TWP Timber and Wood Products
Research Centre

FLEXURAL TESTS ON TWO-SPAN CONTINUOUS, NAIL PLATED LAMINATED HARDWOOD BEAMS

for

J.B. HINZ & SONS
THE CAVES

C.G. McDowall, A.I.W.Sc.,
M.I.E. Aust
March, 1986
TWP Report No 130

ROCKHAMPTON, AUSTRALIA 4700. TELEPHONE (079) 361177 TELEX AA49176

TABLE OF CONTENTS

SUMMARY

This report briefly describes beam construction, test procedure and presents the results obtained for mid-span concentrated loading of four, two span continuous nail plate laminated beams and one solid beam.

Nail plate laminated beam dimensions were 45 x 147 mm consisting of two laminates of either all red gum or red gum and stringy bark interconnected by nail plates producing beams spanning 6 m continuous over three supports. The solid beam was of red gum with dimensions of 50 x 150 mm. All timber was stress graded at F14 and the nail plates were manufactured by Bostitch.

FLEXURAL TESTS ON TWO-SPAN CONTINUOUS NAIL PLATE LAMINATED HARDWOOD BEAMS

1. INTRODUCTION

Four nail plated laminated beams 45 x 147 mm consisting of two laminates, and one solid red gum beam 50 x 150 mm were supplied for testing by J.B. Hinz & Sons, The Caves. The beams were continuous over two, three metre spans, and were subject to a concentrated load applied mid-span of one span and in one instance a concentrated load applied simultaneously to mid-span of both spans.

The testing program was performed to assess the load response characteristics of the beams with particular attention focused on beam failure mode.

Mr. Henry Hinz, representing J.B. Hinz & Sons, was present during testing of the solid and three of the four nail plate laminated beams which was performed on 18 March, 1986 in the Heavy Structures Laboratory, Department of Civil Engineering, Capricornia Institute. The forth nail plated beam was modified by addition of a plate to the tension side of the butt joint and was tested in the presence of Mr. Hinz on 21 March, 1986.

2. BEAM CONSTRUCTION

The nail plate laminated beams consisted of two laminates, of approximately 45 x 75 mm non-continuous members, interconnected by Bostitch nail plates located either side of the joint as shown in Figure 1. The laminates were in general red gum, however in one beam, some stringy bark laminates were used. The stress grade of the laminates and the solid timber beam was F14.

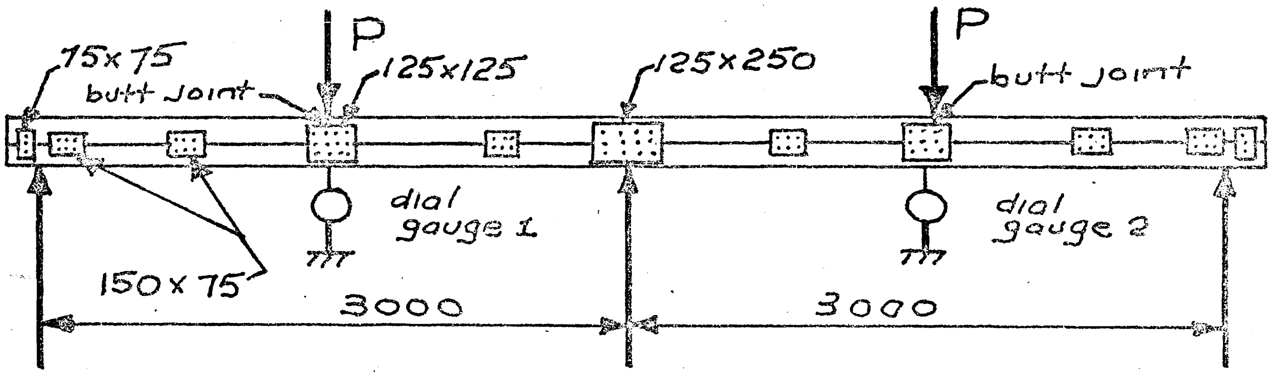


FIGURE 1

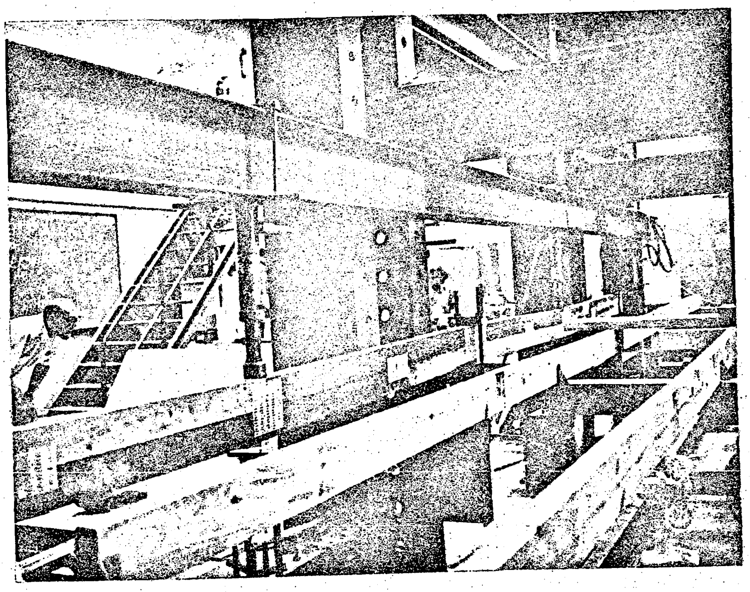
Plates positioned over end supports and quarter points were 150 x 75 mm, over the centre support 250 x 125 mm, and at mid-span 125 x 125 mm.

