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BUILDING RESEARCH ASSOCIATION OF NEW ZEALAND

TEST REPORT

FR 966
16 NOVEMBER 1984

REPORT ON THE FIRE RESISTANT PROPERTIES OF A TIMBER FRAMED LOADBEARING FLOOR/CEILING SYSTEM

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Report On The Fire Resistance Properties Of A Timber Framed Loadbearing Floor/Ceiling System

1. INTRODUCTION

1.1 Test Sponsor

New Zealand Fibrous Plaster Association Inc
P O Box 1087
Wellington
NEW ZEALAND

1.2 Test Specification

As the Australian test standard AS 1530 Part 4-1975 "Fire Resistance Tests of Elements of Building Construction" is currently under revision, the test was conducted to the latest draft version available, which was the 8th pre-postal ballot draft. This allowed the test authority to use the same criteria and operating procedures as currently apply in Australia.

1.3 Performance Criteria - AS 1530 Part 4

The fire resistance of the floor/ceiling system is the time expressed in minutes to failure under one or more of the following criteria:

1.3.1 Stability

a) If collapse of the test specimen occurs; or
b) If a vertical deflection exceeding 1/30 of the span occurs at any point on the floor. In this test the specimen fails if a vertical deflection of 136.7 mm or more occurs.

1.3.2 Integrity

If cracks, fissures or other openings develop through which flames or hot gases can pass.

1.3.3 Insulation

a) If the average temperature of the unexposed surface of the test specimen rises by more than 140 K above the initial temperature; or
b) If the temperature of the unexposed surface at any of the measuring points rises by more than 180 K above the initial temperature or reaches a temperature higher than 220°C.

2. DESCRIPTION OF TEST SPECIMEN

2.1 General

The test specimen consisted of a timber joist floor/ceiling system designed for use in a commercial situation. The specimen was mounted on a nominal 4 m x

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3 m concrete frame, with the actual span, measured between the centres of the bearing areas, being 4100 mm. The width of the specimen was 2965 mm. The edge joists were supported only at their ends so that one way action only was developed.

2.2 Framing

2.2.1 Joists

The joists were nominal 250 x 50 dressed No. 1 framing grade Pinus Radiata. The range of depths of the joists was 239 to 243 mm, with an average of 241 mm. The range of thicknesses was 42 to 46 mm, with an average of 45 mm. The joists were kiln dried to a moisture content of about 14%, but at the time of construction an offcut was taken from each joist and oven dried to find its moisture content and the range of values was 15.9 to 18.3%, with an average of 17.1%.

2.2.2 Joist Spacing

Starting at one side of the frame, the joists were spaced at approximately 600 mm centres, with the last joist placed at a spacing of 535 mm, at the other edge of the frame.

2.2.3 Solid Blocking

Three rows of solid blocking were placed as shown on Morrison Cooper and Partners drawing No. L83045/1 (Figure 6), constructed of the same material as the joists. The blocks were fixed with three 100 mm flat head nails at each end.

2.2.4 Dwangs

Dwangs were placed under any joint in the particle board flooring which did not fall along a joist. They were of nominal 100 x 50 No. 1 framing grade Pinus Radiata.

2.3 Flooring

The flooring was 20 mm thick urea formaldehyde bonded flooring grade particle board. It was fixed with 60 mm x 2.8 mm jolt head nails at 150 mm centres on the perimeters of the sheets, and at 300 mm centres along each intermediate joist. The layout of the sheets was as shown on Figure 5.

2.4 Ceiling

2.4.1 Sheet Material

The ceiling was made of 12.5 mm thick Plasterglass "Fyrwall". Two sizes of sheet were used: - 3000 mm x 1200 mm, and 1500 mm x 1600mm. Two of each size were used, arranged as shown on Figure 6. A simulated wall was also made from the same material. The joint between the ceiling and the simulated wall was sealed with 50 mm Plasterglass cornice as in normal practice.

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2.4.2 Fixing of Sheets

Two different methods of fixing were used, with half the sheets being fixed with either method, as shown on Figure 6. The two fixing methods were as follows:

(i) Wadded

The sheets were fixed with 40 mm x 2.5 mm galvanised flat head clouts at 100 mm centres on the perimeters, where this was possible, i.e. where the perimeter fell on a joist or solid block. In the field of the sheet the fixings were by wadding at 300 mm centres on each joist.

A "wad" consisted of a handfull of glass fibres dipped in wet plaster mix. This was then draped over a 100 mm galvanised flat head nail which had been partially driven into the side of the joist. Where it was possible to reach the fixing point by hand or with a stick, the wad was placed over the nail after the sheet had been partially fixed by perimeter nails, with some temporary nails in the field of the sheet. The wad was spread out across the sheet to give as large an area of fixing as possible.

Where it was not possible to reach the fixing point, the wad was hung over the nail, and the board was pushed up against the wads and perimeter nailed with some temporary nails in the field of the sheet.

