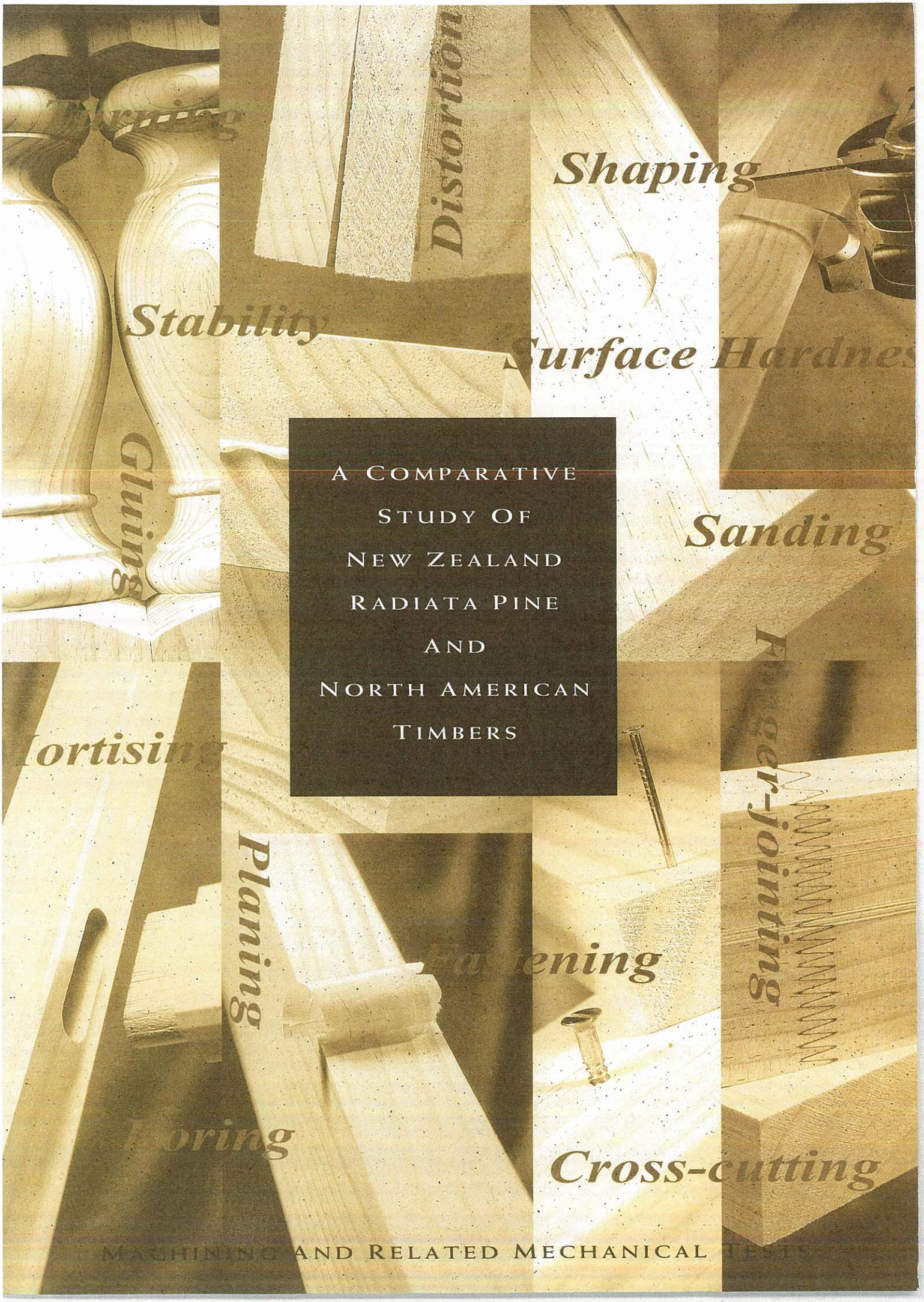


A Comparative Study Of New Zealand Radiata Pine And North American Timbers

Machining And Related Mechanical Tests

RADIATA PINE - A VERSATILE TIMBER

New Zealand's radiata pine is one of the world's most versatile softwoods - an ideal material for a wide range of commercial applications. The timber's status as a good quality, multi-application resource has been endorsed by a recent comparison with 13 North American timbers. All have similar characteristics and uses.

A comprehensive series of tests evaluated the timbers in terms of their machining and related mechanical properties. Radiata pine achieved first place with an overall score of 70% - against an average score of 59% (see back cover for table).

Radiata pine is widely used for packaging and temporary construction, but its performance in the comparative study confirms its suitablity for a broad range of uses - including plywood production, general joinery and the manufacture of furniture.

Many of the North American timbers are currently used in these applications.

The reports in this folder provide detailed results of each timber's performance in a variety of specific tests.

THE TIMBERS

Radiata pine (Pinus radiata) was compared with 13 North American timbers sourced by the University of California, Berkeley, and widely used in the construction and manufacturing industries:

Common Name	Botanical Name	Common Name	Botanical Name
Shortleaf pine	*(Pinus echinata)*	White fir	*(Abies concolor)*
Sugar pine	*(Pinus lambertiana)*	Douglas fir	*(Pseudotsuga menziesii)*
Western white pine	*(Pinus monticola)*	Western hemlock	*(Tsuga heterophylla)*
Ponderosa pine	*(Pinus ponderosa)*	Red alder	*(Alnus rubra)*
Red pine	*(Pinus resinosa)*	Yellow poplar	*(Liriodendron tulipifera)*
Eastern white pine	*(Pinus strobus)*	Eastern cottonwood	*(Populus deltoides)*
Loblolly pine	*(Pinus taeda)*		

THE TESTS

The study was undertaken by the New Zealand Forest Research Institute in collaboration with the University of California, Berkeley.

