JAMES COOK CYCLONE STRUCTURAL TESTING STATION

CYCLONE TESTING STATION

WITHDRAWAL STRENGTH OF GROOVED NAILS IN PINE

Part 1 — RESULTS and ANALYSIS

TECHNICAL REPORT No. 16

September 1983

DEPARTMENT OF CIVIL & SYSTEMS ENGINEERING
POST OFFICE JAMES COOK UNIVERSITY
TOWNSVILLE QLD 4811

CYCLONE TESTING STATION

WITHDRAWAL STRENGTH OF GROOVED NAILS IN PINE

Part 1 - Results and Analysis

G.F. Reardon

Technical Report No. 16

Reardon, G.F. (Gregory Frederick), 1937- .
Withdrawal strength of grooved nails in pine.

ISBN 0 86443 113 9
ISSN 0158 - 8338

1. Nails and spikes - Testing. I. James Cook University of North Queensland. Cyclone Testing Station. II. Title. (Series: Technical report (James Cook University of North Queensland. Cyclone Testing Station); no. 16).

621.8'84

WITHDRAWAL STRENGTH OF GROOVED NAILS IN PINE

Part 1 - Results and Analysis

G.F. REARDON

SUMMARY

Withdrawal tests have been conducted on six different types of grooved nail driven into seven species of seasoned pine. There were twenty replications of most nail timber combinations. Plain shank nails and power driven screws were included to represent the two extremes of embedded fasteners.

The results showed that the nails with pronounced grooving had better holding power than others whose grooves were not accentuated as much. There was virtually no correlation between nail holding power and density of individual sticks of timber.

Design withdrawal loads for pairs of nails or single screws have been derived for each species and for various density groupings including joint strength group JD4.

TABLE OF CONTENTS

		Page
1.	Introduction	1
2.	Test Programme	2
	2.1 Details of Nails	2
	2.2 Timber	4
	2.2.1 Species	4
	2.2.2 Density	5
	2.3 Test Specimens	6
	2.4 Screws	7
	2.5 Departure from Code Specifications	8
3.	Analysis of Results	10
	3.1 Nail performance	10
	3.2 Effect of Species	13
	3.2.1 Effect of Density	13
	3.2.2 Variability between Species	14
	3.2.3 Variability within Species	15
4.	Power Driven Screws	17
5.	Derivation of Design Loads	18
	5.1 Method of Calculating Design Load	18
	5.2 Design Loads for each Species	19
	5.3 Design Loads for Joint Group JD4	19
	5.4 Comparison of Derivation of Design Loads	20
	5.4.1 Density Ranges	20
	5.4.2 Percentile Values	21
	5.5 Design Loads for Screws	23
6.	Conclusions	23
7.	Acknowledgements	25
8.	References	25
	Appendix A	27

1. INTRODUCTION

Over the past eight or nine years the manufacturers of roofing materials have significantly improved the capacity of fasteners used to secure roofing to roof structure. It is now common for roofing fasteners or tile clips to be tested for cyclone conditions by applying a series of load cycles. This research is meant to ensure that the roofing remains securely anchored to the house during a wind storm. However all that is really achieved is that the roofing is well fastened to the battens. If the battens are not securely fixed to the rafters or trusses, the research of the roofing manufacturers may be of little advantage. The roofing material may still be blown off, but with battens attached.

The above statements are not meant to question the accuracy or the value of the manufacturers' research, but to highlight the need for information on the strength of batten joints. One cannot expect roofing manufacturers to provide this information any more than, say, truss manufacturers to whose product the battens are attached. Batten joints have not had the direct interest of large product manufacturers, nor the engineering input of roof trusses.

The main concern of batten joints is that wind uplift pressures, which act on the roofing, cause withdrawal forces to act on the fasteners. For most fasteners this represents action in their weakest direction. In fact the 1975 edition of the Timber Engineering Code (SAA, 1975) contains a clause recommending that designs avoid having load components parallel to the axis of a smooth shank nail. A simple way of avoiding forces on fasteners is to use metal strap or patented framing anchors, but such devices take more time to install.

Deformed shank or grooved nails have been readily available in Australia for more than a decade, but they have only become popular in recent years, with the availability of nailing guns. It is so easy with a nailing gun to join two members crossing each other. However this practice has put the building industry in somewhat of a predicament, in that there is very little published information on the strength of joints made with grooved nails. Also there is no industry standard which defines grooved nails. Therefore at the request of the Timber Research and Development Advisory Council (TRADAC), the Cyclone Testing Station undertook an extensive test programme to determine the holding power of various grooved nails in different species of seasoned pine.

2. TEST PROGRAMME

2.1 Details of Nails

Six different types of grooved nail were included in the programme. All were nominally 75 mm long and had measured diameters varying from 3.1 to 3.75 mm on the plain portion of the shank. The nails were supplied by Able Staples, Bostitch, Jambro, National and Sidney Cooke. Two different types of Jambro nail were included. Figure 1 shows the different nails. Both the National and the Sidney Cooke nail were hand driven whereas the others were driven by nailing guns supplied by the manufacturer.

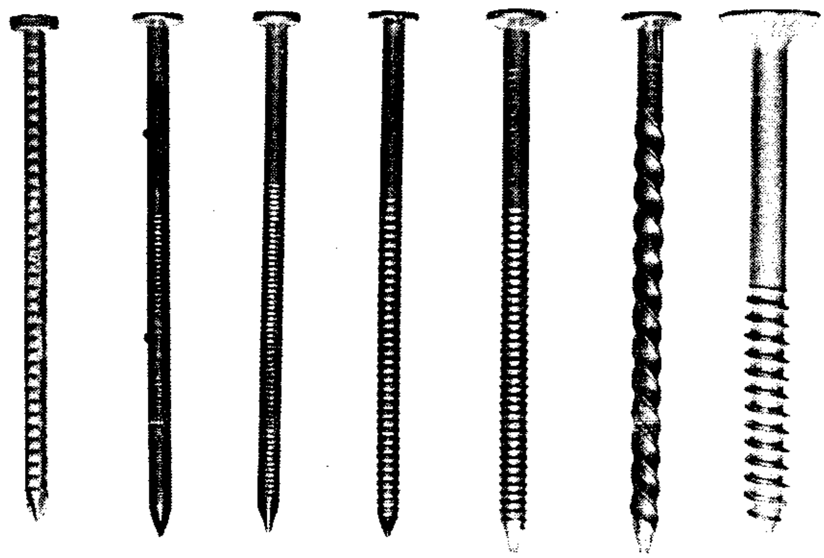

FIGURE 1 Fasteners used in test programme (l. to r. Jambro 1, Bostitch, Able Staples, Jambro 2, National, Sidney Cooke, Deutsher Screw).

A description of each nail is given below.

(a) Able Staple - power driven
Length: 74 mm from point to top of head
Diameters: 3.1 mm on shank, 3.2 mm on grooves
Type of groove: annular

Number and length: 56 grooves in 44 mm

(b) Bostitch - power driven
Length: 75 mm from point to top of head
Diameters: 3.2mm at shank, 3.4 mm on grooves
Type of groove: annular, double
Number and length: 29 grooves in a section 20 mm from the start of the point, 7 mm plain shank, 18 grooves in next 14 mm.

(c) Jambro Square - power driven (Jambro 1)
Length: 73 mm from point to top of head
Diameter: profile approximately 3.1 mm square
Type of groove: shallow serrations
Number and length: 36 serrations along the whole length.

(d) Jambro Annular - power driven (Jambro 2)
Length: 75 mm from point to top of head
Diameters: 3.2 mm on shank, 3.5 on grooves
Type of groove: annular, double
Number and length: 35 grooves in 44 mm.

(e) National - hand driven
Length: 75 mm from point to underside of head
Diameters: 3.75 mm on shank, 4.15 mm on grooves
Type of groove: annular
Number and length: 35 grooves in 44 mm.

(f) Sidney Cooke - hand driven
Length: 75 mm from point to under side of head
Diameters: 3.75 mm on shank, 4.15 mm on grooves
Type of groove: helical
Type and length: 3 start, 13 mm pitch, 58 mm length.