(ii) Wadded and Nailed

The remainder of the sheets were fixed as above, but also single nailed with 40 mm x 2.5 mm galvanised flat head clouts at 300mm centres alternate with the wads.

2.4.3 Joints

All joints between sheets were arranged such that they did not fall on a joist except that the outside edges of the specimen all fell on a joist or solid block. All joints between sheets were wadded. This was achieved by cutting a strip of Plasterglass "Fyrwall" sheet 100 mm wide and fixing it to the top of the previously fixed sheet on one side of the joint with cornice cement. It was fixed such that half of the strip was protruding. The next sheet was then brought up to the strip and attached with cornice cement.

2.4.4 Cornices

The cornices were fixed with cornice cement.

2.4.5 Stopping

All nail heads were punched and stopped with plaster. The holes where temporary nails had been removed were also stopped with plaster. All joints, both on the ceiling and the simulated wall were caulked with cornice cement, then covered with 40 mm wide open weave fibreglass bandage. This was then covered and smoothed over with "FFFF" plaster.

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2.5 Mounting in Frame

The specimen was mounted in the nominal 4m x 3m concrete frame with the joists spanning in the 4m direction and landing on 100 mm x 50 mm bearing plates. The edge details were as shown on Figure 6. All the joists were loadbearing.

3. TEST PROCEDURE

3.1 General

The specimen was tested on 4th October 1984 in the presence of representatives of the sponsoring organisation. The test was carried out at the BRANZ Fire Testing Station at Judgeford, NZ.

The frame holding the specimen was sealed to the furnace, and the temperature and pressure conditions controlled as closely as possible to those specified in the latest draft of AS 1530 Part 4.

3.2 Duration

The test was terminated after the specimen had been exposed to the standard fire test for one hour and fifteen minutes.

3.3 Loading

At the request of the sponsor a load of 2.50 kPa was applied to the floor specimen. This was done using twenty drums partially filled with water and placed as evenly as possible over the floor surface. Each drum had three 100 mm legs with a 100 mm x 100 mm particle board foot mounted on a ball joint on each leg. Figure 4 shows the distribution of the water drums.

Appendix I comprises the calculations supplied by the sponsor's consultant, Morrison Cooper and Partners.

3.4 Furnace Temperature Measurement

Temperature measurement within the furnace was made using 12 chromel-alumel thermocouples uniformly distributed in a horizontal plane approximately 200 mm from the exposed face of the specimen.

3.5 Specimen Temperature Measurement

The temperature on the unexposed face of the specimen was measured using chromel-alumel thermocouples according to AS 1530, Part 4 Section 2.2.3. Five thermocouples were placed on the floor, one at the approximate mid-point, and one at the approximate centre of each of the quarters. The thermocouples were placed so as not to be directly above any joist, dwang or solid block.

3.6 Temperature Recording

All the thermocouples described in sections 3.4 and 3.5 were connected to a microcomputer controlled data logging system which sampled the temperatures at one minutes intervals.

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3.7 Pressure Measurement

The furnace pressure was adjusted such that it was not less than 8 Pa on a horizontal plane 100 mm below the exposed face of the specimen. The pressure was monitored using a micromanometer connected to a continuously reading recorder.

3.8 Deflection Measurements

The deflections were measured by two methods:

(i) using linear potentiometers, which were connected to the microcomputer system, and read at one minute intervals.

(ii) using graduated wooden staffs, read by a theodolite at 15 minute intervals.

The positions of the potentiometers and staffs are shown on Figure 4. The potentiometer at the middle of the specimen had a range of 200 mm.

4 OBSERVATIONS

4.1 Severity of Test

A measurement of the severity of a fire-resistance test can be established by comparison of the area beneath the time-temperature curve of the test with the area beneath the standard time-temperature curve for the same period. Figure 1 shows the standard time-temperature curve from AS 1530 Part 4 in relation to the actual furnace temperature.

The severity of this test as calculated by the above comparison for the first 75 minutes duration of the test was [illegible]%.

4.2 Average Specimen Temperature Rise

The average specimen temperature did not exceed the failure criterion of 140 K rise. At 69 minutes the temperature rise had reached 70 K.

4.3 Maximum Specimen Temperature Rise

The maximum specimen temperature did not exceed the failure criterion of 180 K rise. At 71 minutes the temperature rise had reached 77 K.

A graph showing maximum and average specimen temperatures is included as Figure 2.

4.4 Specimen Integrity

The integrity of the specimen was maintained until a foot of the drum in the south west corner (see Figure 4) penetrated the particle board flooring. At this stage large amounts of smoke and steam were issuing from the ends of the specimen, obscuring a large proportion of the top surface. This made it impossible to determine the exact time at which the penetration occurred, but it is estimated to be 72 ± 2 minutes.

After the penetration had occurred, large amounts of smoke and hot gases were issuing from the top surface of the specimen.