An extensive series of tests formed the basis for the comparison. Using techniques of the American Society for Testing and Materials (ASTM), tests were designed to evaluate the timbers in terms of their machining and related mechanical properties.

Machining Tests	Related Mechanical Tests
Cross-cutting(x2)	Gluing (x2)
Planing (x2)	Hardness
Shaping	Nail-withdrawal
Turning(x2)	Nail-splitting
Boring (x3)	Screw-splitting
Mortising	Staple application
Finger-jointing	Stability (x2)
Sanding	Distortion

The tests were specifically selected to assess the timbers' suitability for panelling, mouldings, joinery and furniture manufacture and included evaluations in planing, shaping, turning, sanding and gluing.

Each species was represented by a batch of 20 lengths of 19mm thick lumber. Samples of the North American timbers were obtained from US lumber merchants, and together with the radiata pine samples, conditioned to 8% equilibrium moisture content.

The radiata pine was of average quality in terms of wood density and stand history. The trees were 33 years old at the time of felling and had been thinned three times in that period to maintain growth rates. They had also been pruned at three stages - a technique designed to promote the recovery of clear grades of lumber. This treatment is typical of all NZ radiata pine.

continued on back cover

Each test was carried out on 20 samples per species. The mean results were graded (from 5 to 1) to reflect the overall quality of the samples for each species.

Grade	Percentage of Samples with Acceptable Grade
5	90% +
4	70 - 89%
3	50 - 69%
2	30 - 49%
1	0 - 29%

To provide the timbers with an overall rating, each test was given a 'weighting' (1 or 2) according to the perceived importance of the characteristic being tested. The grading for each test was multiplied by the weighting. These results were then added together to give an overall value out of a possible perfect score of 100.

Example:

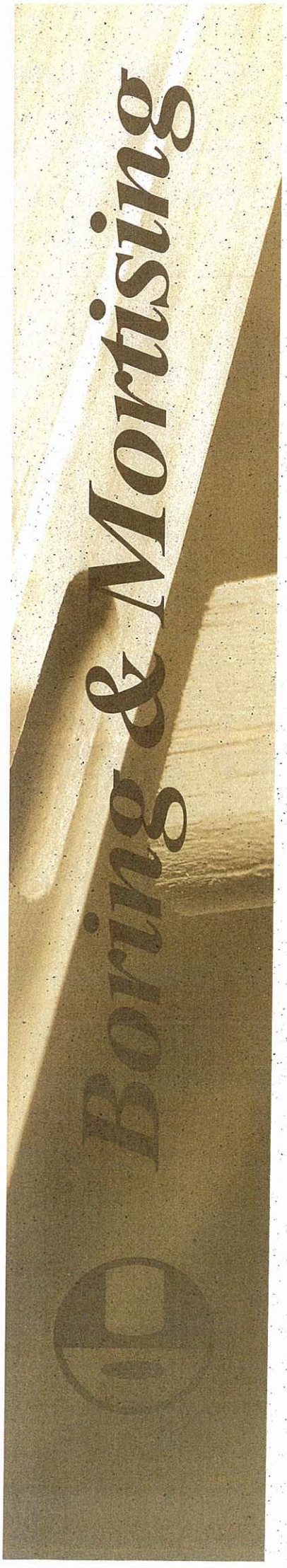
Radiata pine	Assessment Categories														
Weighting	2	2	2	1	1	1	2	1	2	1	1	1	1	2	
x Grading	4	5	3	4	3	4	4	4	4	3	2	2	4	2	
	8	10	6	4	3	4	8	4	8	3	2	2	4	4	=70%

TABLE OF OVERALL RESULTS

Common Name	PLANING	SHAPING	TURNING	CROSS-CUTTING	BORING	MORTISING	SANDING	FINGER-JOINTING	GLUING	HARDNESS	NAIL-WITHDRAWAL	NAIL-SPLITTING	SCREW-SPLITTING	STABILITY	OVERALL RATING %
Weighting	2	2	2	1	1	1	2	1	2	1	1	1	1	2	
Radiata pine	8	10	6	4	3	4	8	4	8	3	2	2	4	4	70
Shortleaf pine	2	8	6	4	3	5	8	4	6	3	2	2	4	2	59
Sugar pine	6	8	4	4	3	3	8	5	6	2	1	4	5	8	67
Western white pine	4	6	6	4	2	4	4	5	6	2	1	2	4	2	52
Ponderosa pine	4	10	4	4	3	5	8	5	6	2	1	4	5	4	65
Red pine	6	10	4	3	2	5	10	5	6	2	1	3	5	2	64
Eastern white pine	6	10	6	3	3	4	6	5	6	2	1	3	5	2	62
Loblolly pine	4	8	2	3	2	5	8	4	6	3	2	2	4	2	55
White fir	2	6	2	4	2	2	8	5	6	2	2	2	4	4	51
Douglas fir	4	10	2	5	2	5	8	5	6	2	2	2	5	6	64
Western hemlock	2	6	2	4	2	4	8	4	6	2	2	2	4	4	52
Red alder	8	10	4	2	3	5	4	4	8	3	2	2	5	2	62
Yellow poplar	6	10	8	4	3	5	6	4	8	3	3	1	5	2	68
Eastern cottonwood	2	4	4	2	3	5	2	4	6	2	2	3	5	2	46

Average 59%

NEW ZEALAND RADIATA PINE



Boring & Mortising

Red alder, yellow poplar and Douglas fir returned the best results in the boring and mortising tests. White fir recorded the worst overall result. All other species, including radiata pine and ponderosa pine, were assessed as 'Fair'.