Butt joints in the first two beams tested, identified NLB1 and NLB2, were located on the compression side at mid-span. Butt joints in NLB3 were positioned on the tension side at mid-span and over the centre internal support.

Premature failure in the tension zone of the nail plates located at mid-span of NLB3 resulted in NLB4 being modified in this region. A tension plate with the nails manually driven was added in an attempt to increase the moment capacity of the joist.

3. TEST ARRANGEMENT

Plate 1 shows a beam being subjected to a concentrated load at mid-span of each of the two continuous bays.



BOTH BAYS OF JOIST LOAD

PLATE 1

To provide the three supports to the beams universal beam sections were bolted to the main columns of the Three Dimensional Loading frame. Cap plates with a piece of 38 mm diameter round welded to them, with the plates in turn being welded to the top of the UB, provided a line support to the underside of the beams. Threaded rods were also welded to the cap plates to allow beams to easily pass through. A plate with holes drilled to fit over the threaded rods and with a piece of 38 mm diameter round welded to the underside held the beam in position. Nuts were tightened to little more than finger tightness to provide restraint but not to lock the joint.

The 120 kN capacity Ritch jacks were connected through a manifold to a handpump. The jacks could be operated singly or in tandem, each applying the same load. A pressure gauge calibrated against a load cell enabled the load per jack to be monitored to within an estimated accuracy of 5%.

Dial gauges were located on the underside of each beam and independent of test arrangement to measure mid-span deflections. Difficulty was encountered in trying to fit the yoke to the beam to eliminate measuring embeddment deformations hence its use was abandoned. Because hardwood was being tested it was felt deflection results, up to the estimated design load, would not be unduly affected.

No lateral supports, other than that provided by the jacks, were used when testing the beams.

4. LOADING CONDITIONS

In sizing the members of a domestic floor system (1) requires two separate conditions of loading to be considered:

(a) a concentrated load of 1.8 kN
(b) a uniformly distributed load of 1.5 to 3.0 kPa

The above loading case producing the most adverse stress resultants in the member under design must then be used to size the beam.

Satisfying strength requirements is a necessary but not sufficient condition in designing a satisfactory floor system. A further requirement is that the floor does not deflect excessively under static load conditions. This criteria, if properly invoked, prevents vibration of normal spanning floor systems.

Because the beams were continuous over two spans the loading conditions shown in Figure 1 were considered. Also shown are the associated shear force and bending moment diagrams (2).