Some of the above descriptions need amplification. The statement "annular double" means that in profile each annular ring has two crests about a quarter of a millimetre apart. The Jambro Square nails have shallow, flat topped grooves which appear to have been made by two pairs of opposing rollers, resulting in the nominally square cross section. All stated lengths of grooving exclude the length of the point, but overall lengths include it. All of the power driven nails, except the Jambro annular, had part of the head removed so that the nails could be closely stacked in line in the gun magazines. The Jambro uses coil stacking. The number of grooves stated above may occasionally be in error as they were difficult to count.

As well as the six grooved nails, a 75 x 3.75 plain shank nail was included in the test programme. This was used as a datum against which the performance of the grooved nails could be measured. It is called the "control nail" in the results.

2.2 Timber

2.2.1 Species

The tests were designed to determine the holding power of grooved nails in seasoned pine species. It is evident that in the near future most of Australia's building timber will be pine, as demand outstrips supply from the hardwood forests, and much of the plantation grown pine is nearing maturity. Also some limited information on the holding power of grooved nails in hardwood has already been published (Reardon, 1979a, 1979b).

Seven species of pine were chosen by TRADAC as representing typical building timber. The choice included six Australian grown species, radiata, Caribbean, slash, hoop, loblolly and patula, and the imported mixed species, spruce-pine-fir (SPF).

With the exception of radiata, twenty sticks of each species were supplied. There were ten sticks of radiata. Whilst the Cyclone Testing Station was not able to verify that each stick was cut from a different tree, the ring growth pattern indicated that this was likely, especially for those sticks containing pith.

Subsequent to the test programme, the Queensland Department of Forestry indentified the individual species within the SPF group. It contained three sticks of spruce, fourteen pine and three fir. This ratio was considered by TRADAC to be not typical of the general population of SPF, which normally contains much less pine, the strongest species in the grouping. However the results have still been included in this report.

2.2.2 Density

It has long been accepted that strength properties of timber are proportional to density. Mack (1979) shows that average withdrawal loads for plain shank nails and screws are also proportional to density, on a logarithmic basis. In an earlier publication (Mack, 1978) he proposed revised limits for joint strength groups, J1 to J4, as defined in AS1720, Timber Engineering Code (SAA, 1975). These revised group limits have been included in the draft edition of a revision of the timber fastener standard, AS1649, (SAA, 1983). The draft standard also includes a range of densities in which test specimens should lie. Table 1 lists these density ranges.

TABLE 1
JOINT GROUP AND TEST SPECIES DENSITY RANGES

Joint Group	Density Range (Kg/m^3)		
	Joint group (from AS1720-1975)	Joint group (proposed in draft revision of AS1649)	for Test species (proposed in draft revision of AS1649)
J1	> 700	> 750	750 - 850
J2	650 - 695	600 - 745	600 - 670
J3	500 - 645	475 - 595	475 - 520
J4	< 500	380 - 470	380 - 420
JD1		940	940 - 1030
JD2		750 - 935	750 - 850
JD3		600 - 745	600 - 670
JD4		475 - 595	475 - 520

AS1720-1975 did not contain a separate grouping for dry timber, JD1 - JD4.

The addition in the draft, of a recommended range of densities for test is meant to help overcome anomalies in testing that may arise from using samples at the high end of the joint group range. However confusion may still arise in respect of species mean densities. When reviewing the appropriate literature for mean densities of the seven species tested, the author became concerned at the discrepencies in density values published by highly respected authors. For example Kingston and Risden (1961) measured air dry density samples from 46 different trees of plantation grown radiata pine as having a mean of 593 Kg/m^3. Bolza and Kloot (1963) measured samples from 78 trees to obtain a mean value of 506 Kg/m^3. TRADAC (1980) publish a value of 540 Kg/m^3, from Queensland Department of Forestry data. One would expect much closer agreement of mean values determined from sample sizes as large as 46 and 78.

The main reason for drawing attention to these discrepancies is to alert other researchers of the likely variation in density of scantling sizes from published data based on small clear specimens, as the range of values for test given in Table 1 is quite restrictive. It means that even if a species has a published average density within the required range, the density of the test sample could still be outside that range. For interest, published mean air-dry densities together with those measured from the twenty sticks of the test species are given in Table 2.

All the values in Table 2 have been corrected to 12% moisture content. The values in the first set of brackets represent the range or the coefficient of variation of the sample. The value in the second set of brackets is the number of trees in the sample. The number of trees of SPF is considered unknown. Density values of individual sticks from each species are given in Table A1 of Appendix A.

2.3 Test Specimens

Simple batten joints were chosen as the most convenient and representative test specimens. The batten material was unseasoned hardwood, dressed exactly to 38 mm thickness. Although this meant that the nails would have slightly different depths of penetration into the pine, it was considered to better represent practice than to ensure the same depth of penetration. After all, the nail lengths are slightly different and that difference should be reflected in the test results. Two nails were used in each joint. Figure 2 shows a typical test joint.

The cross-sectional dimension of the pine was 70 x 35 mm for all species except SPF which was 90 x 35 mm. Some of the species, particularly patula, loblolly and Caribbean, included sticks containing pith and knots. No attempt to dodge knots was made when cutting the pine for the specimens, but when fabricating the joints the nails were driven into the surface less affected by knots.

TABLE 2
MEAN DRY DENSITIES OF SPECIES TESTED

Species	Dry Density Values ø (Kg/m³) published by			Dry Density Measured from Test Samples
	Kingston & Risden	Bolza & Kloot	TRADAC	
RADIATA	593 (437 - 724)* (46)‡	506 (11.8%)** (78)	540	552 (5.8%)** (10)
SLASH	596 (-) (4)	525 (7½%) (8)	625	573 11.2% (20)
HOOP	514 (413 - 613) (77)	520 (12.5%) 42	575	495 (9.9%) (20)
LOBLOLLY	628 (477 - 780) (10)	482 (13.5%) (7)	595	548 (9.7%) (20)
CARIBBEAN	-	-	575	530 (11.2%) (20)
PATULA	-	-	545	465 (6.7%) (20)
SPF	-	-	-	483 (7.2%) -

* Range of values
** Coefficient of variation
‡ Number of trees
ø Based on specimens free from defects

Considerable care was taken to ensure that the nail heads were driven exactly flush with the top surface of the batten. To facilitate driving the hand-driven nails, the hardwood battens were often pre-drilled, but of course the pine rafters were not.

2.4 Screws

As previously mentioned, plain shank nails were included in the test programme as a lower limit comparison. As an upper comparison, power driven self-drilling "type 17" screws were also tested. Joints were made with one 75 mm long,

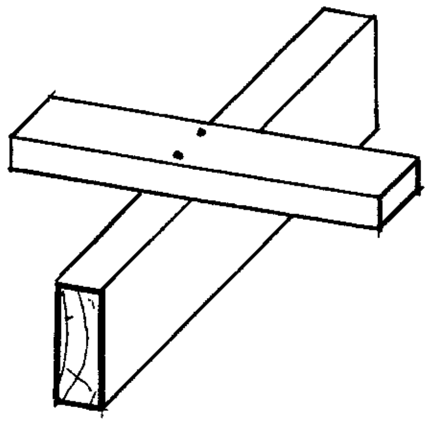

FIGURE 2   Typical test joint.

number 14 screw driven through 38 mm thick hardwood battens into the pine rafters. Only ten replications of this type of joint in each species were tested.

It should be noted that for conventional steel wood screws, with cut threads, the size number relates to the shank diameter which is the same as the thread diameters. A number 14 wood screw has a nominal shank diameter of 6.3 mm. This is not the case with self drilling "type 17" screws which have rolled threads. The screw number is apparently related to the outer diameter of the thread. A "type 17" screw of number 14 size has a shank diameter of about 5.1 mm.

2.5 Departures from Code Specifications.

Australian Standard AS1649-1974 specifies procedures for sampling, the testing of specimens and the derivation of working loads. These experiments on the holding power of grooved nails were designed to follow the intent of the code if not all the specific requirements thereof. For various reasons a few departures from the strict code specifications had to be made. Considerable thought was given to these departures before they were taken, and it is believed that none of them would have any significant effect on the results.