Both boring and mortising are commonly used to form joints between wood components. Boring is typically used in dowel joints or to attach legs to chairs. A mortise and tenon joint is customarily used to join top rails or lock rails to stiles in doors.

As woodworking characteristics, boring and mortising may not rate as highly as planing or shaping, but they are still important considerations in the general use of lumber.

The Tests

To comply as closely as possible with the ASTM standard, the test used manual boring (a 24mm auger at 2000 rpm) and hollow chisel mortising.

Since much of this type of work is now performed by automatic machines, a second trial was undertaken using a router bit in a CNC machine to drill a 10mm hole and to create a 'square' mortise hole 22 x 22mm.

A final hole was made using a 10mm double-twist, brad-point drill in a hand-fed electrical drill press.

Each of these five holes was graded according to the ASTM standards on smoothness of internal faces and cleanness of the entrance hole.

Boring & Mortising

The Results

Overall Douglas fir, red alder and yellow poplar were rated 'good' - slightly better than any of the other timbers. Nevertheless, nearly all species met the requirements for mortising with both the router bit and hollow chisel and the timbers achieved their best result in the manually-fed 10mm boring test.

Radiata pine, red alder and yellow poplar displayed the best results in the gluing characteristic tests. Their combination of strength and glue-bonding properties gave them consistently superior results to the other timbers.

THE TEST

Two different glues were used in the tests to provide a comprehensive picture of gluing properties.

Cross-linked polyvinyl acetate (PVA) is the most commonly used glue used in North America for door and window joinery.

Isocyanate glue is used when a totally water proof adhesive is desirable.

The glues were prepared and applied to manufacturers' specifications and complied with the ASTM requirements. Each species was tested 20 times - ten joints with each glue type. As with all the other tests, the wood was conditioned to 8% equilibrium moisture content.

Performance was based on a combination of:

- the force required to break the bond and
- the percentage of wood failure in the separated faces.

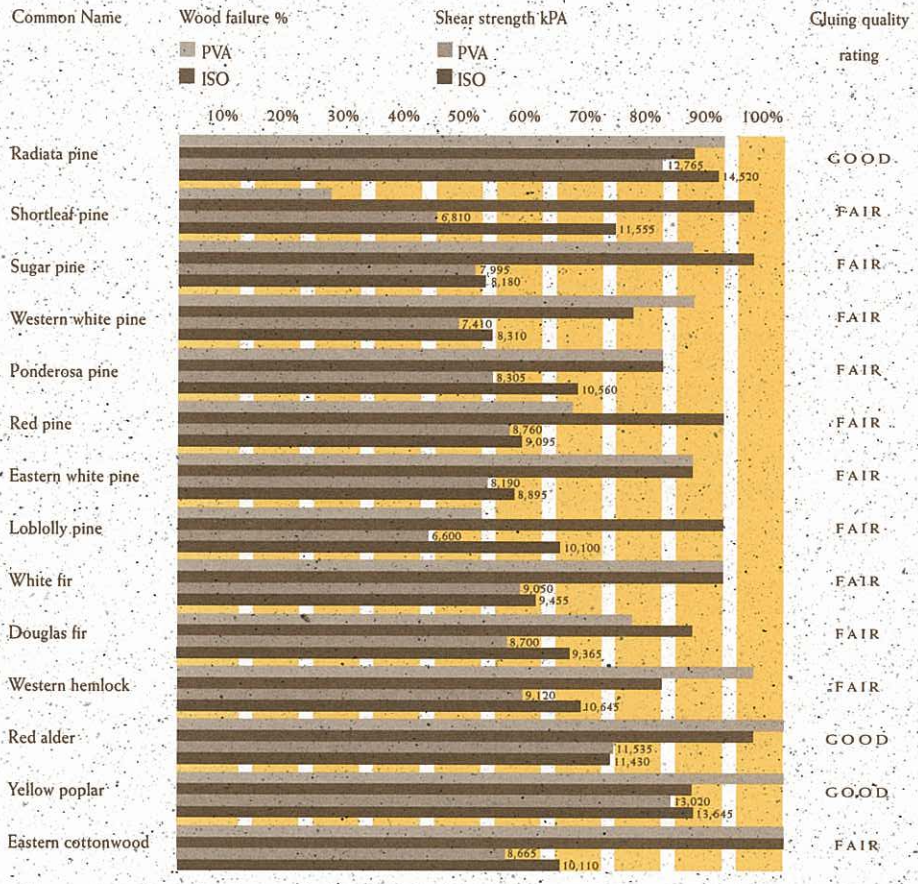
Grading was based on the following scale:

Excellent	greater than 14,000 kPa,
Good	10,001 to 14,000 kPa
Fair	6,001 and 10,000 kPa
Poor	2,001 to 6,000 kPa
Very Poor	2,000 kPa and less.

