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**TECHNICAL PAPER No 26**

THE EFFECT OF CHANGE OF TEMPERATURE ON THE APPARENT  
MODULUS OF ELASTICITY OF RADIATA PINE SCANTLING  
WITH PARTICULAR REFERENCE TO MECHANICAL STRESS GRADING

By

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**FORESTRY COMMISSION OF N.S.W.**

**Wood Technology and Forest Research Division**

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## Summary

Measurements of the stiffness of kiln dried radiata pine scantling of various stress grades show that the apparent modulus of elasticity increased by an average of 4.9% as the temperature of the timber is lowered from 22°C to 3°C.

## Introduction

This investigation was initiated in an attempt to quantify the effect of low temperature on the apparent modulus of elasticity of radiata pine scantling. The temperature effect is of some significance in the estimation of the accuracy of timber grading machines that measure stiffness because the temperature of mechanically graded timber during laboratory testing can be quite different to its temperature at the time of mechanical grading.

It is well known that the modulus of elasticity (M of E) of small clear samples increases with decreasing temperature. According to Sulzberger<sup>1</sup> the effect of temperature on the M of E is slight at zero moisture content but appreciable at the higher moisture contents of the hygroscopic range. The effect on M of E is also of increasing significance as the temperature is increased, and thus it is at its most significant at high moisture contents and high temperatures. From the Sulzberger modulus of elasticity versus temperature curves for small clear samples, the increase in M of E that could be expected with a temperature change from 22°C to 3°C would be about 4% for material with a moisture content of 12%.

Direct application of Sulzberger's figures to radiata pine scantling was thought to be questionable, hence this investigation was undertaken.

## Material

The material used for this investigation consisted of 72 routine quality control samples sent to the Wood Technology and Forest Research Division for testing by two 'Compuermatic' machine operators. Specifications for this sampling are contained in the attached document "Quality control of mechanically graded timber". (Appendix A).

The samples were approximately two metres long and included cross sections varying from 35 x 70 mm to 45 x 140 mm. The following table shows the percentage in each size group.

X-section (mm <sup>2</sup> )	% of total in size group
35 x 70	7
35 x 90	29
35 x 120	22
35 x 140	4
45 x 90	32
45 x 120	2
45 x 140	4

The moisture content distribution of the samples as measured with an electric resistance moisture meter was as follows:-

Moisture Content %	% of total in M.C. group
9	14
10	19
11	28
12	10
13	7
14	14
15	5
16	1.5
17	1.5

For the normal moisture content range of kiln dried radiata pine and for the temperature range considered here the effect of moisture content is considered to be of no practical importance. The average moisture content of the samples tested was 11.6% with a standard deviation of 2.0%.

The mechanical strength rating (F grade) distribution of the samples was as follows:-

Grade	% of total in grade
F11	8.5
F8	25
F5	40
F4	18
Less than F4	8.5

Test Conditions and Experimental Procedure

The samples were allowed to attain the laboratory temperature of 22°C and the moisture content was then taken. Each sample was subsequently tested for stiffness in bending on the flat, simply supported over a span of 0.914 metre (36 inches) with the worst defect in the middle of the span. The test method used is described in the attached document "Specifications for determination of M of E and M of R of mechanically graded timber" (Appendix B).

The load applied and the maximum stress developed for each sample size were as follows:-

Size (mm <sup>2</sup> )	Load (N)		Maximum Stress MPa
	initial	final	
35 x 70	50	740	11.84
35 x 90	50	940	11.69
35 x 120	100	1290	12.04
35 x 140	100	1490	11.92
45 x 90	100	1540	11.59
45 x 120	100	2025	11.43
45 x 140	100	2345	11.35

The samples were then wrapped in plastic sheeting in groups of 5 and placed in a cool room set at 3°C. After 3 days at 3°C the samples were retested in groups using conditions identical to those pertaining during the tests performed when the samples were at 22°C. The maximum delay in the testing of any sample after its removal from the cool room was eight minutes.

The apparent M of E was calculated for each sample at the two temperatures and the percentage increase at 3°C was calculated using the formula:-

$$\frac{(M \text{ of E at } 3^{\circ}\text{C}) - (M \text{ of E at } 22^{\circ}\text{C})}{(M \text{ of E at } 22^{\circ}\text{C})} \times 100$$

It is worth noting that all the samples increased their apparent M of E as their temperature was lowered.

