	Mid-span Defl'n (mm)	Time (min)	Load (N)	1	2	3	4	5	6
1	0:40	330	4.16	2:20	310	3.37	2:30	155	1.61								
	1:20	660	7.50	6:40	310	3.63	7:20	465	4.30								
	2:00	988	9.55	11:40	310	3.67	15:40	465	4.53								
	7:00	988	9.64	22:00	0	–	20:40	465	4.58								
	10:20	0	0.21				31:00	0	0.05								
2	0:30	330	4.08	2:40	310	4.49	2:50	310	3.90	0:50	310	0.48	2.97	0.49	0.03	–	–
	1:25	660	7.35	7:00	620	6.94	7:40	620	7.33	2:30	620	0.82	5.55	0.88	0.08	–	–
	2:30	988	9.30	12:00	620	7.01	16:00	930	8.85	5:20	930	1.02	7.10	1.05	0.09	–	–
	7:30	988	9.38	22:20	0	0.67	21:00	930	8.94	10:20	930	1.02	7.29	1.05	0.09	–	–
	11:00	0	0.10				31:20	0	0.40	20:00	0	–	0.58	–	–	–	–
3	0:30	330	3.45	3:00	310	3.21	3:10	310	3.24	1:00	310	–	0.52	2.39	0.31	0.03	–
	1:10	660	6.19	7:20	620	5.32	8:00	620	5.80	2:40	620	–	0.88	4.42	0.58	0.04	–
	1:50	988	7.18	12:20	620	5.40	16:20	930	7.18	5:20	930	–	1.14	5.58	0.72	0.05	–
	6:50	988	7.89	22:40	0	0.25	21:20	930	7.28	10:20	930	–	1.14	5.72	0.78	0.05	–
	10:00	0	0.13				31:40	0	0.12	20:00	0	–	–	0.17	0.01	–	–

TABLE 2.1

APRI WALL PANEL TESTS

DATE TESTED:

TEST PANEL №16

FLEXURE TEST DATA SHEET

SHEET 2 OF 2

Loaded Stud I.D.	Unsheathed Panel			Fully Sheathed Panel													
	Design Load/Stud			Proof Load			Full Design Load			Full Design Load/Stud		Mid-span stud deflections (mm)					
	Time (min)	Load (N)	Mid-span Defl'n. (mm)	Time (min)	Load (N)	Mid-span Defl'n (mm)	Time (min)	Load (N)	Mid-span Defl'n (mm)	Time (min)	Load (N)	1	2	3	4	5	6
4	0:30	330	3·63	3:20	310	3·22	3:30	310	3·02	1:00	310	–	0·07	0·32	2·47	0·31	–
	1:30	660	6·53	7:40	620	5·48	8:20	620	5·75	2:20	620	–	0·13	0·57	4·64	0·52	–
	2:20	988	8·41	12:40	620	5·57	16:40	930	7·14	5:00	930	–	0·19	0·76	5·94	0·64	–
	7:20	988	8·48	23:00	0	0·38	21:40	930	7·24	10:00	930	–	0·19	0·76	6·08	0·64	–
	10:00	0	0·30				32:00	0	0·01	19:00	0	–	–	–	0·46	–	–
5	0:30	330	3·58	3:40	310	3·09	3:50	310	2·75	1:00	310	–	–	0·03	0·30	2·14	0·45
	1:10	660	6·33	8:00	620	4·78	8:40	620	5·05	2:40	620	–	–	0·06	0·50	3·81	0·78
	2:00	988	8·09	13:00	620	4·88	17:00	930	6·22	5:40	930	–	–	0·06	0·61	4·80	1·01
	7:00	988	8·17	23:20	0	0·35	22:00	930	6·29	10:40	930	–	–	0·06	0·61	4·92	1·02
	10:30	0	0·10				32:20	0	0·03	20:00	0	–	–	–	–	0·20	–
6	0:30	330	3·82	4:00	310	3·90	4:10	155	3·27								
	1:00	660	6·85	8:20	620	4·18	9:00	465	3·83								
	1:50	988	8·61	13:20	620	4·22	17:20	465	5·03								
	6:50	988	8·71	23:40	0	0·10	22:20	465	5·07								
	10:00	0	0·17				32:40	0	0·09								

TABLE 2.1

WALL PANEL TEST RESULTS

TEST PANEL NO. 16 TEST LOAD TYPE: RACKING

Time (min.)	Racking Load (kN)	Dial Gauge Reading (mm)							
		Test Frame	Panel Defln.	Rigid Body	Horiz. Defln.	Panel Rotation			Actual Racking
		1	2	3	Δ	4	5	6	Δ_R
0:00	0·00		0·00	0·00		0·00	0·00	0·00	0·00
	0·45		0·06	0·00		0·00	0·00	0·00	0·06
	0·90		0·14	0·00		0·00	0·00	0·00	0·14
	1·35		0·31	0·01		0·02	0·01	0·00	0·30
	1·80		0·45	0·01		0·06	0·02	-0·01	0·44
	2·25		0·68	0·02		0·12	0·03	-0·06	0·66
3:30	2·70		1·15	0·03		0·18	0·03	-0·11	1·12
8:30	2·70		1·27	0·04		0·22	0·01	-0·16	1·23
9:30	0·00		0·29	0·00		0·16	0·00	-0·04	0·29
16:00	0·00		0·22	0·00		0·00	0·00	0·00	0·22
	0·90		0·41	0·00		0·00	0·00	0·01	0·41
	1·80		0·64	0·00		0·05	0·01	0·01	0·64
	2·70		1·16	0·0		0·08	0·01	-0·06	1·16
	3·60		1·87	0·04		0·21	0·04	-0·14	1·83
19:30	4·50		2·62	0·09		0·50	0·13	-0·18	2·53
25:30	4·50		2·74	0·10		0·54	0·15	-0·20	2·64
26:00	0·00		0·80	0·09		0·30	0·06	-0·06	0·71

TABLE 2·2

PROOF LOAD: 2·7 kN DEFLECTION: 1·13 mm

ULTIMATE LOAD: ______ DEFLECTION: ______

TEST PANEL N°16

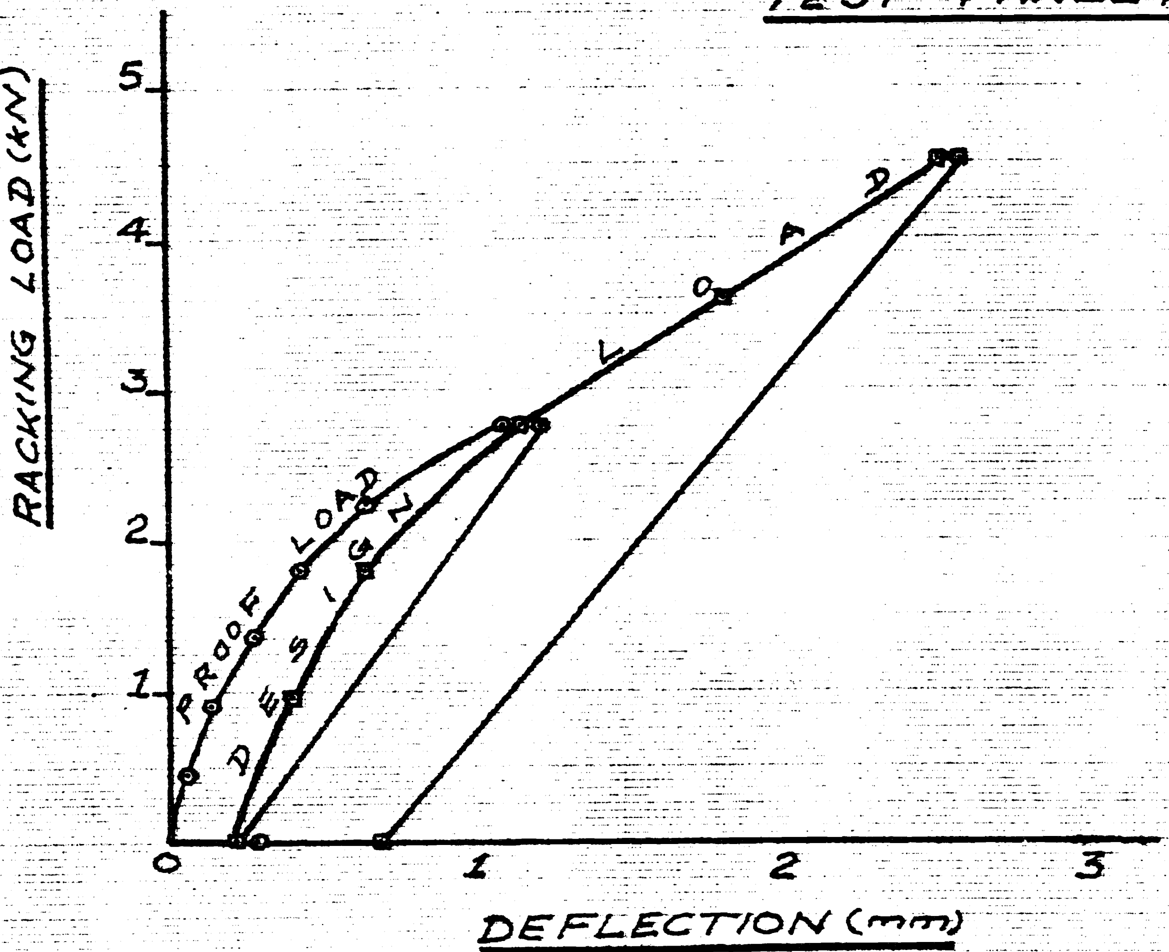


FIGURE 2·1

WALL PANEL TEST RESULTS

TEST PANEL NO. 16 TEST LOAD TYPE: RACKING

Time (min.)	Racking Load (kN)	Dial Gauge Reading (mm): Test Frame	Panel Defln.	Rigid Body	Horiz. Defln.	Panel Rotation			Actual Racking
		1	2	3	Δ	4	5	6	Δ_R
0:00	0.00		0.00	0.00		0.00	0.00	0.00	0.00
	0.45		0.12	0.01		0.02	0.00	-0.01	0.11
	0.90		0.25	0.01		0.03	0.01	-0.02	0.24
	1.35		0.51	0.01		0.07	0.01	-0.06	0.50
	1.80		0.80	0.01		0.11	0.01	-0.10	0.79
	2.25		1.09	0.00		0.15	0.00	-0.16	1.09
3:00	2.70		1.26	0.00		0.20	0.00	-0.17	1.26
8:00	2.70		1.32	0.00		0.21	0.00	-0.18	1.32
10:50	0.00		0.16	0.00		0.17	0.00	-0.05	0.16
15:00	0.00		0.12	0.00		0.00	0.00	0.00	0.12
	0.90		0.32	0.00		0.00	0.00	0.00	0.32
	1.80		0.80	0.00		0.01	0.00	-0.06	0.80
	2.70		1.30	0.00		0.08	0.00	-0.12	1.30
	3.60		1.69	0.00		0.20	0.03	-0.15	1.69
	4.50		2.38	0.04		0.48	0.13	-0.18	2.34
	5.40		3.15	0.10		0.77	0.24	-0.20	3.05
	6.30		4.02	0.20		1.14	0.37	-0.23	3.82
	7.20		5.01	0.32		1.61	0.57	-0.27	4.69
	8.10		6.35	0.46		2.16	0.81	-0.31	5.89
	9.00		7.52	0.55		2.65	1.00	-0.35	6.97
	9.90		8.38	0.64		3.13	1.20	-0.36	7.74
	10.80		9.52	0.73		3.69	1.44	-0.36	8.79
	11.70		10.82	0.81		4.36	1.71	-0.32	10.01
	12.60		12.20	0.88		5.05	1.98	-0.29	11.32
	13.50		13.53	0.95		5.97	2.31	-0.29	12.58
24:00	14.40		~15.00						~15.00