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4.5 Specimen Stability

The timber framing remained adequate to support the applied load for the duration of the test.

4.6 Specimen Deflections

After 45 minutes theodolite readings became impossible as the staffs were obscured by steam and smoke, so for the latter part of the test potentiometer readings only were taken. The maximum deflection occurred at the centre point of the specimen and a graph of its behaviour is shown as Figure 3. The failure criterion of 136.7 mm was not reached.

4.7 Specimen Condition Following the Test

After the termination of the heating period the load was removed from the specimen, and the specimen was removed from the furnace.

The specimen was extinguished by hosing from top and bottom.

The particle board flooring was observed to have been penetrated at two locations, both between the first and second joists from the south side. The Plasterglass ceiling was observed to have remained intact throughout the test. On removal of the Plasterglass, charring was observed to have occurred on the bottom and sides of all the joists, dwangs and blocks, and on the underside of the particle board.

5. SUMMARY

The fire resistance in minutes achieved by the floor/ceiling system was as follows:

Insulation:	No failure at 75 minutes.
Integrity:	The integrity of the specimen failed at approximately 72 minutes.
Stability:	No failure at 75 minutes.

Test report prepared by:- S. King, Engineer, Fire Research Division.

D Bastings
ENGINEER, FIRE RESEARCH DIVISION

H L Baber
HEAD, FIRE RESEARCH DIVISION

APPENDIX 1: SPECIMEN DESIGN CALCULATIONS

1. VARIATIONS IN DEPTH AND THICKNESS OF JOISTS

Joist No.	d	b
1	243	46
2	241	45
3	239	46
4	241	46
5	240	46
6	240	45
Mean	240.67	45.67
Rounded to	241	46

PROPERTIES OF JOISTS

b = 46mm

d = 241mm

A = 11,086 mm^2

I = 53.66×10^{-6} m^4

Z = $.445 \times 10^{-3}$ m^3

2. LIVE LOAD TO BE PLACED UPON FLOOR

Use latest Draft of AS 1530 Part 4 "Methods for Fire Tests on Building Materials, Components and Structures. Fire-Resistance Tests of Building Components and Structures".

This states " the test load shall be ...... for specimens of timber ..... that load which stresses the specimen to the maximum permissable stress."

Timber floor is designed to:

NZS 3604 : 1981 Code of practice for Light Timber Frame Buildings not requiring specific design.
NZS 4203 : 1976 Code of practice for General Structural Design and Design Loadings for Buildings.

Timber is dry, Radiata Pine, No 1 framing.

Basic Working Stress, F'b = 6.0 MPa.

Duration of load

Live loads in service will typically be 2.5 kPa

i.e. exceed 2.0 kPa.

Therefore duration of load factor K_1 = 1.25

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If load is placed upon the specimen greater than one week before the fire test:

medium duration load test
$K_1 = 1.25$

Therefore design conditions will actually be simulated during the fire test.

NOTE: That by using this method, (i.e. loading the test specimen for longer than one week to ensure the K_1 factor during the test equals the K_1 factor during the service) means that we can also meet the requirements of:

BS 476: Part 8 - 1972
AS 1530, Part 4 - 1975
ISO 834-1975

which typically state "subject to a loading which produces stresses of the same order of magnitude and same nature as would be produced by the maximum permissible loads in accordance with appropriate standards". Thus we adhere to all codes.

Other factors

Stability factor $K_8 = 1.0$

i.e. fully restrained by flooring.

$Fb = 1.25 \times F'b$
$= 1.25 \times 6.0$ MPa
$Fb = 7.50 \times$ MPa

Fb = 7.50 MPa.

3. CALCULATE LOAD ON JOISTS

1. Assume that flooring and ceiling do not add significant strength.

At maximum stress fb = Fb = 7.50 MPa.

$$fb = \frac{M}{Z}$$

$$M = fb \times Z$$
$$= 7.5 \text{ MPa} \times .445 \times 10^{-3} \text{ m}^3$$
$$= 3.338 \text{ kNm/joist}$$

Joists spaced at 600mm centres

$$M = \frac{3.338}{0.6} = 5.563 \text{ kNm/m width}$$

Joists are simply supported - span 4.0m

$$M = \frac{wL^2}{8} \qquad w = \frac{8M}{L^2} = \frac{8 \times 5.563}{4^2} \frac{\text{kNm/m}}{\text{m}^2}$$

