Experience with Performance-based Visual Grading of Dimension Lumber.

Bryan Walford, Senior Scientist, Scion & Douglas Gaunt, Scientist, Ensis

Summary

New Zealand produces grades of dimension lumber by both visual and mechanical grading. A system of in-mill quality verification was set up after concern was raised over the changeable quality of visually graded lumber from fast-grown forests. The same system of quality verification is applied to the lumber regardless of the method of grading – visual, mechanical or a combination of both. Quality records are analysed to show the limitations and effectiveness of the QC system, and of the grading methods.

1. Introduction

The early European settlers in New Zealand initially copied the style of housing used by the indigenous Maori or used tents. Many also built in stone, cob (adobe) or brick, using the skills common in Britain where most of the settlers originated. Once sawmilling developed they quickly copied the style of housing familiar to North Americans – the 2x4 system. In 1921 a large earthquake on the East Coast of the North Island of New Zealand, at Napier, demonstrated the need for a building code and the relative safety of the 2x4 system of construction in earthquakes. This earthquake stimulated the government to draft a code for house construction. At the time, indigenous timbers were abundant but it was evident that they would be depleted by the 1960s. Radiata pine was found to be an easily established, fast growing and versatile timber and extensive planting of this species began in the 1920s. Rules for grading this timber were published in 1962 [1], establishing two grades for dimension lumber of radiata pine for use in house construction.

They were:

No. 1 Framing, intended for joists, rafters and members subjected to bending

No. 2 Framing, for studs and secondary members.

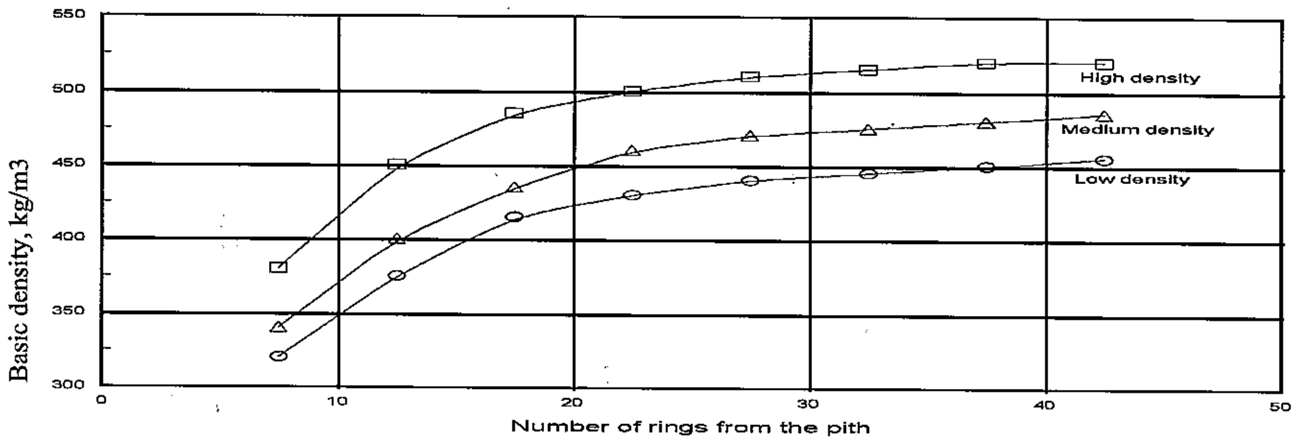
Design stresses were not published for these grades but the timber design code [2], published in 1964, listed stresses for three grades: "Select", "Standard" and "Selected No. 1 Framing" grades. Selected No. 1 F was the same as No. 1 F for house construction but with added limitations on the occurrence of pith, which is the parenchyma tissue at the centre of the log. However, Select and Standard grades were never described in a Standard so until 1981 we had the odd situation of having stresses for undefined grades, and grades with undefined stresses. In 1981 the grading rules and the timber design code were revised to define "Engineering" and "No. 1 Framing" grades for radiata pine and provide design stresses for them, based on in-grade tests of the timber being produced at that time [3].