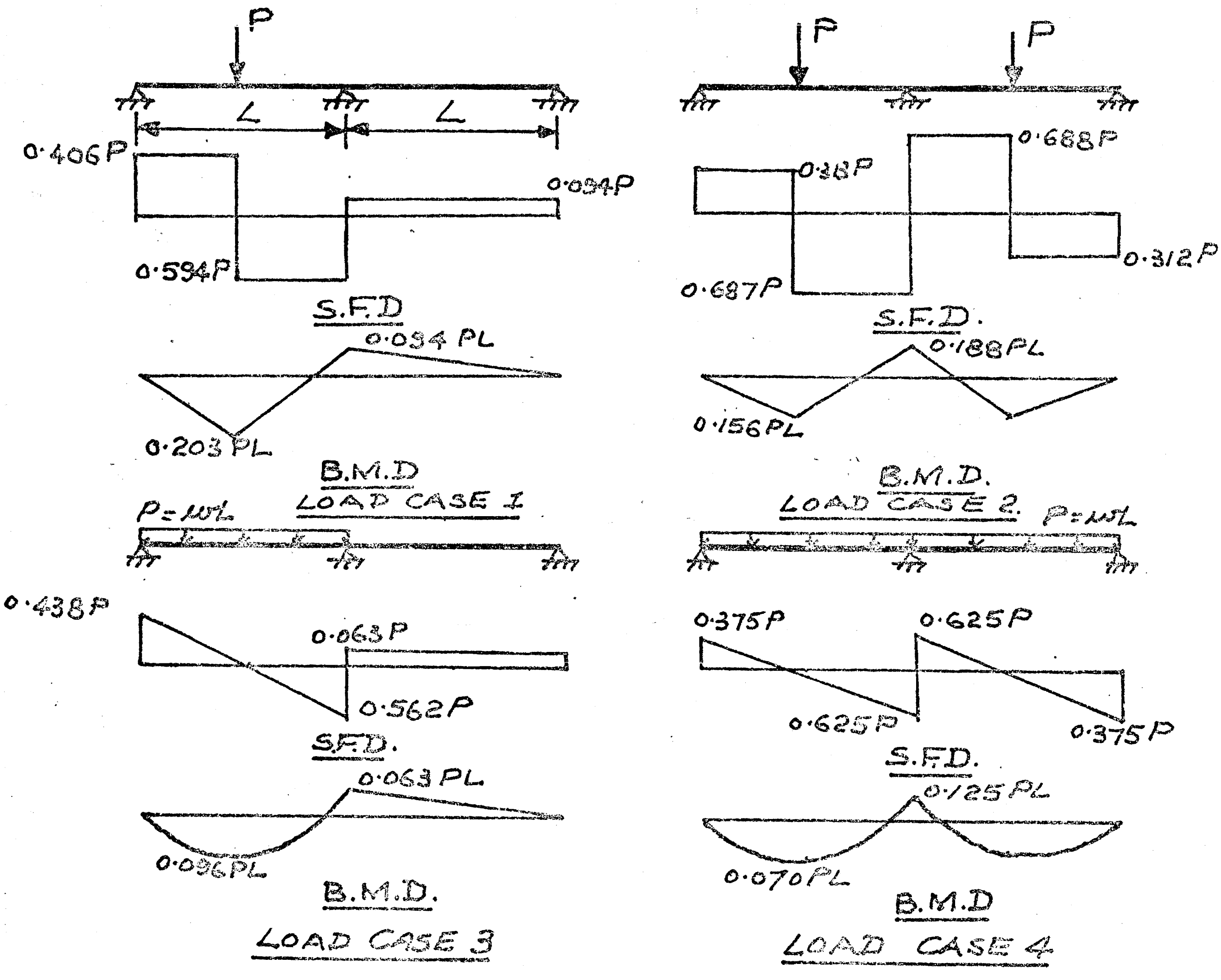


FIGURE 2

From Figure 2 it can be seen that Load Case 1 produces the largest moment and 86.5% of the worst shear condition of Load Case 2 at mid-span of the loaded bay. Therefore, a plated joint located in this vicinity would be subjected to the most severe case of combined moment and shear. It was on this basis that all beams were failed with a single concentrated load at mid-span of one bay.

4·1 Test Load

In a test situation several options are open in determining the type and magnitude of the load to be applied to the structure. In keeping with the requirements of (2) the load may be:

(a) concentrated
(b) uniformly distributed

The application of uniformly distributed loads is time consuming and in most test situations of questionable value. This method of load application was not considered in the performing of these tests.

Two other possibilities for establishing the test load are:

(i) on the basis of allowable bending stress, work backwards to determine a design load

(ii) determining the Equivalent Test Load (3) for prototype testing

<u>For 3 kPa Live Load</u>

For joists at 450 mm centres and including 0.2 kPa to account for floor dead load:

$$w = \frac{(3.2 \times 0.45 \times 3)}{1.4} \text{ kN}$$

$$w = 3.1 \text{ kN}$$

The 1.4 is a load duration factor which normalises the load to one of permanent application.

For strength equivalence based on a concentrated load applied at mid-span of one bay of a two span continuous system, producing the same bending moment as a uniformly distributed loading over the same span, gives:

$$P_{eq} = 3.1 \times \frac{\text{B.M. coeff of Load Case 3}}{\text{B.M. coeff of Load Case 1}}$$

$$= (3.1 \times \frac{0.096}{0.203}) \text{ kN}$$

$$P_{eq} = 1.47 \text{ kN} < 1.8 \text{ kN}$$

<u>Stressing to Allowable Bending Stress</u>

For this condition:

$$F_{all} = \frac{M \cdot y}{I} = \frac{M}{Z}$$

For a beam of rectangular cross-section:

$$Z = \frac{bd^2}{6}$$

using F14 timber and short duration loading:

$$F_b = 1.4\, F'_b = (1.4 \times 14)\ \text{MPa}$$

$$F_b = 19.6\ \text{MPA}$$

Also:

$$M_{des} = F_{all} Z = F_b\ \frac{bd^2}{6}$$

$$= \frac{19.6 \times 45 \times 147^2}{6}$$

$$M_{des} = 3.18\ \text{kN-m}$$

But from Load Case 1:

$$M = 0.203\ PL$$

$$P_{des}\ 0.203.3 = 3.18$$

$$P_{des} = 5.2\ \text{kN} > 1.8\ \text{kN}$$

Based on Equivalent Test Load (ETL)

From (3) the ETL for prototype testing is given by:

$$ETL = \frac{2.2 \times k_{26} \times k_{27} \times k_{28}}{k_1}\ (P_D + P_L)$$

$$= \frac{2.2 \times 2.4 \times 1.0 \times 1.0}{1.7}\ (3.2)\ \text{kPa}$$

$$ETL = 9.9\ \text{kPa}$$

Conversion to a concentrated load at mid-span of one bay gives:

$$ETL = (9.9 \times 0.45 \times 3 \times \frac{0.096}{0.203})\ \text{kN}$$

$$ETL = 6.3\ \text{kN} > 5.2\ \text{kN}$$

Summarizing it can be seen:

(a) satisfying the requirements of (1) dictates:

$$P = 1.8\ \text{kN}$$

(b) loading the beam until it attains its allowable bending stress requires:

P = 5.2 kN

(c) using the ETL calculated from (3) gives:

P = 6.3 kN

Since condition (c) would clearly overstress the joists a test load of 5 kN was used throughout the testing program. This is not unreasonable because satisfactory joist performance will be stiffness rather than strength related when spanning three metres.

5. TESTING PROCEDURE

The testing procedure followed as closely as practicable that described for Prototype Testing in (3).

An initial load of 2 kN was applied at the mid-span of one bay, held for 2 minutes, then released. No deflections were measured during this loading. The joist was then allowed 5 minutes to recover before further loading.

The test load of 5 kN was then applied at mid-span to one span of the joist in 1 kN increments. During loading the deflections of dial gauges 1 and 2 (see Fig. 1) were monitored. The test load was held for five minutes and the deflections recorded. The load was then released, residual deflections were noted, and after a 5 minute recovery period they were again taken. Results are given in Tables 1 through 5. The joists were then loaded to failure in the initially loaded span and except for NLB1 deflection readings were not monitored. NLB1 was also the only joist tested with the concentrated test load applied simultaneously at mid-span of both bays.