TABLE 2.3

PROOF LOAD: 2.7 kN DEFLECTION: 1.26 mm

ULTIMATE LOAD: 14.40 kN DEFLECTION: ~15.0 mm.

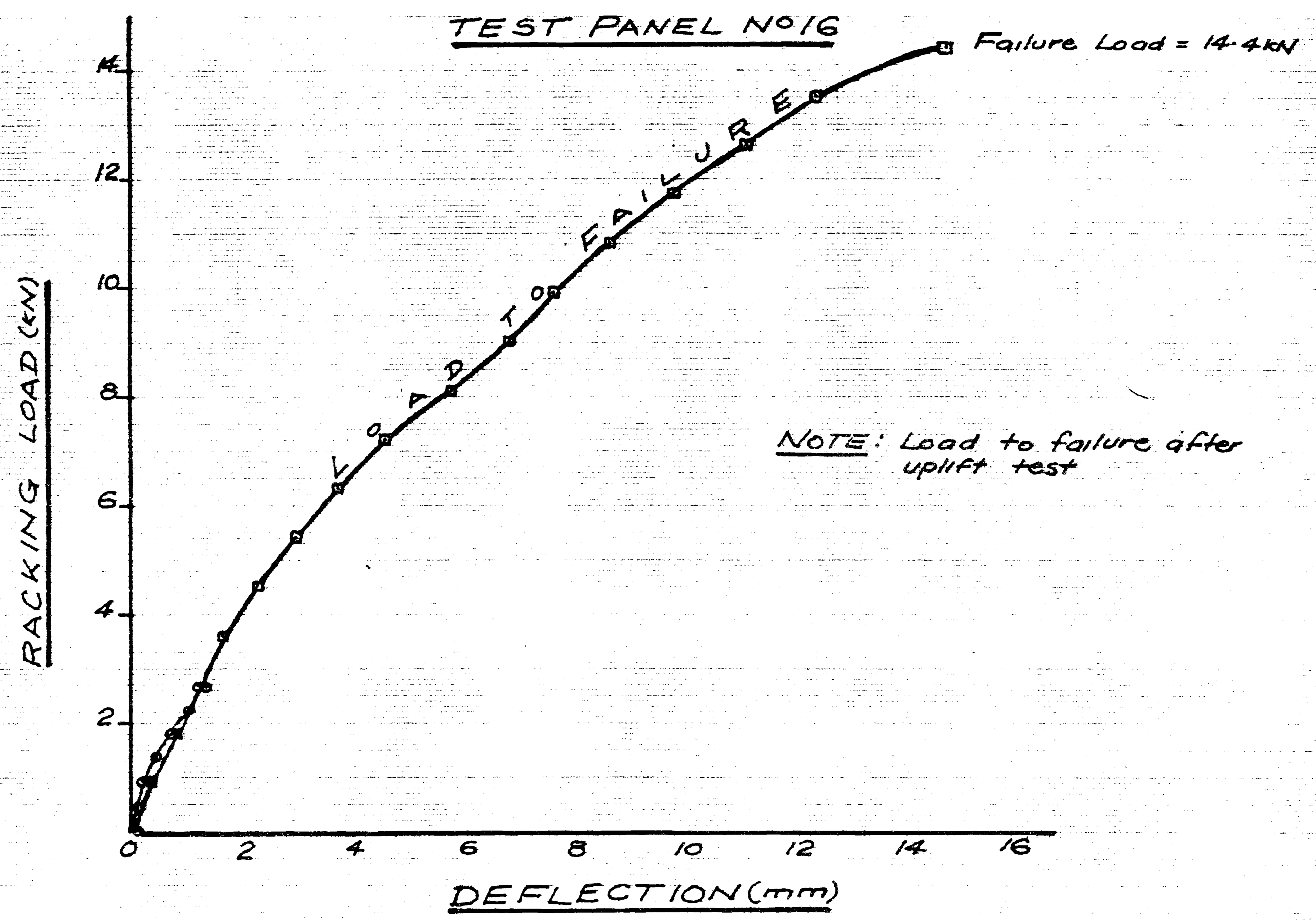

TEST PANEL No 16
Failure Load = 14·4kN
LOAD TO FAILURE
NOTE: Load to failure after uplift test
RACKING LOAD (kN)
DEFLECTION (mm)
0
2
4
6
8
10
12
14
16

FIGURE 2·2

WALL PANEL TEST RESULTS

TEST PANEL NO. 16 **TEST LOAD TYPE: UPLIFT**

Time (min.)	Load/ Rafter	Dial Gauge Readings (mm) 1 Top Plate	2 Bottom Plate	3 Relative Plates	4 Sheathing Deform.
0:00	0·00	0·00	0·00	0·00	0·00
	0·50	0·00	0·01	0·00	0·00
	1·00	0·86	0·04	-0·07	-0·01
2:30	1·50	1·75	0·04	-0·21	-0·06
7:30	1·50	1·77	0·04	-0·21	-0·08
8:00	0·00	1·41	-0·02	-0·12	-0·01
13:30	0·00	0·00	0·00	0·00	0·00
	0·50	0·04	0·01	-0·02	0·00
	1·00	0·22	0·03	-0·07	-0·03
	1·50	0·42	0·06	-0·11	-0·05
15:00	2·00	1·60	0·08	-0·36	-0·10
20:00	2·00	1·67	-0·05	-0·47	-0·13
21:00	0·00	0·98	-0·12	-0·33	-0·04

TABLE: 2·4

PROOF LOAD: 1·5 kN/rafter

ULTIMATE LOAD: ______

2.3 TEST PANEL NO. 18

Test Panel 18 consisted of the reverse side of the 90 x 45 mm F8, Radiata pine frame used for Test Panel 17, but in this case sheathed with 6 mm Fineline. The nailing pattern was the standard 150/300 centres.

Flexure tests were not carried out on this panel nor Test Panel 19. These two tests were performed to obtain further racking test data on the 6 mm Fineline and 6 mm Texpan sheathing under simulated wind loading of 42 m/s.

2.3.1 Racking - Test Results

Time-load-deflection results are given in Table 2.5 for the panel proof loaded to a total racking load of 4.0 kN, held for five minutes and released, then reloaded to the design value of 6.75 kN and again released. The panel was then tested to the proof and desing load in uplift.

Figure 2.3 shows a load-deflection plot on proof loading, unloading nd reloading to the full desing value and again unloading. Residual deformations after attaining each of these load levels are also shown. Reloading to the design load shows an increase in stiffness of the panel, which after reaching the proof load of 4 kN, reduces to about the original panel stiffness. This is a similar response to that observed for Test Panel 17.

Table 2.6 shows the time-load-deflection data for the panel reloaded to the proof load, holding for five minutes, unloading then reloading to failure. At no stage of loading were there any obvious observable signs of sheathing buckling.

Panel failure occurred at a load of 16.1 kN. The failure mode was that due to the board being pulled over the first three or four nails in the bottom plate nearest the loaded end. This was followed by board pull-out behind subsequent nails for more than half the length of the sheet at the loaded end. This failure mode, ie., nail pull through the sheathing, had not previously been observed with any of hte panels nor had this amount of nail deformation been previously observed in an unrodded Fineline sheathed panel. This no doubt accounts for the higher failure load attained compared to that of Test Panel 5.

The load-deflection curve of Figure 2.4 shows a linear response to an estimated limit load of 3.6 kN which corresponds to a racking deflection of 1.6 mm. It can be seen at the design load of 6.75 kN the panel had only deflected about 4 mm with a first loaded stud separation from the bottom plate of about 1 mm.

2.3.2 Uplift - Test Results

Time-load-deflection results are set out in Table 2.7 for a proof load of 2 kN/rafter which was held for five minutes and released. Following proof loading the four dial gauges were rezeroed and the panel reloaded to its design value of 3 kN/rafter.