Some of the departures are obvious. The code specifies that a single nail be used for withdrawal tests. A pair of nails representing a real joint was considered more appropriate for these tests. Also the joints were not conditioned in an atmospheric environment controlled to 20°C and 65% relative humidity, as such facilities were unavailable.

The two main departures were that nails were not driven into two adjacent faces of the same specimen, and that delayed tests three months after fabrication were not included. It was not practicable to make joints in adjacent faces of the 70 x 35 mm pine, as the performance of the fasteners could well be affected by the shallow depth in the 35 mm direction. With the exception of the sticks containing pith, the nails were in a direction generally tangential to the growth rings, as illustrated in Figure 3. This departure from the code requirements was justified by reference to a statement by Mack (1979) claiming that analysis of his data showed no significant difference between withdrawal strength of nails in the radial face and those in the tangential face.

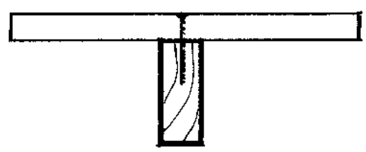

FIGURE 3 Nail penetration tangential to growth rings.

Because of the large number of specimens that would have to be duplicated, it was decided not to test specimens three months after driving, as required by the Code. The decision was made on the basis of some very early work on grooved nails in pine by Mack (1960), which showed a 17% average increase in holding power for dry specimens tested three months after fabrication, see Figure 4. Recent research conducted by the Cyclone Testing Station (Reardon, 1979a) showed a similar increase for unseasoned grey satinash. As the Code

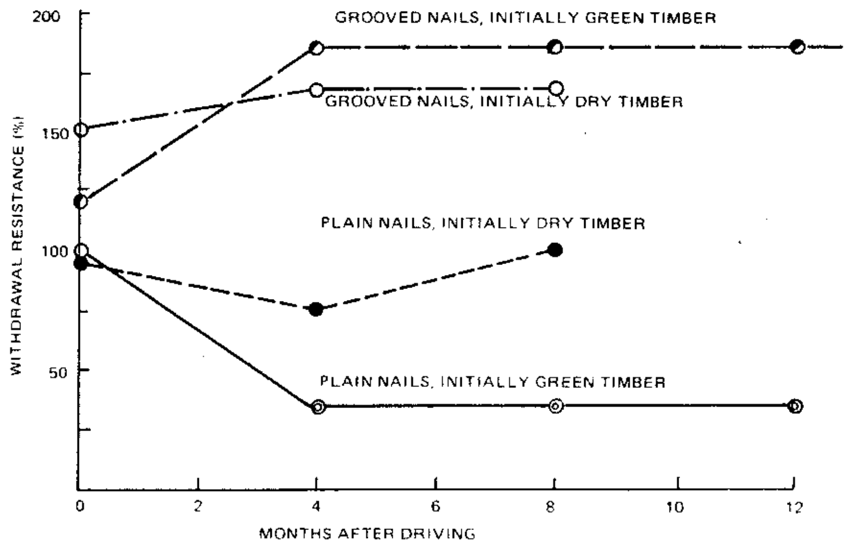

FIGURE 4 Increase in holding power of grooved nails with time. (After Mack.)

requires design values to be based on the lower result of immediate and delayed tests, it was considered valid on the basis of these previous tests to disregard the Code requirement for delayed testing.

3. ANALYSIS OF RESULTS

Maximum withdrawal loads for individual tests on each type of grooved nail are listed in Appendix A. It must be stressed that the failing loads given throughout this report relate to double nailed joints, not to single nails.

3.1 Nail Performance

Table 3 lists the average failing load for each nail type in each species. This can be used as a basis of comparison between types of nail or species of pine.

The geometry of each nail type has been given in Section 2.1. Although the nails are all nominally 75 mm long, the other geometric features are different, and lead to the different values of withdrawal resistance. The following nail features are assumed to influence withdrawal resistance:

shank diameter,
diameter across top of grooves,
depth of grooves,

pitch of grooves,
total length of grooves.

Depth of penetration is also a parameter affecting withdrawal resistance, however in these tests it was virtually eliminated by carefully machining the battens to 38 mm thickness.

TABLE 3
AVERAGE FAILING LOADS FOR DOUBLE NAILED JOINTS

Species of pine	Average Failing Loads (kN)						
	Control	National	Sid Cooke	Bostitch	Able	Jambro 1	Jambro 2
radiata	1.64	4.18	5.15	3.64	3.70	1.68	4.41
hoop	2.74	5.28	5.44	2.83	3.67	2.09	4.48
caribbean	1.47	4.80	5.90	3.09	3.50	1.39	4.60
slash	1.54	5.10	5.15	3.72	3.35	1.80	3.18
loblolly	1.62	3.44	3.93	2.46	3.55	2.09	3.41
s.p.f.	1.49	3.82	3.62	2.14	2.78	1.64	3.59
patula	1.48	3.61	3.74	2.13	3.13	2.07	3.71
Grand Average	1.71	4.32	4.70	2.86	3.38	1.82	3.91

In broad terms, the effect of these parameters can be seen in the grand averages of Table 3. Sidney Cooke and National, with their larger shank diameter and pronounced grooving have the greatest failing loads. Jambro square nail (listed in all tables as Jambro 1) with its shallow serrations shows the least improvement over the control nail. Of the other power driven nails, the Jambro annular (listed as Jambro 2) had the highest average. This can readily be related to the more pronounced grooving of that nail. Likewise, the difference between Able and Bostitch can be attributed to the sharper grooving of the Able nails and the shorter length of grooves of the Bostitch.

The average failing loads should not be emphasized too much as they give no indication of the range of individual values. One of the most significant features of these tests was the wide scatter of failing loads for a given nail-timber combination. This happened not only between species, but also between sticks of the same species. Figure 5 illustrates in histogram form

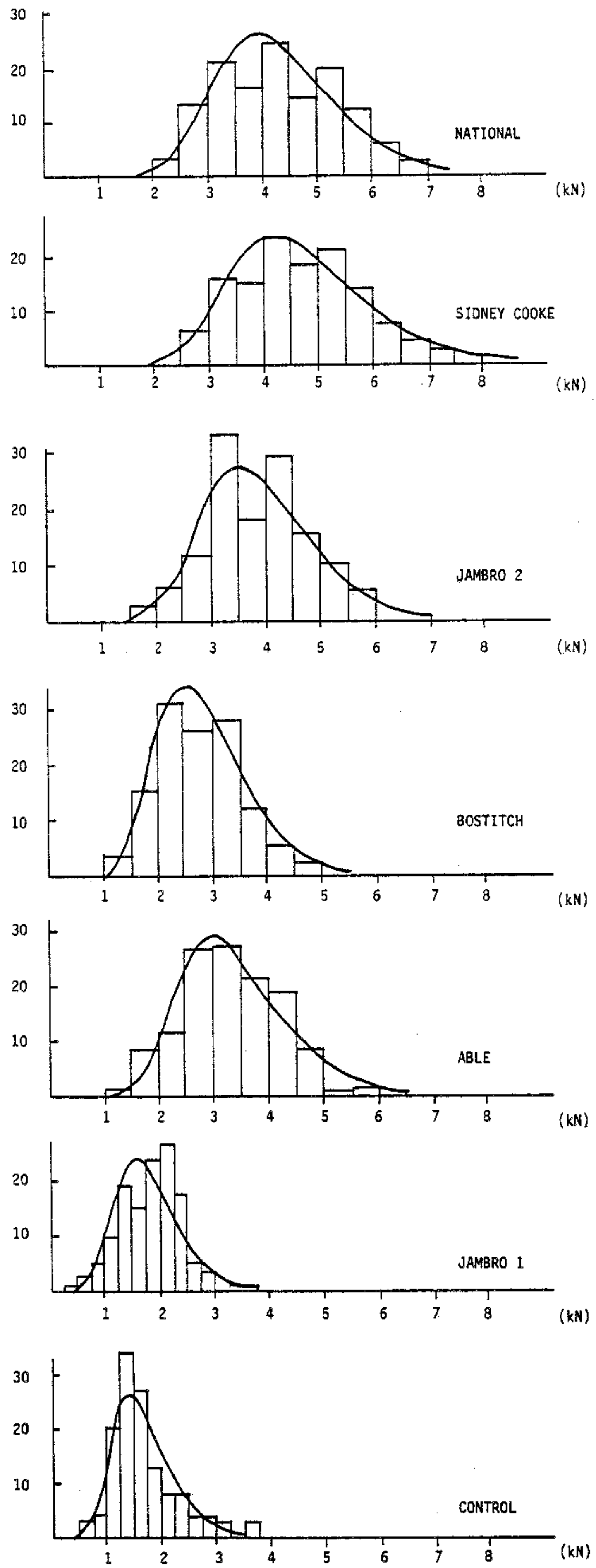

FIGURE 5 Histogram of failing loads for each nail type

the amount of scatter for each nail in all of the species, that is 132 results per nail type.

