JAMES COOK UNIVERSITY

CYCLONE STRUCTURAL TESTING STATION

INVESTIGATION OF DIAPHRAGM ACTION OF CEILINGS

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PREFACE

It should be noted that this progress report is a summary of interim test results obtained as part of an extensive research programme. The authors believe that it is of benefit to the building industry to publish their findings in this manner, but stress that any conclusions drawn from these tests should be considered to be interim until the final report is published. Whilst it is unlikely that subsequent

INVESTIGATION OF DIAPHRAGM ACTION OF CEILINGS

- PROGRESS REPORT 2

George R. Walker
Geoffrey N. Boughton
David Gonano

SYNOPSIS

The Department of Civil and Systems Engineering at James Cook University of North Queensland and the James Cook Cyclone Structural Testing Station are currently engaged in a major joint program of research related to the transmission of wind forces in domestic housing.

One of the major projects within this program is a study of the capacity of the ceiling structure to transmit horizontal forces from the external walls to the bracing walls by diaphragm action. This project, which is being undertaken within the Department of Civil and Systems Engineering, with assistance from the Cyclone Testing Station, is being supported by the Australian Housing Research Council.

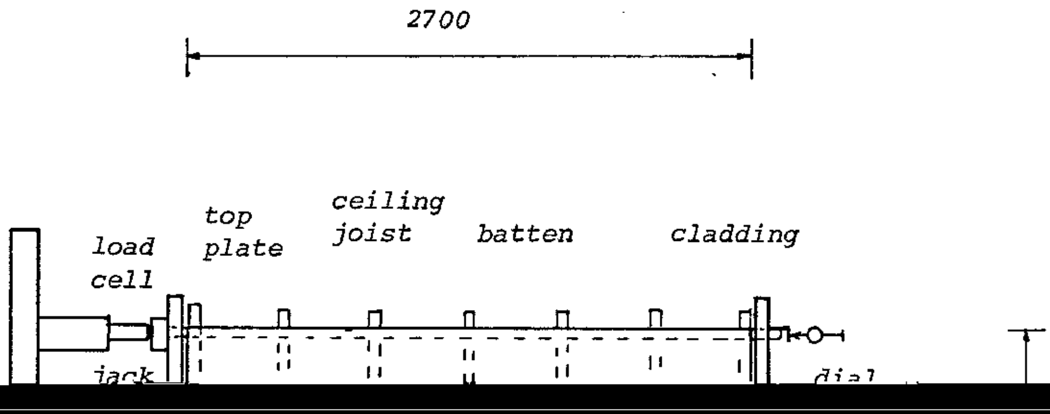
This report describes the results of the second phase of tests on ceiling panel assemblies undertaken as part of this project. Twelve tests are described, nine on plasterboard ('Gyprock') ceiling systems and three on fibre cement ('Versilux') systems. The systems are considered representative of many of the systems used in domestic housing. The size of panels tested and the testing procedure were similar to those used in the first

1. INTRODUCTION

This is the second interim report on a research project funded by the Aust- [redacted]

2. EXPERIMENTAL PROCEDURE

The ceiling panels were tested in the same manner as those in the first phase -i.e. as shear walls using the University Wall Testing Machine.


2700
load
cell
top
plate
ceiling
joist
batten
cladding
jack

...TENERS		BATTENS		JOIST SPACING mm	ULTIMATE LOAD kN	EQUIVALENT DESIGN LOAD kN/m	EQUIVALENT DESIGN STIFFNESS kN/mm	COMMENTS
	Spacing mm	Material	Spacing mm					
...et	150 perim. 200 ctre.	Pine	450	900	12.0	1.71	-	
...pe	300	Pine	450	900	3.6	0.51	0.55*	*Estimated
...ad ...w	300	CSR Furring ch.	450	750	1.1	0.16	-	
...5 ...pe	300	-	-	395	5.2	0.74	0.84	Fixed diredtly to joists
... ...et	150 perim 200 centre	-	-	395	6.0	0.85	0.80	Fixed directly to joists
... ...et	150 perim 200 centre	Pine	450	790	5.6	0.80	0.51	
... ...et	150 perim 200 centre	Pine	450	790	12.7	1.81	1.31	Edge battens nailed to top plates

Table 1 Summary of Test Results

CLADDING		FASTENERS		BATTENS		JOIST SPACING mm	ULTIMATE LOAD	EQUIVALENT DESIGN LOAD kN/m	EQUIVALENT DESIGN STIFFNESS kN/mm	COMMENTS
...erial	Size mm x mm	Type	Spacing mm	Materials	Spacing mm					
...rock mm	3 x 2700 x 1200	8.18 x 25 Hi-Lo Type S Screws	300	Pine	450	790	8.0	1.14	1.24	Gap at edge of sheet filled with plaster
...rock mm	2 x 2700 x 1200	6.2 x 25 Bugle Head Tek Screws	300	CSR Furring ch.	450	790	4.5	0.64	0.27	Gap at edge of sheet filled with plaster
...rock mm	2 x 2700 x 1200	8.18 x 25 Hi-Lo Type S Screws	300	Pine	450	790	6.0	0.85	1.04	Nogging at edges
...rock mm	2 x 2400 x 1350	8.18 x 25 Hi-Lo Type S Screws and glue	Screw 270 Glue 225	-	-	395	6.2	0.88	0.87	Glued and Screwed directly to joists
...rock mm	2 x 2700 x 1200	6.2 x 25 Bugle Head Tek Screws	300	Lysaght steel battens	450	790	4.5	0.64	0.60	Battens pierce fixed to joists
...rock mm	2 x 2400 x 1350	8.18 x 30 Hi-Lo Type S Screws	265	-	-	395	6.8	0.97	0.99	Fixed directly to joists
...rock mm	2 x 2400 x 1350	8.18 x 30 Hi-Lo Type S Screws	265	-	-	395	5.7	0.81	0.70	Fixed directly to joists
...rock mm	2 x 2700 x 1200	8.18 x 30 Hi-Lo Type S Screws	300	Pine	450	900	3.75	0.53	0.63	

Table 1 Summary of Test Results

(continued)

do underestimate deflections at lower loads and over estimate deflections at recommended 30 mm long screws).

An increase of 120 percent in the ultimate load capacity was obtained and a

[redacted]

[redacted]

[redacted]

least of the order of thirty to forty percent. The inconsistency is greater previous test with 'versilux' cladding, and in which the cladding was attached to pine battens and to noggings between the battens along the edges of the [illegible]

alent plasterboard tests -i.e. with the plasterboard fixed directly to the ceiling joists.

The test suggests that this system is adequate for W42 construction providing bracing walls are restricted to a maximum spacing of 6.5 m and the internal building width is not less than 7 m.

4.2.2 Test 6

[illegible]

This confirms the opinion given following Test 1 based on observed distress of cladding fasteners that the panel was close to failure due to pull through of the cladding fasteners when the batten/ceiling joist connection failure occurred. It also confirmed that nogging between the battens along