WALL PANEL TEST RESULTS

TEST PANEL NO. 18 TEST LOAD TYPE: RACKING

Time (min.)	Racking Load (kN)	Dial Gauge Reading (mm)							
		Test Frame	Panel Defln.	Rigid Body	Horiz. Defln.	Panel Rotation			Actual Racking
		1	2	3	Δ	4	5	6	Δ_R
0:00	0·00		0·00	0·00		0·00	0·00	0·00	0·00
	0·45		0·15	0·00		0·03	0·00	0·00	0·15
	0·90		0·31	0·01		0·07	0·00	0·00	0·30
	1·35		0·48	0·01		0·10	0·00	0·00	0·47
	1·80		0·65	0·01		0·17	0·01	0·01	0·64
	2·25		0·94	0·02		0·24	0·02	0·02	0·92
	2·70		1·16	0·02		0·30	0·02	0·02	1·14
	3·15		1·40	0·03		0·36	0·03	0·03	1·37
	3·60		1·67	0·03		0·44	0·04	0·03	1·64
3:00	4·00		2·02	0·04		0·55	0·07	0·04	1·98
8:00	4·00		2·06	0·02		0·56	0·07	0·05	2·04
9:30	0·00		0·53	0·00		0·20	0·03	0·02	0·53
15:00	0·00		0·50	0·00		0·00	0·00	0·00	0·50
	0·90		0·79	0·01		0·05	0·00	0·00	0·78
	1·80		1·12	0·02		0·13	0·00	0·00	1·10
	2·70		1·44	0·02		0·20	0·01	0·01	1·42
	3·60		1·83	0·03		0·29	0·03	0·01	1·80
	4·50		2·48	0·04		0·49	0·08	0·02	2·44
	5·40		3·27	0·06		0·76	0·15	0·01	3·21
	6·30		4·35	0·10		1·15	0·24	0·02	4·25
19:00	6·75		4·84	0·12		1·34	0·28	0·02	4·72
24:00	6·75		4·98	0·13		1·38	0·29	0·03	4·85
25:30	0·00		1·92	0·07		0·53	0·07	0·03	1·85

TABLE 2·5

PROOF LOAD: 4 kN DEFLECTION: 1·98 mm

ULTIMATE LOAD: ______ DEFLECTION: ______

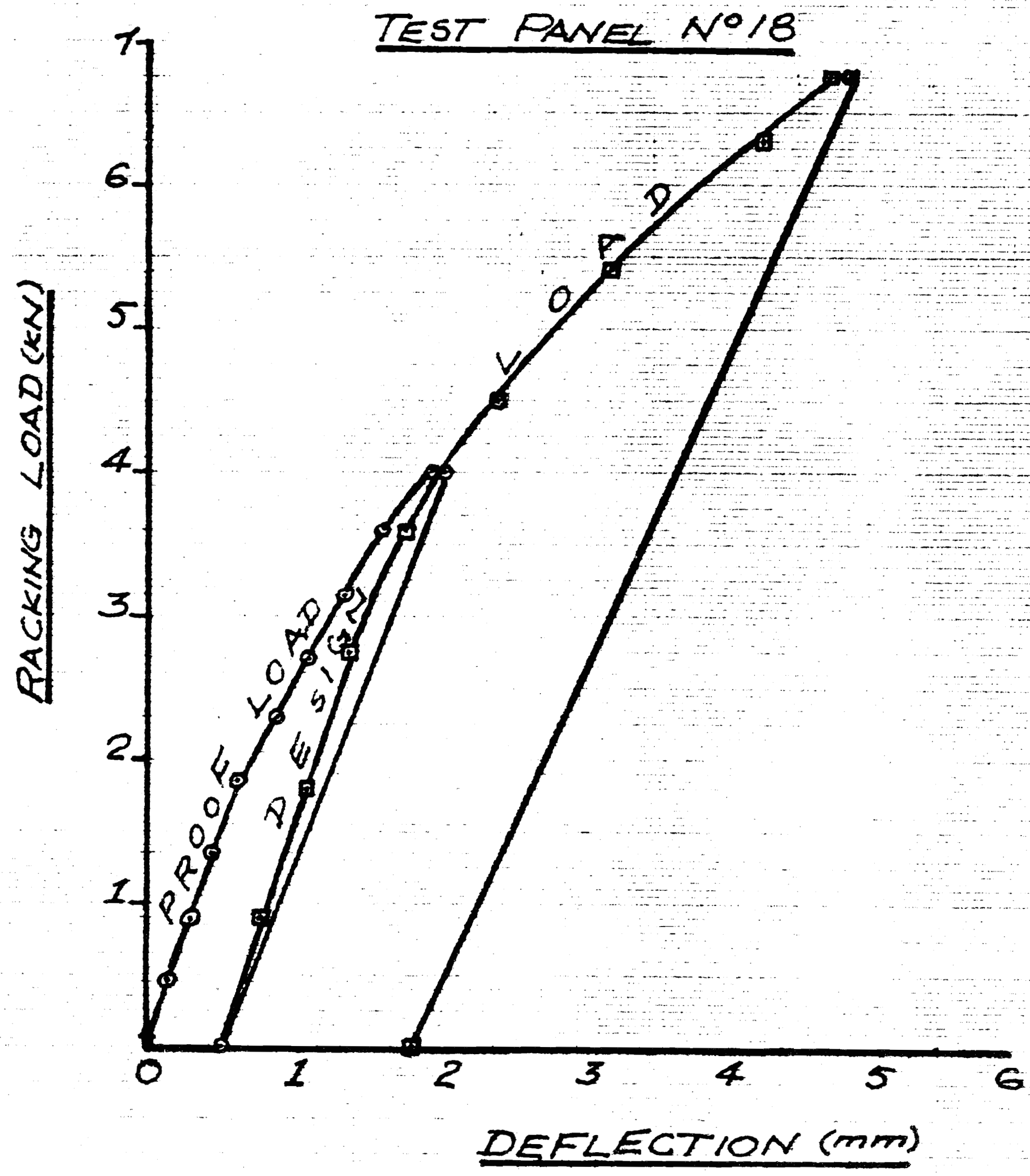

TEST PANEL N°18
RACKING LOAD (kN)
DEFLECTION (mm)
PROOF LOAD
DESIGN
0
1
2
3
4
5
6
7

FIGURE 2.3

WALL PANEL TEST RESULTS

TEST PANEL NO. 18 TEST LOAD TYPE: RACKING

Time (min.)	Racking Load (kN)	Dial Gauge Reading (mm) Test Frame	Panel Defln.	Rigid Body	Horiz. Defln.	Panel Rotation			Actual Racking
		1	2	3	Δ	4	5	6	Δ_R
0:00	0:00		0·00	0·00		0·00	0·00	0·00	0·00
	0·45		0·19	0·01		0·05	0·00	0·00	0·18
	0·90		0·34	0·01		0·08	0·00	0·00	0·33
	1·35		0·49	0·01		0·11	0·00	0·00	0·48
	1·80		0·66	0·01		0·15	0·02	0·00	0·65
	2·25		0·87	0·02		0·20	0·02	0·01	0·85
	2·70		1·04	0·02		0·24	0·03	0·01	1·02
	3·15		1·27	0·02		0·29	0·05	0·01	1·25
	3·60		1·50	0·03		0·35	0·06	0·02	1·47
4:00	4·00		1·76	0·03		0·42	0·08	0·02	1·73
9:00	4·00		1·82	0·03		0·43	0·09	0·02	1·79
10:00	0·00		0·34	0·01		0·07	0·02	0·01	0·33
16:00	0·00		0·30	0·00		0·00	0·00	0·00	0·30
	0·90		0·62	0·00		0·09	0·01	0·00	0·62
	1·80		0·93	0·01		0·16	0·03	0·00	0·91
	2·70		1·26	0·02		0·24	0·05	0·01	1·24
	3·60		1·62	0·02		0·32	0·07	0·01	1·60
	4·50		2·20	0·03		0·50	0·12	0·01	2·17
	5·40		2·99	0·04		0·74	0·20	0·00	2·95
	6·30		3·68	0·07		0·95	0·28	-0·01	3·61
	7·20		4·39	0·10		1·24	0·36	-0·02	4·29
	8·10		5·32	0·14		1·63	0·48	-0·02	5·18
	9·00		6·42	0·19		2·12	0·57	-0·02	6·23
	9·90		7·55	0·23		2·62	0·79	-0·02	7·32
	10·80		9·05	0·30		3·27	1·01	-0·03	8·75
	11·70		10·55	0·35		4·00	1·23	-0·03	10·20
	12·60		12·15	0·41		4·31	1·46	-0·03	11·74
	13·50		14·55	0·47		4·31	1·80	-0·02	14·08
	14·40		16·45	0·53		6·85	2·25	-0·04	15·92
	15·30		18·50	0·61		9·00	3·95	-0·40	17·89
27:00	16·10		+20·00						+20·00

TABLE 2·6

PROOF LOAD: 4·0 kN DEFLECTION: 1·73 mm

ULTIMATE LOAD: 16·1 kN DEFLECTION: +20 mm

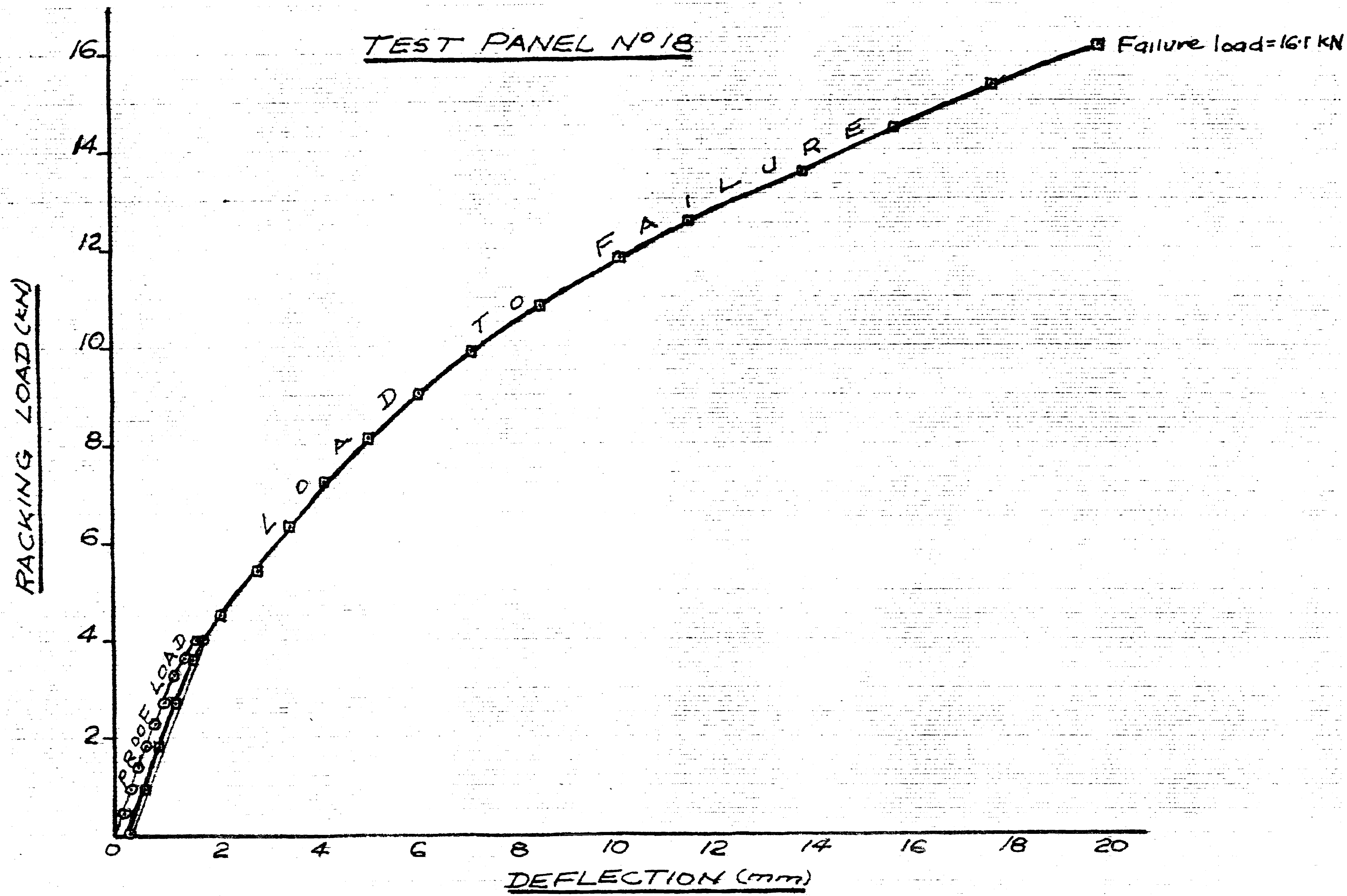

TEST PANEL No 18
Failure load=16·1 KN
LOAD TO FAILURE
PROOF LOAD
RACKING LOAD (KN)
DEFLECTION (mm)
16
14
12
10
8
6
4
2
0
2
4
6
8
10
12
14
16
18
20