These measurements represent the timbers' shear strength and the quality of the bond between the adhesive and the wood surface. The better the bond, the higher the percentage of wood failure when the faces are separated.

The bond is affected by the permeability of the wood and the mixture of chemicals in the wood commonly referred to as extractives.

Quality Of Gluing



The Results

Although the isocyanate glue gave consistently higher strength values than those of the PVA glue, the latter's were still within the general strength groupings.

The most marked difference between the glues was in the values for the two southern pines (shortleaf pine and loblolly pine) where a very low percentage of wood failure occurred in the PVA bonds. This was attributed to poor bonding of the typically high-density summerwood in these timbers.

Radiata pine performed particularly well with both glue types. This is attributable to its reasonable wood strength, evenness of grain within growth rings, good permeability and low extractives content, which make radiata pine highly suitable for glue jointing.

Planing

Radiata pine and red alder were the top achievers in comparative planing tests between the 14 timbers. Four other species scored 'Fair' and the remainder 'Poor' or 'Reject'.

Planing is one of the most common machining applications in industries using timber for high-end manufacture (panelling, joinery and furniture), and the quality of finish is critical.

While most finishes do require sanding, the severity and type of defect resulting from planing will impact on the cost (time, effort and materials) required to bring the product to an acceptable finish.

The Test

The samples, selected at random throughout the trial to prevent bias, were fed through a modern computerised planing machine. Its settings were as follows:

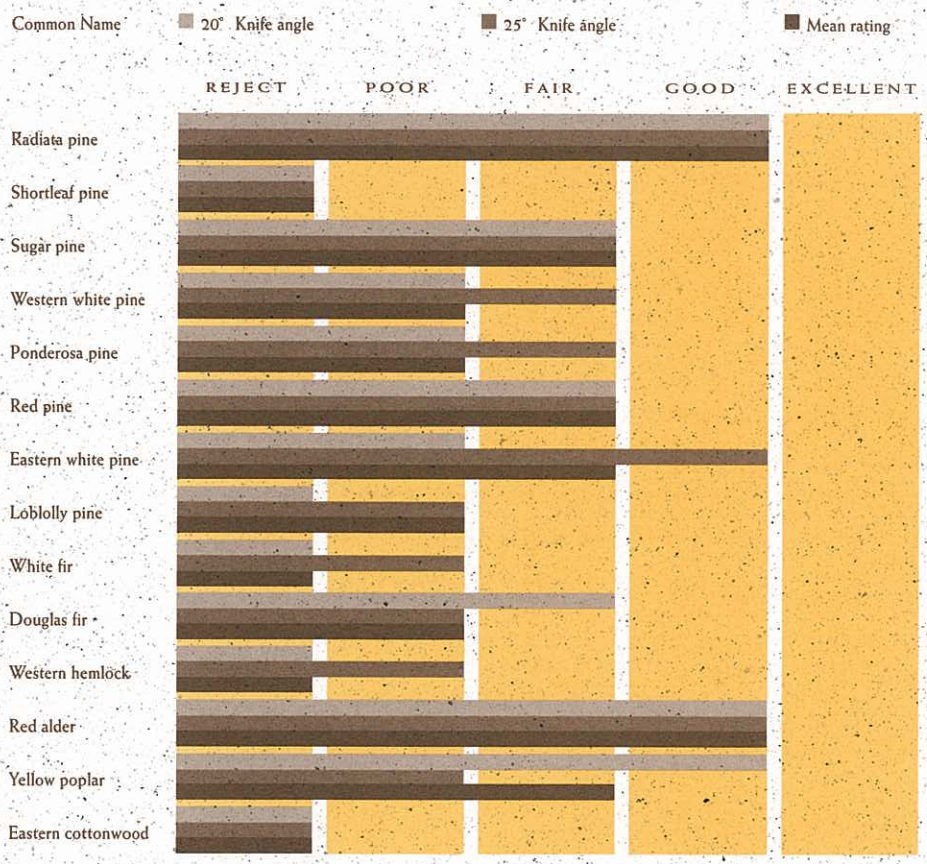
Machine feed speed	9.5 metres/minute (31 feet/minute)
Cutter mark pitch	2.1mm (11.7 knife marks/inch)
Depth of cut	1.6mm (1/16 inch)
Knife angles	
Top head	20 degrees
Bottom head	25 degrees

The quality of finish was determined by visually grading each sample on a five-point scale:

	Grade
5	Excellent
4	Good
3	Fair
2	Poor
1	Reject

The kind of defects noted included chipping, torn grain, fuzziness of finish and raised grain.

Smoothness Of Planed Surface



The Results

As might be expected, most of the softwoods performed better with the higher cutting angle (25 degrees), while the hardwoods preferred the lower angle. The main exception was Douglas fir which had a significantly better result at 20 degrees.

Species with a high contrast between spring-wood and summer-wood density (loblolly and shortleaf pines) suffered from raised grain. Yellow poplar and eastern cottonwood revealed fuzzy grains after planing. None of the other species reflected a dominant defect.

Sugar pine recorded the best results in all stability and distortion tests, while red alder proved to be the least stable of the 14 timbers.

Radiata pine was ranked in the top half of the species assessed, and its performance was very similar to that of ponderosa pine.