$$w = 2.781 \text{ kPa.}$$

w = 2.78 kPa

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Check: if load = 2.8 kPa

$w = 2.8 \times 0.6 = 1.68\ kNm^{-1}$ per joist

$M = \frac{wL^2}{8} = 3.360\ kNm$

$fb = \frac{M}{Z} = \frac{3.360}{.445} = 7.55\ MPa$

4. CHECK DEAD LOADS

1. Particle board, .690 kg/m³, 20mm thick
   $w = 6.9 \times 1m \times 1m \times .020m$ = 0.138 kPa

2. Joists: $4.7\ kN/m^3 \times .241m \times .046m \times 1m \times 1.0/_{0.6}$ = 0.087 kPa

3. Blocking: $\frac{4.7\ kN/m^3 \times .241m \times .046m \times 3.0m}{4m \times 3.0m}$ = 0.013 kPa

4. Plasterglass 13.7 kg/m² 0.137 kPa

   0.375 kPa

Say D = 0.38 kPa

L = w - D
  = 2.78 - 0.38
L = 2.40 kPa Applied Live Load

5. STRENGTH OF PARTICLE BOARD

Nominal thickness = 20mm
Actual thickness = 19mm

$Z = \frac{1000 \times 19^2}{6} = 60.17 \times 10^{-6}\ m^3$

for a 1m wide strip

Joist spacing = 600m
flooring span = 600m

D = 0.14 kPa
L = 2.40 kPa
D + L = 2.54 kPa w = 2.54 kNm⁻¹

$M = \frac{wL^2}{12} = \frac{2.54 \times 0.6^2}{12} = 76.2\ Nm$

floor continuous over several spans

$f'b = \frac{M}{Z} = \frac{76.2}{60.17 \times 10^{-6}\ m^3} = 1.266\ MPa$

Check point load $M = \frac{PL}{4} = \frac{0.6}{4} = 150\ Nm$

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$f'b = 2.49$ MPa
cf Modulus of Rupture = 26 MPa

Therefore particle board is easily strong enough to withstand both the service loads, and the test loads.

Calculations as supplied by Mr Szakats of Morrison Cooper and Partners, 25/9/84.