FIGURE 2·4

WALL PANEL TEST RESULTS

TEST PANEL NO. 18 **TEST LOAD TYPE: UPLIFT**

Time (min.)	Load Rafter	Dial Gauge Readings (mm) 1 Top Plate	2 Bottom Plate	3 Relative Plates	4 Sheathing Deform.
0:00	0·00	0·00	0·00	0·00	0·00
	0·50	0·00	0·01	0·00	0·00
	1·00	0·15	0·03	0·00	-0·02
	1·50	0·17	0·03	-0·06	-0·04
3:00	2·00	1·35	0·03	-0·26	-0·09
8:00	2·00	1·56	0·03	-0·27	-0·09
9:00	0·00	1·08	0·00	-0·24	-0·02
13:30	0·00	0·00	0·00	0·00	0·00
	0·50	0·00	0·00	0·00	-0·01
	1·00	0·08	0·01	-0·02	-0·03
	1·50	0·19	0·02	-0·08	-0·04
	2·00	0·41	0·03	-0·14	-0·06
	2·50	1·55	0·03	-0·45	-0·10
16:30	3·00	2·65	0·02	-0·82	-0·14
21:30	3·00	3·35	0·02	-0·84	-0·15
22:30	0·00	2·59	-0·01	-0·66	-0·02.

TABLE: 2·7

PROOF LOAD: 2 kN/rafter

ULTIMATE LOAD: ________

2.4 TEST PANEL 31

The timber framing used to construct the panel was 90 x 45 mm, F8 Radiata pine. The nail spacing was the standard 150/300 mm centres. A cyclone rod was fitted to the loaded end of the panel.

Time-load-deflection results were given in Tables 2.8 and 2.9 for the system loaded to the design and failure loads respectively. The design load of 6.75 kN was held for five minutes and then released. After a further five minutes under no load the panel was then loaded to failure.

Figure 2.5 shows a load-deflection plot of the data in Tables 2.9 and 2.10. The load to failure curve is linear to a load of approximately 9 kN where the corresponding deflection is slightly more than 3 mm.

Panel failure occurred at a racking load of 28.8 kN. Failure resulted in the edge of the middle sheet remote from the loaded end popping over the nails for the full length of the stud. The bottom nail in the centre stud of the middle sheet had been pulled out by about 15 mm. All nails of the individual sheets were deformed in the general directions consistent with individual sheet rotation. Head rotations of all nails, except those in the centre studs of the full sheets, was very pronounced but not accompanied by material tear-out along the bottom plate nearest the loaded end.

The panel surface was flat after positioning the loading frame with no signs of buckling up to the design load.

WALL PANEL TEST RESULTS

TEST PANEL NO. 31

TEST LOAD TYPE: RACKING

Time (min.)	Racking Load (kN)	Dial Gauge Reading (mm)							
		Test Frame	Panel Defln.	Rigid Body	Horiz. Defln.	Panel Rotation			Actual Racking
		1	2	3	Δ	4	5	6	Δ_R
0:00	0.00		0.00	0.00		0.00	0.00	0.00	0.00
	0.45		0.06	0.00		0.00	0.00	0.00	0.06
	0.90		0.15	0.01		0.00	0.00	0.00	0.14
	1.35		0.26	0.01		0.01	0.00	0.00	0.25
	1.80		0.39	0.01		0.03	0.00	0.01	0.38
	2.25		0.50	0.02		0.04	0.01	0.02	0.48
	2.70		0.66	0.02		0.05	0.01	0.03	0.64
	3.15		0.80	0.02		0.07	0.02	0.04	0.78
	3.60		0.93	0.03		0.08	0.03	0.05	0.90
	4.05		1.09	0.03		0.10	0.03	0.05	1.06
	4.50		1.23	0.04		0.12	0.04	0.05	1.19
	4.95		1.47	0.04		0.15	0.04	0.05	1.43
	5.40		1.79	0.04		0.20	0.04	0.06	1.75
	5.85		1.97	0.05		0.24	0.04	0.06	1.92
	6.30		2.12	0.05		0.25	0.05	0.06	2.07
7:00	6.75		2.30	0.05		0.28	0.05	0.07	2.25
12:00	6.75		2.40	0.05		0.28	0.07	0.07	2.35
13:00	0.00		0.42	0.00		0.04	0.07	0.07	0.42

TABLE 2.8

PROOF LOAD: 6.75 kN

DEFLECTION: 2.35 mm.

ULTIMATE LOAD: ______

DEFLECTION: ______

WALL PANEL TEST RESULTS

TEST PANEL NO. 31 **TEST LOAD TYPE:** RACKING

Time (min.)	Racking Load (kN)	Dial Gauge Reading (mm)							
		Test Frame	Panel Defln.	Rigid Body	Horiz. Defln.	Panel Rotation			Actual Racking
		1	2	3	Δ	4	5	6	Δ_R
18:00	0·00		0·36	0·00		0·00	0·00	0·00	0·36
	0·90		0·53	0·01		0·00	0·00	0·00	0·52
	1·80		0·78	0·02		0·03	0·00	0·00	0·76
	2·70		0·97	0·02		0·05	0·00	0·00	0·95
	3·60		1·21	0·03		0·08	0·00	0·00	1·19
	4·50		1·47	0·04		0·12	0·01	0·01	1·43
	5·40		1·94	0·04		0·19	0·01	0·01	1·90
	6·30		2·22	0·05		0·23	0·01	0·01	2·17
	7·20		2·53	0·06		0·27	0·02	0·01	2·47
	8·10		2·86	0·07		0·32	0·04	0·02	2·79
	9·00		3·25	0·08		0·40	0·05	0·02	3·17
	9·90		3·78	0·09		0·51	0·06	0·03	3·69
	10·80		4·26	0·10		0·63	0·08	0·04	4·16
	11·70		4·83	0·12		0·76	0·11	0·05	4·71
	12·60		5·45	0·15		0·90	0·15	0·06	5·30
	13·50		6·15	0·18		1·04	0·19	0·07	5·97
	14·40		6·95	0·20		1·17	0·26	0·09	6·75
	15·30		7·89	0·27		1·35	0·35	0·10	7·62
	16·20		9·00	0·31		1·52	0·45	0·11	8·69
	17·10		10·30	0·41		1·70	0·58	0·14	9·89
	18·00		11·75	0·55		1·87	0·75	0·15	11·20
	18·90		13·25	0·75		2·07	0·95	0·18	12·50
	19·80		15·30	0·97		2·30	1·18	0·23	14·03
	20·70		17·20	1·15		2·50	1·42	0·27	17·05
	21·60		19·20	1·30		2·73	1·65	0·32	17·90
32:00	28·80		44						

TABLE 2·9

PROOF LOAD: ______ **DEFLECTION:** ______

ULTIMATE LOAD: 28·8 kN **DEFLECTION:** 44 mm.