It is of concern to record withdrawal values having ratios of highest to lowest as great as 5 to 1. This is especially so considering that the timber is all from the one general industry classification called "seasoned pine". The effect of this scatter of results is to reduce the design load that can be calculated for each nail type, as the design load is based on the strength below which only one value in 100 would fall (the one percentile value),

Also shown in Figure 5 is the lognormal distribution that can be calculated from the results in each sample. The superposition of the curve over the histogram demonstrates that this form of distribution fits the test results quite well.

As well as individual test results, Appendix A lists for each nail the mean, coefficient of variation and one percentile value of the results for each species. This allows a comparison of performance between species, which will be discussed later, but also highlights the variability within a nail-species combination. It is not uncommon to note ratios of 3 or more between the highest and lowest values. This is reflected in the calculated coefficients of variation, up to 30%.

The variability between joints is further highlighted by comparing withdrawal loads for Sidney Cooke and the control nail from stick 13 of loblolly pine. In this case the grooved nails, which have been shown on average to be almost three times as strong as the control nails, had a lower failing load than the control.

3.2 Effect of Species

3.2.1 Effect of density

Figure 6 (after Mack, 1979) shows his measured relationship between withdrawal resistance of 2.8 mm plain shank nails and air dry density. His plot of average values on a log-log scale over a wide range of densities reveals a linear relationship with a correlation coefficient of 0.98. This is an excellent result and, because it is so linear, demonstrates an apparently close relationship between air dry density and withdrawal resistance.

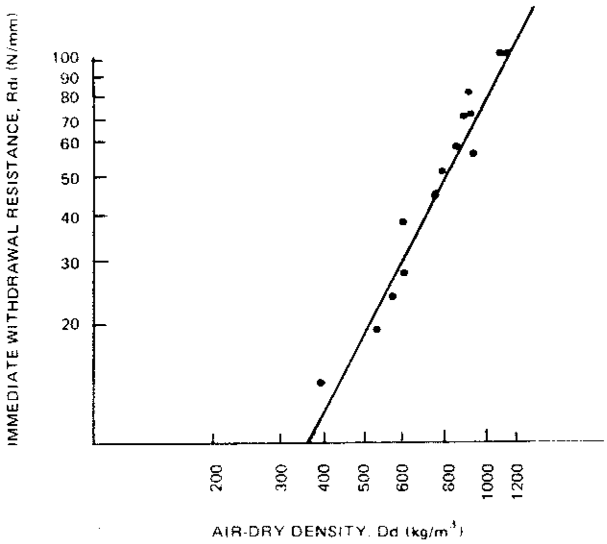

FIGURE 6 Relationships between withdrawal resistance and air dry density for plain shank nails (After Mack.)

However such a relationship was not at all in evidence for these test results. Figure 7 shows a plot of withdrawal load and air dry density for all of the joints with National nails. As can be seen, there is only a mild hint of a relationship between higher density and increased withdrawal load. A statistical analysis shows a correlation coefficient of only 0.3. The Bostitch nail showed the best relationship, but even then the correlation coefficient was only 0.5. The value for the control nail was 0.08.

The contrast between Figure 6 and Figure 7 must lie in the averaging of the individual results in Figure 6, and the relatively small range of density values available for plot in Figure 7. However the results of Figure 7 demonstrate very clearly that the withdrawal resistance of an individual sample, or even a species, is not necessarily directly related to its density. Other factors also influence this strength.

3.2.2 Variability between species

The intrinsic nail holding power of the individual species can be assessed by comparing the average failing loads given in Table 3. Looking at individual species, hoop pine is clearly the leader, having either the highest or second highest value for six of the seven nail types. Similarly radiata pine performed well, as for five different nail types it registered within the highest three average failing loads. At the other end of the scale, spruce pine fir was always in the lowest three values, and patula pine was five times in the bottom two values.

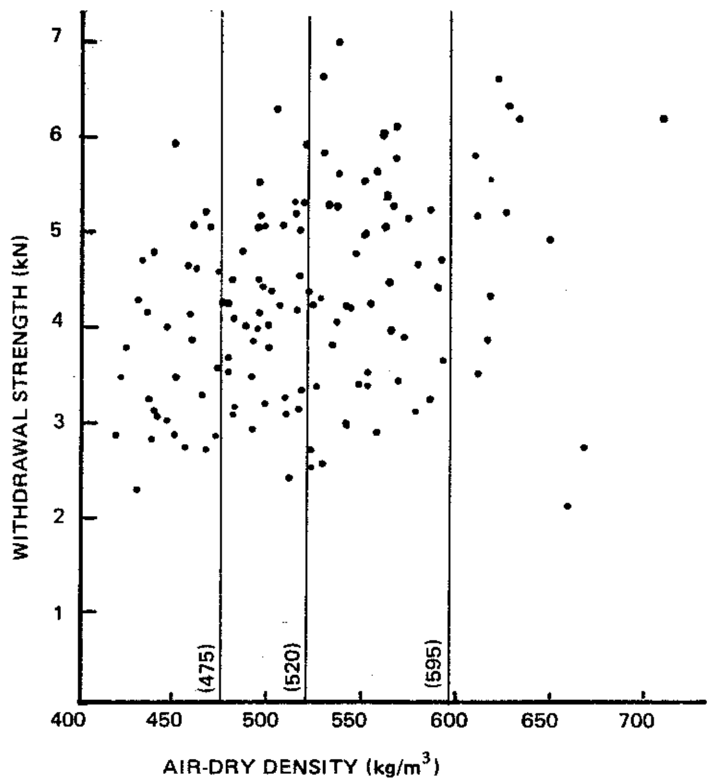

FIGURE 7 Plot of withdrawal resistance of National nails and air dry density.

The performance of Caribbean pine is interesting insomuch as it showed the lowest holding power for the control and the lightly grooved Jambro square nail, but gave high values for the nails with pronounced grooving. This implies an elasticity of fibres that could lock into the grooves after the nails had been driven.

By contrast, loblolly pine tended to perform better with the smoother nails, but the effect was not so obvious.

3.2.3 Variability within species

As has been stated previously, the variability of individual maximum withdrawal loads for a nail type in a given species is as much as 3:1. Table 4 has been drawn up to determine if this variability is apparently random, or if some sticks always have a higher holding power than others. The values given in Table 4 are the positions in ascending order from minimum to maximum withdrawal load for each of the nail types in Caribbean pine, eg. for the control nail stick number 20 had the lowest withdrawal load of the twenty replications, stick 16 had the second lowest, etc., and stick 10 had the highest withdrawal load. Also included in Table 4 is the order of the densities. Caribbean pine was chosen at random for this exercise.