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FIG. 1 FURNACE TEMPERATURE

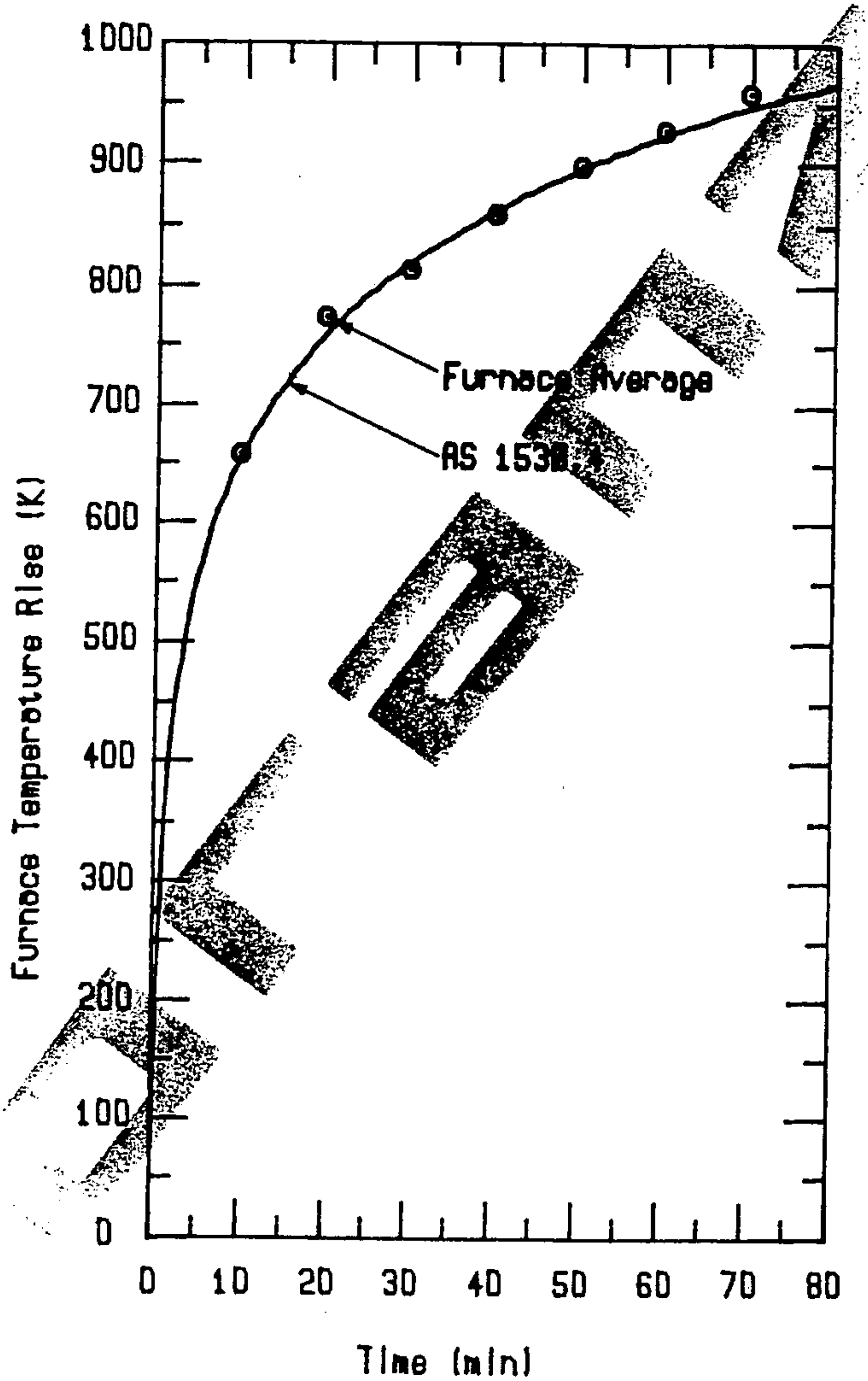

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FIG 2 SPECIMEN TEMPERATURES

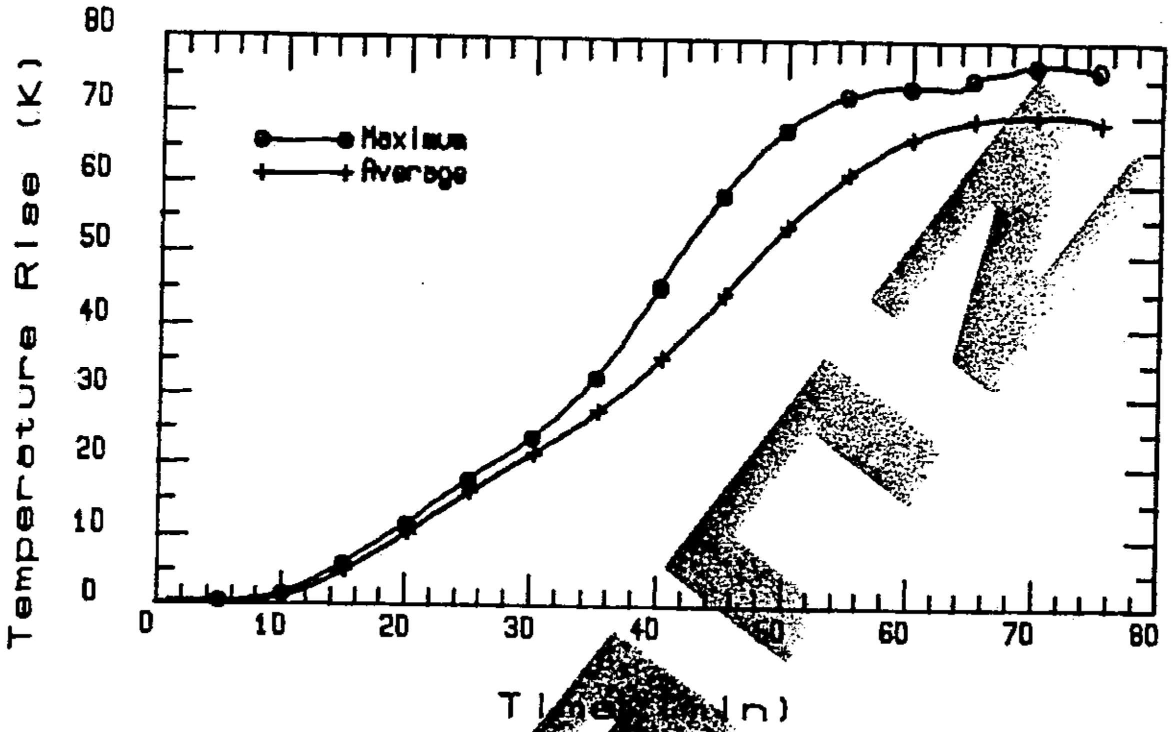
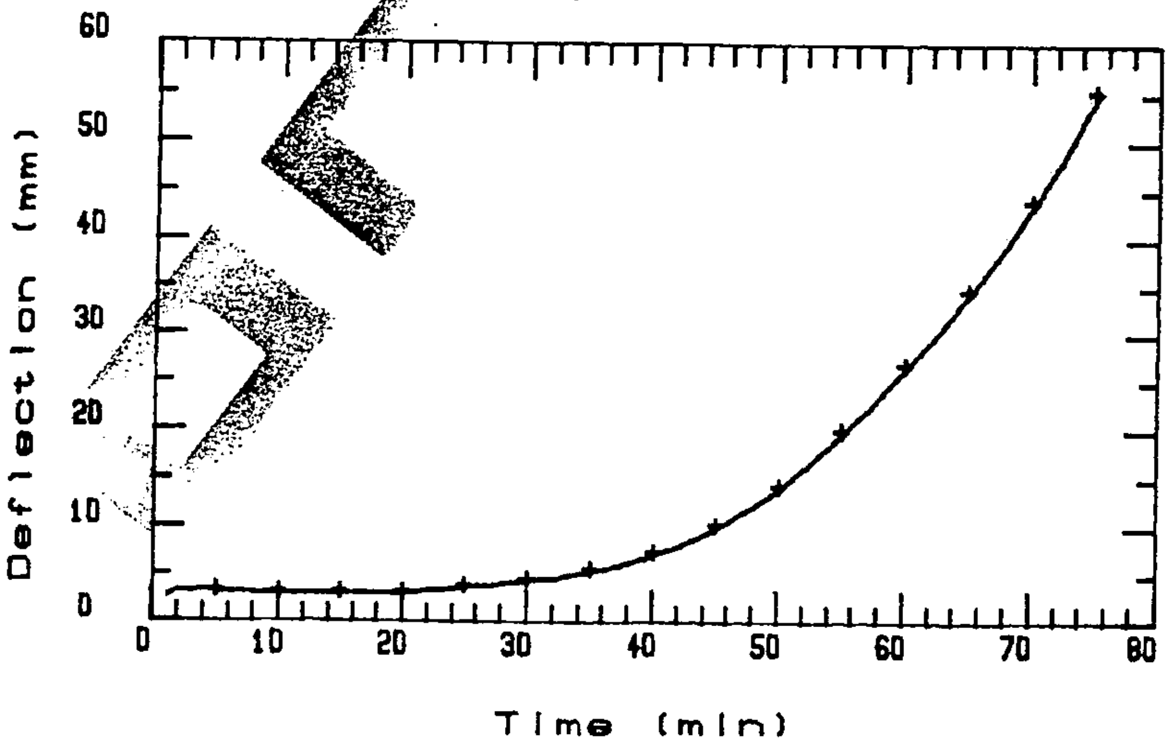