### Results and Discussion

Some relevant statistics of the percentage increase in apparent M of E at 3°C over that at 22°C are listed below:-

No. of samples	=	72
Mean Value	=	4.9%
Standard Deviation	=	2.11%
Skewness <sup>2</sup> ( $\alpha_3$ )	=	0.30
Kurtosis <sup>2</sup> ( $\alpha_4$ )	=	2.68
Maximum Value	=	10.1%
Minimum Value	=	0.7%

The mean value of 4.9% increase in apparent M of E as a result of the temperature change is in close agreement with the results obtained by Sulzberger<sup>1</sup> in tests using small clear samples.

A statistical test shows that there is a significant change in apparent modulus of elasticity as a result of a temperature change from 22°C to 3°C.

The accompanying graph shows a plot of apparent M of E at 22°C Vs the percentage increase in apparent M of E at 3°C. It is worth noting that the higher stiffness material does not show as wide a scatter of change in M of E as is evident in the lower stiffness material. This could be the result of the occurrence of a large variety of defects in the lower stiffness material.

### Conclusion

Winter conditions in some areas in Australia could result in timber with a temperature around zero °C being mechanically graded. If timber at 3°C was mechanically graded or laboratory tested and if it was subsequently regraded or laboratory tested at 22°C, its apparent M of E would be expected to decrease by an average of approximately 5%. This is assuming that the moisture content of the timber does not change.

This fact has to be taken into account when machine accuracy is being checked because the M of E of any piece of scantling timber at normal moisture contents will increase as its temperature is lowered.

Consideration should also be given to the effect of high temperatures on the M of E as it is not uncommon for mechanical grading operations to be performed in temperatures above 35°C. An investigation of the effect of high temperatures on the M of E of scantling material has not yet been carried out, but using Sulzberger's<sup>1</sup> curves for clear timber as a guide an average decrease of around 8% in the M of E at 40°C over that at 22°C appears likely.

It should be remembered that without temperature correction the mechanical grading of timber will be to some degree conservative at high temperatures and non-conservative at low temperatures. This can be rectified by the adjustment of the load applied during the grading operation.

If timber is kiln dried then sufficient time must be allowed for it to cool before it is mechanically graded, otherwise the grading will be conservative.

### References

1. Sulzberger, P.H. - "The effect of temperature on the strength of Wood, plywood and glued joints". Dept. of Supply, Aeronautical Res. Consultative Committee, Report ACA - 46, December, 1953.
2. Hahn, G.J. and Shapiro, S.S. - "Statistical Models in Engineering". John Wiley & Sons 1967.

## FORESTRY COMMISSION OF N.S.W.

WOOD TECHNOLOGY DIVISION

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Quality Control of Mechanically Stress Graded Timber

For the purpose of controlling the quality of Mechanically Graded Timber it is required that:-

1. Graded lengths of timber be selected during production runs in a manner specified by the Controlling Authority. From these graded sticks bending test samples are to be cut according to the following rules:
  - (a) Each sample is to have a minimum length of approximately fifteen times the width of the graded stick (see table below).
  - (b) The middle region of the cut sample (see table below) is to contain the lowest grade zone of the graded stick and the associated defect (if any).
  - (c) If the graded stick contains more than one lowest grade zone then the one to be chosen for the bending test sample is the zone nearest the trailing end.

WIDTH	MINIMUM LENGTH OF TEST PIECE IN	MINIMUM DISTANCE OF OBVIOUS DEFECT OR LOW GRADE MARK FROM ONE END
mm	mm	mm
70-75	1125	450
90-100	1500	600
120-125	1875	750
140-150	2250	900
170-175	2500	1075
190-200	2500	1075

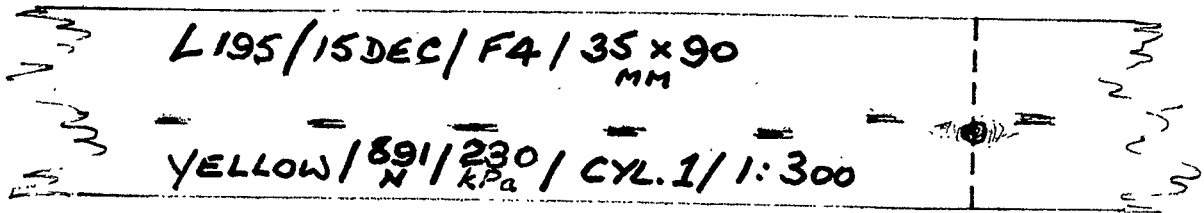
2. The bending test samples have the following information written on them as shown in Fig. 1.
  - (a) Operator Code (consisting of a letter or letters of the alphabet) and Sample Number.
  - (b) Date
  - (c) Grade of Sample