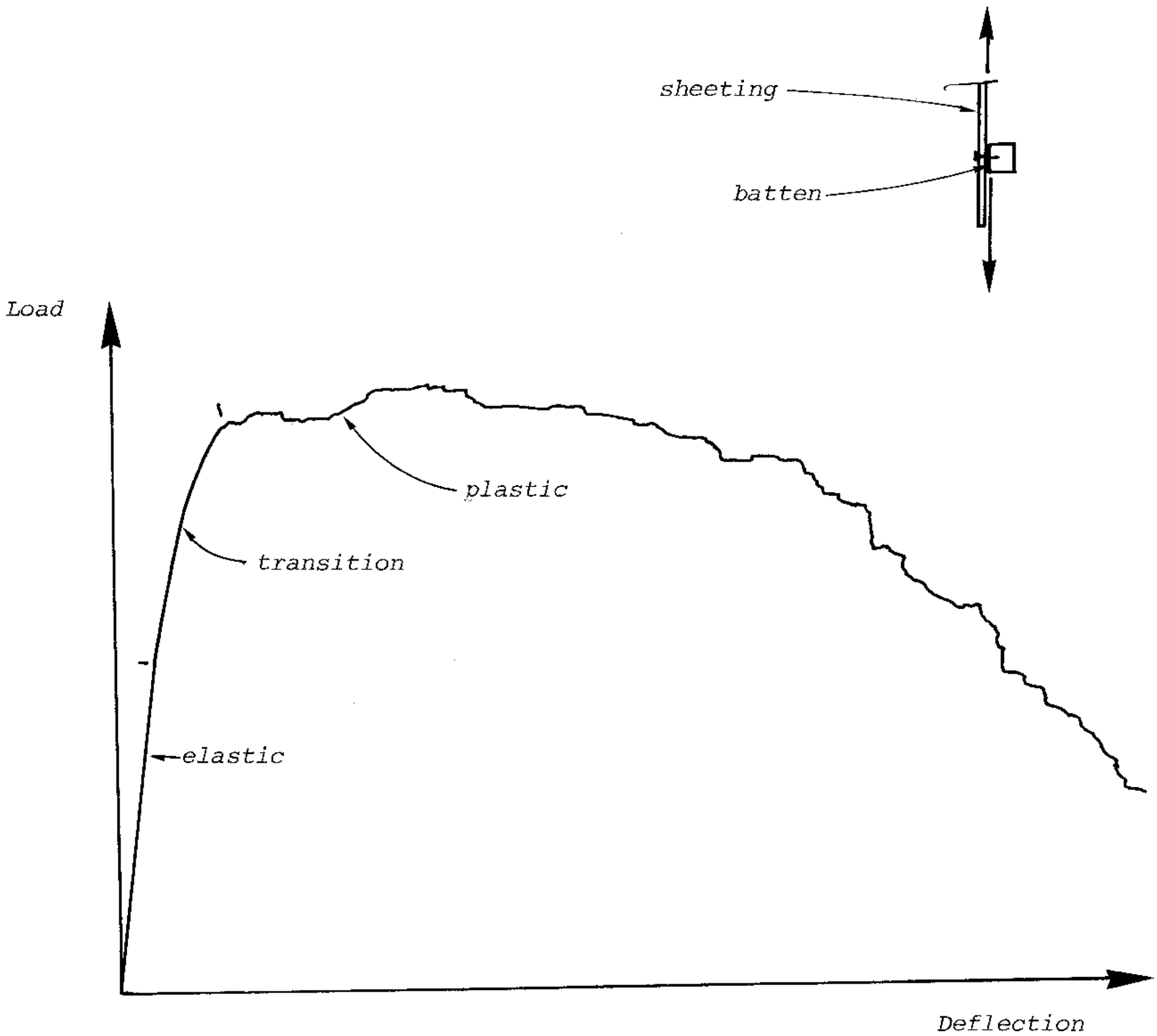
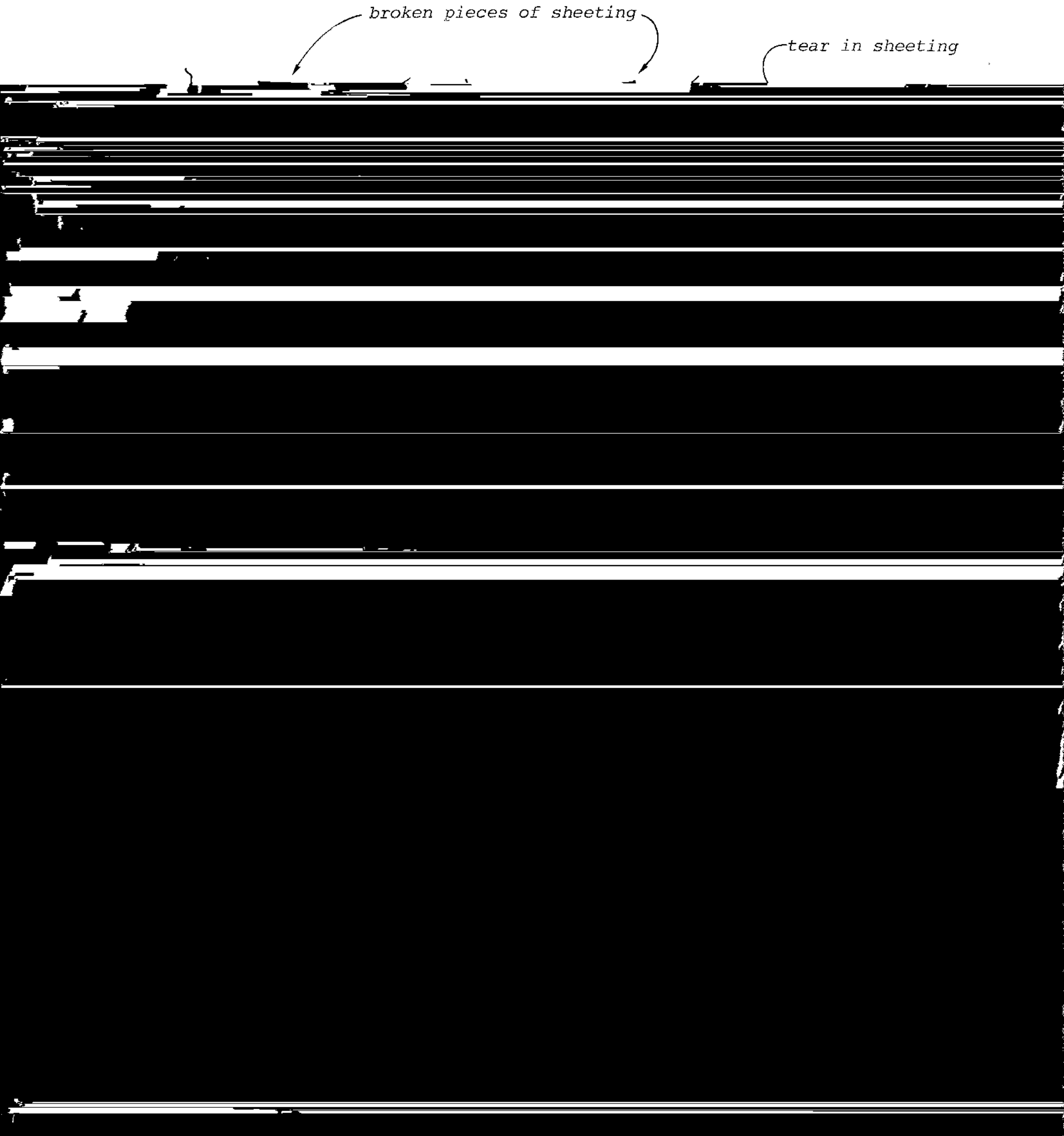


Figure 3 Load - Deflection Curve for a Single Fastener Loaded in-plane of the Sheeting.

of the system under test. This can be appreciated when the failure patterns


broken pieces of sheeting
tear in sheeting

[redacted]

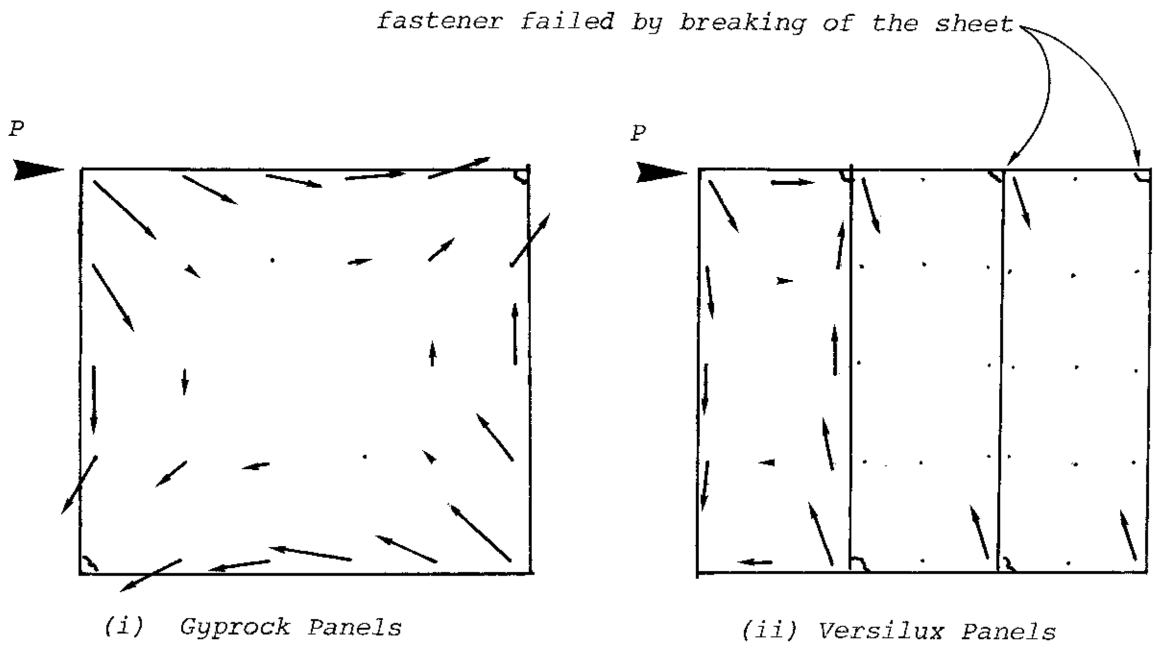


Figure 7 Deflections of Fasteners in Sheeting during the Transition Portion of the Test