FIG. 3 MID-POINT DEFLECTION



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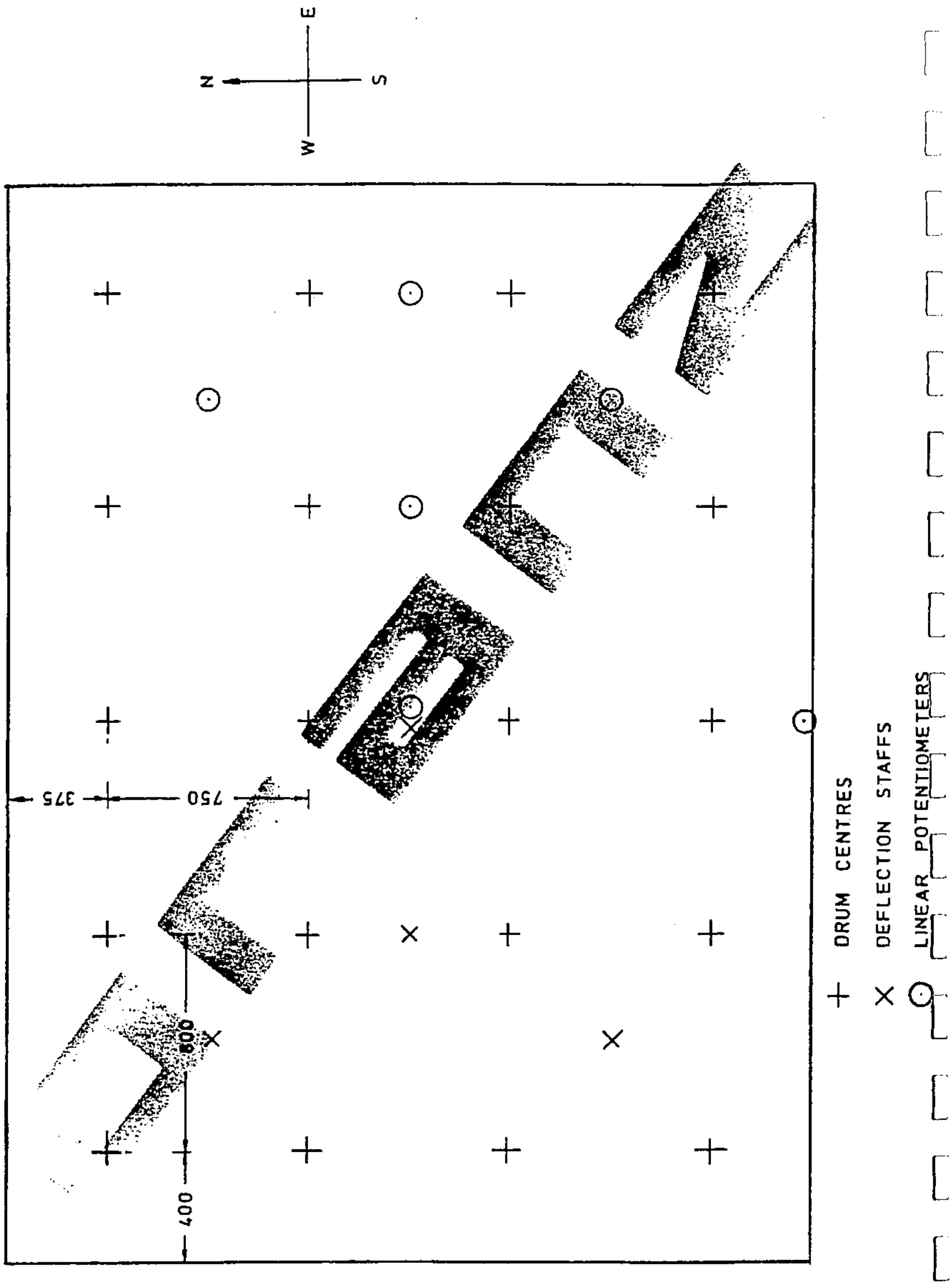

