THE JAMES COOK UNIVERSITY OF NORTH QUEENSLAND
CYCLONE STRUCTURAL TESTING STATION

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THE STRENGTH OF BATTEN—TO—RAFTER JOINTS

Part 1

TEST RESULTS & DERIVATION OF DESIGN LOADS

TECHNICAL REPORT NO. 2

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AN INVESTIGATION INTO THE STRENGTH OF VARIOUS BATTEN-TO-RAFTER JOINTS

Part 1

Test Results and Derivation of Design Loads

by

G.F. Reardon

INTRODUCTION

The passage of wind over the roof of a house causes uplift or "suction" forces to act on the leeward slope, and sometimes over the whole roof area. During most of the lifetime of a building these uplift forces are of little consequence, however during a wind storm they can overcome the gravitational forces acting on the roofing material causing it to strain at its fastenings and endeavour to free itself from the roof structure. This phenomenum starts to occur for sheet roofing when a wind of about 10 m/s (36 km/hr) strikes the building. For a tiled roof a wind of 24 m/s (86 km/hr) is needed to overcome the mass of the tiles. Winds of these speeds are expected to occur periodically throughout the life of all buildings in Australia.

When a severe wind storm hits a community considerable damage can occur (Ref. 1). When buildings are hit by a cyclone, the damage can be an order of magnitude greater (Ref. 2). During cyclone Tracy, when Darwin suffered a prolonged period of buffetting by severe wind gusts, many sheets of metal roofing failed by cracking around the fasteners (Ref. 3) and became dislodged from the roof structure. In some instances the roofing battens were pulled off the rafters, but more often the sheeting alone became detatched. This type of repeated loading failure of metal sheeting had not been observed previously and thus it led to a considerable amount of research both by Government (Ref. 4) and by industry (Ref. 5). As a result of this research industry has made recommendations for improved methods of fastening roof sheeting to roofing battens. However, little research has been undertaken to investigate the performance of various types of fasteners used to construct the joint between batten and rafters. The anticipated improvement in performance of roof sheeting during cyclones will cause more severe loading to be applied to that joint. Thus this investigation was initiated, to determine the holding power of some of the fasteners more commonly used in the cyclone-prone areas of Australia.

TYPES OF FASTENERS

The intent of this investigation was to determine the strength of typical joints that are being used in cyclone-prone areas. It was not intended to conduct an in-depth study of the holding power of one particular type of fastener in various timber species, nor was it intended to investigate such parameters as nail diameter or depth of penetration. Therefore the joints investigated were made in the same manner as they would be on site, and where necessary using the power driven equipment that would be used on site.

Nine different types of joint were fabricated using the following fasteners:

- (i) two 75 x 3.35 mm diameter plain shank nails, power driven
- (ii) one 75 mm and one 100 mm x 3.75 mm diameter plain shank nails, hand driven
- (iii) two 75 x 3.15 mm diameter helically grooved nails, power driven
- (iv) two 75 x 3.15 mm diameter annualarly grooved nails, power driven
- (v) two 100 x 3.35 mm diameter plain shank nails, power driven
- (vi) one 75 x 4.88 mm diameter self drilling "type 17" screw*, power driven
- (vii) 30 mm wide x 1 mm thick galvanized steel strap fastened with six 30 mm x 2.8 mm diameter clouts (see Figure 1 for configuration)
- (viii) same size strap and clouts as for (vii), but with strap bent under rafter and up the rear face (see Figure 2)
- (ix) one 10 mm diameter cup head bolt.

SIZE, SPECIES AND MOISTURE CONTENT OF TIMBER

In all cases the batten size was 75 x 38 mm and the rafter size was 100 x 38 mm.

The species of timber used for the battens was either mainly spotted gum or water gum, but this was actually immaterial as the batten species did not affect the strength of the joint. Two different species were chosen for the rafter section, Johnstone River hardwood as being typical of the dense timber being used for roof truss construction and rafter material in North Queensland, and Grey satinash considered to be rather typical of the less dense timber also available for roof construction. Johnstone River hardwood is classified as J1 in the Timber Engineering Code (Ref. 6), and Grey satinash as J3.