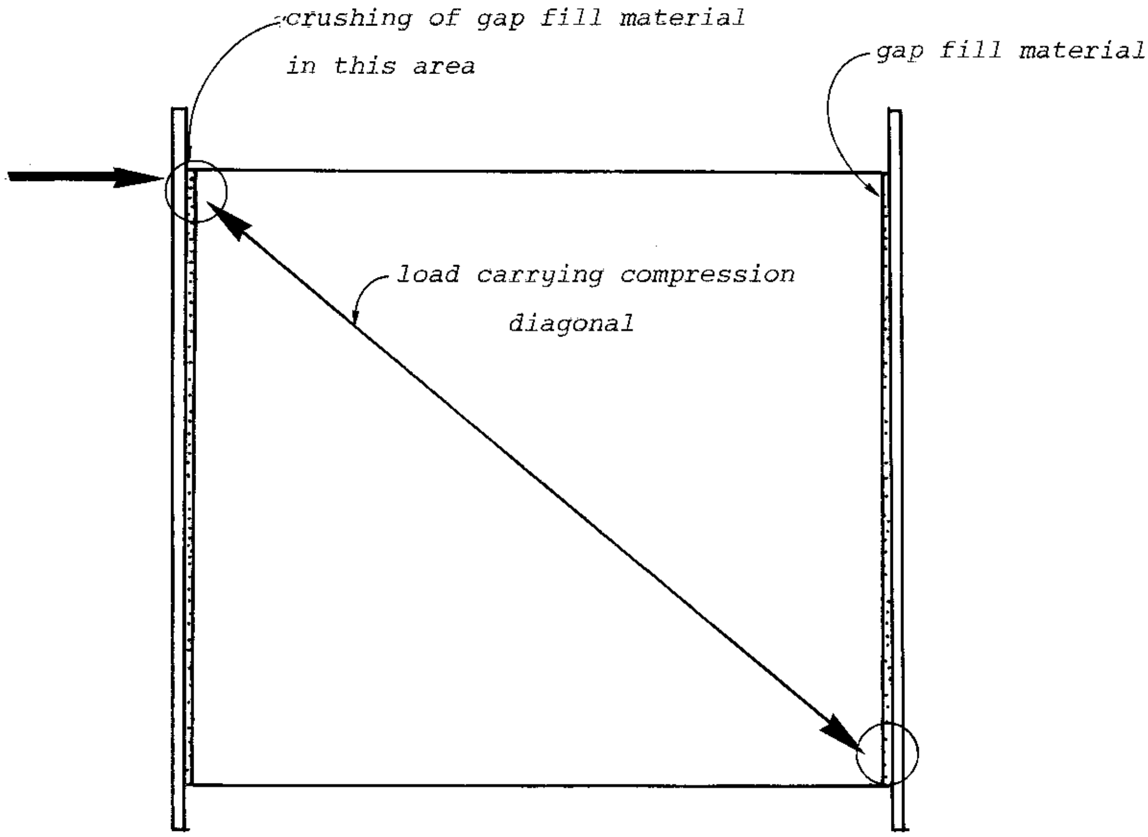


Figure 8 Bearing of Gap Fill Material along the Compression Diagonal

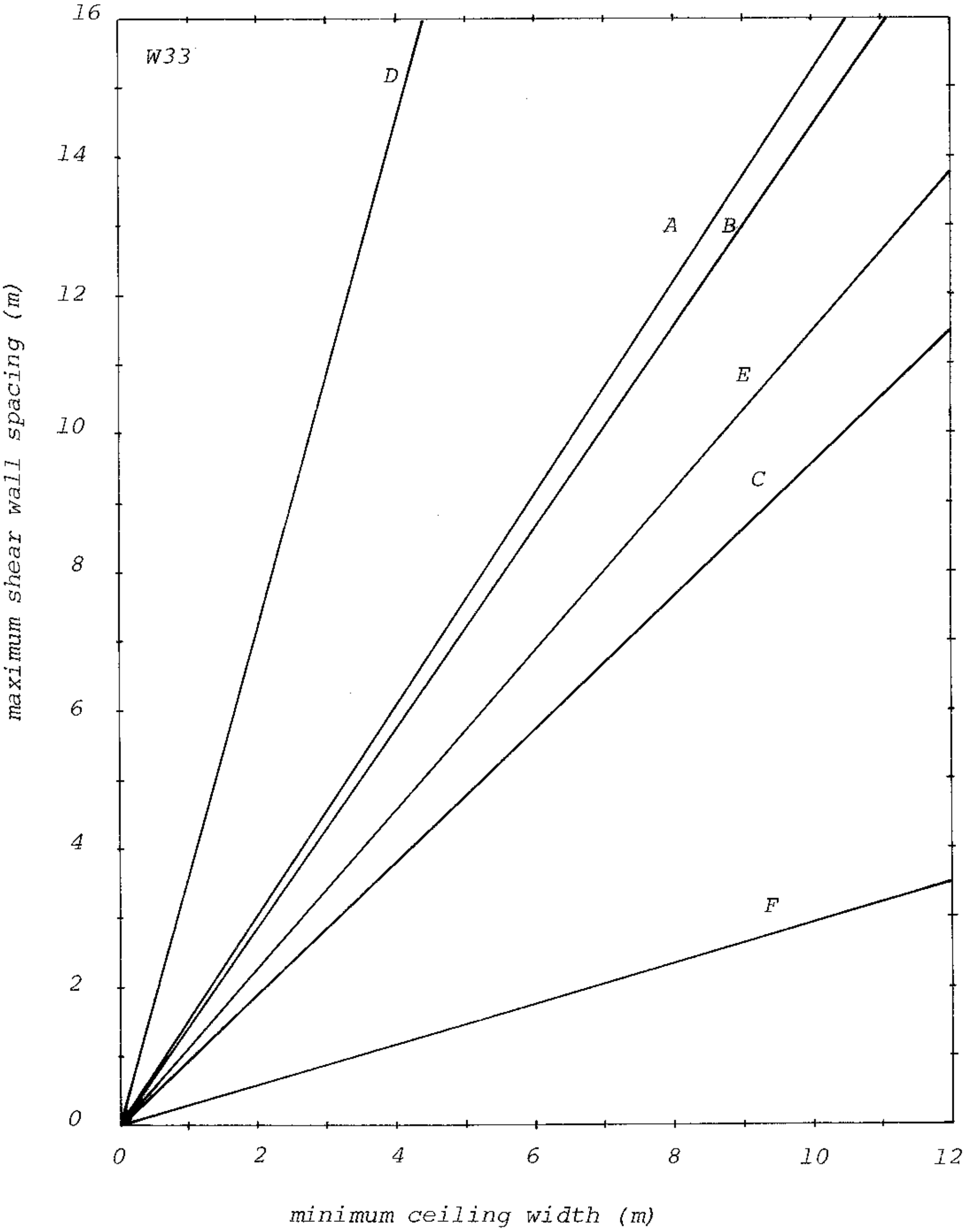
ing away from the sheeting through an edge, causes load on the remaining fasteners to change in both magnitude and direction. Thus the load - deflection curve for a particular fastener changes due to load redistribution as tests proceed. Typically characteristics change from those shown in figure 4(ii) towards those shown in figure 4(iii) which tends to prolong the plastic portion of the panel load - deflection curve.

At the failure point, failure of one fastener and subsequent load redistribu- [illegible]

Some general conclusion are:

. systems in which the cladding is directly attached to the ceiling

[redacted]



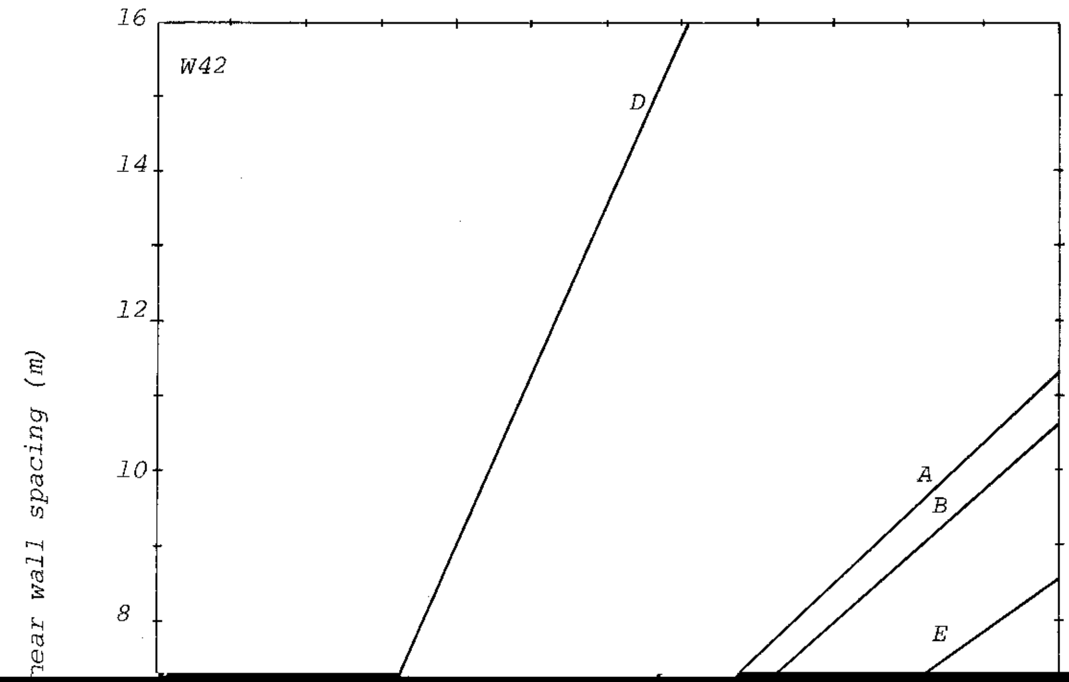
A - Gyprock and Versilux direct to joists as per Tests 13 and 5 respectively