A timber's 'lack of stability' is related to moisture movement - either entering or leaving the timber. This causes the wood to swell or shrink. It can also cause the timber to 'warp' - a defect measured as 'bow,' crook,' cup' or 'twist'.

Timbers that are prone to these changes are less desirable for joinery, furniture or even general construction.

The Tests (Stability)

There are few published methods to determine wood stability, and this test was designed to measure short-term and long-term stability.

Short-Term Stability

To determine short-term stability, samples were conditioned at 65% relative humidity (RH), measured, exposed to 95% RH and then remeasured. Performances were graded as follows:

Excellent	less than 1.4% tangential movement
Good	1.4% to 1.8%
Fair	1.9% to 2.1%
Poor	2.2% to 2.6%, and
Very poor	greater than 2.6%

Long-Term Stability

For long-term stability the samples were conditioned at high humidity (90% RH), measured, conditioned to equilibrium at a lower humidity (60% RH) and then remeasured.

The sum of the tangential and radial shrinkage was used to describe the movement. Performances were graded as follows:

Excellent	2.5% shrinkage or less
Good	2.6% to 3.5%
Fair	3.6% to 4.5%
Poor	4.6% to 6.0%, and
Very poor	greater than 6.0% total shrinkage

Stability

The Tests (distortion)

Distortion was assessed on boards 600mm in length. This test measured warp after conditioning the samples to 8% equilibrium moisture content and again after raising it to 15%. Since there are no standards for comparison, results have simply been tabulated.

Warp comparisons (mm of distortion per 1% moisture content change)

Common Name	Spring	Cup	Bow	Twist	Common Name	Spring	Cup	Bow	Twist
Radiata pine	0.023	0.043	0.044	0.075	Loblolly pine	0.027	0.047	0.047	0.104
Shortleaf pine	0.035	0.060	0.041	0.082	White fir	0.028	0.044	0.032	0.082
Sugar pine	0.026	0.039	0.035	0.055	Douglas fir	0.036	0.042	0.044	0.059
Western white pine	0.027	0.028	0.032	0.058	Western hemlock	0.036	0.022	0.061	0.042
Ponderosa pine	0.035	0.051	0.067	0.074	Red alder	0.046	0.069	0.066	0.108
Red pine	0.022	0.040	0.048	0.078	Yellow poplar	0.026	0.067	0.048	0.101
Eastern white pine	0.033	0.055	0.027	0.096	Eastern cottonwood	0.033	0.034	0.049	0.061

The Results

In the international range of values for all timber these species all recorded indifferent results in the stability and distortion tests. Radiata pine did however reflect above average results, demonstrating its suitability as an alternative timber to many of the others tested.

Cross-cutting & Finger-jointing

North American Douglas fir achieved the highest overall result in the comparative cross-cutting and finger-jointing tests. Radiata pine's overall cross-cutting performance was rated 'Good.'

Cross-cutting is one of the most basic applications in preparing lumber for any end use. It is used in all areas of production - from the basic elimination of blemishes or defects to the finer cuts required for cabinetry and furniture manufacture.

When defects are 'cut' from timber, the lengths of timber often need to be rejoined. One commonly used method for this is finger-jointing. For this reason, the timbers' suitability for finger-jointing was also assessed.

The Tests

The cross-cutting test was firstly carried out on a manual radial arm saw in which the basic saw movement is across the width of the timber. This action is comparable to that carried out during the manual removal of defects in millwork plants.

A second series of cuts was made with an automatic electronic cross-cutting machine. This machine is becoming more common for 'defect removal' and the quality of cut is closer to that required in joinery.

The results were assessed by eye using a five-step scale of quality.