* *There was no brand name evident on these screws.*

Six lengths of each of the rafter species were purchased in the unseasoned condition and stored in a "fog" room to ensure that the timber did not dry out. In choosing the sticks of timber, every effort was made to ensure that each stick came from a different tree, but this cannot be guaranteed.

Fourteen replications of most of the nine joint types were made. Ten replications were kept in the "fog" room to maintain their moisture content, while the other four were stored in a sheltered outdoor environment and allowed to dry out. After each test a moisture sample was taken to determine whether the timber had been at the correct moisture content, that is, in excess of 30% for green timber, and approximately 12% for dry timber. All the tests satisfied these requirements.

With regard to the joints that were fabricated green and allowed to dry, it was found that the drying rate was such that after six months they were still at a moisture content of approximately 18%. The joints were then transferred to a drying kiln to rapidly achieve the desired moisture content.

Density samples were taken from each stick, and these closely matched the published basic density values for each of the species. The average measured basic density for Grey satinash was 614 kg m^{-3} compared to the published value of 610 kg m^{-3}. For Johnstone River hardwood the average measured value was 810 kg m^{-3} which compares very well with the published range of densities of 720 to 900 kg m^{-3}.

TEST PROCEDURE AND ANALYSIS OF RESULTS

For the joints tested in the green condition the test procedure and derivation of basic loads were conducted according to the Australian Standard 1649-1974 (Ref. 7). Although the Code specifies the recording of deformation for the type of joints using metal strap and nails, this was not done because strength is the basic requirement to resist cyclone winds and deformation is of little consequence.

Because failure of the steel was recorded for both the bolted joints and the longer steel strap joints in the green condition, they were not tested in the dry state. Only four replications of each joint were tested after drying, thus although a reliable average value was achieved a full statistical analysis was not meaningful. However the average value was used in the deviration of recommended design loads for each type of joint.

A summary of the test results for Johnstone River hardwood is given in Table 1, and for Grey satinash it is given in Table 2. The entire results are included in Appendix A.

TABLE 1

Failing Loads for Joints Fabricated from Johnstone River Hardwood

Joint Type	Made green tested green		Made green tested dry
	Average failing load (kN)	Coefficent of Variation (%)	Average failing load (kN)
two 75 x 3.35 mm plain shank nails	2.9	11.8	0.8
one 75, one 100 x 3.75 mm plain shank nails	4.7	10.6	1.8
two 75 x 3.15 mm helically grooved nails	4.7	9.4	3.2
two 75 x 3.15 mm annularly grooved nails	5.4	14.6	2.2
two 100 x 3.35 mm plain shank nails	5.6	14.4	1.9
one 75 x 4.88 "type 17" screw	8.1	6.2	9.4 *
30 x 1 mm steel strap, six 30 x 2.8 clouts (Fig. 1)	13.2	7.3	10.3
30 x 1 mm steel strap, six 30 x 2.8 clouts (Fig. 2)	19.1	5.0	-
one 10 mm cup head bolt	26.2	5.5	-

* *Average of three results, one screw broke*

TABLE 2

Failing Loads for Joints Fabricated from Grey Satinash

Joint Type	Made green tested green		Made green tested dry
	Average failing load (kN)	Coefficient of Variation (%)	Average failing load (kN)
two 75 x 3.35 mm plain shank nails	2.8	15.5	1.7
one 75, one 100 x 3.75 mm plain shank nails	3.5	16.5	2.9
two 75 x 3.15 mm helically grooved nails	3.5	15.8	4.8
two 75 x 3.15 mm annularly grooved nails	4.2	16.0	5.3
two 100 x 3.35 mm plain shank nails	4.4	19.0	2.7
one 75 x 4.88 mm "type 17" screw	5.5	10.3	6.9
30 x 1 mm steel strap, six 30 x 2.8 mm clouts (Fig. 1)	10.0	6.6	9.8
30 x 1 mm steel strap, six 30 x 2.8 mm clouts (Fig. 2)	17.8	4.5	-
one 10 mm cup head bolt	18.5	7.5	-