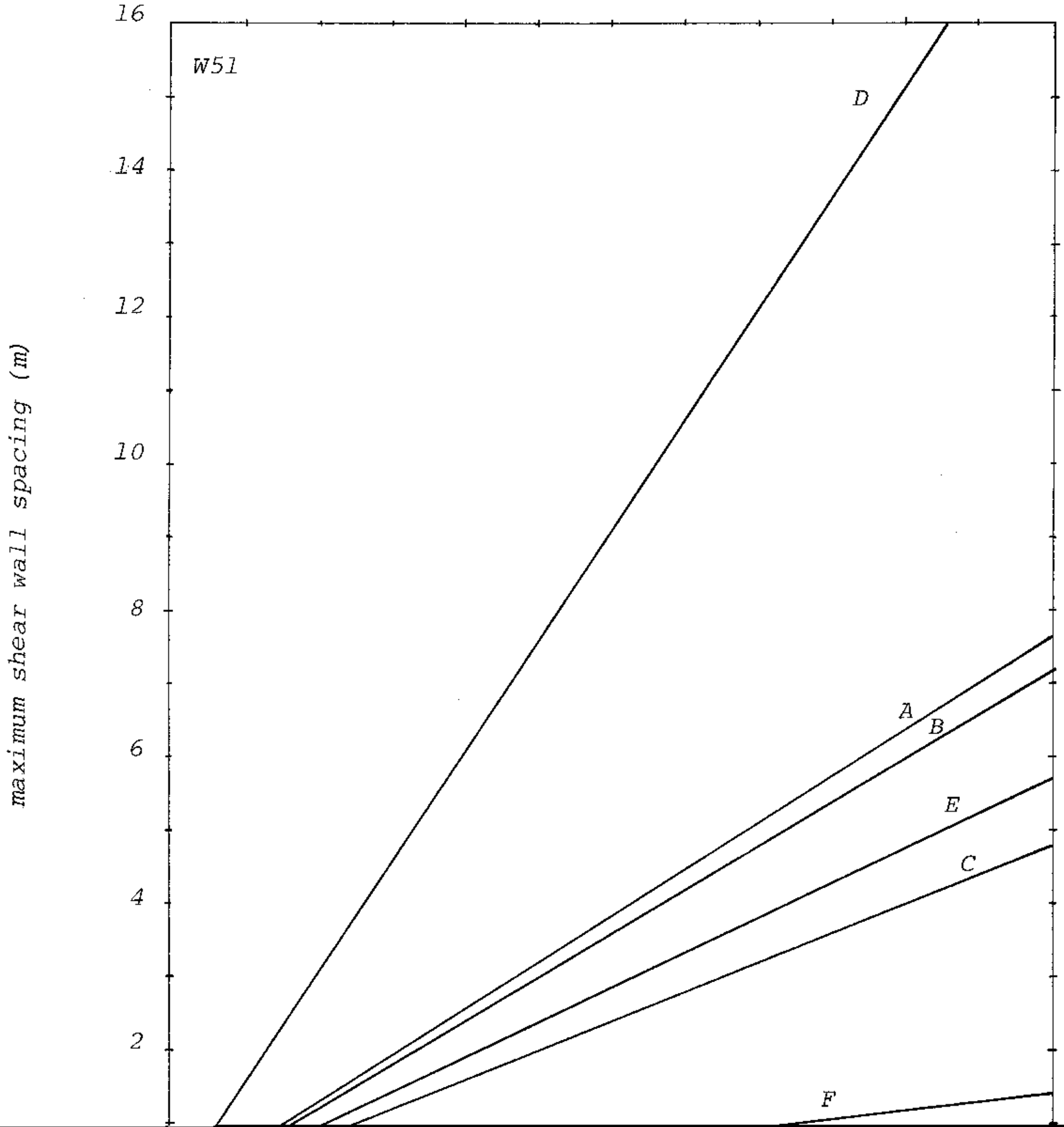
B - Versilux on timber battens as per Test 6

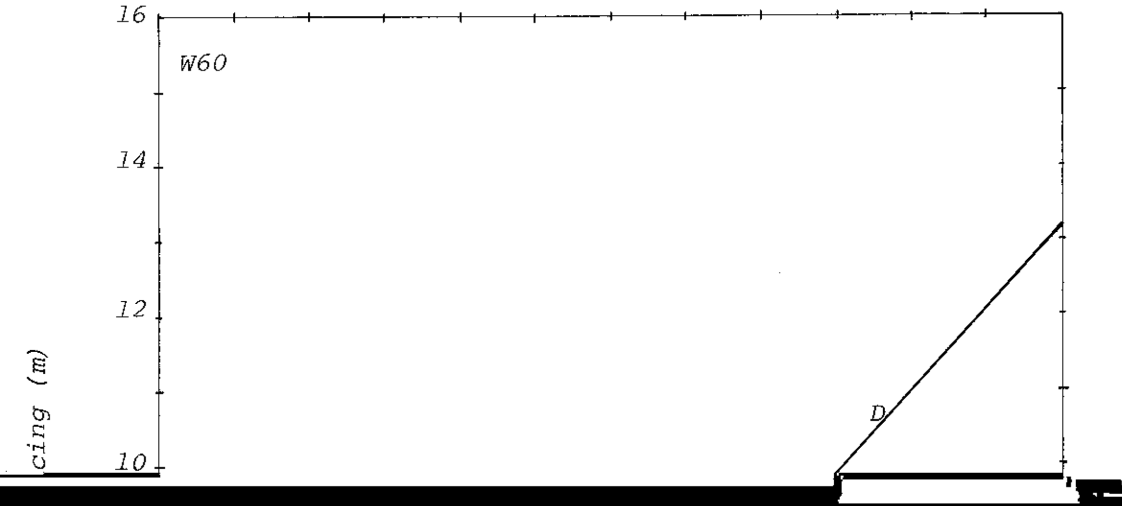
C - Gyprock on timber battens as per Test 15

D - Versilux on timber battens and nogging as per Test 7

[illegible]


16
14
12
10
8
W42
D
A
B
E
wall spacing (m)


W51
D
A
B
E
C
F
16
14
12
10
8
6
4
2
maximum shear wall spacing (m)


16
W60
14
12
cing (m)
10
D

8. REFERENCES

1. Walker, G.R. and Gonano, D. Investigation of Diaphragm Action of Ceilings - Progress Report 1. Technical Report No. 10, James Cook Cyclone Structural Testing Station, November, 1981.

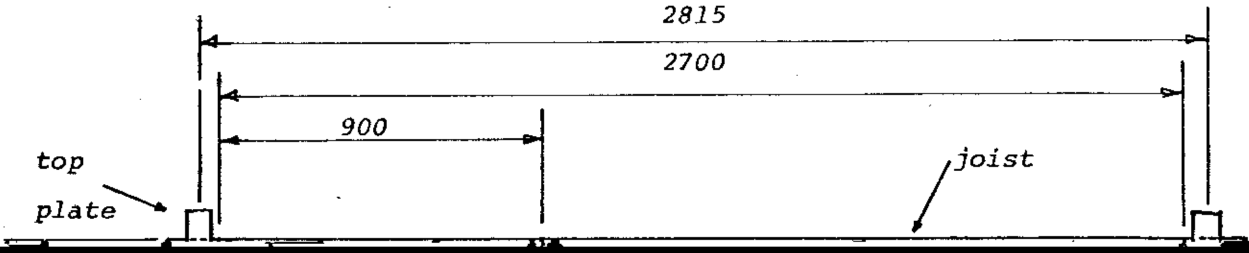
2. Guidelines for Cyclone Product Testing and Evaluation. Technical Record 440, Experimental Building Station, Sydney, 1977.