2. Changes in Timber Quality

Since the 1980s, the typical age of pine plantations at harvesting has reduced from about 50 years to less than 30, accompanied by pruning and thinning regimes that produced sawlogs of 30 to 60 cm (12 to 24 inch) small end diameter. This change in resource age affects the quality of timber produced and has implications concerning the accuracy of design properties published in design codes and of the data used to describe radiata pine in trade literature. The change in timber quality has to do with the gradient in density and other properties from the pith to the bark that generally occurs in pines. The lower density wood in the 5 to 10 growth rings around the log centre is called juvenile or corewood.

The distinction between corewood and outerwood is somewhat arbitrary as there is a steady gradient in properties from the pith to the bark. Figure 1 shows the typical relationship between wood density and number of rings from the pith in radiata pine for three density categories. Desirable wood properties such as strength and stiffness also increase with increasing distance from the pith while undesirable properties, such as those which cause distortion, decrease.

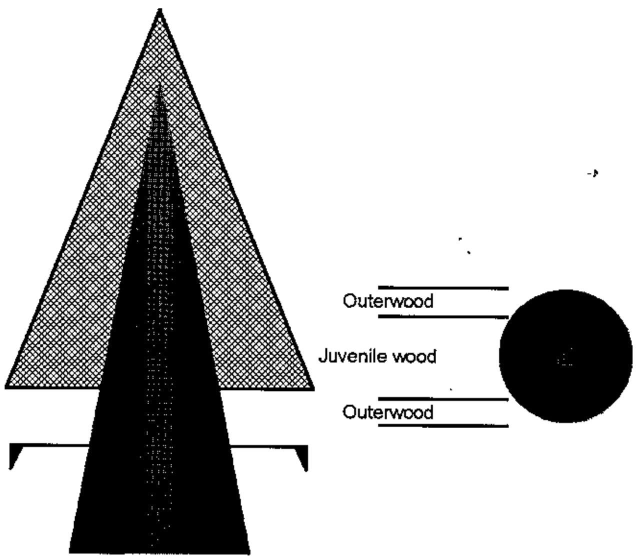
Figure 1. Density variation within radiata trees



The high, medium and low density categories referred to in Figure 1 are geographic regions determined by climate but they will not be discussed in detail as the major source of density variation is within trees, not between them. Corewood exists throughout the tree as shown schematically in Figure 2. The top logs are entirely corewood.

Because of the importance of stiffness in structural lumber, logs are now usually sorted at forest skid sites, using a device that measures the speed of a stress wave through the log. This enables a decision to be made as to whether a log should be sent to a mill producing dimension lumber or to one producing non-structural componentry.

Fig 2. Schematic representation of density distribution within a radiata tree about 25 years old.



3. Industry Concerns

In 2000 design engineers, truss manufacturers and some builders began reporting problems of occasional lack of stiffness in radiata visually graded as No. 1 Framing. One engineer who was designing multistorey, multiresidential units asked "Why can't I get certified timber like I can get certified steel or concrete?" Strength did not appear to be a problem.

A compilation of in-grade data, as shown in Table 1, indicated that while the MoE of No. 1 Framing met the assigned value of 8 GPa on average, there was considerable variation.