DISCUSSION OF TEST RESULTS

The most significant result from the tests is the drastic loss of holding power exhibited by the nails in the Johnstone River hardwood as the timber dried out. Although this trend was not totally unexpected, the magnitude of the loss was greater than anticipated. Mack (Ref. 8) demonstrated a loss of holding power of some 60% for fine gauge plain shank nails in messmate stringybark, whereas loss of strength in excess of 70% is shown in Table 1. Che Lah (Ref. 9) recorded a loss of approximately 50% for plain shank nails in Johnstone River hardwood, but the nails had been driven into predrilled holes therefore minimizing splitting during the drying process.

The plain shank nails in Grey satinash showed a loss in holding power of of about 40%. The reason for this better performance was obvious, as the satinash exhibited hardly any splitting on drying, whereas the hardwood split severly around the nail holes during the early stages of drying.

It was anticipated that the grooved nails would increase in holding power as the timber dried. In his tests, Mack gained about 70% increase in holding power, and Che Lah gained about 40% increase for nails in pre-drilled holes in Johnstone River hardwood. Although the satinash showed an increase of about 30%, the hardwood showed a loss of strength of between 30% and 60%. Again this loss of strength must be attributed to splitting during the drying process. Although such splitting could have been reduced by predrilling, that practise is considered impracticable.

Of the two other fastener types that were tested in both the green and seasoned state, the power driven screw gave the more consistent performance. In each timber it gained strength on drying. The nails driven through the steel strap demonstrated that such a connection is less dependent upon holding power of the fastener, and more dependent upon its lateral bearing strength.

With regard to the fastener types that were tested in the green timber only, it is interesting to note that at least fify percent gain in holding power is achieved by bending the strap around the rafter as shown in Figure 2. It is anticipated that a similar gain would be achieved if the connections were tested in the dry state.

DERIVATION OF DESIGN LOADS

As previously mentioned, a sample of four test results from the specimens

TABLE 3

Calculated Design Loads to Resist Wind Forces

Joint Type	Design Load (kN)	
	Johnstone River Hardwood	Grey Satinash
two 75 x 3.35 mm plain shank nails	0.25	0.46
one 75, one 100 x 3.75 mm plain shank nails	0.62	0.75
two 75 x 3.15 mm helically grooved nails	1.15	0.91
two 75 x 3.15 mm annularly grooved nails	0.63	1.1
two 100 x 3.35 mm plain shank nails	0.54	0.59
one 75 x 4.88 mm "type 17" screw	3.3	1.9
30 x 1 mm steel strap, six 30 x 2.8 mm clouts (Fig. 1)	3.8	3.7
30 x 1 mm steel strap, six 30 x 2.8 mm clouts (Fig. 2)	7.6	7.2
one 10 mm cup head bolt	10.2	6.7

fabricated green and allowed to dry is too small from which to estimate a coefficient of variation. It is therefore considered to be not unreasonable to use the same value as estimated from the tests on the green joints. The calculated design loads given in Table 3 are based on that assumption, using the load factors recommended in AS 1649-1974 (Ref. 7). It should be noted that values given in Table 3 relate to the joints, not to each individual element forming the joint. Also the values were calculated only for design to resist wind forces. For screws, bolts and steel strap with clouts "basic loads" as defined in the Timber Engineering Code should be taken as being half the values given in Table 3.

Table 4 lists the load factors that were applied to the one percentile values calculated from the test results. It should be stressed again that these factors relate only to the design loads to be used for calculating the resistance to wind forces. As such they should not be used out of the context of this document. It may be noted that the load factor recommended for screws is greater than the value of 1.25 which would be derived from the Fastener Code, allowing for wind conditions. Such a value was considered to be too small, as it would be completely nullified if the coefficient of variation of the total population was 12% rather than the 6% derived from the sample used in these tests. A more realistic value of 2.0 is therefore recommended to be in general agreement with the load factors for other fasteners.