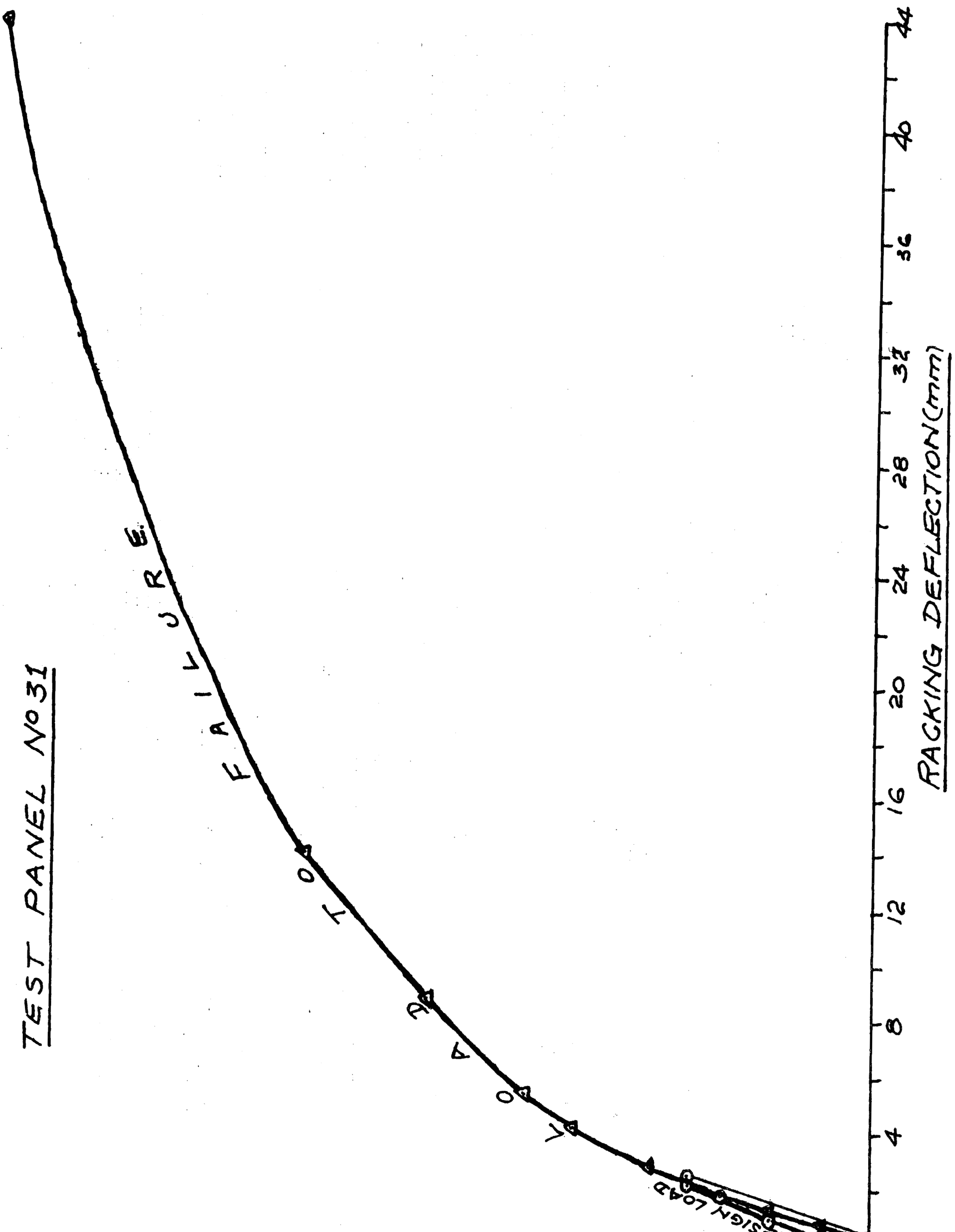

TEST PANEL No 31
LOAD TO FAILURE
DESIGN LOAD
RACKING DEFLECTION (mm)
RACKING LOAD (kN)
0
4
8
12
16
20
24
28
32
36
40
44

FIGURE 2.5

2.5 TEST PANEL 33

The timber framing used to construct the panel was 90 x 45 mm, F8 Radiata pine and the sheathing was 6 mm Hydroline. The nail spacing was the close pattern of 75/150 mm centres. No cyclone rod was fitted for this test.

Time-load-deflection results are given in Table 2.10 for the system loaded to the design and failure loads respectively. The design load of 6.75 kN was held for five minutes under no load. After a further five minutes under no load the panel was then loaded to failure.

Figure 2.6 shows a load-deflection plot of the data in Table 2.10. The load to failure curve is linear only to a load of 3.6 kN with a corresponding deflection of about 2 mm. This is a particularly low proportional limit load in view of the fact that the close nailing pattern was employed.

Panel failure occurred at a racking load of 24.3 kN. Failure resulted from material tear-out behind the third, sixth, eighth, and tenth nails in the bottom plate nearest the loaded end. There was little observable nail movement along the bottom plate of the middle and half sheets. Individual sheet rotation, although observable was only slight.

The panel surface was flat after positioning in the loading frame with no signs of buckling up to the design load.

WALL PANEL TEST RESULTS

TEST PANEL NO. 33

TEST LOAD TYPE: RACKING

Time (min.)	Racking Load (kN)	Dial Gauge Reading (mm)							
		Test Frame	Panel Defln.	Rigid Body	Horiz. Defln.	Panel Rotation			Actual Racking
		1	2	3	Δ	4	5	6	ΔR
0:00	0.00		0.00	0.00		0.00	0.00	0.00	0.00
	0.45		0.14	0.00		0.00	0.00	0.00	0.14
	0.90		0.25	0.01		0.00	0.00	0.00	0.24
	1.80		0.52	0.02		0.06	0.00	0.00	0.50
	2.25		0.71	0.02		0.11	0.01	0.00	0.69
	3.15		1.09	0.02		0.22	0.02	0.03	1.07
	3.60		1.38	0.03		0.29	0.04	0.05	1.35
	4.05		1.58	0.04		0.36	0.04	0.06	1.54
	4.95		2.30	0.05		0.59	0.10	0.07	2.25
	5.85		2.92	0.06		0.79	0.13	0.09	2.86
	6.30		3.20	0.07		0.89	0.15	0.10	3.13
5:00	6.75		3.51	0.08		0.99	0.17	0.12	3.43
10:00	6.75		3.59	0.09		1.02	0.17	0.12	3.50
11:00	0.00		1.02	0.00		1.41	0.08	0.11	1.02
16:00	0.00		0.95	0.00		0.00	0.00	0.00	0.95
	0.90		1.26	0.01		0.05	0.01	0.01	1.25
	1.80		1.48	0.02		0.09	0.01	0.01	1.46
	2.70		1.72	0.03		0.13	0.02	0.01	1.69
	3.60		2.01	0.03		0.20	0.03	0.00	1.98
	4.50		2.50	0.04		0.34	0.05	-0.01	2.46
	5.40		3.01	0.04		0.49	0.09	-0.01	2.97
	6.30		3.40	0.05		0.60	0.10	-0.01	3.35
	7.20		3.85	0.07		0.73	0.13	-0.04	3.78
	8.10		4.45	0.13		0.94	0.15	-0.06	4.32
	9.00		5.44	0.43		1.18	0.18	-0.09	5.01
	9.90		6.22	0.68		1.37	0.21	-0.10	5.54
	10.80		7.15	0.97		1.60	0.26	-0.10	6.18
	11.70		8.04	1.25		1.83	0.32	-0.11	6.79
	12.60		8.80	1.47		2.18	0.41	-0.11	7.33
	13.50		9.55	1.63		2.34	0.50	-0.11	7.92
	14.40		10.25	1.77		2.62	0.60	-0.11	8.48
	15.30		11.00	1.89		2.90	0.70	-0.09	9.11
	16.20		11.85	1.98		3.23	0.83	-0.06	9.87
	18.00		13.30	2.09		3.86	1.18	0.00	11.21
	19.80		15.20	2.21		4.80	1.46	0.10	13.00
	22.50		19.00						19.00
27:00	24.30		24.00						24.00

TABLE 2.10

PROOF LOAD: 6.75kN DEFLECTION: 3.50 mm

ULTIMATE LOAD: 24.30kN DEFLECTION: +24 mm.

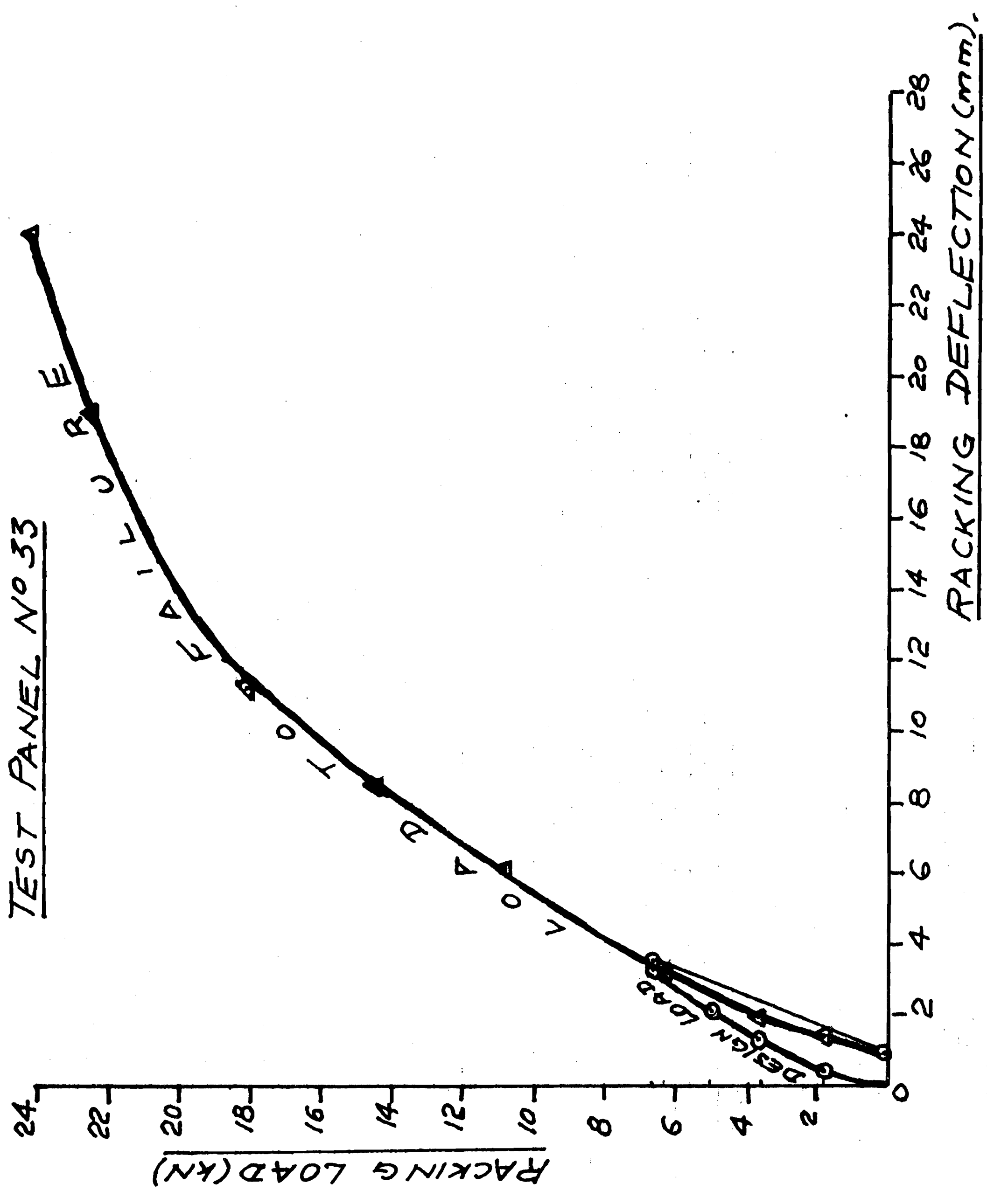

TEST PANEL No 33
LOAD TO FAILURE
DESIGN LOAD
RACKING LOAD (kN)
RACKING DEFLECTION (mm).
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28

FIGURE 2·6

2.6 TEST PANEL 35

The timber framing used to construct the panel was 70 x 45 mm, F8 Radiata pine and the sheathing was 6 mm Hydroline. The close 75/150 mm centres nailing pattern with no cyclone rod was used.

Time-load-deflection results are given in Table 2.11 for the system loaded to the design and failure loads respectively. The design load of 4 kn was held for five minutes and then released. After a further five minutes under no load the panel was then loaded to failure.