Table 1. Summary of in-grade data on No. 1 Framing grade radiata

Grade	Size	No.	Characteristic		Date, source	Reference
			Fb, MPa	E, GPa		
2F	4x2	211	10.6	7.7	1988, Kaingaroa, Chilean study	Walford
	8x2	269	13.1	9.0	1988, Kaingaroa, Chilean study	Walford
1F	4x2	69	14.1	7.9	1978, Kaingaroa, biased	PTEC'84
		178	20.6	9.8	1978, Auckland, biased	PTEC'84
		63	18.8	8.6	1978, Nelson, biased	PTEC'84
		82	16.4	10.4	1979, FCF for UK approval	PTEC'84
		306	16.2	7.6	1981, 24 yr-old, Kaingaroa	PTEC'84
		55	17.9	9.5	1979, FCF for UK approval	PTEC'84
		150	15.2	7.8	1985, 28 yr-old, Kaingaroa	Bier. NZJFSc
		276	17.6	9.6	1988, Kaingaroa, Chilean study	Walford
		29	-	6.3	1990, South Is, Pryda study	Lapish/Hunt
		30	-	5.0	1990, North Is, Pryda study	Lapish/Hunt
		11	32.9	8.8	2001, North NI mill	Gaunt
		5	-	9.4	2001, Central NI mill	Gaunt
		11	9.2	8.0	2001, South NI mill	Gaunt
		7	-	8.1	2001, North SI mill	Gaunt
		12	9.8	10.5	2001, Central SI mill	Gaunt
		12	22.2	9.4	2001, South SI mill	Gaunt
		58	18.3	9.4	2001, six mills combined	Gaunt
			15.1	6.2	2001, Fertile site 1	Gaunt
			22.6	8.1	2001, Fertile site 2	Gaunt
	6x2	32	28.3	8.5	1956, Kaingaroa, to 4063	PTEC'84
		62	13.1	7.1	1979, FCF for UK approval	PTEC'84
	8x2	53	30.1	9.7	1956, Kaingaroa, to 4063	PTEC'84
		83	9.3	7.3	1978, Kaingaroa, biased	PTEC'84
		148	11.5	8.5	1978, Auckland, biased	PTEC'84
		30	9.9	7.7	1978, Nelson, biased	PTEC'84
		110	14.3	7.6	1981, 24 yr-old, Kaingaroa	PTEC'84
		34	10.5	7.2	1985, 28 yr-old, Kaingaroa	Bier. NZJFSc
		140	16.7	10.2	1988, Kaingaroa, Chilean study	Walford
	10x2	41	31.5	10.1	1956, Kaingaroa, to 4063	PTEC'84
	4x4	19	26.5	9.9	1999, Whangarei	Walford

The resolution reached through a process of deliberation by standards committees was to establish a new set of lumber grades and stresses, and set up a system of property verification that was to be applied regardless of the method of grading.

4. Derivation of the New Grades and Stresses

A system of three MGP grades (MGP10, 12 and 15) had been in place in Australia since 1994. MGP stands for "Machine Graded Pine" and the numeral refers to the design MoE for that grade. This system was set up following an intensive Australia-wide in-grade study of the structural properties of softwoods grown there [4]. The Australian resource produces very little timber below MGP10, while the NZ resource produces very little timber above MGP10. Figure 3 compares the MSG grades with the in-grade bending strength and stiffness of 90x45 mm ungraded lumber from 28-year-old trees from Kaingaroa forest which is New Zealand's largest plantation. Forest Research proposed two new grades with E = 8 and E = 6 to cover the New Zealand resource. These were created by simple extrapolation from the three established grades. The grades were renamed MSG for machine graded and VSG for visually graded with the characteristic stresses listed in Table 2.