TABLE 4

ORDER OF WITHDRAWAL LOADS FOR CARIBBEAN PINE
(Ascending order of magnitude)

Stick number	Density	Control	National	S.Cooke	Bostitch	Able	Jambro square	Jambro annular
1	14	4	17	8	12	16	5	11
2	3	18	7	7	4	15	17	14
3	5	9	8	9	15	6	8	8
4	18	17	15	16	18	17	12	5
5	11	10	4	13	8	5	9	1
6	8	5	6	3	9	2	11	13
7	13	11	10	18	11	13	10	19
8	19	19	20	17	14	14	18	4
9	9	14	11	15	3	7	2	12
10	15	20	19	19	19	20	20	9
11	16	8	18	10	20	11	15	10
12	10	3	16	4	5	4	6	20
13	6	15	14	5	1	10	19	18
14	7	7	12	14	7	9	4	15
15	2	13	3	2	10	19	7	16
16	20	2	1	1	2	1	1	6
17	1	12	9	12	13	3	14	17
18	4	16	2	6	16	8	3	7
19	17	6	13	20	17	12	13	3
20	12	1	5	11	6	18	16	2

The table shows that stick 16 had the highest density but gave the lowest withdrawal loads. The stick was observed to have a large patch of resin staining, covering about one third of its cross-sectional area. The stain followed the ring growth. As this was the only stick with such resin staining, one must assume that it affected the holding power of the nails, possibly offering some form of lubrication.

In contrast, stick 10 had very high holding power, and a reasonably high density.

It is interesting to note that most sticks do not exhibit consistantly high or consistantly low withdrawal strengths. In fact, only stick 16 has only single digit order numbers and only stick 7 has only double digit order numbers. The position of the other stick numbers within the ordered groups varies widely, eg. stick 12 had five results in the bottom six in the ordered groups, and the other two values in the top five. The Jambro annular nail was most often away from the trend of the other nails.

4. POWER DRIVEN SCREWS

The joints made with one power driven 14 x 75 mm "Type 17" screw were tested as a comparison to the nails. Details of the screw have been given in Section 2.4.

Ten specimens were made from each of the seven species of pine. The ten sticks were chosen arbitrarily from each group of twenty. The specimens were tested in the same manner as the nailed ones.

Table 5 lists the average failing loads for each species, together with the coefficient of variation and the one percentile value. Results of the individual tests are listed in Table A9 of Appendix A.

The results shown in Table 5 indicate that a single screwed joint has an average strength about one kilonewton greater than average of the strongest pair of grooved nails included in the test programme, see Table 3. However this advantage over the pair of Sidney Cooke nails does not always extend to the one percentile values. The greater variability within the sample of screwed joints leads to calculated one percentile values for some species being lower than for the strongest pair of nails.

The results of the screw tests reiterate the grouping of species found from the nail tests. The four species radiata, hoop, Caribbean and slash pine show much greater holding power than loblolly, SPF or patula pine.

TABLE 5

RESULTS OF SCREWED JOINTS
(One 14 x 75 mm "Type 17" screw per joint)

Timber species	Average Withdrawal Load (kN)	C. of V. (%)	one percentile (kN)
radiata	6.07	16	3.78
hoop	6.61	19	3.76
Caribbean	5.86	16	3.66
slash	6.86	24	3.19
loblolly	5.13	30	1.94
SPF	4.80	29	1.98
patula	4.42	25	2.17
Grand average	5.68		

5. DERIVATION OF DESIGN LOADS

5.1 Method of Calculating Design Load

Australian Standard AS1649-1974 (SAA, 1974) specifies in its Appendix B, the method for computing the mean, standard deviation and one percent lower probability limit of a set of test results, based on a log-normal distribution. It also specifies that the basic withdrawal load (design load) shall be calculated as 0.5 times the 1% value for nails or 0.4 times the 1% value for screws.

The proposal, in the draft document for revision of that code, to introduce a range of densities for test samples has been discussed earlier. Another proposed amendment in that draft requires that the five percentile lower probability limit be used as the characteristic value from which the design load can be calculated. This value can be estimated with more accuracy from a limited set of data than can the 1% value. The recommended multiplying factor for determining design load from the five percentile value is 0.45, for both screws and nails.

The effect of these proposed amendments will be discussed later in this section.

5.2 Design Loads for each Species

The design load calculated for each type of nail in each species is listed in Table 6. This information could be used when the designer is sure that a particular species of pine would be used, for example radiata pine in Adelaide.

TABLE 6
DESIGN LOADS FOR DOUBLE NAILED JOINTS
IN INDIVIDUAL SPECIES OF DRY PINE

Species of pine	Design Loads (kN)						
	Control	National	Sid Cooke	Bostitch	Able	Jambro 1	Jambro 2
radiata	0.34	0.92	1.45	0.80	0.89	0.46	1.28
hoop	0.72	1.74	2.00	0.96	0.81	0.55	1.08
Caribbean	0.40	1.30	1.90	0.98	0.78	0.29	1.58
slash	0.37	1.40	1.44	1.08	0.78	0.30	0.64
loblolly	0.35	1.02	1.14	0.68	0.81	0.54	1.00
s.p.f.	0.42	1.30	1.26	0.67	0.61	0.28	1.16
patula	0.32	1.03	0.99	0.58	0.87	0.50	1.08

The trend of the design loads is similar to that of the average failure loads given in Table 3. The Sidney Cooke joint still shows up as the strongest, but the difference between the top four species and the bottom three is not quite as marked as for the average values. This reflects the influence of variability of the samples in the calculation of design loads.

5.3 Design Loads for Joint Group JD4

Whilst design loads for fasteners in specific species of seasoned pine may be of academic interest to researchers or nail manufacturers, they are of little use in practice. Designers need recommendations for the general group "seasoned pine", or JD4 (joint group 4, dry timber). Therefore design loads for double nailed joints of each nail type have been calculated using the test results relating to those sticks with a measured density in the recommended test range for JD4, that is, 475-520 kg/m^3. This group consisted of forty sticks, and the mean, coefficient of variation, one percentile value and calculated design load for each joint type are listed in Table 7.

TABLE 7

STATISTICS AND DESIGN LOADS FOR DOUBLE NAILED JOINTS
IN STRENGTH GROUP JD4
(based on density range 475-520 kg/m^3)

	Control	National	Sid Cooke	Bostitch	Able	Jambro 1	Jambro 2
Mean Load (kN)	1.72	4.22	4.53	2.51	3.28	1.81	3.91
C. of V (%)	32.3	21.6	24.0	22.4	26.0	39.3	25.5
1% value (kN)	0.73	2.42	2.44	1.41	1.67	0.64	2.02
Design Load (kN)	0.36	1.21	1.22	0.70	0.84	0.32	1.01

The design values given in Table 7 split the joints into three groups, the two hand driven nails, National and Sidney Cooke, the well grooved power driven nails Able, Bostitch and Jambro 2, and the control nail and square Jambro 1. The influence of variability within the sample is shown in reducing the Sidney Cooke nails to the same design load as the National. Also the very wide variation of Jambro 1 results reduces its design value to that of the control nail.

The design value for the control nailed joint is the only one that can be directly compared with other published values. The Timber Engineering Code lists in its Table 4.2.2 the permissible withdrawal load for a 3.75 mm plain nail in J4 timber as 5.1N/mm penetration. It states that this value should be used whether the timber is green or dry. Assuming that the applied force is shared equally by the two nails in the joints tested in this series, and taking the depth of penetration to be 37 mm (that is, including the point), the design load of 0.36 kN for the control nailed joint can be reduced to 4.9 N/mm per nail.

This is excellent agreement considering the process by which the design load is calculated, and it imparts confidence in the design loads derived for the grooved nailed joints for which no comparison is available.

5.4 Comparison of Derivation of Design Loads

5.4.1 Density ranges

Of the 132 sticks of seasoned pine used in these experiments, only 87 were within the specified density range for JD4 (see Table 1). Of those, 40 were within the specified range for test, and the results of those 40 have been used to determine design loads given in Table 7. Conversely, the results of 92 tests on each nailed joint type have been disregarded in the calculation of design load. An investigation has therefore been made into the statistics of these discarded results to compare them with the "chosen 40".

There were three obvious groupings based on measured density, those in the JD4 range, those above it and those below it. 87 sticks were in the JD4 range (including the 40 in the test range), 31 sticks had densities below JD4 and 14 sticks had densities above JD4 range. Table 8 lists the calculated statistics for each group.

The means listed for each nail type in Table 8 tend to follow the trend of increased withdrawal load with increased density. Those which do not follow the trend have very similar values for two of the three groups. The one percentile values, upon which design loads are based, do not follow the trend so well. This is possibly caused by the relatively small sample of results for sticks above JD4, leading to wide variability.