TABLE 4

Load Factors used in the Derivation of Design Loads

Fastener Type	Load factor applied to 1% value
Nails in withdrawal	2.0
Screw	2.0
Strap and nails	2.15
Bolt	2.15

COMMENTS ON DESIGN LOADS

At the outset of this series of tests, the aim was to produce a set of design loads for the various types of fasteners in timbers that are used extensively in the cyclone-prone areas, and that are typical of groups J1 and J3 as defined in the Timber Engineering Code. Recommendations could therefore be made for those particular joint groups. However it is clear from the loads listed in Table 3 that this cannot be achieved, as the holding power of the fasteners in the timber designated J1 is generally lower than that for J3 timber, whereas for nails it should be 50% greater. Further for the few instances where a comparison can be drawn between the J3 values in Table 3 and the recommendations of the Code, the Table 3 values are slightly lower than the Code values.

It would be imprudent therefore to recommend that the values given in Table 3 be taken as design loads to resist wind forces for the two joint groups tested. Recommended design loads are therefore given in Table 5. These are based on the results of a selection of the types of fastener tested in Grey satinash except that the allowable load for the plain shank nails has been increased slightly to bring it to the value recommended in the Timber Engineering Code for J3 species. No recommendations are being made for J1 species as other timbers classified in this group may well perform similarly to Johnstone River hardwood, although it would probably be satisfactory to use loads for screws and bolts given in Table 3.

CONCLUSION

Although the tests have not resulted in the information sought at their outset, they have shown that the holding power of fasteners is not solely dependent upon density of timber, other parameters such as fissility should be taken into consideration. While it is obviously convenient to use the same timber grouping system for the performance of nails loaded axially as for nails loaded laterally, the validity of this assumption is questionable. Although it is well known that the lateral strength of a nail is dependent upon the bearing strength of timber, which is closely related to density, it appears that this relationship is rather tenuous when considering withdrawal strength of nails. It is therefore recommended that the joint grouping system used in the Timber Engineering Code be reviewed, as the performance of Johnson River hardwood in these tests showed it to be far below the expectations of a J1 group timber and little better than that expected of a J4 group timber.

With regard to the comparative performance of the fasteners, the grooved nails exhibited 100% increase in holding power over the plain shank nails. It is not considered valid to make comparisons between the annularly and helically grooved nails, as their performance was governed more by the amount of splitting around the nail than by the profile of the groove.

The best performance was given by the screws which demonstrated an increase in holding power as the timber dried, and produced significantly greater holding power in the denser timber. Presumeably the screw diameter and depth of thread were sufficiently large to be unaffected by the drying splits.

TABLE 5

Recommended Design Loads to Withstand Wind Forces

(suitable only with battens 38 mm thick or less)

Joint Type	Design Load (kN)
two 75 x 3.35 mm plain shank nails	0.55
two 75 x 3.15 mm grooved nails	0.90
one 75 x 4.88 mm "type 17" screw	1.9*
30 x 1 mm steel strap, six 30 x 2.8 clouts (Fig. 1)	3.7
30 x 1 mm steel strap, six 30 x 2.8 clouts (Fig. 2)	7.2
one 10 mm cup head bolt	6.7†

* *May be increased by up to 75% for J1 timbers*

† *May be increased by up to 50% for J1 timbers*

The steel strap performed as would have been expected for the satinash, but demonstrated a loss of strength in the dried out hardwood, resulting in approximately the same design load for the two species. It was interesting to note that approximately 100% increase in strength was gained by the steel strap bent around to the rear face of the rafter.

Since the completion of this work the author's attention has been drawn to some other test results (unpublished) which show a considerably better performance by nails withdrawn from Johnstone River hardwood. The results relate to the withdrawal of single nails from timber, and thus raise questions about the potential holding power of multiple nail joints. The Timber Engineering Code recommends a reduction in design load for groups of five or more nails, but numbers of nails are rarely used to resist withdrawal forces. It appears that there could be a serious reduction in potential holding power of joints having two or three fasteners. Further work needs to be conducted in this area.