Figure 2.7 shows a load-deflection plot of the data in Table 2.11. The load to failure curve is linear to a racking load of approximately 4.5 kN and a corresponding deflection of 1 mm. At the 4.5 kN load the panel softens and the load-deflection curve is fairly linear to an estimated load of 15 kN.

Panel failure occurred at a racking load of 29 kN. The first sign of stud from bottom plate separation was observed to be at a racking load of 8.1 kN. Failure was due to material tear-out behind the first and second nails from the loaded end in the bottom plate. Nail deformations intimate total panel action (but more likely a truss type, partial panel action) rather than individual sheet rotation. In fact, there was considerable relative rotation between the middle and first sheet from the loaded end, however ther elative movement between the half and middle sheet was small.

The panel surface was reasonably flat when positioned in the loading frame although there were some indications of construction humps along the joist where the half and middle sheet butted together. These bumps did not worsen at the design load.

WALL PANEL TEST RESULTS

TEST PANEL NO. 35 **TEST LOAD TYPE:** RACKING

Time (min.)	Racking Load (kN)	Dial Gauge Reading (mm)							
		Test Frame	Panel Defln.	Rigid Body	Horiz. Defln.	Panel Rotation			Actual Racking
		1	2	3	Δ	4	5	6	ΔR
0:00	0.00		0.00	0.00		0.00	0.00	0.00	0.00
	0.45		0.09	0.01		0.00	0.01	0.00	0.08
	0.90		0.19	0.01		0.00	0.01	0.00	0.18
	1.35		0.29	0.01		0.01	0.01	0.00	0.28
	1.80		0.40	0.02		0.04	0.01	0.00	0.38
	2.25		0.56	0.02		0.06	0.01	0.00	0.54
	2.70		0.71	0.03		0.08	0.01	0.00	0.68
	3.60		0.86	0.03		0.10	0.01	0.00	0.83
3:00	4.00		1.02	0.04		0.13	0.01	0.00	0.98
8:00	4.00		1.06	0.04		0.14	0.00	0.00	1.02
00	0.00		0.20	0.00		0.14	0.00	0.00	0.20
14:00	0.00		0.18	0.00		0.00	0.00	0.00	0.18
	0.90		0.43	0.01		0.01	0.00	0.00	0.42
	1.80		0.58	0.02		0.04	0.00	0.00	0.56
	2.70		0.79	0.03		0.07	0.01	0.00	0.76
	3.60		1.05	0.03		0.11	0.01	0.00	1.02
	4.50		1.37	0.05		0.16	0.03	0.00	1.32
	6.30		2.25	0.06		0.44	0.12	0.00	2.19
	7.20		2.65	0.09		0.60	0.16	0.00	2.56
	8.10		3.08	0.11		0.78	0.22	0.00	2.97
	9.00		3.55	0.14		1.03	0.28	0.00	3.41
	10.80		4.53	0.19		1.57	0.41	0.02	4.34
	11.70		5.08	0.23		1.88	0.48	0.02	4.85
	13.50		6.20	0.30		2.54	0.63	0.05	5.90
	14.40		6.73	0.35		2.88	0.71	0.06	6.38
	15.30		7.38	0.41		3.23	0.82	0.08	6.97
	17.10		8.82	0.54		4.09	1.01	0.11	8.28
	18.00		9.54	0.61		4.56	1.14	0.14	8.93
	18.90		10.25	0.67		4.99	1.25	0.16	9.58
	19.80		11.10	0.75		5.45	1.38	0.20	10.35
	21.60		12.90	0.89		6.46	1.68	0.27	12.01
	22.50		13.90						13.90
	24.80		16.30						16.30
	27.80		20.80						20.80
	29.00		22.50						22.50

TABLE 2.11

PROOF LOAD: 4.00kN **DEFLECTION:** 1.02 mm

ULTIMATE LOAD: 29.00kN **DEFLECTION:** + 22.5mm.

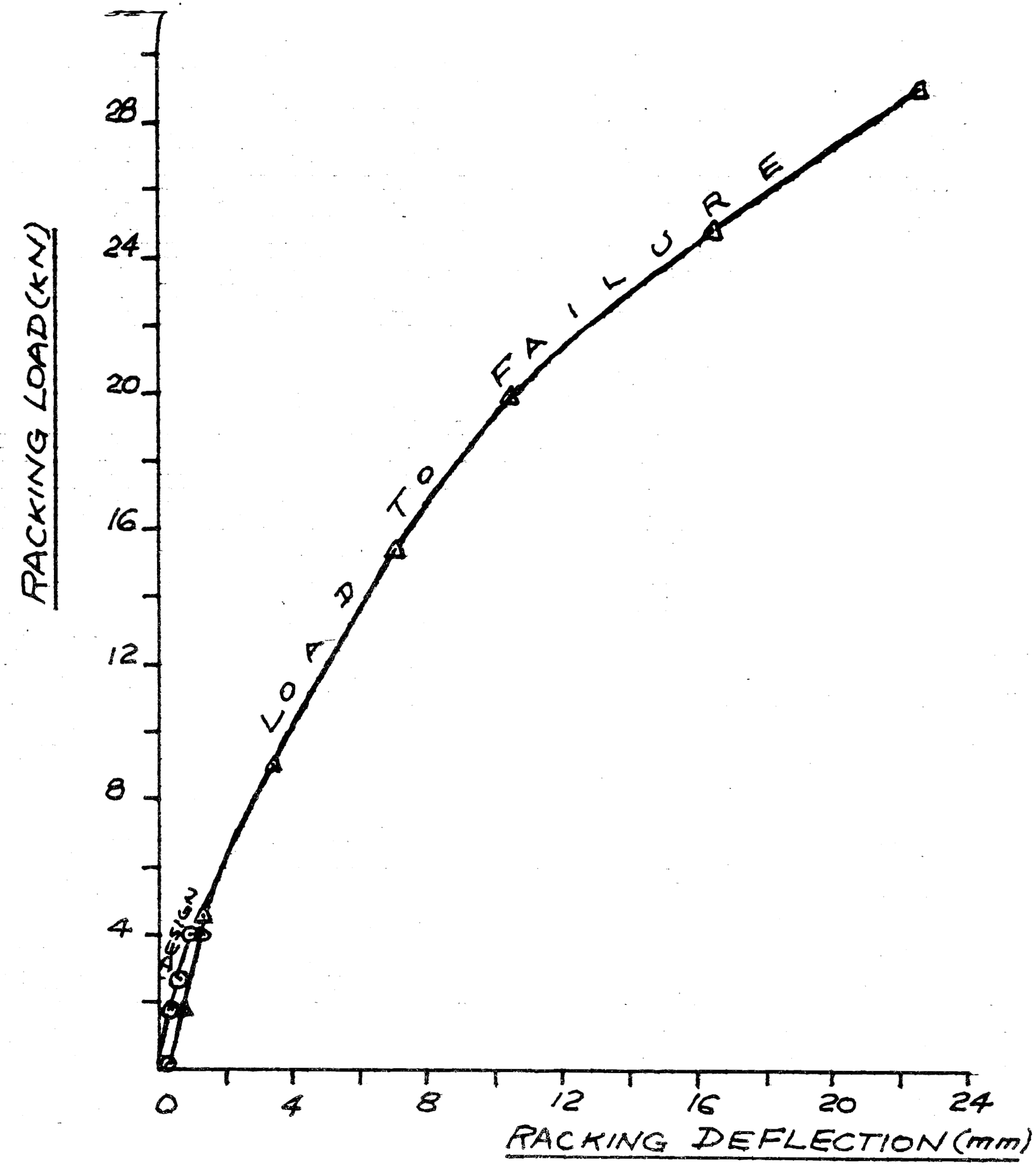

RACKING LOAD (kN)
28
24
20
16
12
8
4
0
4
8
12
16
20
24
RACKING DEFLECTION (mm)
LOAD TO FAILURE
DESIGN

FIGURE 2.7

2.7 TEST PANEL 38

The timber framing used in construction of the panel was sized for depth but not for width to 70 x 38 mm x F11 hardwood. The nail spacing was the standard 150/300 mm centres and no cyclone rod was fitted to the panel. All studs were generally free from any major defects.

Time-load-deflection results are given in Table 2.12 for the system loaded to the design and failure loads respectively. The design load of 4 kN was held for five minutes and then released. After a further five minutes without load the panel was then loaded to failure.

Figure 2.8 shows a load-deflection plot of the data in Table 2.12. The load to failure curve is linear to a load of 4 kN with a corresponding deflection of approximately 1.5 mm.

Panel failure occurred at a racking load of 18.6 kN. Failure resulted in mateiral tear-out behind the first two nails from the loaded end in the bottom plate. The third nail had commenced to withdraw fromt hebottom plate and the head was several millimetres clear of the sheathing. The fourth nail had partially pulled through the sheathing with a resulting material bearing failure behind it. Relative rotation between the two full sheets was in evidence whilst considerable relative rotation occurred between the half and middle sheets.

The panel surface was flat after location in the loading frame with no signs of buckling up to the design load.