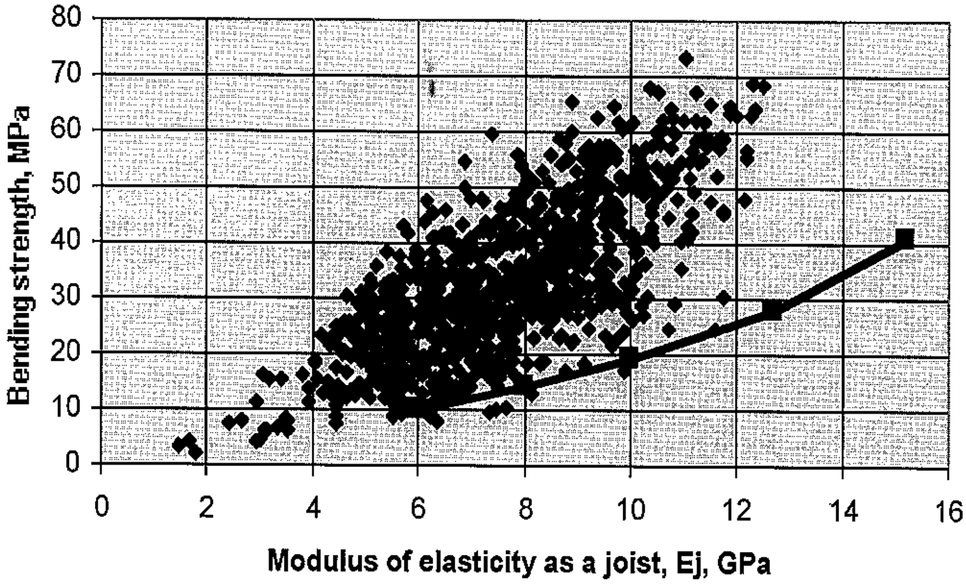


Fig 3. Distribution of radiata bending properties compared to MSG grades

Table 2. Characteristic stresses assigned to MSG and VSG grades of radiata.

	Grade	Bending strength	Compr. strength	Tension strength	Shear strength	Bearing strength	Modulus of elasticity
		Fb, MPa	*Fc, MPa*	*Ft, MPa*	*Fs, MPa*	*Fp,MPa*	*E, GPa*
Dry, machine	MSG15	41.0	35.0	23.0	3.8	8.9	15.2
graded	MSG12	28.0	25.0	14.0	3.8	8.9	12.0
	MSG10	20.0	20.0	8.0	3.8	8.9	10.0
	MSG8	14.0	18.0	6.0	3.8	8.9	8.0
	MSG6	10.0	16.0	4.0	3.8	8.9	6.0
Dry, visually	VSG10	20.0	20.0	8.0	3.8	8.9	10.0
graded	VSG8	14.0	18.0	6.0	3.8	8.9	8.0
Green, visually	VSG10	15.0	14.0	5.0	2.4	5.3	8.0
graded	VSG8	11.7	12.0	4.0	2.4	5.3	6.5

5. Verification

The system defined in NZS 3622 [5] calls for lumber that is continuously monitored to be sampled at a rate of one board in every 1000 produced. These specimens are to be tested in bending according to AS/NZS 4063 [6]. The requirements are that:

a) The mean modulus of elasticity, E_{mean}, of the last 30 specimens tested shall be greater than or equal to E_{target}, i.e. $E_{mean} > E_{target}$

And

the fifth percentile modulus of elasticity of the last 30 specimens shall comply with: where $E_{0.05, sample} > 0.67 E_{target}$ where $E_{0.05, sample}$ is taken as the minimum modulus of elasticity of the last 30 specimens

b) Either:

the fifth percentile bending strength of the last 30 specimens, $f_{0.05, sample}$ shall be greater than or equal to f_{target} where $f_{0.05, sample}$ is taken as the minimum bending strength of the last 30 specimens tested.

Or

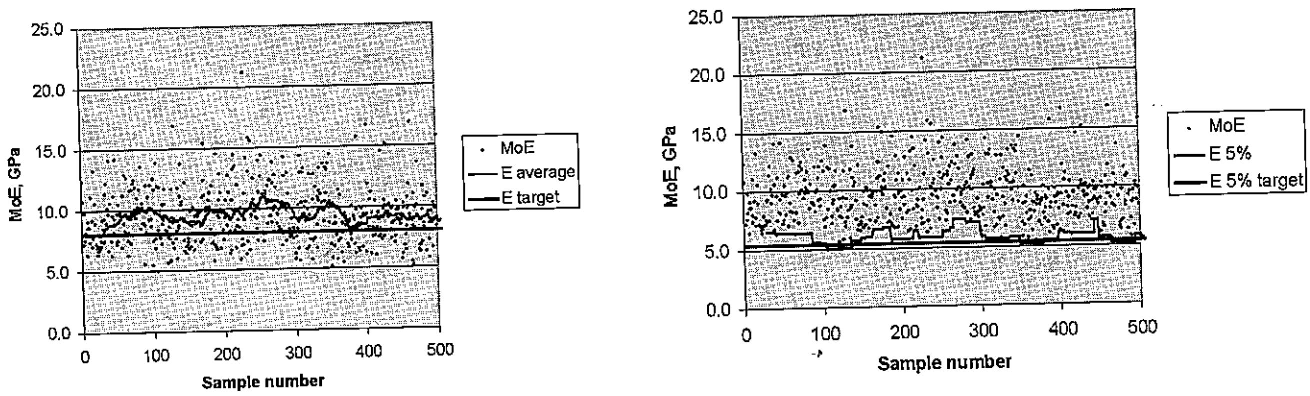
if the pieces sampled are proof tested to no more than their characteristic strength, then none shall fail at less than 90% of the characteristic bending strength.