APPENDIX
DETAILS OF TESTS

A.1 TEST 4

A.1.1 Test Panel

[redacted]


2815
2700
900
top
plate
joist

were fastened perpendicular to the ceiling joists using 25 x 1.8 mm Flex Sheet nails at 150 mm spacing around the perimeter of each sheet and 200 mm spacing [illegible]

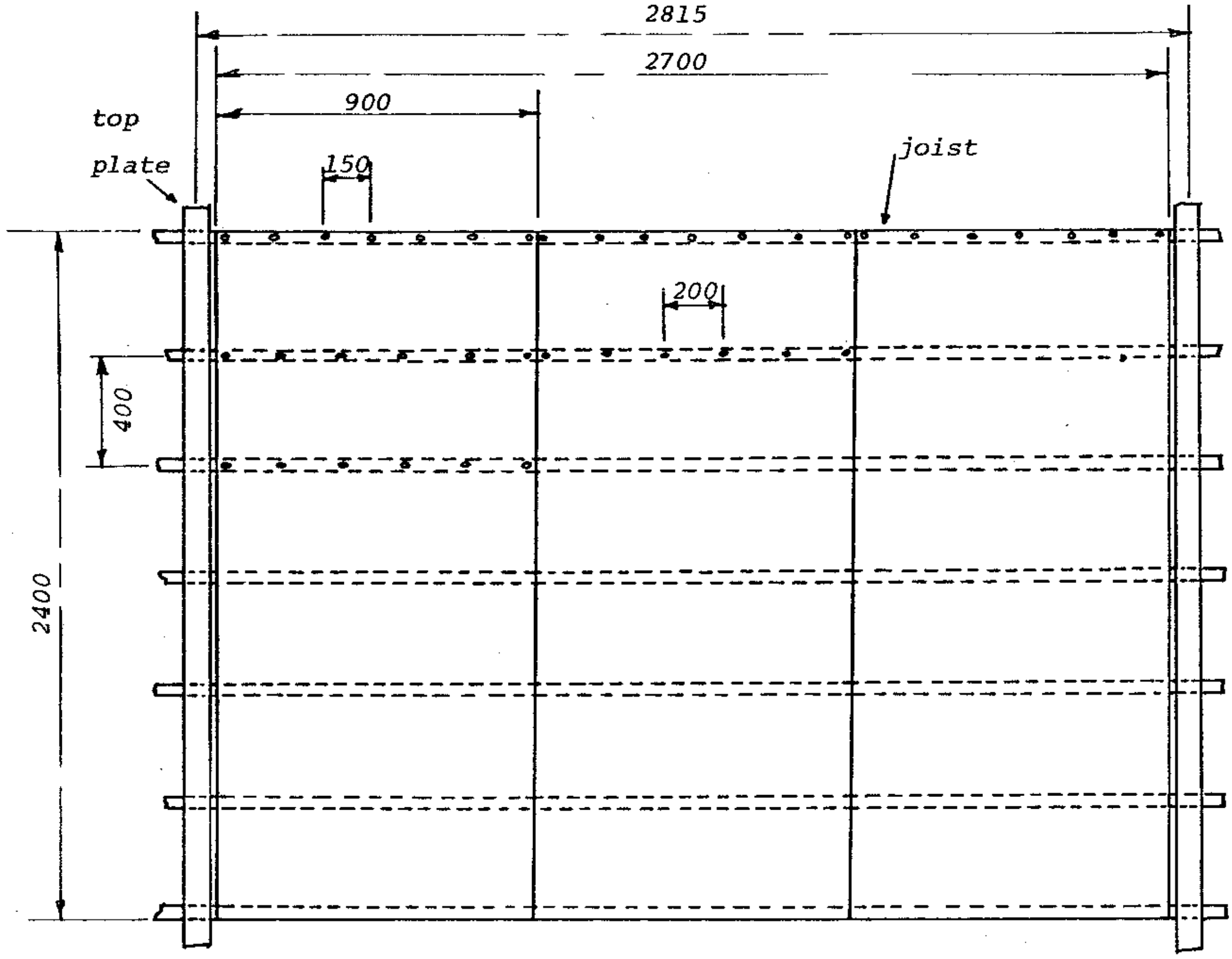


Figure A.3 Test Panel 5

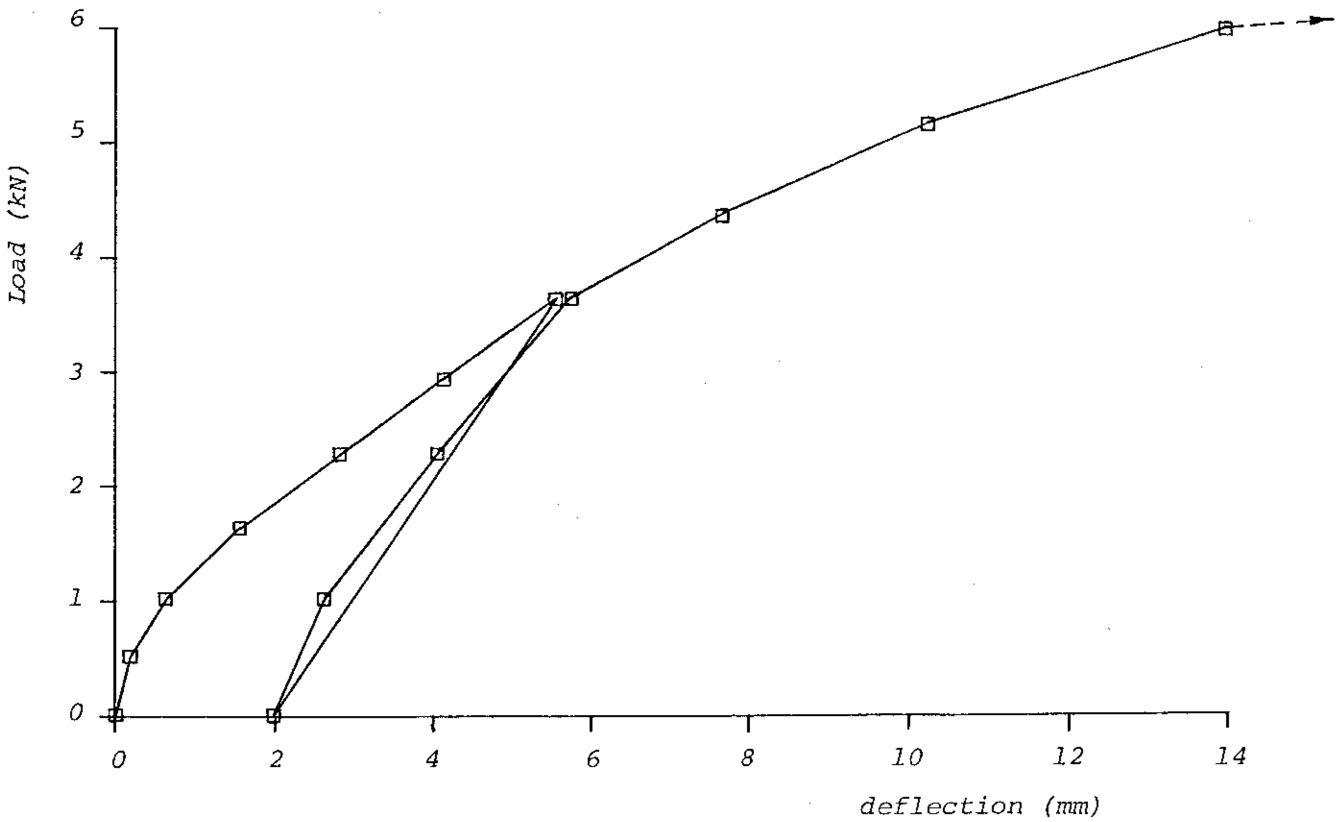
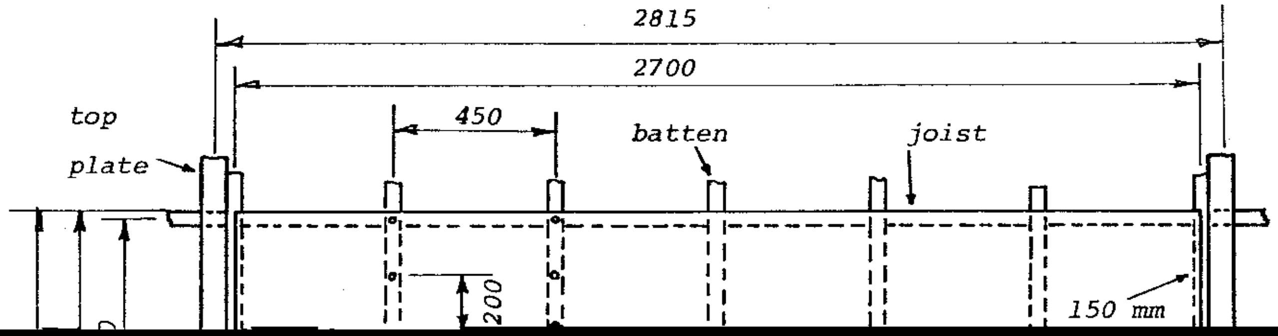


Figure A.4 Load - Deflection Curve Test 5


2815
2700
top
plate
450
batten
joist
200
150 mm

4.3.2. Test Results

[redacted]

A.4.3 Test Results

The panel failed at a load of 12.7 kN as a result of the fasteners pulling through the cladding. The observed load - deflection behaviour of the panel is shown in figure A.8. The effect of nailing the end battens to the top plate as well as the joists was to restrict the relative displacement between the battens and joists to less than 5 mm.

Little rotation of the individual cladding elements occurred due to the small displacement of the battens relative to the ceiling joists.