After loading the first span to failure and noting the ultimate load the second span was then loaded to failure. No load/deflection data was recorded during these loadings.

Only one span of SB1 was loaded to failure.

6. TEST RESULTS

Results obtained from testing the solid and four nail plated laminated joists are discussed herein.

6.1 Beams NLB1, NLB2, SB1

NLB1 and NLB2 were tested with the butt joints arranged as shown in Figure 1, i.e., such that they were located on the compression side in the loaded span.

Loading each bay of NLB1 singly and simultaneously to the test load of 5 kN resulted in no visible distress of the nail plates. For single span loading the maximum deflection was 23.7 mm at mid-span and for both spans loaded simultaneously maximum mid-span deflections were 18.3 and 19.9 mm respectively. Table 1 gives the load/deflection data for each of the previously mentioned load cases. Loading bay 1 to failure resulted in initial creaking at 7.5 kN. At 10 kN their was no visible signs of plate distress in bay 2,

DataSheet/41

CAPRICORNIA INSTITUTE

DEPARTMENT OF CIVIL ENGINEERING

DATA SHEET NO 1 OF 5

FIRM: J.B. HINZ & SONS, THE CAVES

TEST LABORATORY: Heavy Structures Laboratory

LOADING: Jack Capacity: 2 @ 120kN

Load Cells: @

Pressure Gauge 100psi = 1kN

DATE OF TEST: 18-3-86

BEAM SPECIFICATION: Supported Spans — Single: mm; Two Spans: 3000 mm; 3000 mm; Three Spans: mm; mm; mm

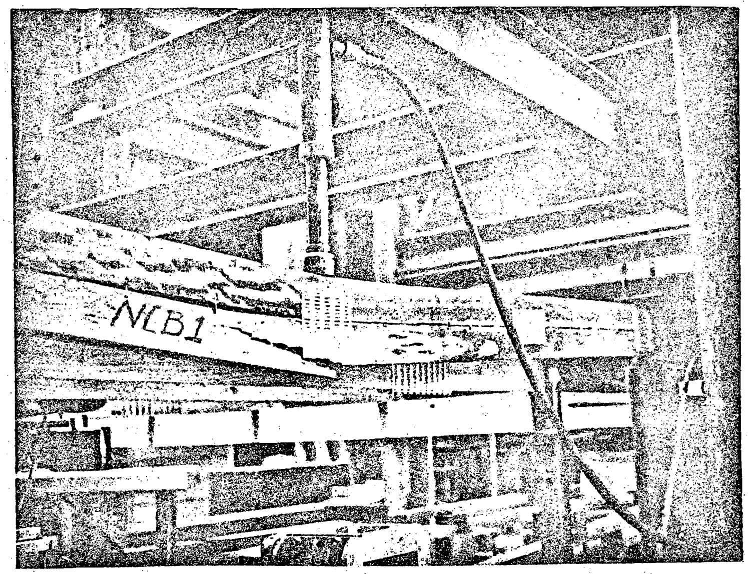
Dimensions: Width = 45 mm; Depth = 147 mm

BEAM IDENTIFICATION: NLB1 (all red gum laminates, 9% m.c.)

LOAD (kN)	TIME (mins)	DIAL GAUGE READINGS (mm) 1	2	3	4	COMMENTS
0·0	0:00	0·00	0·00			
1·0		3·82	-1·55			
2·0		9·40	-2·96			
3·0		13·52	-4·00			Load at mid-span
4·0		18·93	-5·28			of 1st bay
5·0	3:19	23·70	-6·21			
0·0	9:54	0·03	-0·19			
0·0	15:00	0·03	-0·10			
0·0	0:00	0·00	0·00			
1·0		+3·10	4·47			
2·0		+6·80	8·04			Load at mid-
3·0		+10·80	12·15			span of both
4·0		+14·27	15·65			bays.
5·0	2:53	+18·30	19·90			
5·0	8:00	+18·30	19·91			
0·0	8:30	+0·65	2·35			
0·0	15:30	+0·46	2·09			
0·0	0:00	0·00	0·00			
1·0		5·24	-1·51			Loading to failure
2·0		10·63	-2·91			for 1st bay.
3·0		15·40	-4·10			
4·0		20·01	-5·32			
5·0	1:35	24·65	-6·11			Dial Gauges removed

TABLE 1

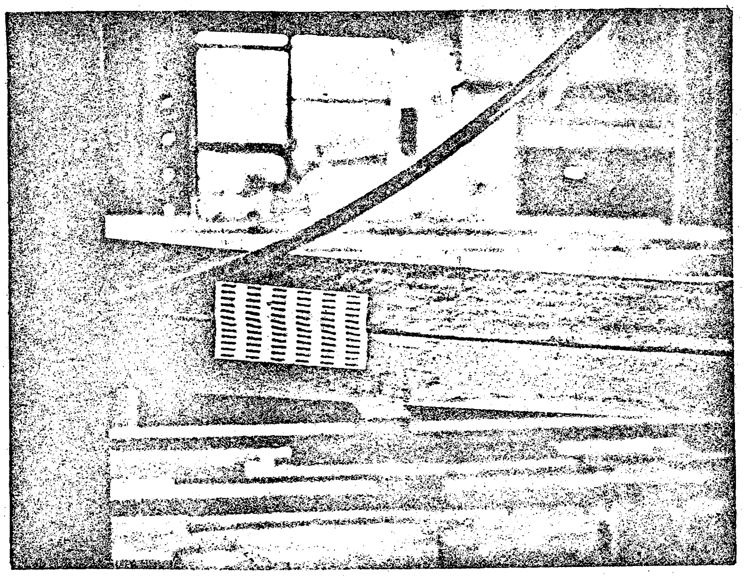
however, shear deformations were visible in the plate nearest the internal support in the loaded bay. Failure occurred at a load of 10.5 kN resulting in tension failure of the timber under the load point as shown in Plate 2. Failure in bay 2 occurred at a load of 14 kN resulting in tension failure of the timber under the load point.