Grade

5 Excellent

4 Good

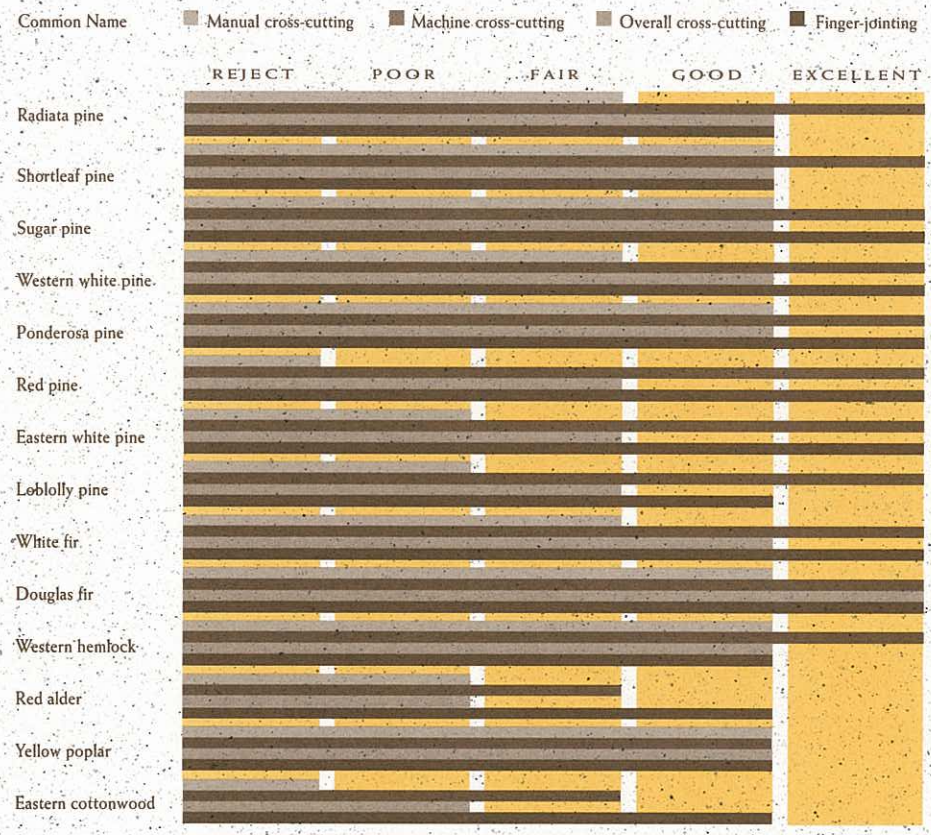
3 Fair

2 Poor

1 Reject

In addition to these tests, an industrial finger-jointing machine was used to form a number of 12mm face-to-face finger-joints in boards of each species.

Smoothness Of Cut Surface



The Results

Important criteria in cross-cutting and finger-jointing are a smooth, clean cut with a minimum of crushing or splintering at the cut surface or face.

All species produced acceptable levels of quality in the automatic cross-cutting and finger-jointing trials. As expected, the manual cross-cutting results were inferior to those of the automatic machine, but with the exception of red pine and eastern cottonwood, all species performed adequately in the manual test.

In comparative wood-turning trials yellow poplar achieved the best result. Four other timbers, including radiata pine, were rated 'Fair'. All other species gave lower quality results.

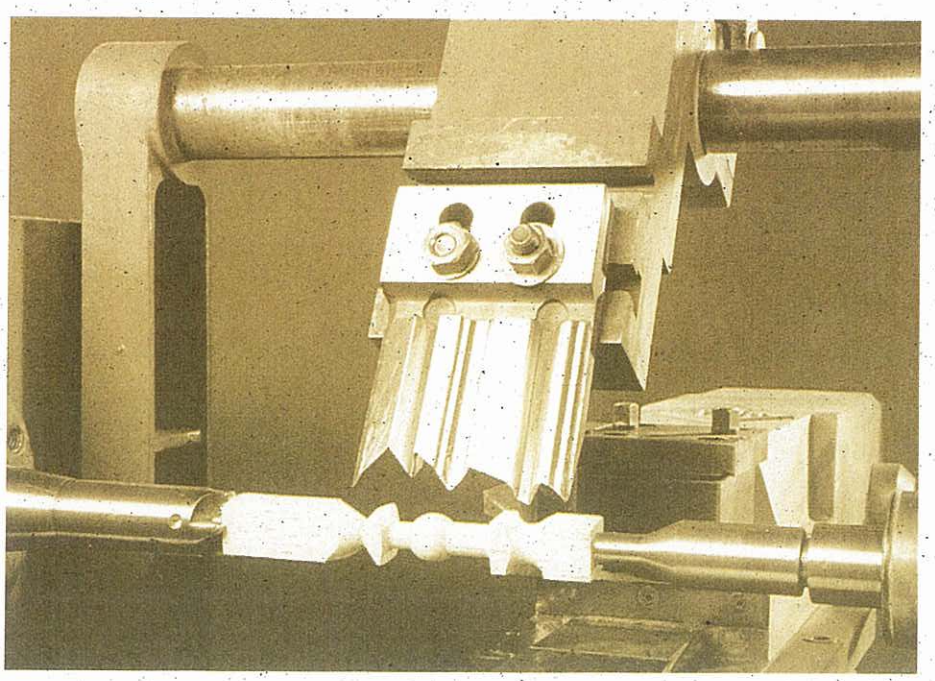
Turning is used extensively in the timber industry today to manufacture a wide variety of products. These include handles, furniture components, stair newels, bowls, sporting goods and toys.

The Tests

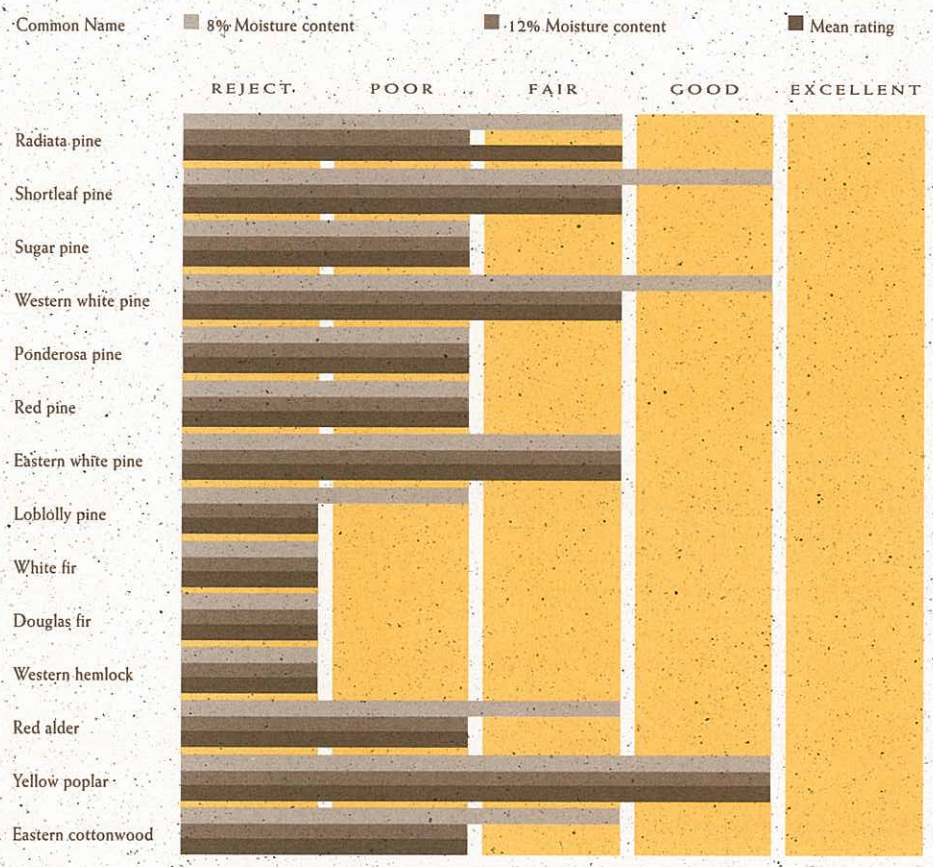
Matched samples were cut from 20 lengths of (19mm) lumber for each species. One set of samples was conditioned to 8% equilibrium moisture content, and a second set to 12%.