A.5 TEST 8

A.5.1 Test Panel

In this test two 2900 x 1200 x 10 mm 'Gyprock' sheets were fixed perpendicular to the timber battens. The gap between the end of the sheets and the top plate was filled with plaster cement (figure A.9).

The panel geometry for this test was as follows:

distance between top plates	2815 mm
spacing of ceiling joists	800 mm


furring channel or timber batten

A.5.3 Test Results

[redacted]

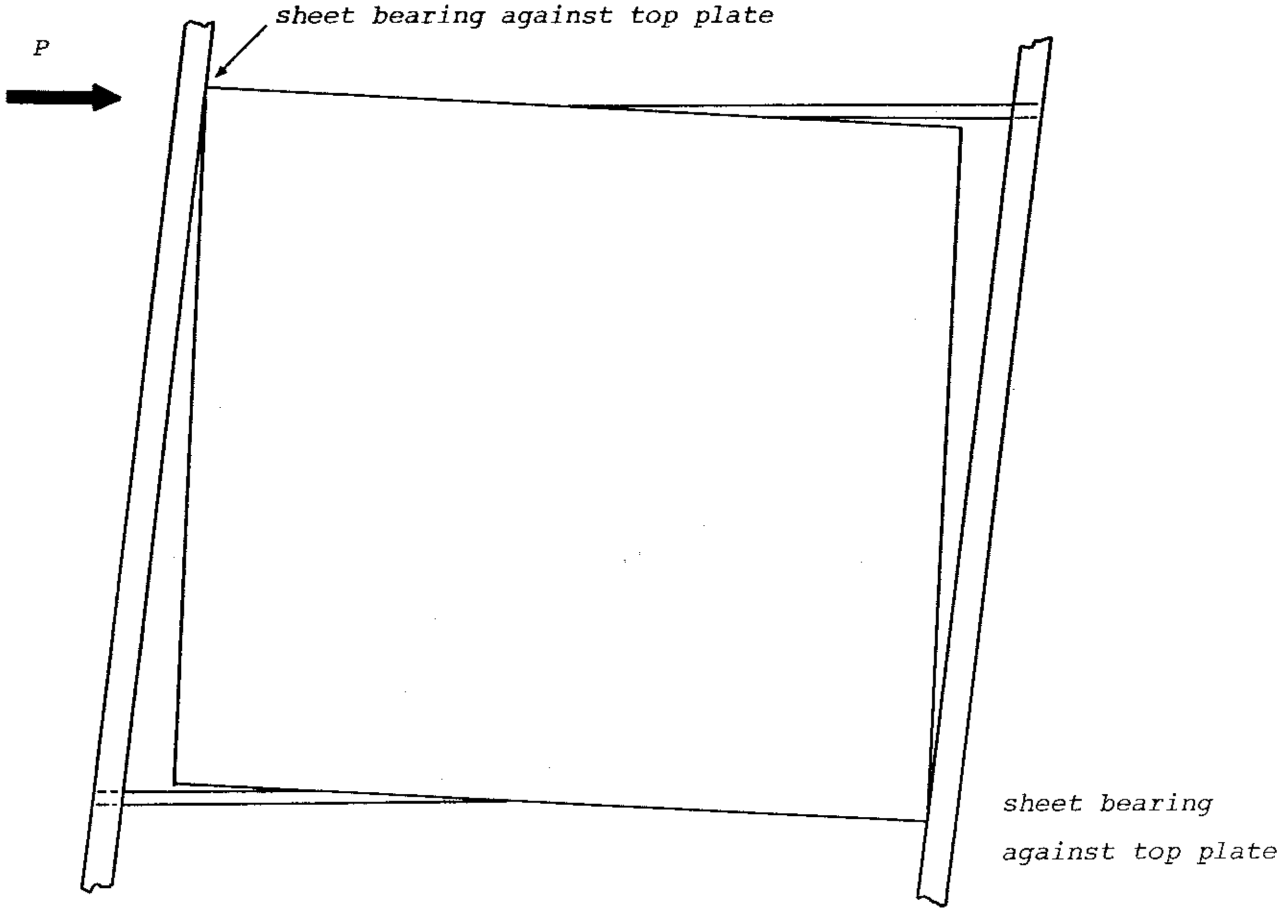


Figure A.11 Crushing of Plasterboard and Gap Fill Material

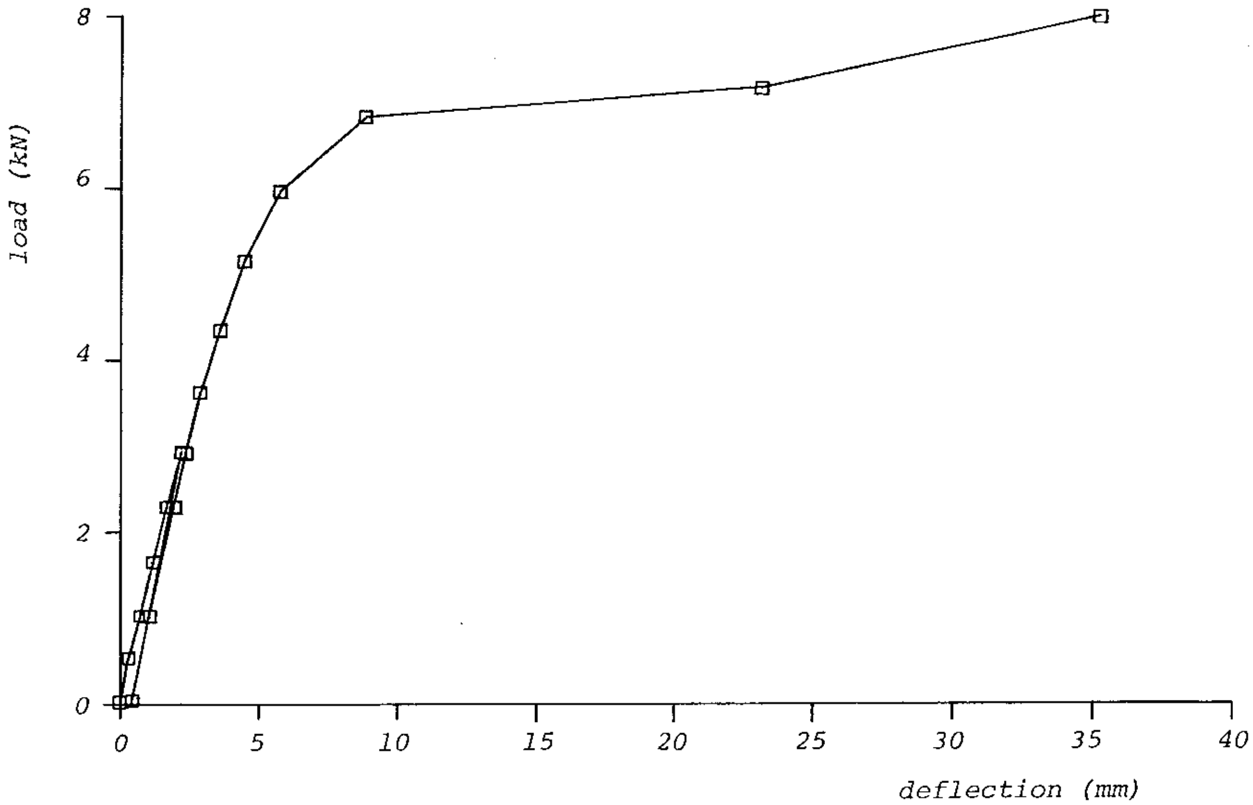
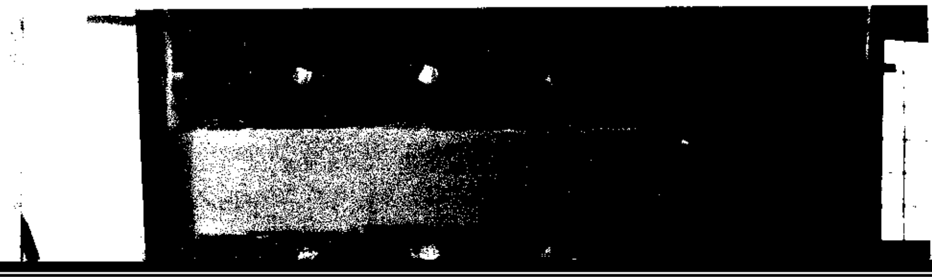
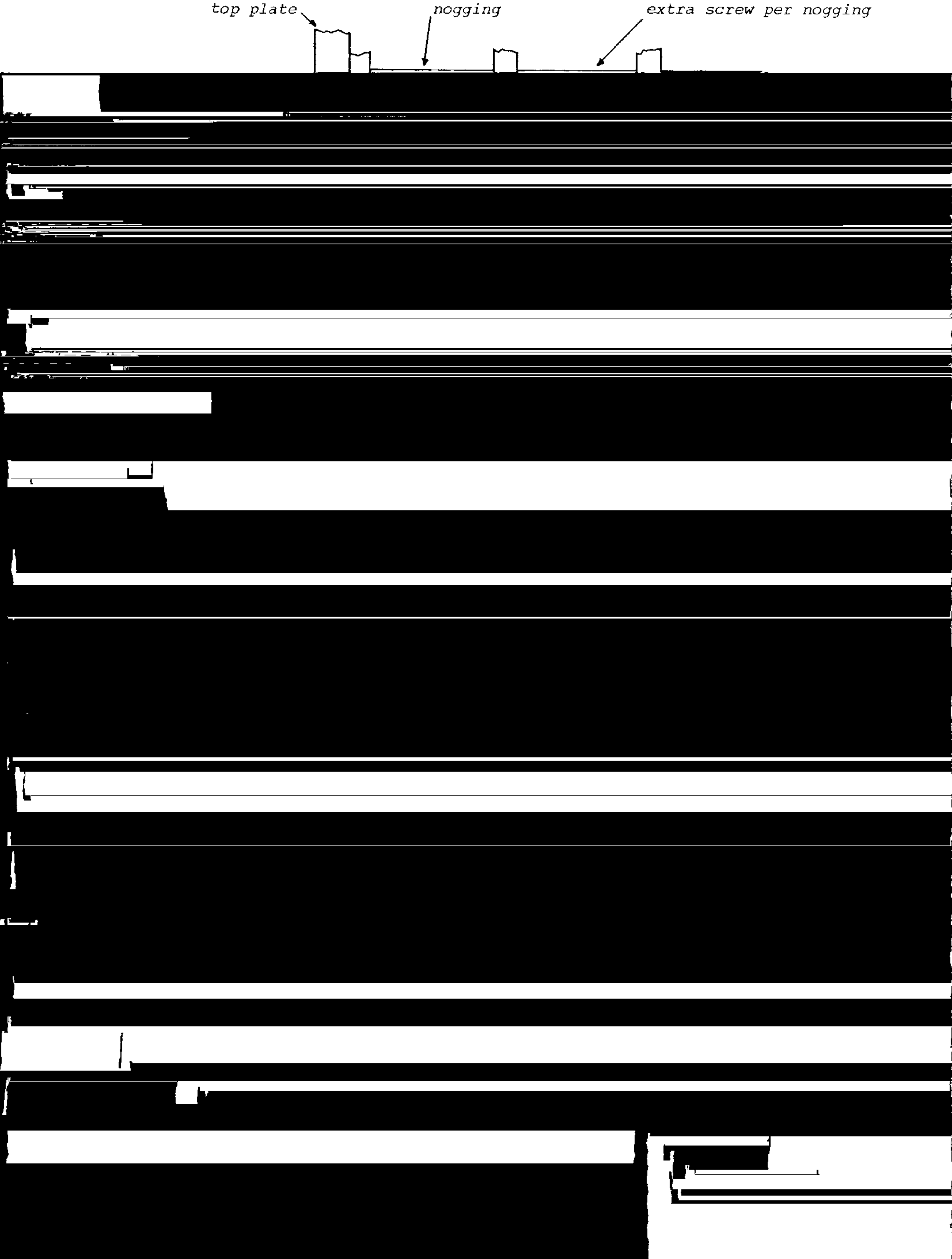
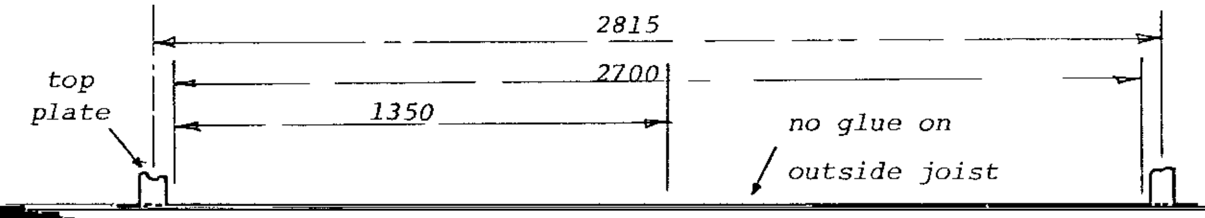