6. Example of In-mill Application

6.1 Machine grading

A mill using a Metriguard CLT machine to grade dimension lumber to MSG8 and MSG12 grades, has opted to sample at a rate of 1 in 500 boards, to test 1 in 10 of these specimens to failure, with the rest being proof tested to the characteristic bending stress for one grade above the particular grade.

Figure 4a. shows records for the control of average MoE for 90x45 mm MSG8 grade lumber. Over the period shown, March 2006, the rolling average of 30 specimens ranged from 8.1 to 10.9 GPa, with an overall average of 9.4 GPa. This indicates that the machine settings are conservative for average MoE which has a target characteristic value of 8 GPa.



Figures 4a and 4b. Control charts for average and lower 5 percentile MoE.

Figure 4b. shows control of the lower 5 percentile MoE over the same period. This shows that the 5 percentile value dipped below the target of 5.4 GPa on three occasions, by 6, 2 and 2% respectively. This indicates that the machine settings are about right for 5 percentile MoE.

Figure 5. shows control of the lower 5 percentile strength over the same period. This shows that bending strength dropped below the target of 14 MPa on two occasions. Data from the 51 specimens loaded to failure show a mean of 37 MPa, a coefficient of variation of 47% and a lower 5 percentile of 14.1 MPa. This indicates that the machine settings are about right for strength.