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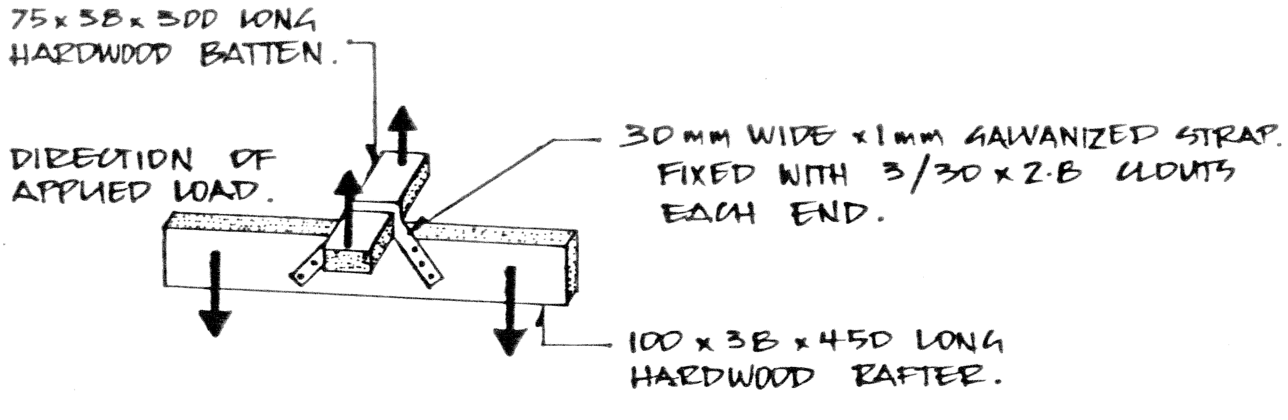

Figure 1.

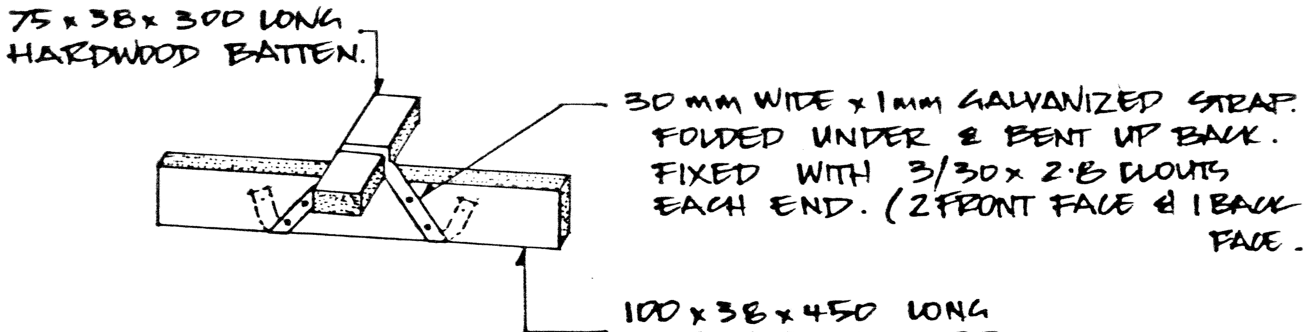

Figure 2.

APPENDIX A.

The results of all the tests conducted on the joints are contained herein. Those showing a moisture content in excess of 30% were tested in the unseasoned (green) condition. Those with a moisture content of about 12% were tested after they had dried out.