WALL PANEL TEST RESULTS

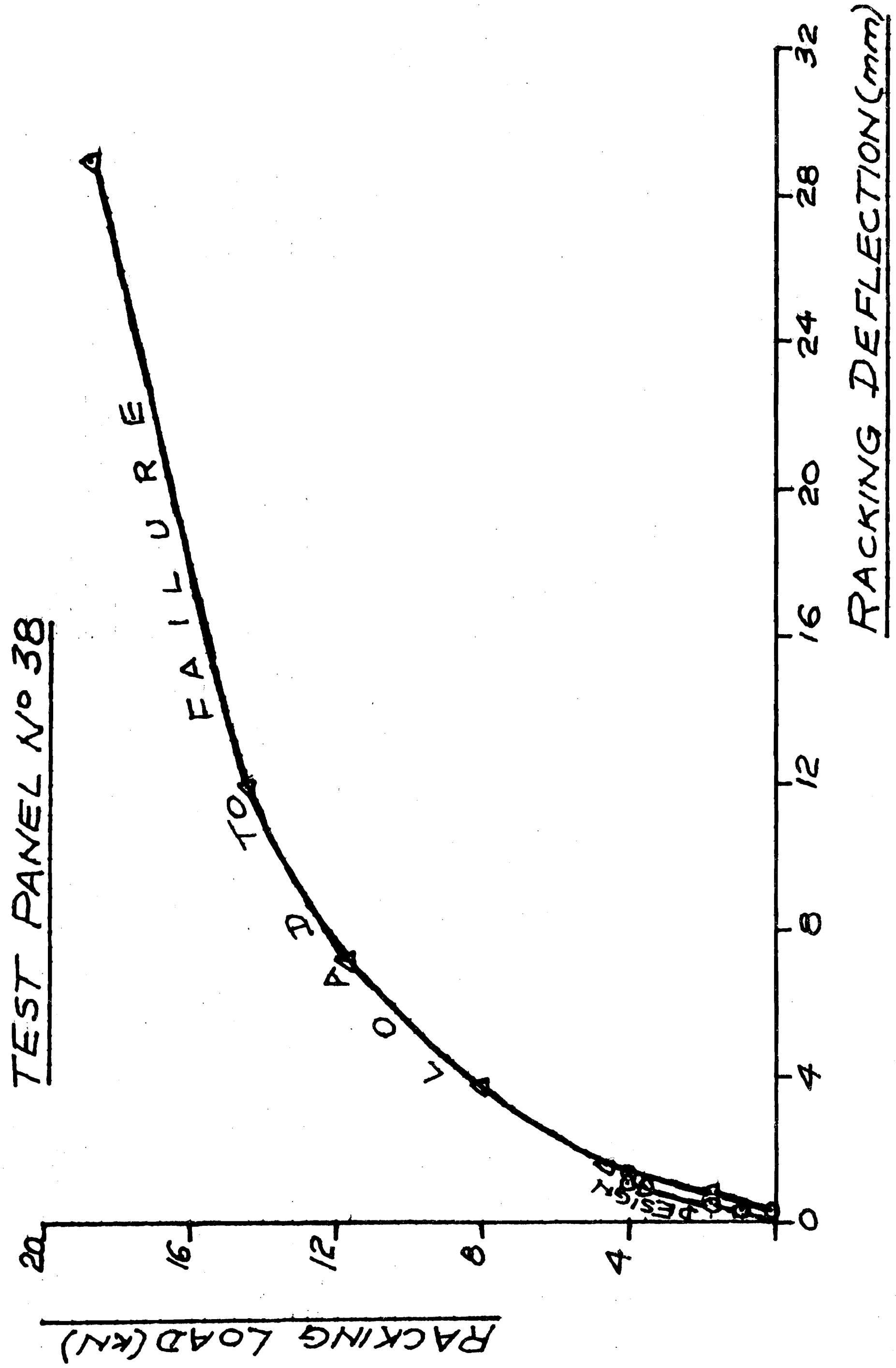
TEST PANEL NO. 38 TEST LOAD TYPE: RACKING

Time (min.)	Racking Load (kN)	Dial Gauge Reading (mm) Test Frame	Panel Defln.	Rigid Body	Horiz. Defln.	Panel Rotation			Actual Racking
		1	2	3	Δ	4	5	6	Δ_R
0:00	0.00		0.00	0.00		0.00	0.00	0.00	0.00
	0.45		0.25	0.01		0.00	0.01	0.01	0.24
	0.90		0.39	0.01		0.00	0.01	0.02	0.38
	1.35		0.42	0.02		0.00	0.01	0.05	0.40
	1.80		0.58	0.03		0.02	0.01	0.07	0.55
	2.25		0.69	0.03		0.03	0.01	0.08	0.66
	2.70		0.87	0.06		0.05	0.01	0.10	0.81
	3.60		1.09	0.11		0.07	0.01	0.11	0.98
3:20	4.00		1.36	0.20		0.09	0.01	0.14	1.16
8:20	4.00		1.49	0.24		0.11	0.02	0.14	1.25
9:00	0.00		0.39	0.19		0.03	0.02	0.06	0.39
14:00	0.00		0.36	0.00		0.00	0.00	0.00	0.36
	0.90		0.61	0.01		0.00	0.00	0.03	0.60
	1.80		0.82	0.02		0.01	0.00	0.05	0.80
	2.70		1.07	0.03		0.04	0.00	0.08	1.04
	3.60		1.45	0.05		0.09	0.00	0.10	1.40
	4.50		1.91	0.26		0.14	0.00	0.13	1.65
	5.40		2.64	0.46		0.27	0.04	0.14	2.18
	6.30		3.31	0.66		0.40	0.07	0.15	2.65
	7.20		4.04	0.85		0.51	0.10	0.20	3.19
	8.10		4.74	0.96		0.69	0.12	0.23	3.78
	9.00		5.48	1.05		0.86	0.16	0.27	4.43
	9.90		6.32	1.11		1.12	0.23	0.32	5.21
	10.80		7.25	1.18		1.50	0.39	0.30	6.07
	11.70		8.65	1.23		2.00	0.55	0.33	7.42
	12.60		10.05	1.27		2.50	0.69	0.35	8.78
	13.50		11.35	1.31		3.15	0.91	0.40	10.04
	14.40		13.35	1.35		3.97	1.16	0.50	12.00
	15.30		14.85	1.38		4.70	1.40	0.62	13.47
	16.20		17.45	1.42		5.90	1.85	0.80	16.03
24:00	18.60		29.00						29.00

TABLE 2.12

PROOF LOAD: 4.00kN DEFLECTION: 1.25 mm

ULTIMATE LOAD: 18.60kN DEFLECTION: +29 mm



TEST PANEL No 38
LOAD TO FAILURE
DESIGN
RACKING LOAD (kN)
0
4
8
12
16
20
24
28
32
RACKING DEFLECTION (mm)

FIGURE 2·8

2.8 DATA REDUCTION - RACKING

Table 2.13 presents all pertinent test and design data for the panels tested as structural bracing systems. The panel grouping of Table 2.13 was developed on the following bases:

(i) whether the framing was pine or hardwood,

(ii) framing member dimensions - from small to large,

(iii) nailing pattern - whether standard or close

(iv) whether or not a rod was fitted

Derivation of design racking loads were determined from the relationship:

$$\text{Design Racking Load/metre} = \frac{\text{Average Panel Test Load}}{\text{Load Factor} \times 3} \qquad (2.1)$$

where: Load Factor = 2.2 to 2.0

Panel Length = 3.0 m

2.8.1 Pine Framed Panels - Standard Nailing, No Rod

Test panels 1, 2, 15, and 16 constructed from 70 x 45 mm, F8 Radiata pine framing with sheathing connected using the standard nailing pattern and no cyclone rod, results in an average failure load in racking of 11.9 kN. Application of Equation 2.1 gives:

DESIGN RACKING LOAD/METRE = 2.0 kN.

Although the above allowable racking load is marginally unconservative on the basis of Equation 2.1 the writer believes it warranted on the basis of the test arrangement used to obtain failure loads for panels 1 and 2.

TEST PANEL IDENT.	P'BOARD TYPES & THICK.	CONNECTION			TIMBER FRAMING MEMBER SPEC.	ROD FITTED	DEFLECTIONS		RACKING FAILURE LOAD (kN)	COMMENTS
		Type	Edge nail crs. (mm)	Int. nail crs. (mm)			Design Load (mm)	Failure Load (mm)		
TP1	6 Fineline HMR	40x2·8ϕ gal. clouts	150	300	70x45xF8 Radiata	No	2·40	+14	9·9	Tested in original test rig
2	"	"	"	"	"	"	1·57	+24	10·4	"
15	6 Texpan HMR	"	"	"	"	"	2·54	+14	12·8	
16	"	"	"	"	"	"	2·64	+15	14·4	
3	6 Fineline HMR	"	75	150	70x45xF8 Radiata	No	1·38	+20	17·1	Tested in original test rig
35	6 Hydroline	"	"	"	"	"	1·02	+22	29·0	
37	"	"	"	"	"	"	1·04	+35	27·0	
E1(F)	6 Fineline HMR	"	150	300	90x45xF8 Radiata	No	5·28	+24	13·2	
E1(T)	6 Texpan HMR	"	"	"	"	"	5·89	+22	15·2	
5	6 Fineline HMR	"	"	"	"	"	4·29	+28	14·9	First test in modified rig
17	6 Texpan HMR	"	"	"	"	"	6·12	+15	12·6	
18	"	"	"	"	"	"	4·85	+20	16·1	
19	"	"	"	"	"	"	2·63	+27	17·9	
7	6 Fineline HMR	"	75	150	90x45xF8 Radiata	No	3·48	+24	21·5	
33	6 Hydroline	"	"	"	"	"	3·50	+24	24·3	

TABLE 2·13

TABLE 2·13

TEST PANEL IDENT.	P'BOARD TYPES & THICK.	CONNECTION Type	CONNECTION Edge nail crs. (mm)	CONNECTION Int. nail crs. (mm)	TIMBER FRAMING MEMBER SPEC.	ROD FITTED	DEFLECTIONS Design Load (mm)	DEFLECTIONS Failure Load (mm)	RACKING FAILURE LOAD (kN)	COMMENTS
TPG	6 Fineline HMR	40x2·8ϕ gal. clouts	150	300	90x45xF8 Radiata	YES	3·25	+36	26·8	
31	6 Hydroline	"	"	"	"	"	2·35	+44	28·9	
8		"	75	150	90x45xF8 Radiata	YES	2·33	+40	44·2	
32		"	"	"	"	"	2·65	+22	+40·0	Jack jumped out of loading frame
38	6 Hydroline	"	150	300	70x38xF11 hardwood	NO	1·25	+29	18·6	
39	"	"	"	"	"	"	1·11	+24	18·6	
25	"	"	"	"	70x50xF11 hardwood	"	3·41	+25	18·9	
36	"	30x2·8ϕ gal. clouts	"	"	"	"	2·57	+24	19·0	
28	6 Hydroline	40x2·8ϕ gal. clouts	150	300	70x40xF17 hardwood	NO	2·70	+14	18·9	
34	"	"	"	"	"	"	2·66	+20	15·9	
12	6 Fineline HMR	"	75	150	70x50xF11 hardwood	NO	2·54	+22	26·3	
27	6 Hydroline	"	"	"	"	"	2·08	+21	28·4	
29	6 Hydroline	"	150	300	70x50xF11 hardwood	YES	3·32	+35	29·7	
30	"	"	"	"	"	"	3·19	+36	28·8	

TABLE 2·13

Tests panels E1(F), E1(T), 5, 17, 18, and 19 constructed of 90 x 45 mm, F8 Radiata pine framing with sheathing connected using the standard nailing pattern, results in an average failure load in racking of 15 kN. Test panels identified as E1(F) and E1(T) were constructed as "control panels" for the exposure testing programme and were tested without having been subjected to weathering. Application of Equation 2.1 gives:

DESIGN RACKING LOAD/METRE = 2.5 kN

2.8.2 Pine Framed Panels - Close Nailing, No Rod

Test panels 3, 35, and 37 constructed of 70 x 45 mm, F8 Radiata pine framing with sheathing connected using the close nailing pattern of no cyclone rod results in an average failure load of 24.4 kN which, on comparison to other results appears high. Bearing in mind that Test Panel 3 was tested in the original loading rig it is proposed that this is a conservative value. However, since it would not be expected, in practice at least, for the closer nailing pattern to double the load carrying capacity, this result has been included. Application of Equation 2.1 gives:

DESIGN RACKING LOAD/METRE = 3.5 kN

Test panels 7 and 33 constructed from 90 x 45 mm, F8 Radiata pine framing with sheathing connected using the close nailing pattern, results in an average failure load in racking of 23 kN. Application of Equation 2.1 gives:

DESIGN RACKING LOAD/METRE = 3.5 kN

2.8.3 Pine Framed Panels - Standard Nailing, Rod Fitted

Test panels 6 and 31 constructed from 90 x 45 mm, F8 Radiata pine framing with sheathing connected using the standard nailing pattern and with a cyclone rod fitted, results in an average failure load in racking of 27.9 kN. Application of Equation 2.1 gives:

DESIGN RACKING LOAD/METRE = 4 kN

2.8.4 Hardwood Framed Panels - Standard Nailing, No Rod

Test panels 38, 39, 25, 36, 28, and 34 construted from 70 x 38 and 70 x 50 mm, F11 hardwood and 70 x 40 mm, F17 hardwood framing with sheathing connected using the standard nailing pattern and no cyclone rod, results in an average failure load in racking of 18.3 kN. Application of Equation 2.1 gives:

DESIGN RACKING LOAD/METRE = 3.0 kN

2.8.5 Hardwood Framed Panels - Close Nailing, No Rod

Test panels 12 and 27 constructed of 70 x 50 mm, F11 hardwood framing with sheathing connected using the close nailing pattern, results in an average failure load in racking of 27.4 kN. Application of Equation 2.1 gives:

DESIGN RACKING LOAD/METRE = 4 kN

2.8.6 Hardwood Framed Panels - Standard Nailing, Rod Fitted

Test panel 29 constructed of 70 x 50 mm, F11 hardwood framing with sheathing connected using the standard nailing pattern and with a cyclone rod fitted gives a failure load of 29.7 kN. This test was performed to determine if any signficant difference resulted between the use of the 90 x 45 mm, F8 Radiata pine and the hardwood framing. Since results were highly compatible the design load for the hardwood framing was taken as:

DESIGN RACKING LOAD/METRE = 4 kN

2.8.7 Pine Framed Panels - Close Nailing, Rod Fitted

Test panels 8 and 32 constructed of 90 x 45 mm, F8 Radiata pine framing with sheathing connected using the close nailing pattern and with a cyclone rod fitted resulted in an average failure load in racking of 44.1 kN. Application fo Equation 2.1 gives:

DESIGN RACKING LOAD/METRE = 6.5 kN.

Table 2.14 groups the panels according to the size of the timber framing members, nailing pattern, and whether or not a cyclone rod is fitted.
From Table 2.14 the condensed results become:

FRAMING	NAILING PATTERN	ROD	DESIGN RACKING LOAD
Pine	Standard	No	2.0 kN/m
Pine	Close	No	3.5 kN/m
Hardwood	Standard	No	3.0 kN/m
Hardwood	Close	No	4.0 kN/m
Pine & Hardwood	Standard	Yes	4.0 kN/m
Pine & Hardwood	Close	Yes	6.5 kN/m

NOTES:

- Allowable racking loads are given for continuous wall panels, ie, without openings
- Rodded panels must have a cyclone bolt fitted at either end of the panel within 100 mm of the end studs.
- Nails to be a minimum diameter of 2.8 mm and must be 40 mm long to attach sheathing to pine studs and a minimum of 30 mm long for connection to hardwood framing.
- Sheathing should be located a minimum of 2 mm from the bottom edge of the bottom plate.
- Outside edge distances to nail centres should be a minimum of 20 mm. Where sheets butt on internal studs the landing should be approximately halved to give the position for driving the nail.
- Where a partial sheet covers only <u>two</u> studs, i.e. 450 or 600 mm sheet, allowable design loads <u>must not</u> be interpolated.

The allowable racking loads have been generated from a test procedure which provides only minimal restraint to the top plate. Further, there is no restraint offered to the racking wall from any transverse wall, which would, in a properly designed dwelling act similarly to a cyclone rod. The writer, therefore considers the allowable racking loads to be generously conservative except for the partial sheet case.

PANEL FRAMING TYPE	NO. OF TESTS	NAILING PATTERN	ROD FITTED (mm)	AV. FAIL RACKING LOAD (kN)	DESIGN RACKING LOAD (kN/m)
70 x 45 x F8	4	150/300	No	11.9	2.0
70 x 38 x F11	2	150/300	No	18.6	
70 x 50 x F11	2	150/300	No	18.9	2.5
70 x 40 x F17	2	150/300	No	17.4	
70 x 45 x F8	3	75/150	No	24.3	3.5
70 x 50 x F11	2	75/150	No	27.4	4.0
70 x 50 x F11	2	150/300	Yes	29.8	4.0
90 x 45 x F8	6	150/300	No	15	2.0
90 x 45 x F8	2	75/150	No	22.9	3.5
90 x 45 x F8	2	150/300	Yes	27.9	4.0
90 x 45 x F8	2	75/150	Yes	44.1	6.5

TABLE 2.14

2.9 CONCLUSIONS

In viewing the complete spectrum of results the parameters held constant for purposes of this report were:

- sheathing thickness (6 mm)
- stud spacing (600 mm centres)
- nail dimensions (TP 36 excepted)

The parameters that were varied were:

- nailing pattern
- stud dimensions
- stud stress grade
- whether or not a rod was fitted
- sheathing material

The two parameters most significantly influencing panel response under racking load were the nailing pattern and whether or not a cyclone rod was incorporated during panel construction. Inclusion of the rod, in conjunction with the standard nailing pattern promoted:

(i) individual sheet rotation causing all nails excepting those at the centre of rotation to deform

(ii) excessive nail deformation with no material tear-out behind nails

(iii) sheathing to transfer only the applied moment from panel racking due to the rod developing the tension causing rigid body rotation.

Using the close nailing pattern, in general, resulted in a panel strength about the same as for inclusion of a rod in conjunction with the standard nailing pattern. However, the exception to this rule was close nailed sheathing on 90 x 45 mm, F8 Radiata pine framing. Hence, a generalisation of performance for these panel groups is precluded, unless additional tests were to indicate differently.

Panels constructed from framing comprising hardwood studs having a stress grade greater than F11 do not show any increase in racking resistance. They do however, show improvement over panels of pine framing, where the standard nailing pattern is used.

Sheathing type appeared to have some marginal effects on results in that the Fineline sheathing (since replaced by Hydroline) consistently yielded lower failure loads in racking than either Texpan or Hydroline. Fineline was a green coloured board which looked very presentable when used in panel construction.

On the question of racking resistance of partial walls, mathematical modelling of the bracing wall, with sheathing discreetly attached by elastic dowel (nail) type connectors, shows the panel stiffness to be given by the expression:

$$\Delta = \frac{h^2}{c} \cdot \frac{I_X + I_Y}{I_X I_Y} \cdot R$$

Where:

K_p = panel stiffness in racking

$I_x I_y$ = second moment of areas of ~~wall~~ nail groups about the group centroidal axes.

For a given, allowable racking deflection, the racking resistance of a panel must therefore be proportional to the parameter $I_x I_y / I_x + I_y$. Figure 2.8 shows a plot of the linearised racking loads based on test results compared to the same range of panels based on their stiffness.

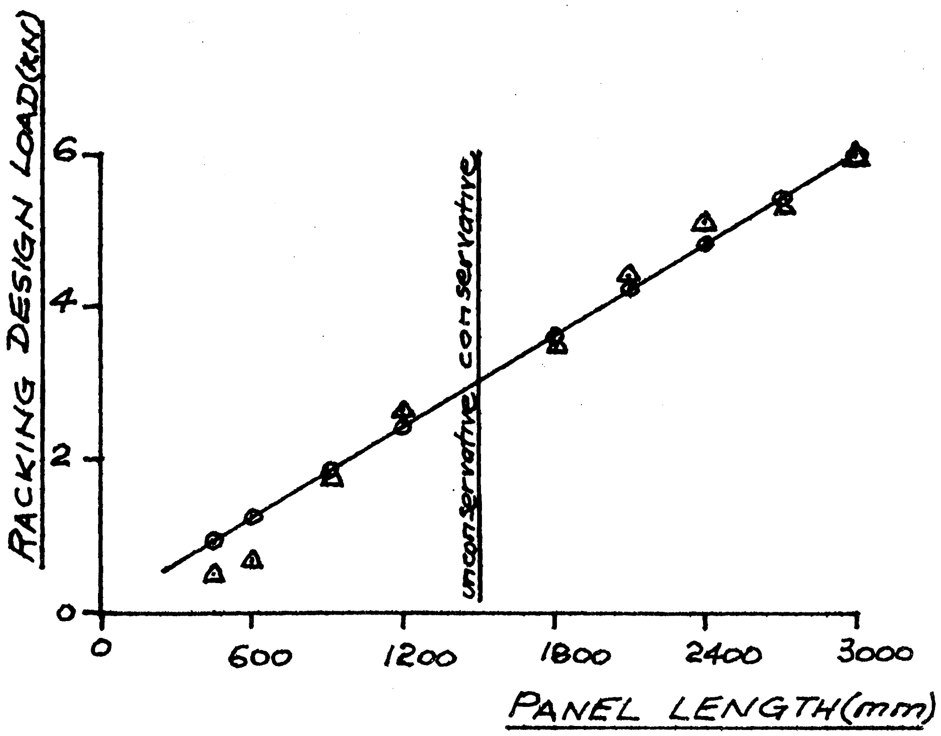


FIGURE 2·8

From the plot of Figure 2.8 it can be seen that panel lengths of 2700, 1800 & 900 are all slightly unconservative but not to the extent to cause any alarm. However, for the partial sheets of 450 & 600mm lengths, it is evident that they are unconservative to a degree worthy of concern. Hence the warning concerning partial sheets in the Notes.