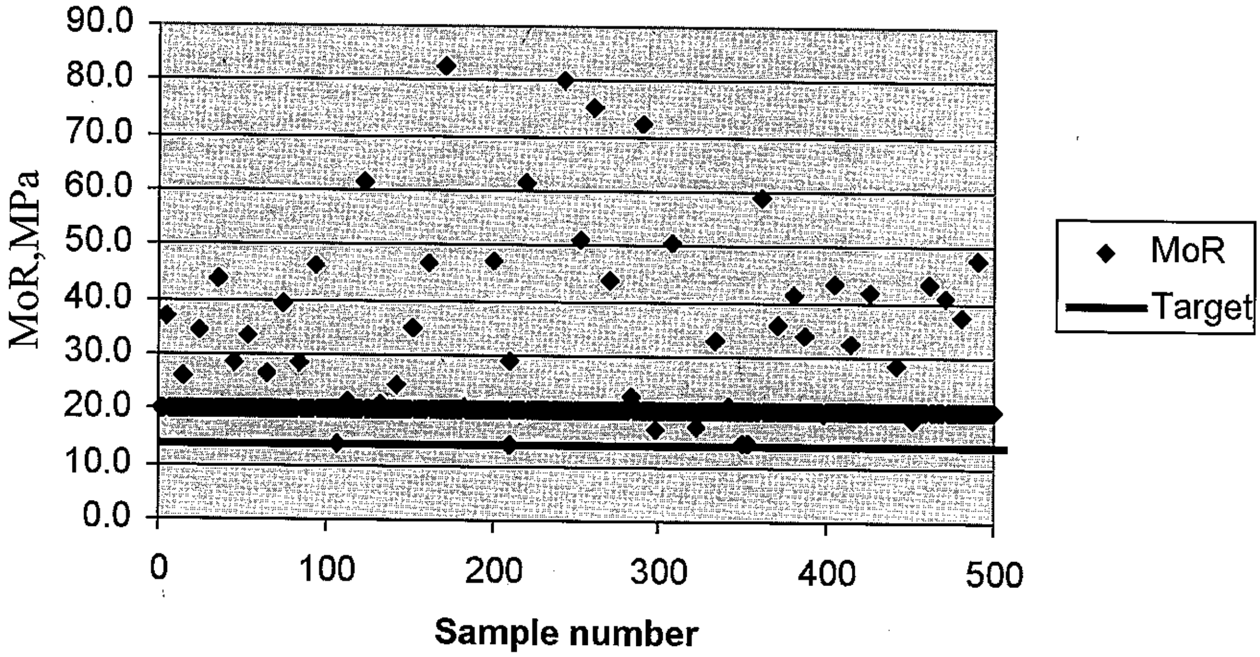


Figure 5. Control chart for lower 5 percentile bending strength of machine graded lumber.

6.2 Hybrid Machine/visual grading

One mill uses an acoustic A-grader machine to sort dimension lumber to MSG 6, 8, 10 and 12 grades. The A-grader measures the average MoE along the entire length of each piece. This is followed by a visual grading to in-mill rules appropriate to the target strength. Sampling is done hourly which is a rate of 1 in 700 to 800 boards. The sampled specimens are proof tested to the characteristic bending stress for one grade above the particular grade. Figure 6. shows the control chart for 90x45 mm MSG8 grade lumber.•