Johnstone River Hardwood

Fastener type: 2 - 75 mm plain shank nails

Specimen	Max. load (kN)	Moisture content at test (%)	Remarks
1	3.5	40.4	Nails withdrew from rafter
2	2.9	37.0	"
3	2.9	35.2	"
4	2.6	40.8	"
5	3.2	38.9	"
6	3.4	39.0	"
7	2.7	38.5	"
8	2.8	38.1	"
9	2.9	39.4	"
10	2.4	39.9	"
Average	2.9		
11	1.0	10.5	Splits up to 75 mm long at each nail
12	0.70	9.6	"
13	0.65	11.2	"
14	0.75	9.1	"
Average	0.77		

Johnstone River Hardwood

Fastener type: 1-100 mm, 1-75 mm plain shank nails

Specimen	Max. load (kN)	Moisture content at test (%)	Remarks
1	4.6	31.8	Both nails withdrew
2	4.8	31.4	"
3	4.0	37.9	"
4	4.5	38.8	100 mm nail pulled through batten
5	3.9	39.3	"
6	4.8	37.3	Both nails withdrew
7	5.1	34.5	100 mm nail pulled through batten
8	5.4	36.6	"
9	5.3	34.6	Both nails withdrew
10	4.6	37.1	"
Average	4.7		
11	3.2	10.2	No splits
12	1.2	10.2	Split 130 mm long
13	1.4	9.4	Split 200 mm long
14	1.4	7.5	Split 110 mm long
Average	1.8		

Johnstone River Hardwood

Fastener type: 2-75 mm helically grooved nails

Specimen	Max. load (kN)	Moisture content at test (%)	Remarks
1	5.3	38.6	Nails withdrew from rafter
2	4.6	36.5	"
3	4.7	36.5	"
4	5.6	35.3	"
5	4.6	35.3	"
6	4.8	35.3	"
7	4.3	34.6	"
8	4.6	35.0	"
9	4.4	33.8	"
10	4.3	32.7	"
Average	4.7		
11	2.1	10.2	Split 160 mm long
12	3.0	10.2	Splits approx 70 mm long at each nail
13	4.0	9.4	"
14	3.8	7.5	"
Average	3.2		

Johnstone River Hardwood

Fastener type: 2 - 75 mm annularly grooved nails

Specimen	Max. load (kN)	Moisture content at test (%)	Remarks
1	6.4	40.0	Nails withdrew from rafter
2	5.5	37.0	"
3	6.4	35.2	"
4	4.9	40.8	"
5	4.4	38.8	"
6	4.4	39.0	"
7	6.4	38.5	Nails pulled through batten
8	5.7	38.1	Nails withdrew from rafter
9	5.0	39.4	"
10	5.0	39.9	"
Average	5.4		
11	3.25	6.1	150 mm long split
12	1.2	10.5	2/100 mm long splits
13	2.4	9.8	2/ 50 mm long splits
14	2.1	8.9	180 mm long split
Average	2.2		

Johnstone River Hardwood

Fastener type: 2 - 100 mm plain shank nails

Specimen	Max. load (kN)	Moisture content at test (%)	Remarks
1	5.6	40.4	Nails withdrew from rafter
2	5.5	37.0	"
3	4.9	35.2	"
4	4.5	40.8	"
5	4.4	38.9	"
6	6.0	39.0	"
7	6.3	38.5	"
8	6.0	38.1	"
9	6.9	39.4	"
10	6.2	39.9	"
Average	5.6		
11	2.2	9.7	Splits approx. 70 mm long at each nail
12	1.6	8.5	"
13	1.6	7.9	"
14	2.2	7.6	"
Average	1.9		

Johnstone River Hardwood

Fastener type: 1 - 4.88 mm ϕ, 75 mm long, power driven screw

Specimen	Max. load (kN)	Moisture content at test (%)	Remarks
1	8.0	31.8	Screw withdrew from rafter
2	8.1	31.4	"
3	8.6	37.9	"
4	8.6	38.8	"
5	9.1	39.3	"
6	7.4	37.3	"
7	7.8	33.5	"
8	8.1	36.6	"
9	7.8	34.6	"
10	7.8	37.1	"
Average	8.1		
11	3.6	9.6	Screw broke (result culled)
12	8.8	10.8	split 65 mm long
13	9.4	10.8	split 70 mm long
14	9.9	9.2	split 110 mm long
Average	9.4		