Of more interest is the comparison between one percentile values in Tables 7 and 8. There is hardly any difference between the calculated values for each nail type based on the test range, and those calculated for the entire JD4 range. This leads to the conclusion that although the specification of a range of low densities for test purposes may appear logical, there is no benefit to be gained by doing so.

It reiterates a statement made earlier, that relatively small changes in test sample density are not necessarily reflected in nail holding power.

5.4.2 Percentile values

The current edition of the fastener code, AS1649-1974, calculates design loads from the estimated one percentile lower probability limit. That is, from a sample of as few as ten results an estimate is made of the likely minimum value if one hundred results were available. Clearly the estimate of that value is very much dependent upon how well the test sample represents the parent population, as the extrapolation from a sample of ten to one of a hundred is

TABLE 8

STATISTICS FOR DOUBLE NAILED JOINTS IN
IN DIFFERENT DENSITY RANGES

Density		Control	National	Sid Cooke	Bostitch	Able	Jambro 1	Jambro 2
	Mean (kN)	1.73	4.91	5.69	3.67	3.87	1.93	3.92
above	C. of V. (%)	24.0	34.1	21.3	29.6	34.7	41.5	22.1
JD4 range (>595 kg/m^3)	1% LPL (kN)	0.87	1.84	3.10	1.57	1.43	0.58	2.09
entire	Mean (kN)	1.76	~~4.39~~	4.73	2.87	3.43	1.86	3.87
JD4 range	C. of V. (%)	35.4	24.4	25.4	26.3	24.9	33.1	27.9
(475-595 kg/m^3)	1% LPL (kN)	0.70	2.38	2.49	1.47	1.83	0.80	1.91
below	Mean (kN)	1.60	3.89	4.07	2.27	2.94	1.72	3.89
JD4 range	C. of V. (%)	32.3	22.7	23.9	22.8	31.6	31.2	21.8
(<475 kg/m^3)	1% LPL (kN)	0.68	2.15	2.18	1.25	1.27	0.75	2.21

quite large.

As previously mentioned, the draft code recommends that the five percentile lower probability limit be used. That is the minimum result of a theoretical sample of twenty. Obviously that value can be predicted from a sample of ten with more confidence than the one percentile value.

To obtain design loads, the five percentile value of withdrawal loads is divided by a load factor of 2.2 instead of 2.0 for the one percentile value. Table 9 compares design loads based on each method for the test range of JD4 densities. It shows that design loads based on 5% values are consistently some ten percent greater than those based on 1% values. Thus, if the load factor for the 5% values is meant to produce design loads similar to those currently produced by the 1% value, a load factor of 2.4 would be more appropriate.

TABLE 9

DESIGN LOADS FROM DIFFERENT PERCENTILE VALUES
(based on density range 475-520 kg/m^3)

	Design Loads (kN) for						
	Control	National	Sid Cooke	Bostitch	Able	Jambro 1	Jambro 2
Based on 1% value	0.36	1.21	1.22	0.70	0.84	0.32	1.01
Based on 5% value	0.43	1.30	1.33	0.76	0.93	0.40	1.12

5.5 Design Loads for Screws

Test results of the joints with one 14 x 75 mm "Type 17" screw were analyzed in the same manner as for the nails. Table 10 shows the design load for each species, based on the provisions of the current code, and the proposals in the draft. The latter figures show improvement based not only on the five percentile value, but also on having the load factor reduced from 2.5 to 2.2.

TABLE 10

DESIGN LOADS FOR SCREWS IN INDIVIDUAL SPECIES
OF DRY PINE

Species	radiata	hoop	Caribbean	slash	loblolly	SPF	patula
Design Loads (kN) (current code)	1.51	1.50	1.46	1.37	0.85	0.79	0.93
Design Loads (kN) (draft code)	2.02	2.07	1.96	1.97	1.21	1.21	1.33

Design loads for screws in seasoned pine have been calculated using the sticks whose density was within the specified test range for JD4 joint group. Table 11 lists the design loads calculated from both the current and the draft code. It shows that if the proposals in the draft code are accepted, the design load in withdrawal for screws embedded 37 mm in JD4 timber will increase by approximately 40%.

6. CONCLUSIONS

The average withdrawal strength of grooved nails in seasoned pine varies from

TABLE 11

DESIGN LOADS FOR 14 x 75 mm SCREWS IN JD4 TIMBER

	Based on current code	Based on draft code
Design Load (kN)	1.10	1.52

two to three times the strength of similar plain shank nails, provided the grooving is pronounced in profile. If the grooving is not well defined, it may offer little advantage.

The design loads in withdrawal for grooved nails are also two to three times those for plain shank nails, provided the grooving is pronounced.

One 14 x 75 mm "Type 17" screw has approximately the same design load as the strongest double nailed joint, although the average failing load of the screw was about 20% higher than that of the strongest double nailed joint.

There was wide variation in the measured joint strengths. This occurred both between species and within species for each nail type. For a given species-nail type combination, variations of one hundred percent were quite common. For a given nail type, variation in strength between the species was as much as three to one.

There was virtually no correlation between individual nail withdrawal strength and measured density of the test samples. The mean withdrawal strengths of some groups of specimens showed a correlation with density, but this was not reflected in the calculated design loads for those groups. This lack of correlation nullified the concept of having a specific density range for test, that was low in the overall JD4 range. Design loads calculated from specimens in the proposed test range were no different from those for the entire range.

If the provisions of the draft edition of the fastener code are accepted without alteration, the design withdrawal loads given herein for nails will increase by about 10%, and those for screws will increase by about 40%.

The relative performance of the fasteners tested was in the order one would expect from inspection. That is, the rougher the nail looked and felt, the better holding power it had.

The wide variation in performance of individual types of grooved nails, all of which could be classified as "75 mm grooved nails", highlights the need for a manufacturing standard to which the nails could be made.

7. ACKNOWLEDGEMENTS

The Cyclone Testing Station is grateful to the Timber Research and Development Advisory Council (TRADAC) who requested and funded the research. It is also grateful to the following fastener manufacturers for co-operating in the programme by supplying nails or screws and, where appropriate, nail guns, and for agreeing to the publication of the test results.

Able Staples Pty. Ltd.
Bostitch Textron
W.A. Deutsher Pty. Ltd.
Jambro Pty. Ltd.
Mayne Industries, (National)
Sidney Cooke Fasteners Pty. Ltd.

8. REFERENCES

Bolza, E. and Kloot, N.H. (1963), "The Mechanical Properties of 174 Australian Timbers", Division of Forest Products Technological Paper No. 25, CSIRO.

Kingston, R.S.T. and Risden, C. June E. (1961), "Shrinkage and Density of Australian and Other Woods", Division of Forest Products Technological Paper No. 13, CSIRO.

Mack, J.J. (1960), "Grooved Nails", The Australian Timber Journal, Vol. 26 No. 8.

Mack, J.J. (1978), "The Grouping of Species for the Design of Timber Joints with Particular Application to Nailed Joints", Division of Building Research Technical Paper (Second Series) No. 26, CSIRO.

Mack, J.J (1979), "Withdrawal Resistance of Plain Steel Nails and Screws in Australian Timbers". Division of Building Research Technical Paper (Second Series) N. 30, CSIRO.

Reardon, G.F. (1979a), "The Strength of Batten-to-rafter Joints, Part 1 - Test results and derivation of design loads", Technical Report No. 2, James Cook Cyclone Structural Testing Station.

Reardon, F.G. (1979a), "The Strength of Batten-to-rafter Joints, Part 2 - Recommendations for high wind areas", Technical Report No. 3, James Cook Cyclone Structural Testing Station.

Standards Association of Australia, (1974), AS1649-1974 "Determination of Basic Working Loads for Metal Fasteners for Timber".

Standards Association of Australia (1983), Draft Australian Standard DR83020 "Methods for the Determination of Basic Working Loads for Mechanical Fasteners for Timber (Revision of AS1649-1974)".

APPENDIX A

The appendix contains the raw data obtained from the tests described in this report.