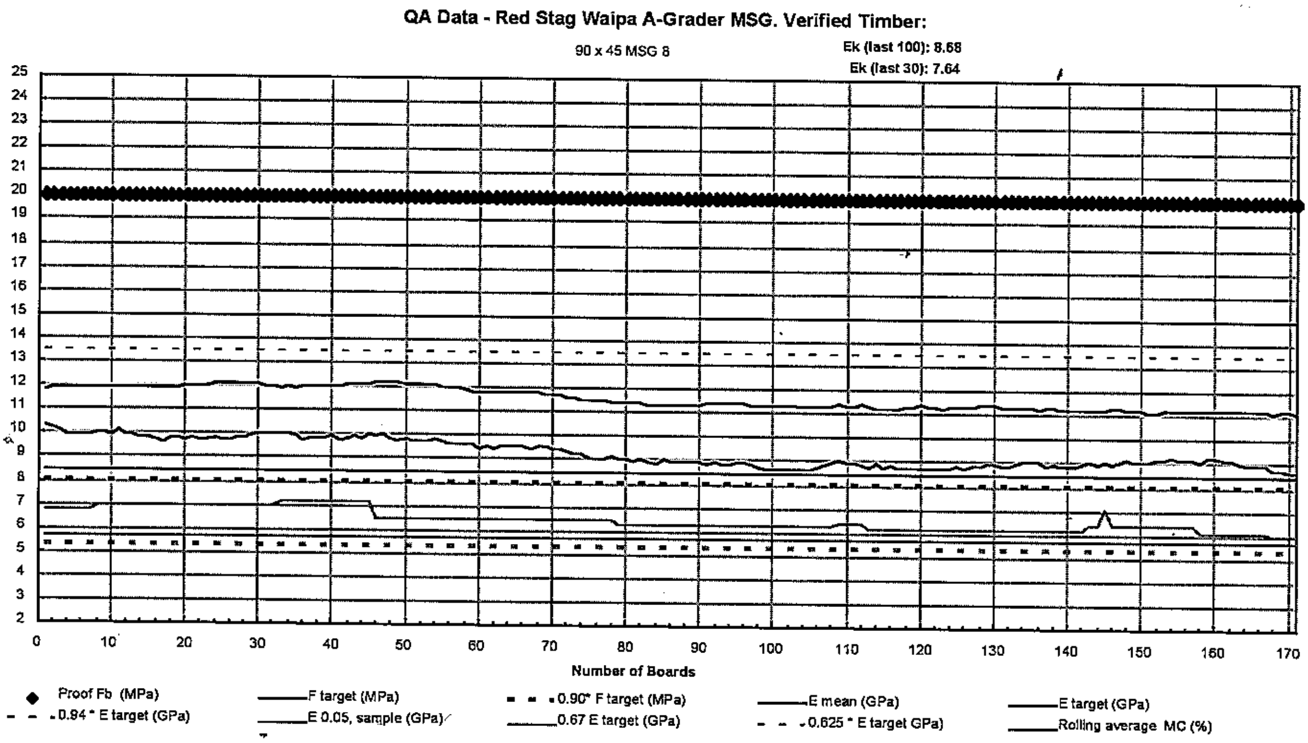


Figure 6. Control chart for hybrid visual/acoustic graded lumber

Over the period shown, 21 March to 1 May 2006, the rolling average of 30 specimens ranged from 8.6 to 10.3 GPa, with an overall average of 9.36 GPa. This indicates that the machine settings are conservative for average MoE since the characteristic target value is 8 GPa.

The lower 5 percentile MoE over the same period ranged from 6.0 to 7.2 GPa and did not fall below the target of 5.7 GPa. This indicates that the machine settings are conservative for 5 percentile MoE.

No specimens failed the proof load of 20 MPa so the lower 5 percentile bending strength was well above the target of 15 MPa. This indicates that the visual grading is conservative for strength.

6.3 Visual grading

Several mills use visual grading only to grade dimension lumber to VSG8 and VSG10 grades. They sample at a rate of 1 in 1000 boards. Figure 7 shows the control chart for 153 tests on 90x45 mm VSG8 grade lumber.