FIGURE 4 LOADING AND DEFLECTION MEASUREMENT

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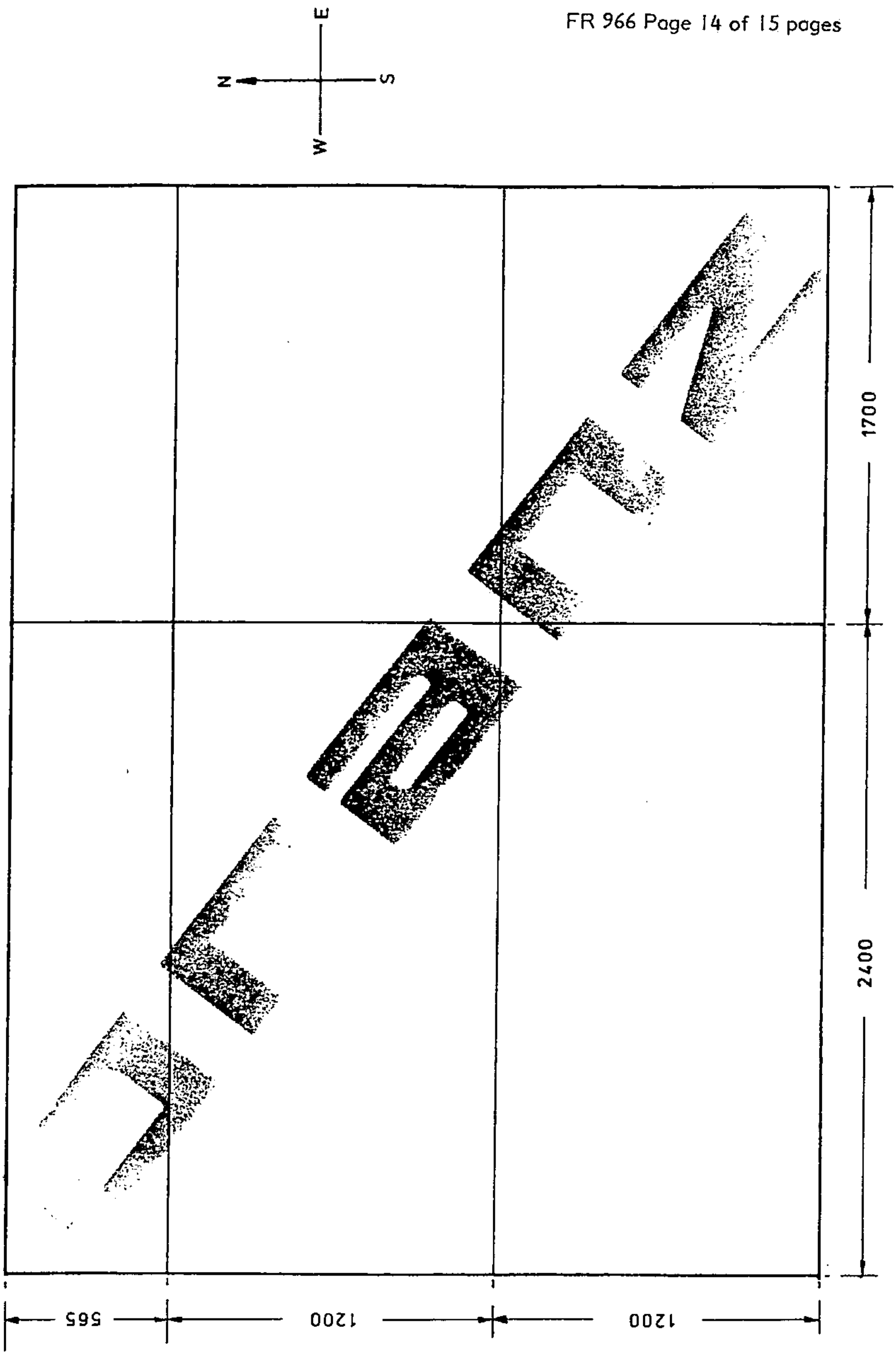