- (d) Stick Dimensions
  - (e) Program
  - (f) Load
  - (g) Gauge Pressure and Cylinder Stage
  - (h) Sample Rate
3. The bending test samples should be delivered to the testing authority as soon as convenient and not longer than 7 days after grading i.e. once a week.
4. All tests be carried out in accordance with the following specifications:
- (A) Clause 7.2.2 of A.S. C01-1972
  - (B) Wood Technology Division grading programs
  - (C) Wood Technology Division "Specification for determination of M of E and M of R of Mechanically Graded Timber."
  - (D) Any other requirements as specified by the Controlling Authority from time to time.
5. The testing authority shall perform the following tests on the bending test samples.
- (A) Check that the correct grading program card and the correct gauge pressure and combination of cylinders were selected during grading for a particular size and species of timber.
  - (B) Measure moisture content with an electric moisture meter.
  - (C) Determine Modulus of Elasticity (W.T.D. Spec.)
  - (D) Determine Modulus of Rupture (W.T.D. Spec.)
6. Reports on the test results will be issued by the testing Laboratory, a permanent record of which must be kept by the operator.

These reports will provide the following:

- (A) Evidence that the timber grading operations, for the batches of timber from which the samples were drawn, were or were not under proper control.
- (B) A warranty for the quality of the graded material.

Fig. 1.



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SPECIFICATIONS

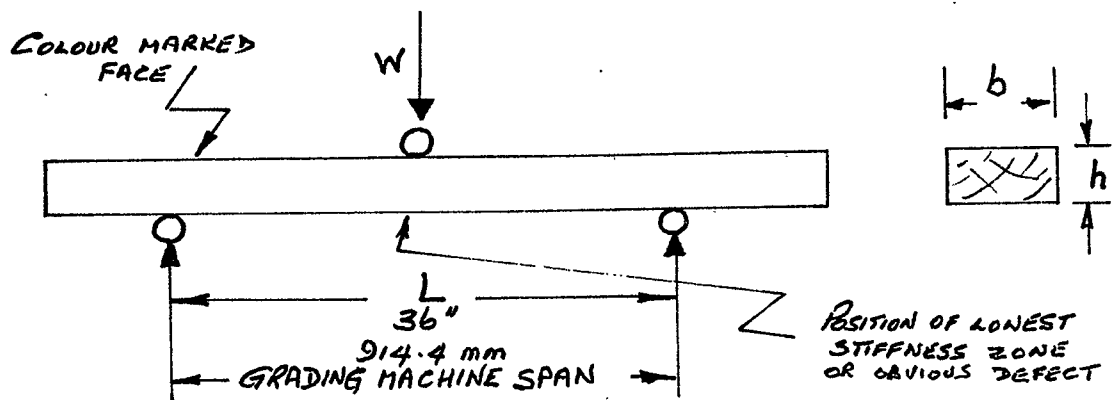
For determination of ME & MR

of

Mechanically Graded Timber

Determination of Apparent Modulus of Elasticity M of E

(i) Modulus of elasticity, M of E, for a test sample shall be determined from deflections measured on the flat over a span "E" when simply supported as a plank with the lowest stiffness zone or obvious defect placed under the load. The span, the end conditions and direction of loading shall be identical to those of a stress grading machine as shown below.



(ii) M of E shall be calculated as follows:

$$E = \frac{L^3}{4bh^3} \times \frac{(W)}{(\delta)} \text{ in MPa}$$

where

E = modulus of elasticity in MPa

L = grading machine span = 36" x 25.4 = 914.4 mm

b = breadth in mm

h = depth in mm

W = load in N

$\delta$  = deflections in mm

$\frac{(W)}{(\delta)}$  = is the slope of the load versus deflection curve in the range of proportionality as shown in Fig. 2.

This slope may be determined by loading the sample with an initial load to eliminate possible zero error, noting the deflection, then applying the final load and again noting the deflection. The initial load shall not exceed 10% of the load applied during grading and the final load shall be equal to the load applied during grading plus the initial load.