Johnstone River Hardwood

Fastener type: 30 x 1 mm steel strap
6 - 30 x 2.8 mm clouts (Fig.1)

Specimen	Max. load (kN)	Moisture content at test (%)	Remarks
1	12.0	38.6	Sheared one or more clouts
2	13.3	36.5	"
3	12.1	36.6	"
4	12.2	35.3	"
5	14.4	35.3	"
6	13.6	35.3	"
7	14.6	34.6	"
8	12.9	35.0	"
9	14.2	33.8	"
10	13.1	32.7	"
Average	13.2		
11	10.0	10.7	"
12	10.5	9.5	"
13	11.2	10.2	"
14	9.5	11.3	"
Average	10.3		

Johnstone River Hardwood

Fastener type: 30 x 1 mm steel strap
6 - 30 x 2.8 mm clouts (Fig.2)

Specimen	Max. load (kN)	Moisture content at test (%)	Remarks
1	19.1	40.4	Strap broke at top nail hole
2	19.6	37.0	"
3	20.0	35.2	"
4	19.2	40.8	"
5	19.6	38.9	"
6	17.8	39.0	"
7	20.4	38.5	"
8	17.4	38.1	"
9	19.2	39.4	"
10	18.4	39.9	"
Average	19.1		
11	-		
12	-		
13	-		
14	-		

Johnstone River Hardwood

Fastener type: 10 mm cup head bolt, standard washer

Specimen	Max. load (kN)	Moisture content at test (%)	Remarks
1	27.3	36.8	Pulled through batten
2	26.5	36.5	Stripped thread
3	27.0	36.6	Bolt failed in tension
4	26.9	35.3	Stripped thread
5	26.1	35.3	Batten split
6	25.2	35.3	Bolt failed in tension
7	25.5	34.6	Rafter split
8	28.2	35.0	Bolt failed in tension
9	23.2	32.7	Batten split
10	-		
Average	26.2		
11	-		
12	-		
13	-		
14	-		

Grey Satinash

Fastener type: 2 - 75 mm plain shank nails

Specimen	Max. load (kN)	Moisture content at test (%)	Remarks
1	3.5	36.1	Nails pulled out of rafter
2	3.3	35.7	"
3	2.0	66.5	"
4	2.8	56.2	"
5	2.8	52.2	"
6	3.0	39.6	"
7	2.6	61.7	"
8	2.9	56.0	"
9	2.5	43.5	"
10	2.5	59.6	"
Average	2.8		
11	2.1	15.0	No splits evident
12	1.5	11.1	"
13	1.4	10.7	"
14	1.8	11.4	"
Average	1.7		

Grey Satinash

Fastener type: 1 - 100 mm, 1 - 75 mm plain shank nails

Specimen	Max. load (kN)	Moisture content at test (%)	Remarks
1	4.0	65.9	75 mm nail withdrew 100 mm nail pulled through batten
2	2.6	38.8	"
3	3.8	70.0	"
4	3.0	61.1	"
5	3.5	55.3	"
6	3.8	65.9	"
7	3.0	38.8	"
8	3.6	70.0	"
9	2.9	61.1	"
10	4.4	55.3	"
Average	3.5		
11	2.2	10.8	No splits evident
12	4.0	11.3	"
13	3.0	12.6	"
14	2.3	9.4	"
Average	2.9		

Grey Satinash

Fastener type: 2 - 75 mm helically grooved nails

Specimen	Max. load (kN)	Moisture content at test (%)	Remarks
1	4.0	36.1	Nails withdrew from rafter
2	4.3	35.7	"
3	2.6	66.5	"
4	3.4	56.2	"
5	2.9	52.2	"
6	4.0	39.6	"
7	3.3	61.7	"
8	3.2	56.0	"
9	4.0	43.5	"
10	3.3	59.6	"
Average	3.5		
11	4.8	10.9	No splits evident
12	4.6	12.8	"
13	4.6	6.4	"
14	5.2	12.2	"
Average	4.8		