A one-piece milled-to-pattern knife was used in a back-knife lathe to produce turnings of considerable detail. (picture)

Quality of finish was determined by visually grading each piece. Defects included severity of chipping, fuzziness of finish and 'picking out' of the end grain.



Quality Of Turning



The Results

All species performed better at back-knife turnery in the drier condition (8% moisture content rather than 12%). Chipping (or torn grain) was the most common defect throughout the tests, although picking-out on the end grain was also evident at the higher moisture content.

In addition to moisture content, factors such as fineness of texture, wood density and evenness of grain affected the quality of turning.

Of the species tested, yellow poplar has the finest texture and thus obtained the highest quality. The density within loblolly pine, by contrast, varies considerably between wood formed in spring and summer, and hence produced a poor result.

Radiata pine has low density variation within the growth rings. Its overall moderate density and medium texture make turning an appropriate processing application.

Shaping & Sanding

Radiata pine - together with six other timbers - achieved the top rating in comparative 'shaping' tests.

Red pine produced the best finish in the sanding tests, but a number of other species (including radiata pine) were also of a high standard.

Shaping is a widely used procedure in furniture manufacture. The process is usually carried out on hand-fed spindle moulders, but Computer Numerical Control (CNC) routers are being used increasingly due to their ability to be programmed to reproduce a variety of compound shapes.

Sanding is almost always required to produce an acceptable, 'quality finish'.

The Tests

The ASTM standard requires the use of 'a commercial size, hand fed spindle shaper', but in view of today's developing industry, it was deemed more applicable to carry out these tests using a router head on a CNC machine centre.

The quality of finish was determined by visually grading each sample on a five point scale and then calculating the percentage of 'acceptable' quality finishes for each species.

	Grade
5	Excellent
4	Good
3	Fair
2	Poor
1	Reject

In the shaping trial, defects which were noted included chipping, fuzziness of finish and raised grain.

The sanding trial used 120 grit sandpaper. Quality was determined from the incidence of scratching and fuzziness of surface.

Shaping & Sanding

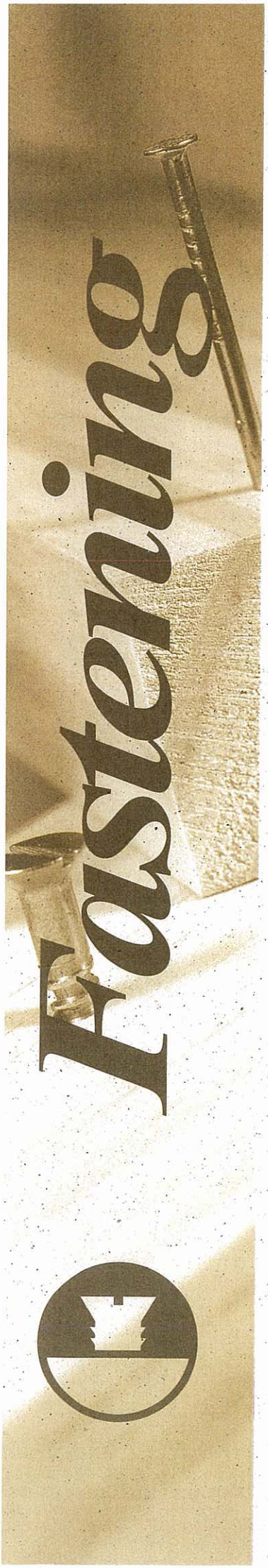
The Results

Most species performed well in the shaping trial.

White fir and western hemlock were exceptions, achieving only a 'fair' rating due to the levels of raised grain and chipping. In particular, the eastern cottonwood produced a severely fuzzy finish.

Radiata pine machined particularly well and was the top ranked wood within the 'excellent' category.

'Fuzziness' of the surface rather than 'scratching' was the most common degrading feature in the sanding trials, and again, this was worst in the eastern cottonwood which failed to produce a single sample of the required standard.



Radiata pine recorded a 'medium' rating in tests examining the mechanical fastening properties of the 14 species.