TABLE A1
DENSITIES OF TEST STICKS

Stick	Density (kg/m^3) at 12% moisture content.						
Number	Radiata	Hoop	Caribbean	Slash	Loblolly	SPF	Patula
1	609	430	555	509	666	505	570
2	521	536	462	560	584	474	472
3	566	465	494	551	564	542	461
4	534	485	625	561	492	501	457
5	534	468	514	517	511	494	437
6	524	550	497	517	498	436	481
7	523	481	546	558	528	424	438
8	578	528	631	567	547	499	441
9	552	493	507	620	478	533	473
10	554	435	560	526	509	499	481
11	609	457	565	707	542	439	460
12	523	514	514	626	613	517	482
13		519	495	608	552	446	465
14		503	497	566	479	479	450
15		549	458	626	568	492	449
16		527	659	540	616	495	456
17		449	433	533	466	515	494
18		588	488	647	584	460	477
19		535	573	531	578	490	446
20		494	523	590	591	421	419
Mean	552	495	530	573	548	483	465
C of V	5.8%	9.9%	11.2%	9.0%	9.7%	7.2%	6.7%

TABLE A2

WITHDRAWAL LOADS PER DOUBLE NAILED JOINT
OF SEASONED PINE SPECIES

NAILS: Control, 2-75 x 3.75 mm

Stick Number	Withdrawal Load (kN) in pine species						
	Radiata	Hoop	Caribbean	Slash	Loblolly	SPF	Patula
1	1.22	1.66	1.18	1.11	1.56	1.23	1.84
2	2.52	3.67	1.76	1.56	1.70	1.34	1.42
3	1.31	2.15	1.40	1.34	1.43	1.54	1.22
4	1.41	3.17	1.62	1.76	1.12	2.48	1.62
5	1.83	2.16	1.47	1.95	1.70	1.62	1.44
6	1.15	2.33	1.30	1.44	1.04	1.46	1.35
7	0.96	2.48	1.49	0.65	0.72	1.47	1.33
8	1.73	3.12	2.07	1.35	2.50	1.46	1.48
9	2.19	3.54	1.53	1.72	1.52	2.00	1.62
10	1.34	1.76	2.38	1.72	1.66	1.20	1.19
11	2.00	2.78	1.39	2.65	1.70	1.64	2.35
12	2.05	2.40	1.12	1.64	1.61	1.30	1.78
13		2.85	1.58	1.66	2.70	1.20	1.07
14		2.95	1.33	1.33	1.34	1.17	1.86
15		3.21	1.52	1.87	1.10	1.54	1.17
16		3.45	1.00	1.52	2.10	1.20	0.80
17		3.76	1.50	1.42	1.43	2.16	1.42
18		2.26	1.59	1.44	1.61	1.34	2.56
19		2.92	1.32	1.36	2.00	1.30	0.72
20		2.10	0.85	1.38	1.83	1.18	1.34
Mean	1.64	2.74	1.47	1.54	1.62	1.49	1.48
C of V	30%	24%	23%	27%	30%	21%	31%
1% LPL	0.68	1.43	0.79	0.74	0.70	0.84	0.63

TABLE A3

WITHDRAWAL LOADS PER DOUBLE NAILED JOINT
OF SEASONED PINE SPECIES

NAILS: National, 2-75 x 3.75 mm

Stick Number	Withdrawal Load (kN) in pine species						
	Radiata	Hoop	Caribbean	Slash	Loblolly	SPF	Patula
1	3.52	4.26	5.66	3.25	2.72	4.22	3.90
2	4.35	5.60	4.47	5.05	3.25	4.56	2.83
3	5.78	5.20	4.48	4.97	3.97	2.94	4.60
4	5.27	4.81	5.21	5.38	2.92	4.39	4.65
5	5.29	5.05	4.17	5.30	2.41	5.04	2.83
6	3.36	4.92	4.40	5.01	3.18	3.22	4.46
7	2.50	4.08	4.76	2.87	2.57	3.76	4.76
8	4.67	5.82	6.22	6.11	3.38	4.01	3.05
9	4.25	5.19	5.06	6.59	3.66	4.07	3.55
10	3.36	4.14	6.00	4.29	3.07	3.77	3.09
11	5.16	4.60	5.82	6.22	4.31	3.08	5.05
12	2.70	4.54	5.29	5.66	3.87	3.34	3.14
13		5.92	5.17	5.79	3.49	3.98	3.27
14		6.30	5.06	6.12	3.52	4.23	3.46
15		5.56	4.13	6.36	3.41	3.84	2.85
16		6.65	2.13	4.23	4.34	4.13	2.73
17		5.93	4.64	3.81	2.70	3.11	3.97
18		4.45	3.99	4.94	5.24	3.85	4.23
19		7.00	5.13	5.29	3.09	3.46	2.99
20		5.52	4.21	4.71	3.64	3.45	2.83
Mean	4.18	5.28	4.80	5.10	3.44	3.82	3.61
C of V	28%	16%	23%	22%	19%	14%	21%
1% LPL	1.85	3.47	2.60	2.80	2.04	2.61	2.06

TABLE A4

WITHDRAWAL LOADS PER DOUBLE NAILED JOINT
OF SEASONED PINE SPECIES

NAILS: Sidney Cooke, 2-75 x 3.75 mm

Stick	Withdrawal Load (kN) in pine species						
Number	Radiata	Hoop	Caribbean	Slash	Loblolly	SPF	Patula
1	4.60	4.41	5.76	3.19	4.39	4.29	2.35
2	4.93	6.25	5.45	4.36	3.50	4.10	3.68
3	6.42	5.54	5.82	5.45	4.21	3.98	3.65
4	5.39	5.30	6.51	5.57	3.67	4.38	4.97
5	5.77	5.24	6.33	4.60	4.24	3.92	4.08
6	4.83	5.13	4.78	5.53	3.64	3.41	3.45
7	3.46	4.50	6.90	5.30	2.60	2.89	4.19
8	5.32	5.40	6.69	5.21	4.98	3.39	3.79
9	4.03	5.28	6.45	8.88	3.19	3.58	4.86
10	5.88	4.94	7.17	4.56	4.25	3.83	4.58
11	6.81	5.41	5.93	6.50	3.20	2.79	3.32
12	4.31	5.79	4.80	5.73	5.10	4.00	5.21
13		5.40	5.02	5.52	2.48	3.42	4.41
14		5.26	6.45	5.43	4.01	4.43	4.16
15		6.21	4.61	5.40	4.15	3.24	3.15
16		5.84	4.23	4.91	4.81	3.69	3.06
17		5.24	6.29	3.53	3.28	3.62	2.35
18		4.66	5.03	4.43	4.90	3.44	3.97
19		5.75	7.73	4.76	4.15	3.06	2.66
20		7.20	5.95	4.20	3.93	2.99	2.85
Mean	5.15	5.44	5.90	5.15	3.93	3.62	3.74
C of V	20%	11%	16%	21%	20%	14%	24%
1% LPL	2.90	4.01	3.81	2.87	2.28	2.51	1.97

TABLE A5

WITHDRAWAL LOADS PER DOUBLE NAILED JOINT
OF SEASONED PINE SPECIES

NAILS: Bostitch, 2-75 x 3.2 mm

Stick	Withdrawal Load (kN) in pine species						
Number	Radiata	Hoop	Caribbean	Slash	Loblolly	SPF	Patula
1	4.70	2.17	3.15	2.78	2.25	1.76	3.07
2	4.80	3.66	2.60	3.85	2.88	2.10	1.71
3	4.20	2.77	3.40	4.19	2.96	2.55	2.86
4	4.25	3.01	3.63	3.40	2.03	2.50	2.05
5	4.40	2.42	2.97	3.82	3.35	1.84	2.80
6	3.05	3.02	2.97	3.22	1.97	1.78	1.50
7	3.22	3.05	3.11	3.48	1.74	3.22	2.00
8	3.29	3.30	3.30	3.34	2.33	1.76	1.50
9	2.19	2.56	2.56	5.66	2.20	2.38	2.22
10	2.68	2.10	3.85	3.40	2.18	2.55	2.38
11	4.54	2.60	3.97	4.00	3.11	1.86	2.40
12	2.35	2.73	2.70	3.92	2.25	2.23	2.14
13		2.73	2.04	4.43	3.08	2.35	1.88
14		3.23	2.96	2.08	2.14	2.31	2.10
15		3.60	3.01	4.00	2.45	2.22	2.04
16		2.71	2.24	3.46	2.76	2.06	1.46
17		3.25	3.26	4.44	2.60	2.00	2.88
18		2.08	3.45	3.64	2.59	1.98	2.00
19		3.04	3.59	3.42	3.00	1.68	2.03
20		2.64	2.94	3.85	1.38	1.62	1.56
Mean	3.64	2.83	3.09	3.72	2.46	2.14	2.13
C of V	28%	16%	17%	20%	22%	17%	22%
1% LPL	1.60	1.85	1.95	2.17	1.36	1.34	1.15