Figure A.12 Load - Deflection Curve Test 8



[redacted]


top plate
nogging
extra screw per nogging

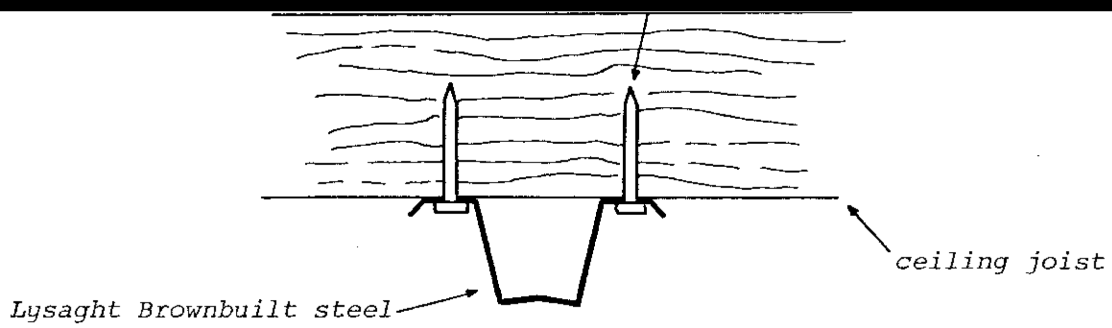

2815
2700
1350
top
plate
no glue on
outside joist

The panel geometry for this test was as follows:

distance between top plates	2815 mm
spacing of ceiling joists	400 mm

[illegible]

[redacted]



[redacted]

2.8 kN, unloaded, and then relaoded in slightly larger load increments to failure.

A. 9 .3 Test Results

The panel failed at a load of 4.5 kN as a result of the fasteners pulling through the cladding. The observed load - deflection behaviour is shown in figure A.19. The end battens showed no displacement relative to the ceiling joist. The entire cladding rotated as a single unit. It was observed that