Pondersosa pine and sugar pine showed the greatest resistance to splitting, but performed poorly in nail holding tests. Yellow poplar had the greatest resistance to nail withdrawal but was the worst for splitting.

THE TESTS

The tests were carried out on 20 samples per species - all conditioned to 8% equilibrium moisture content .

In the nail and screw-splitting tests, the screws and nails were driven close to board end. The performance of the timber is assessed on the size of the splits.

Nail withdrawal tests were chosen to reflect the strength requirement of mechanical fasteners.

In addition, 50mm long staples (15 gauge) were tested across a selection of air pressures to establish typical ranges for staple fastening.

The grades for resistance to nail withdrawal were structured as follows:

Excellent	6.01 N/mm and greater
Good	4.51 - 6.00 N/mm
Fair	3.01 - 4.50 N/mm
Poor	1.51 - 3.00 N/mm
Very Poor	1.50 N/mm and less

Quality Of Mechanical Fastening

* Yellow poplar had 100% failure in the nail-splitting test.

The Results

All species performed well in the screw-splitting tests. Only the largest gauge screw caused significant splitting and in practice this would simply be reduced by adjusting the size of the pilot holes.

Nail splitting was far more common and those timbers with higher nail withdrawal strengths tended to split the most.

These results are a funetion of wood density so that high-density timbers have a higher likelihood of splitting, greater resistance to stapling but greater nail-holding strength.

This is clearly demonstrated with the high-density yellow poplar. Where wood density is low, as with sugar pine, the reverse occurs.

Surface Hardness

In surface hardness tests radiata pine, together with shortleaf pine, red alder, yellow poplar and loblolly pine, was in the top grouping of the 14 species. Western white pine, eastern white pine and sugar pine were the softest of the timbers.

Surface hardness is an important characteristic which indicates the ability of the timber - if used in applications such as furniture and flooring - to withstand the knocks of everyday wear.

The Tests

The Janka hardness test measures the force required to press a ball into the timber surface, which in effect reflects the timber's resistance to indentation.

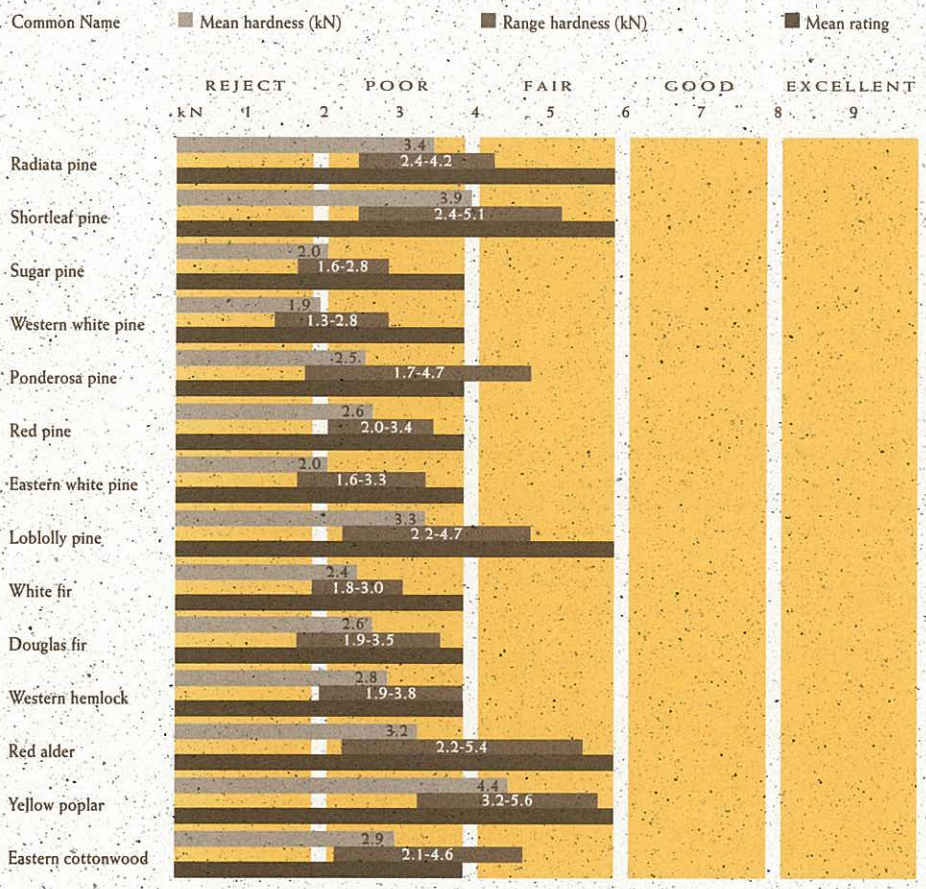
By way of comparison, Janka ball tests record a force of less than 0.5 kN for Balsa wood and about 20 kN for Lignum-vitae - one of the earth's densest timbers.

For the purpose of practical comparison, this range was split into five broad categories:

Excellent	greater than 10 kN
Good	5.1 - 10 kN
Fair	3.1 - 5.0 kN
Poor	1.6 - 3.0 kN
Very poor	1.5 kN and less

Each species was represented by 20 samples and tests were carried out on two faces of each sample which was conditioned to 8% equilibrium moisture content.

Surface Hardness



The Results

The tests show that radiata pine is a robust alternative to many of the timbers where surface hardness is a key consideration.

For more information contact:

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