TENSION FAILURE IN TIMBER

PLATE 2

Loading each bay of NLB2 individually to the test load again resulted in no visible signs of distress of the nail plates. For bay 1 loading the maximum mid-span deflection was 22.09 mm. Table 2 gives the load/deflection data. Failure loads for the two bays were 14.5 kN and 12 kN, respectively. Failure modes were tension failures in the timber under the load point. Shear deformations of the nail plates at the quarter points of the loaded span were clearly visible as can be seen from Plate 3.



NAIL PLATE SHEAR DEFORMATION

PLATE 3

Loading bay 1 of SB1 to the test load resulted in a maximum mid-span deflection of 18.12 mm. Load deflection data is given in Table 3.

DataSheet/41

CAPRICORNIA INSTITUTE

DEPARTMENT OF CIVIL ENGINEERING

DATA SHEET NO 2 OF 5

FIRM: J.B. HINZ & SONS, THE CAVES

TEST LABORATORY: Heavy Structures

LOADING: Jack Capacity: 2 @ 120 kN

Load Cells: @

Pressure Gauge 100psi = 1kN

DATE OF TEST: 18-3-86

BEAM SPECIFICATION: Supported Spans Single ______ mm; Two Spans 3000 mm; 3000 mm; Three Spans ______ mm ______ mm ______ mm

Dimensions: Width = 45 mm; Depth = 147 mm

BEAM IDENTIFICATION: NLB2 (red gum one span, red gum & stringybark oth

LOAD (kN)	TIME (mins)	DIAL GAUGE READINGS (mm)				COMMENTS
		1	2	3	4	
0·0	0:00	0·00	0·00			
1·0	↑	6·62	0·69			
2·0		10·89	-0·11			
3·0		14·39	-0·86			Load at mid-
4·0	↓	17·69	-1·70			span of 1st bay
5·0	3:05	22·09	-2·31			
5·0	8:05	22·21	-2·31			
0·0	8:50	1·14	-0·37			
0·0	14:00	0·74	-0·31			

TABLE 2

DataSheet/41

CAPRICORNIA INSTITUTE

DEPARTMENT OF CIVIL ENGINEERING

DATA SHEET NO 3 OF 5

FIRM: J.B. HINZE & SONS, THE CAVES

TEST LABORATORY: Heavy Structures Laboratory

LOADING: Jack Capacity: 2 @ 120 kN

Load Cells: ____ @ ____

Pressure Gauge 100 psi = 1 kN

DATE OF TEST: 18 - 3 - 86

BEAM SPECIFICATION: Supported Spans

Single	Two Spans	Three Spans
____ mm;	3000 mm;	____ mm
	3000 mm;	____ mm
		____ mm

Dimensions: Width = ____ mm; Depth = 150 mm

BEAM IDENTIFICATION: SB 1 (solid red gum joist, 13% m.c.)

LOAD (kN)	TIME (mins)	DIAL GAUGE READINGS (mm) 1	2	3	4	COMMENTS
0.0	0:00	0.00	0.00			
1.0	↕	4.31	-1.50			
2.0		7.81	-2.81			
3.0		11.00	-3.84			
4.0		14.55	-4.93			Failed in one
5.0	1:36	18.12	-5.94			bay only @ 18kN
5.0	7:00	18.20	-5.94			
0.0	7:24	0.79	-0.23			
0.0	13:00	0.34	-0.10			

TABLE 3

The failure load was 18 kN and the associated failure mode was a tension failure in the timber under the load point.

6.2 Beams NLB3, NLB4

NLB3 and NLB4 were tested with mid-span butt joints located on the tension side.

Following premature failure of NLB3, NLB4 was fitted with a nail plate across the butt joint. These plates were fitted to the beams by manually driving the nails.

Loading each bay of NLB3 individually to the test load resulted in stretching the steel across the joint in the area of maximum normal bending stress. On release of the load, the steel strips that previously stretched, buckled. For bay 1 loading the maximum mid-span deflection was 29.78 mm. Failure load was 5 kN for both bays. Load/deflection data for the initial load case is given in Table 4 which also shows a considerable amount of creep occurring after 5 minutes.

Loading the first bay of NLB4 to the test resulted in no visible signs of nail plate distress. However, during the 5 minute hold time considerable creep occurred. For bay 1 loading the maximum mid-span deflection was 29.68 mm. Load/deflection data is given in Table 5. On loading the second bay to the test load the vertical nail plate under the load failed on the tension side at a load of approximately 5 kN. The maximum deflection was 31.5 mm increasing to 42.5 mm after 5 minutes. Loading bay 2 to failure resulted in the nails of the tension plate pulling out of the timber. The remainder of the plates showed no visible signs of distress. Reloading bay 1 to failure resulted in tearing of the tension plate material at a load of 4.5 kN and complete failure at 5 kN due to fracture of the metal strips of the vertical plate.

Figure 3 shows a combined plot of test load vs mid-span deflection for NLB1 and NLB2. Also shown is the load/deflection graph for the solid joist SB1. Except for the deflection at 1 kN for NLB2 the three response curves are reasonably linear, whilst for the solid beam, it is linear as would be expected.