Grey Satinash

Fastener type: 2 - 75 mm annularly grooved nails

Specimen	Max. load (kN)	Moisture content at test (%)	Remarks
1	4.9	58.0	Nails pulled out of rafter
2	5.6	55.0	"
3	4.1	63.4	"
4	3.8	72.8	"
5	3.1	70.3	"
6	4.2	69.3	"
7	3.9	61.9	"
8	3.8	76.8	"
9	4.4	52.9	"
10	4.4	54.6	"
Average	4.2		
11	5.4	10.4	No splits evident
12	4.8	15.9	"
13	6.5	8.9	"
14	4.6	11.3	"
Average	5.3		

Grey Satinash

Fastener type: 2 - 100 mm plain shank nails

Specimen	Max. load (kN)	Moisture content at test (%)	Remarks
1	5.2	58.0	Nails withdrew from rafter
2	5.7	55.0	"
3	4.4	63.4	"
4	3.5	72.8	"
5	4.0	70.3	"
6	4.1	69.3	"
7	3.1	61.9	"
8	4.0	76.8	"
9	5.6	52.9	"
10	4.5	54.6	"
Average	4.4		
11	2.0	10.8	No splits evident
12	2.6	11.2	"
13	2.5	10.7	"
14	3.9	13.2	"
Average	2.7		

Grey Satinash

Fastener type: 1 - 4.88 mm dia. power driven screw

Specimen	Max. load (kN)	Moisture content at test (%)	Remarks
1	5.8	42.4	Screws withdrew from rafter
2	6.4	31.0	"
3	4.6	62.0	"
4	5.9	53.7	"
5	5.1	61.3	"
6	5.6	53.3	"
7	4.7	65.9	"
8	5.7	45.0	"
9	5.3	59.5	"
10	6.0	57.1	"
Average	5.5		
11	7.3	14.9	No splits evident
12	6.7	10.4	"
13	6.6	11.5	"
14	7.0	10.7	"
Average	6.9		

Grey Satinash

Fastener type: 30 x 1 mm steel strap
6 - 30 x 2.8 mm clouts (Fig.1)

Specimen	Max. load (kN)	Moisture content at test (%)	Remarks
1	10.2	68.7	Nails withdrew from rafter
2	10.1	42.2	"
3	10.6	63.7	"
4	10.9	51.6	"
5	8.8	69.4	"
6	10.0	73.9	"
7	9.2	64.0	"
8	10.6	51.6	"
9	9.5	68.0	"
10	10.1	72.1	"
Average	10.0		
11	9.8	11.1	"
12	10.0	12.2	"
13	8.8	11.7	"
14	10.6	14.3	"
Average	9.8		

Grey Satinash

Fastener type: 30 x 1 mm steel strap
6 - 30 x 2.8 mm clouts (Fig.2)

Specimen	Max. load (kN)	Moisture content at test (%)	Remarks
1	18.0	53.2	Strap broke at top nail hole
2	18.8	39.4	"
3	18.4	58.7	"
4	18.0	52.7	"
5	17.7	63.9	"
6	16.7	53.3	Nails withdrew from rafter
7	18.6	64.1	Strap broke at top nail hole
8	17.5	49.0	"
9	16.3	63.5	Nails withdrew from rafter
10	17.8	59.6	Strap broke at top nail hole
Average	17.8		
11	-		
12	-		
13	-		
14	-		

Grey Satinash

Fastener type: 1 - 10 mm cup head bolt

Specimen	Max. load (kN)	Moisture content at test (%)	Remarks
1	18.8	51.7	Bolt pulled through rafter
2	18.3	36.2	Bolt pulled through batten
3	17.0	60.5	Bolt pulled through rafter
4	20.4	56.2	Bolt pulled through batten
5	19.5	63.1	Bolt pulled through rafter
6	17.0	63.7	Bolt pulled through batten
7	18.4	61.9	Bolt pulled through rafter
8	20.2	47.8	"
9	16.2	55.3	"
10	18.7	60.0	"
Average	18.5		
11	-		
12	-		
13	-		
14	-		