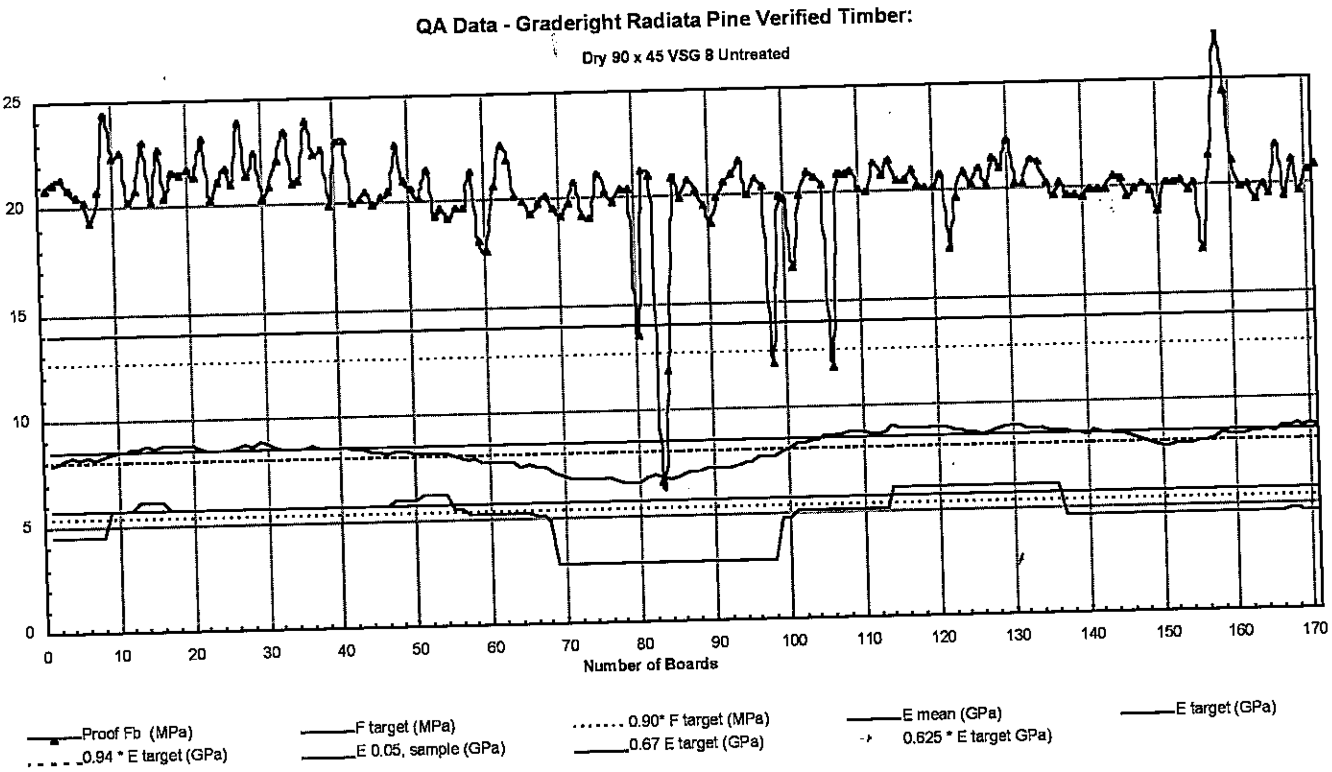


Figure 7. Control chart from a visual grading operation

Over the period shown, the rolling average MoE of 30 specimens ranged from 6.01 to 8.96 GPa, with an overall average of 8.17 GPa. This indicates that visual grading is giving the correct average MoE but the variation is large.

The 5 percentile MoE value was below the target of 5.7 GPa more than half the time, by up to 50%. This indicates that visual grading cannot control the 5 percentile MoE.

Bending strength dropped below the target of 14 MPa on four occasions. Data from the 200 specimens loaded to failure show a mean of 20.5 MPa, a coefficient of variation of 11% and a lower 5 percentile of 17.9 MPa. This indicates that visual grading is effective for strength but there are still some “rogue” pieces of low strength.

Because New Zealand Standards now force lumber producers to actually measure the properties of their lumber, they are slowly recognizing the inadequacies of visual grading and are installing some type of stiffness-measuring device.

7. Conclusions

- New Zealand has a long tradition of house construction by the 2x4 system.
- The 2x4 system has considerable inherent load sharing so that the stiffness of timber is usually critical, rather than strength.
- Plantation-grown radiata pine has become the principal building timber in New Zealand, replacing the once-abundant supplies of indigenous timbers.
- Forest management regimes have emphasized fast growth and log shape to the detriment of inherent wood stiffness in radiata pine.
- Stress wave devices are used to sort logs at forest skid sites.
- Changes to timber grading standards have been made to reduce variability in the structural properties of radiata dimension lumber.
- The changes are a system of stress grades and property verification for dimension lumber that is applied regardless of the method of grading.
- The verification records show that visual grading will control strength but not stiffness.
- New Zealand lumber producers are slowly coming to realize that they need to use some form of machine grading.

8. References

[1 Anon, 1962. Classification and grading of New Zealand building timber (National grading rules). NZSS 169:1962. New Zealand Standards Institute, Wellington.

[2] Anon, 1964. New Zealand Standard Model Building Bylaw, Chapter 9, Design and Construction, Division 9.1, Timber. NZSS 1900 Chapter 9.1:1964. New Zealand Standards Institute, Wellington.

[3] Walford G.B. 1979. Basic working stresses for radiata pine derived from in-grade bending tests. Timber Engineering Report No. 28, Forest Products Division, Forest Research Institute, Rotorua, New Zealand.

[4] Bolden S, Leicester R H, Young, F, and Seath, C, 1994. In-grade evaluation of Australia pine. Proc. of the Pacific Timber Engineering Conference, Australia, Vol. 2, pp716-724

[5] Anon. 2004. Verification of timber properties. NZS 3622:2004. Standards New Zealand, Wellington.
Calendar of Events 2006/07