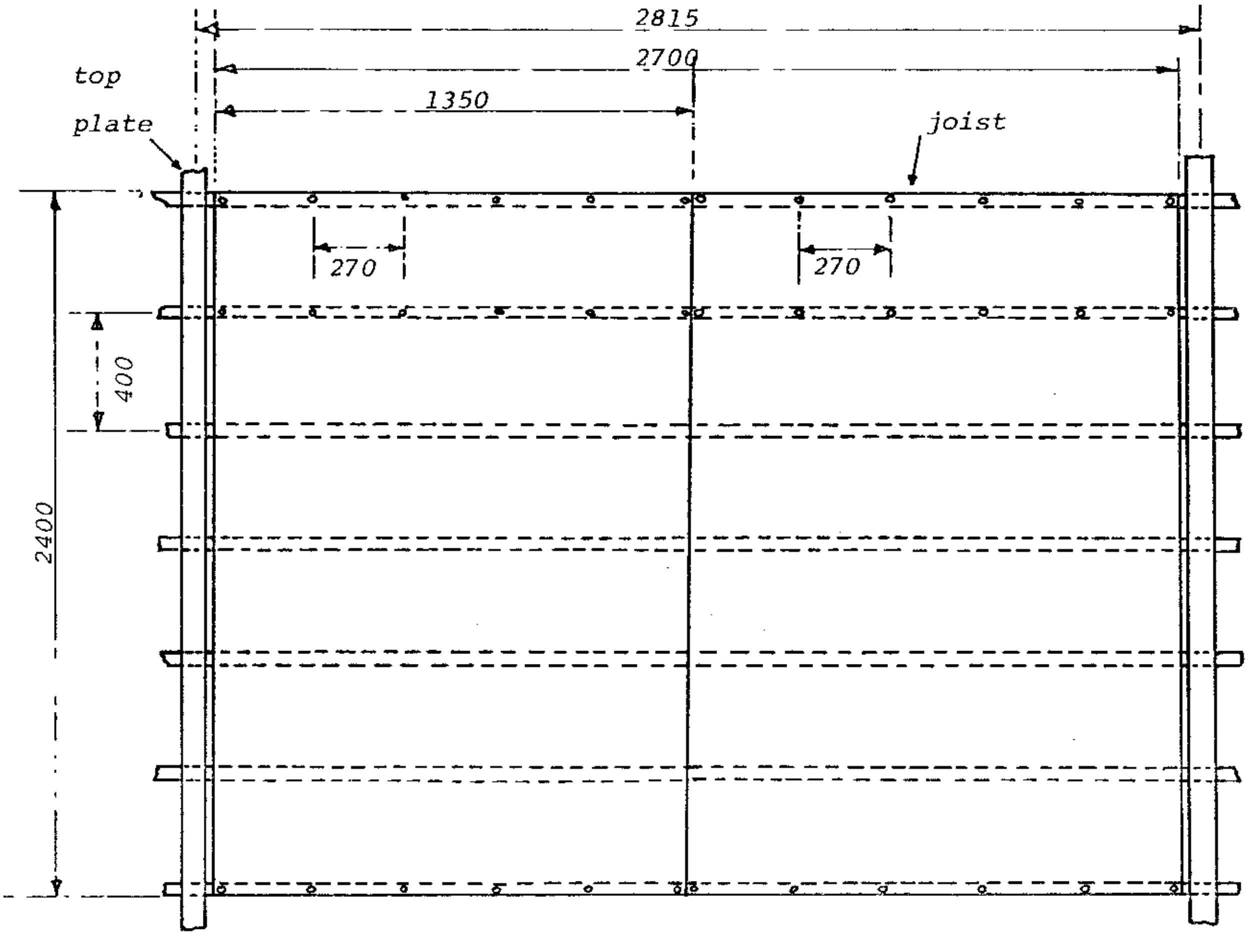
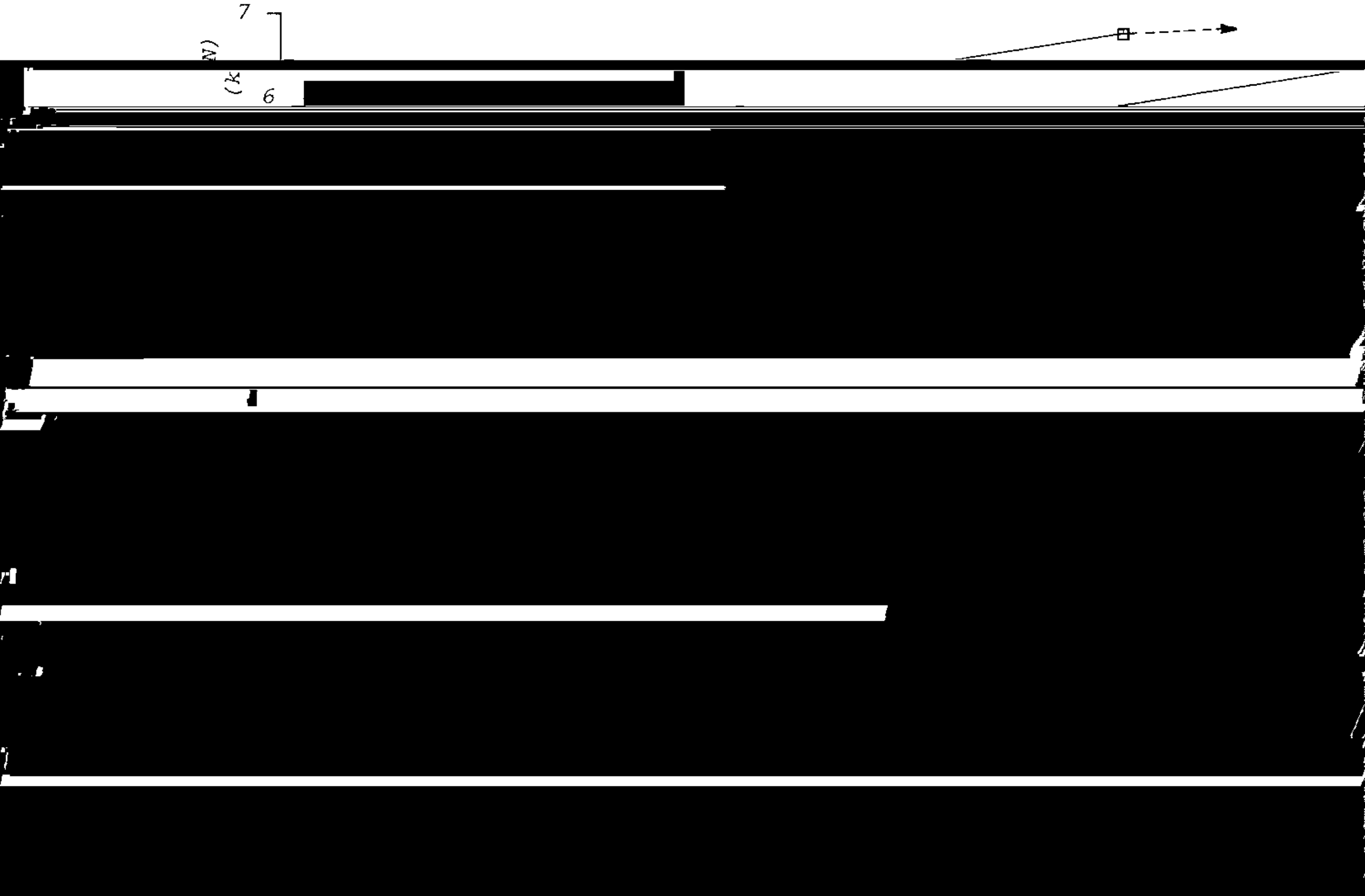


Figure A.20 Test Panels 13 and 14



A.10.3 Test Results

The panel failed at a load of 6.75 kN as a result of the fasteners pulling through the cladding. The observed load - deflection behaviour of the panel is shown in figure A.21. The entire cladding rotated as a single unit.

A.11 TEST 14

A.11.1 Test Panel

Test panel 14 was identical to the panel used in Test 13 (figure A.20).

A.11.2 Loading Pattern

The panel was loaded in increments of approximately 0.5 kN up to a load of 2.2 kN, unloaded, and then reloaded to failure in slightly larger load increments.

A.11.3 Test Results

The observed load - deflection behaviour of the panel is shown in figure A.22. Failure occurred at a load of 5.1 kN as a result of fasteners pulling through the cladding. The cladding rotated as a single unit with the recessed joint

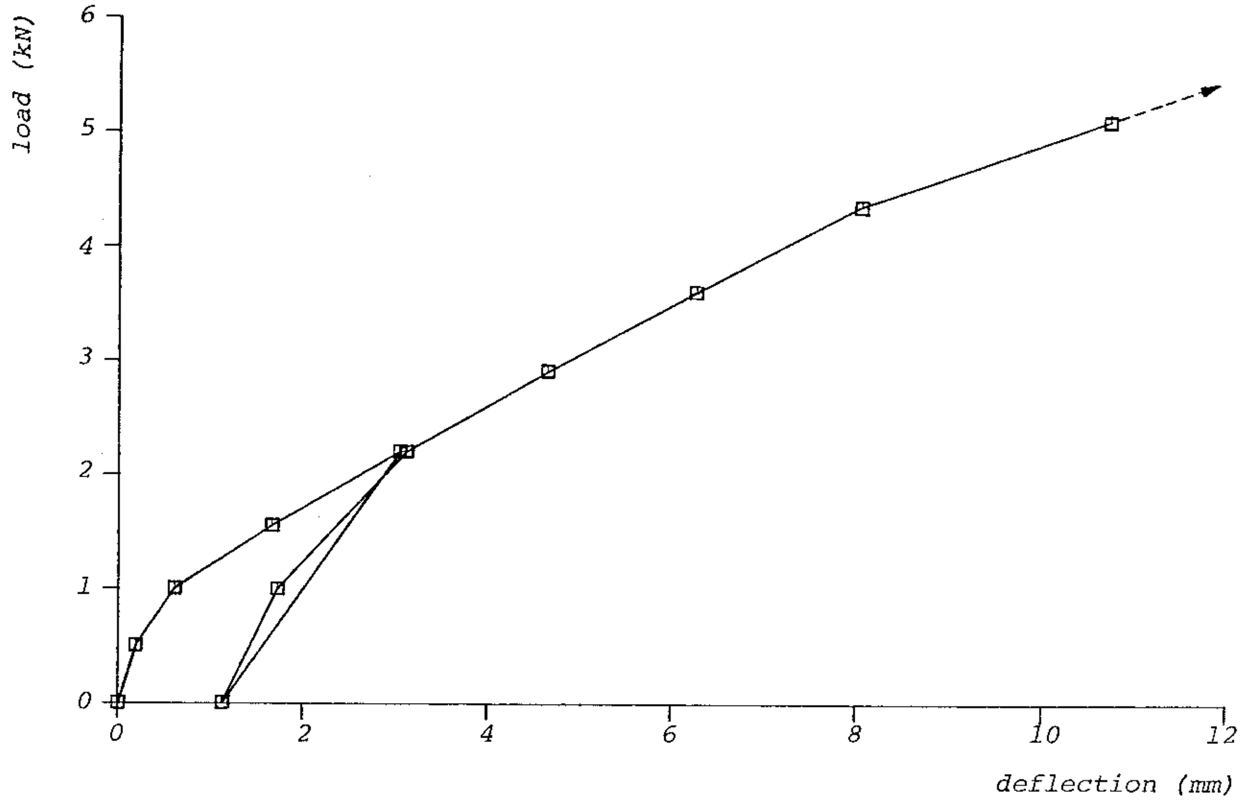


Figure A.[illegible] Load - Deflection Curve - Test 14

2.2 kN, unloaded and then reloaded to failure.

A.12.3 Test Results

The panel failed at a load of 3.75 kN as a result of fasteners pulling through the cladding. The observed load - deflection curve is shown in figure A.23. The entire cladding rotated as a single unit. There was no relative displacement between the timber battens and the ceiling joists.