TABLE A6

WITHDRAWAL LOADS PER DOUBLE NAILED JOINT
OF SEASONED PINE SPECIES

NAILS: Able Staple, 2-75 x 3.1 mm

Stick	Withdrawal Load (kN) in pine species						
Number	Radiata	Hoop	Caribbean	Slash	Loblolly	SPF	Patula
1	4.52	2.15	4.16	1.95	4.46	3.76	4.75
2	4.23	3.71	4.08	2.43	3.58	3.94	3.38
3	3.66	3.83	3.07	2.80	2.40	3.38	2.18
4	3.35	4.06	4.18	3.77	2.76	2.61	2.68
5	4.14	3.44	2.82	5.60	3.98	2.72	3.18
6	4.97	3.10	1.79	2.53	1.77	1.29	3.65
7	3.56	3.80	3.96	2.53	3.16	2.81	2.60
8	3.82	5.06	4.02	3.95	4.39	3.16	3.20
9	2.89	3.02	3.17	4.64	3.22	2.90	2.84
10	2.25	1.78	5.52	2.91	3.73	2.49	4.40
11	4.60	4.42	3.70	3.86	4.34	1.61	3.10
12	2.45	3.42	2.80	4.51	4.80	3.16	3.38
13		4.91	3.40	2.97	3.29	1.81	2.53
14		6.10	3.32	2.65	3.40	2.34	4.10
15		4.20	4.34	4.39	3.54	2.81	3.65
16		4.55	1.63	2.95	1.81	3.48	2.23
17		3.43	2.53	3.08	4.15	3.29	2.41
18		2.37	3.27	3.82	4.90	2.56	2.87
19		3.00	3.91	3.41	4.18	3.61	2.86
20		3.00	4.23	2.19	3.20	1.83	2.64
Mean	3.70	3.67	3.50	3.35	3.55	2.85	3.13
C of V	25%	30%	30%	28%	29%	30%	22%
1% LPL	1.78	1.62	1.55	1.56	1.62	1.23	1.74

TABLE A7

WITHDRAWAL LOADS PER DOUBLE NAILED JOINT
OF SEASONED PINE SPECIES

NAILS: Jambro square, 2-75 x 3.1 mm

Stick	Withdrawal Load (kN) in pine species						
Number	Radiata	Hoop	Caribbean	Slash	Loblolly	SPF	Patula
1	2.10	1.72	1.16	0.65	2.76	2.06	3.66
2	2.12	2.14	1.76	1.92	1.21	1.56	1.70
3	1.53	2.43	1.27	2.05	1.79	2.30	1.32
4	1.26	2.10	1.44	1.41	2.36	1.02	2.42
5	1.69	1.80	1.27	0.81	2.69	0.65	2.92
6	1.99	1.87	1.37	2.68	1.92	0.75	2.08
7	1.72	2.82	1.27	2.07	2.42	1.34	1.61
8	1.64	1.98	1.90	0.99	2.15	1.85	1.44
9	1.35	1.13	0.96	1.30	2.12	1.81	2.02
10	1.60	1.14	2.08	2.17	2.03	1.31	2.44
11	2.18	1.76	1.51	2.18	2.54	0.78	1.73
12	1.20	2.28	1.25	2.28	1.99	2.40	2.40
13		2.24	1.98	2.20	2.96	2.34	1.61
14		2.30	1.11	2.48	1.46	2.30	2.12
15		2.38	1.26	1.95	1.78	1.82	1.46
16		2.35	0.50	1.19	2.25	1.76	1.65
17		2.52	1.51	2.18	1.17	1.93	2.08
18		2.26	0.99	1.95	2.15	1.42	2.31
19		2.15	1.50	1.48	2.05	1.72	2.59
20		2.40	1.72	2.02	1.94	1.60	1.76
Mean	1.70	2.09	1.39	1.80	2.09	1.64	2.07
C of V	20%	24%	32%	39%	25%	39%	26%
1% LPL	0.94	1.10	0.58	0.61	1.07	0.55	1.01

TABLE A8

WITHDRAWAL LOADS PER DOUBLE NAILED JOINT
OF SEASONED PINE SPECIES

NAILS: Jambro annular, 75 x 3.2 mm

Stick Number	Withdrawal Load (kN) in pine species						
	Radiata	Hoop	Caribbean	Slash	Loblolly	SPF	Patula
1	4.42	5.12	4.49	3.61	3.40	4.24	4.49
2	5.96	6.70	4.86	3.37	4.01	3.42	3.71
3	4.16	4.21	4.30	4.91	2.88	3.54	3.45
4	3.43	2.89	4.14	2.28	3.16	4.12	4.62
5	5.82	4.52	3.46	1.90	3.70	3.18	4.29
6	4.04	3.63	4.81	2.86	2.88	2.53	4.07
7	4.53	3.65	5.69	1.61	3.08	3.57	2.74
8	4.64	3.40	4.11	3.16	4.11	3.36	3.31
9	4.26	2.33	4.79	3.29	3.30	2.80	3.23
10	4.12	4.90	4.45	1.72	3.18	2.87	4.91
11	4.37	4.63	4.48	5.40	3.10	3.16	3.95
12	3.06	5.10	5.93	2.33	3.98	4.46	3.70
13		4.34	5.21	2.95	3.28	3.07	4.32
14		5.29	5.01	3.31	2.66	4.08	4.93
15		6.04	5.16	5.16	3.64	3.68	3.12
16		4.58	4.17	3.17	3.87	3.86	2.37
17		3.88	5.18	2.89	4.03	4.32	3.22
18		3.38	4.30	3.33	2.36	4.51	3.40
19		4.36	3.86	3.02	5.18	3.53	2.91
20		6.72	3.63	3.36	2.38	3.56	3.47
Mean	4.41	4.48	4.60	3.18	3.41	3.59	3.71
C of V	19%	27%	14%	33%	20%	16%	20%
1% LPL	2.56	2.16	3.16	1.29	2.01	2.33	2.17

TABLE A9

WITHDRAWAL LOADS PER SINGLE SCREWED JOINT
OF SEASONED PINE SPECIES

SCREW: 14-10 x 75 mm "type 17"

Stick Number	Withdrawal Load (kN) in pine species						
	Radiata	Hoop	Caribbean	Slash	Loblolly	SPF	Patula
1	7.22			4.59	7.59	5.30	4.02
2	5.55			5.70			
3	7.88			7.02		5.65	
4	6.60				4.17	4.56	
5	6.44		6.16		8.52		
6	5.15		6.20				
7	5.30		6.34			7.31	
8	5.79		7.91	6.87	4.03	4.55	
9	6.00		4.70	10.04	4.70		
10	4.78		5.94		5.13		
11		5.28	5.41		5.25		
12		6.65	6.01				3.67
13		5.72	5.18				4.95
14		7.87		6.86	4.35		7.50
15		8.08		8.39		4.77	4.06
16		7.70					4.33
17		7.88	4.75	6.01	3.46	5.02	4.55
18		5.13		7.73		4.72	3.35
19		6.46				3.74	4.40
20		5.29		5.41	4.12	2.41	4.42
Mean	6.07	6.61	5.86	6.86	5.13	4.80	4.42
C of V	15.6	18.5	15.5	22.7	28.5	28.8	23.1
1%	3.78	3.76	3.66	3.42	2.12	1.98	2.17