Figure 4 shows a combined plot of test load vs mid-span deflection for bay 1 loading for NLB3, NLB4, and SB1. For the nail plated laminated joists the response is reasonably linear to 4 kN and then becomes non-linear.

DataSheet/41

CAPRICORNIA INSTITUTE

DEPARTMENT OF CIVIL ENGINEERING

DATA SHEET NO 4 OF 5

FIRM: J.B. HINZ & SONS, THE CAVES

TEST LABORATORY: Heavy Structures

LOADING:

Jack Capacity: 2 @ 120kN

Load Cells: @

Pressure Gauge 100 psi = 1kN

DATE OF TEST: 18-3-86

BEAM SPECIFICATION: Supported Spans — Single: mm; Two Spans: 3000 mm; 3000 mm; Three Spans: mm; mm; mm

Dimensions: Width = 45 mm; Depth = 147 mm

BEAM IDENTIFICATION: NLB 3

LOAD (kN)	TIME (mins)	DIAL GAUGE READINGS (mm)				COMMENTS
		1	2	3	4	
0.0	0:00	0.00	0.00			
1.0	↑	6.44	-1.35			
2.0		11.58	-2.44			
3.0		16.92	-3.55			Butt joint on
4.0	↓	22.63	-4.60			tension side
5.0	1:55	29.78	-5.81			under applied
5.0	7:20	31.31	-5.81			load – no strap.
0.0	8:30	4.64	-0.50			across joint
0.0	13:30	4.27	-0.44			

TABLE 4

DataSheet/41

CAPRICORNIA INSTITUTE

DEPARTMENT OF CIVIL ENGINEERING

DATA SHEET NO 5 OF 5

FIRM: J.B. HINZ & SONS, THE CAVES

TEST LABORATORY: Heavy Structures

LOADING: Jack Capacity: 2 @ 120kN

Load Cells: @

Pressure Gauge 100psi = 1kN

DATE OF TEST:

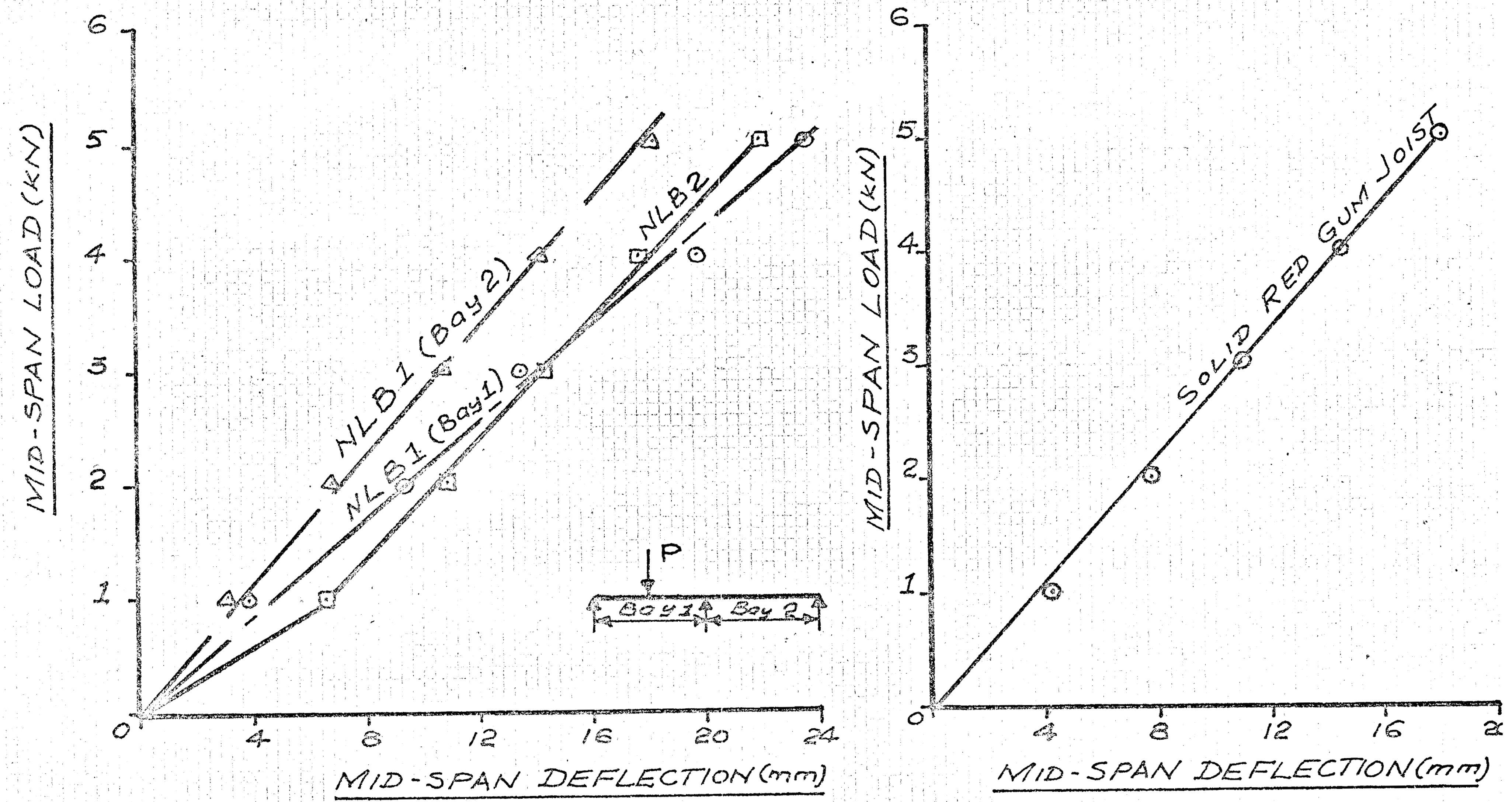
BEAM SPECIFICATION: Supported Spans — Single: mm; Two Spans: 3000 mm; 3000 mm; Three Spans: mm; mm; mm