Figure 5 Particle Board Layout

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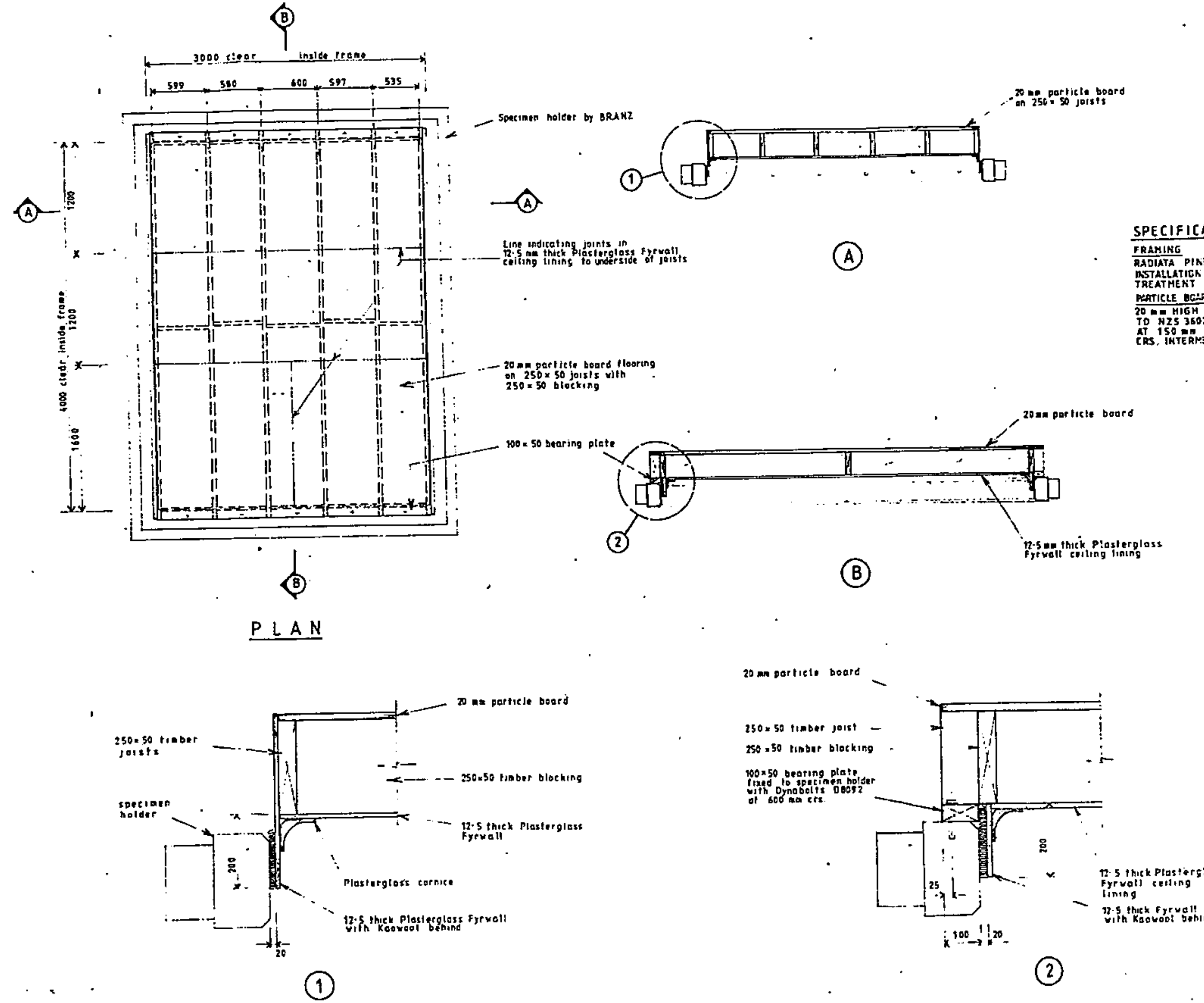

Contractor shall verify all dimensions prior to construction. Do not scale.

A — REDRAWN - AS BUILT

SPECIFICATION

FRAMING

RADIATA PINE N° 1 FRAMING TO NZS 3602. INSTALLATION MOISTURE CONTENT - 14 TO 18% TREATMENT CB TO T.P.A. SPECIFICATION

PARTICLE BOARD

20 mm HIGH DENSITY PARTICLE BOARD TO NZS 3602 JOLT HEAD NAILS 60 × 2·8 AT 150 mm CRS TO EDGES AND AT 300 mm CRS. INTERMEDIATE

MORRISON, COOPER & PARTNERS
CONSULTING ENGINEERS,
REGISTERED ARCHITECTS,
P.O.BOX 6214,
TEL 851-835,
WELLINGTON.

NEW ZEALAND FIBROUS PLASTER ASSOCIATION

FIRE RESISTANCE TEST FLOOR SPECIMEN

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