F = Final load  
I = Initial load  
W = Load used during grading

Hence Final Load =  $W + I$

or

$$W = F - I$$

where

$$I \leq 0.1 W$$

The difference between the deflections measured when the initial and final load are applied corresponds to deflection due to load W which can directly correlate with the deflection range indicated by the machine.

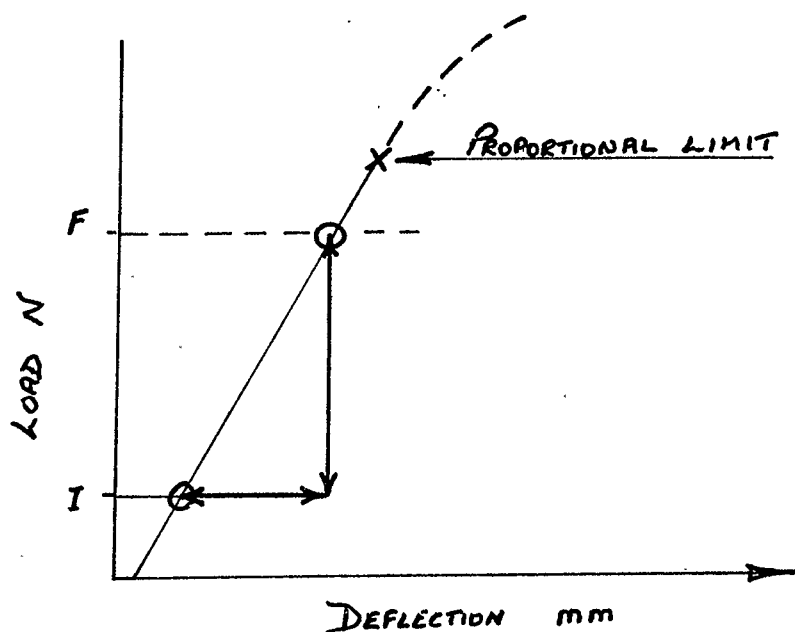


Figure 2

#### Determination of Modulus of Rupture M of R

(i) Modulus of rupture, M of R, shall be determined from the maximum load recorded when testing the sample to destruction as a joist, at the point where modulus of elasticity on the flat has been determined, by 4 point bending over a span as indicated in the table below with any obvious strength reducing defect placed on the tension side; i.e. a knot near the edge would be placed on the tension side. The above method is essentially the same as the A.S.T.M. method for testing scantling using a slightly different span.

(ii) Modulus of rupture shall be calculated as follows:

$$MR = \frac{3 WC}{bh^2} \text{ in MPa}$$

where

MR = Modulus of Rupture in MPa

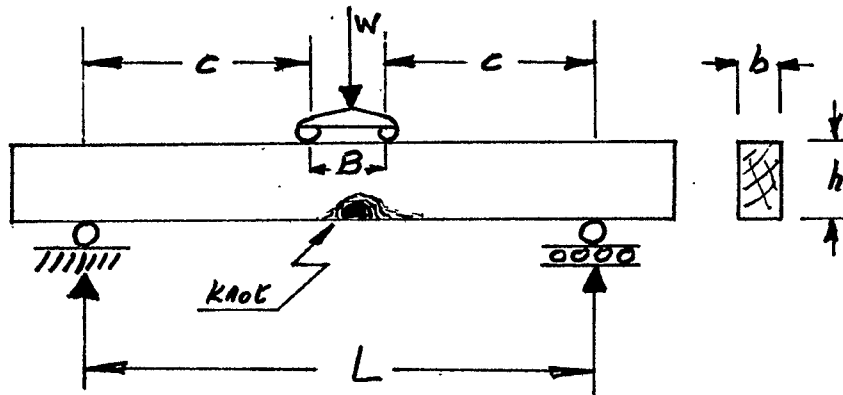
W = Maximum load in N

L = Span in mm

C = Distance between supports and loading points in mm

b = breadth in mm

h = depth in mm



Depth (h) mm	L mm	B mm	C mm
70 - 75	1000	300	350
90 - 100	1300	300	500
120 - 125	1580	380	600
140 - 150	1860	460	700
170 - 175	2200	540	830
190 - 200	2200	540	830

The above tests should be performed at a speed of testing in accordance with the recommendations given in A.S.T.M. D198-67 a standard methods of static tests of timbers in structural sizes.

APPARENT M. of E. AT 22°C Vs PERCENTAGE INCREASE IN APPARENT M. of E. AT 3°C OVER THAT AT 22°C