Dimensions: Width = 45 mm; Depth = 147 mm

BEAM IDENTIFICATION: NLB4 (nail plate across tension side of butt joint)

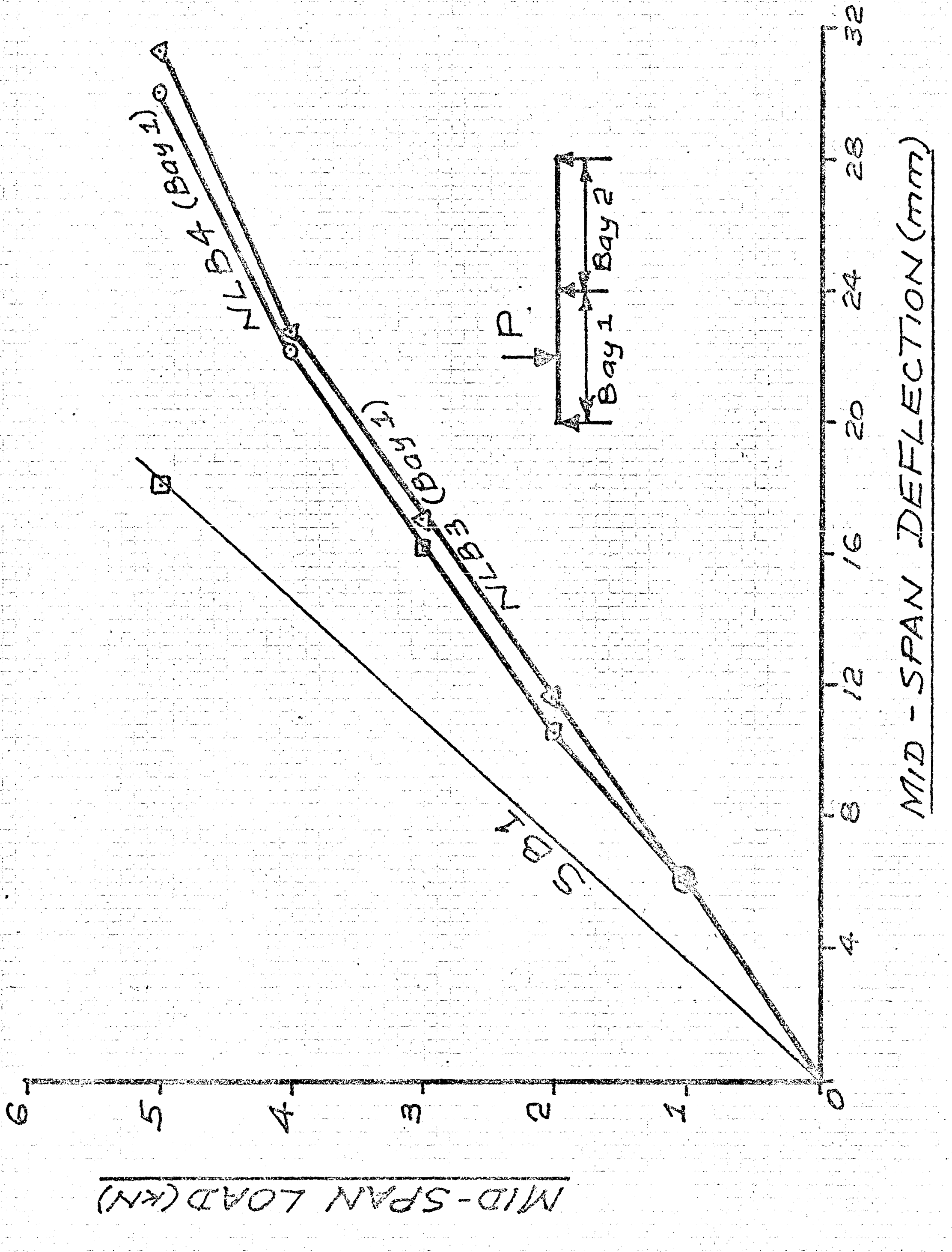
LOAD (kN)	TIME (mins)	DIAL GAUGE READINGS (mm) 1	2	3	4	COMMENTS
0.0	0:00	0.00	0.00			
1.0		6.03	—			
2.0		10.72	-2.30			Load at mid-
3.0		16.25	-3.			span of 1st bay
4.0		22.28	-4.52			
5.0	2:30	29.68	-5.38			
5.0	8:00	31.22	-5.78			
0.0	8:10	5.43	-0.56			
0.0	13:35	4.80	-0.41			
0.0	0:00	0.00	0.00			
1.0		-1.09	6.10			
2.0		-2.38	10.70			
3.0		-3.49	15.87			Load at mid-
4.0		-4.96	22.48			span of 2nd bay
5.0	2:05	-7.29	31.50			
5.0	7:17	-7.53	42.50			
0.0	8:42	-3.32	16.00			
0.0	14:00	-3.24	15.90			

TABLE 5



MID-SPAN LOAD (kN)
MID-SPAN DEFLECTION (mm)
NLB1 (Bay2)
NLB1 (Bay1)
NLB2
P
Bay 1
Bay 2
SOLID RED GUM JOIST

FIGURE 3



NLB4 (Bay 1)
NLB3 (Bay 1)
SB1
P
Bay 1
Bay 2
MID-SPAN DEFLECTION (mm)
MID-SPAN LOAD (kN)
0
4
8
12
16
20
24
28
32
1
2
3
4
5
6

FIGURE 4.

7. ANALYSIS OF RESULTS

Failure loads for NLB3 and NLB4 were 5 kN in each case. Examination of Figure 4 shows a limit load to exist at 4 kN for both joists. Since this load is less than that estimated to stress the timber to its allowable value in bending this arrangement of the joists would be unacceptable in its present form.

The failure mode for NLB3 and NLB4 was associated with tearing of the steel strips in the tension zone of the nail plate positioned under the load.

Failure loads for each and mid-span deflections at the test load of 5 kN are summarized in Table 6 for NLB1, NLB2, and SB1.

BEAM IDENT	FAILURE LOAD (kN) BAY 1	BAY 2	MID-SPAN DEFLN (mm) @ TEST LOAD
NLB1	10.5	14.0	23.70
NLB2	14.5	12.0	22.09
SB1	18.0	Not failed	18.12

TABLE 6

Failure load for either bay does not result in a failure load less than 2 x Test Load. Also, load response is generally linear to the test load. Further, joist failure resulted in a tension failure of the timber under the applied load in every case.

From Table 6 it is apparent the solid joist is both stronger and stiffer than the nail plated laminated members. How significant this apparent shortfall in strength and stiffness maybe is difficult to assess and will not be considered further in this report. In view of the fact the joists were spanning 6 m continuous over three supports it may well be expected that stiffness and associated dynamic problems would far outweigh any adversities related to strength requirements.

To obtain a more realistic comparison of the strength and stiffness characteristics of the joists their MOR's and MOE's were evaluated for single bay loading and are given in Table 7. Assuming linear joist response to failure MOR is given by the relationship:

$$\text{MOR} = \left(\frac{0.203 \times P_{fail} \times L \times 10^6}{Z}\right) \text{ MPa}$$

where P_{fail} = single bay failure load in kN

L = single bay spanin metres

Z = section modulus = $\frac{bd^2}{6}$

Evaluation of MOE based on the test load of 5 kN is given by:

$$\text{MOE} = \left(\frac{0.032 \times P \times L^3 \times 10^{12}}{\delta_D \times I}\right) \text{ MPa}$$

where:

P = single bay test load in kN

L = single bay span in metres

δ_D = mid-span deflection in mm at the test load

I = second moment of area in mm^4

$$= \frac{bd^3}{12}$$

BEAM IDENT	MOR (MPa)	MOE (MPa)	NORMALISED MOR	MOE
SB1	58.5	16953	1.00	1.00
NLB1	39.5	15302	0.68	0.90
NLB2	54.5	17417	0.93	0.97

TABLE 7

The MOR for NLB1 was based on the lowest failure load and for NLB2 on the highest ultimate load. The average of these loads is 12.5 kN resulting in an MOR of 47 MPa which is 0.8 of the MOR of the solid joist. SB1 registered a moisture content of 19% and on drying to the equilibrium moisture content would result in an increased MOR.

The average MOE is given as (3) 12,500 MPa which is less than any MOE determined for the three joists.

It should be noted the MORs of Table 7 are for short term loading and would have to be reduced by a factor of somewhere between about 4 and 7 to account for:

- duration of load
- grade factor
- factor of safety
- statistical considerations

7. OBSERVATIONS & CONCLUSIONS

On the basis of the limited tests performed the following observations are noteworthy:

(i) joists with butt joints on the tension side in zones of high shear and moment, even if strapped, are unsatisfactory in their present form both from a strength and stiffness viewpoint.

(ii) joists with butt joints on the compression side (NLB1 and NLB2) in zones of high shear and moment develop, on average, of the order of 80% of the strength and 94% of the stiffness of the solid beam.

(iii) Failure of NLB1 and NLB2 resulted from tension falure of the timber at the nail plate directly under the load. This failure was in all probability influenced by the fact that the nails were pressed into the timber along the edge subjected to high flexure stresses.

(iv) nail plates located at the quarter point were clearly permanently deformed (see Plate 3) at joist failure.

(v) although the joists were tested in isolation there was no evidence of the occurrence of lateral torsional buckling.

Finally the writer concludes:

(a) If joists are to be manufactured to the present design specification their stress grade should be reduced from that of the equivalent solid member of the same laminates.

(b) To improve performance, if considered necessary, increased shear resistance at laminate interfaces needs to be developed.

However, the degree of improvement would seem to depend on removing, or at least minimising, the affect the nails of the nail plates appear to have on propagating somewhat premature tension failure of the timber in the zone of high shear and moment.

Testing the beams in isolation deprived them of any chance of improved performance through the decking providing:

- lateral load distribution
- tee-beam action

These structural actions would no doubt be present in practice to some degree and could be expected to significantly influence joist performance.

9. REFERENCES

(1) AS 1170 Part 2 - Dead & Live Loads, 1981

(2) Steel Designers, Manual, Crosby Lockwood, 1966

(3) AS 1720 - Timber Engineering Code - 1975