COMPARISON OF VARIOUS STANDARDS FOR THE CHARACTERISTIC STRENGTH AND STIFFNESS OF STRUCTURAL TIMBER

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SUMMARY

Comparing published design stresses for radiata pine with those for both visual and machine grades from Australia USA, UK and ISO, in the nominal 150x50 mm dimension, it was found that:

- Radiata pine has a relatively high assigned strength compared to other visual grades.
- For US visual grades radiata pine No. 1 Framing is closest to the Ponderosa #1 grade, Redwood #2 grade and Douglas fir – south #1 grade.
- For US machine stress rated (MSR) timbers, No. 1 Framing radiata equates closest to 1200/1.2 grade while Engineering grade radiata equates closest to 1950/1.5 grade.
- The MGP system tracks very closely with the ISO system for softwoods, with MGP8 grade equating to the ISO S14 grade.
- The Australian F-grade system clearly does not suit softwoods.
- No. 1 Framing radiata is closest to C16 grade in the EN 338 (Eurocode) system.

INTRODUCTION

The stresses assigned to grades of structural timber can have an important influence of their international competitiveness. The assigned stresses must represent their properties as accurately as possible yet some form of grouping is necessary, simply to make their use in design manageable. There are well-established strength grouping systems in use in Australia and the UK. There are strength class systems set up under ISO standards and Eurocodes. There are sets of stresses assigned to species/grade combinations in use in USA/Canada and in spite of efforts to rationalise these into a strength grouping system, the industry there has resisted all efforts, probably due to the belief it would lose them a market niche, or there would be legal liability issues to face if they changed anything. There are also the effects of grading method – machine grading sorts for stiffness very effectively while visual grading is usually more efficient at sorting for strength. This means that machine-graded timber will generally have a higher stiffness for a given strength than will visually graded timber of the same species. In practice, it is the stiffness property (Modulus of Elasticity or MoE or Young's Modulus), that is limiting in the design of most timber structures for everyday use. Hence machine grading is the more relevant grading method. Data from published design standards have been converted to the same basis and are compared. Because of the size effects on timber stresses, particularly for visually graded timber, the ISO standard of nominal 150x50 mm size has been used.

As a species group, Japanese standards consider radiata pine to be equivalent to the WWPA Spruce-Pine-Fir (SPF) group. For machining and general non-structural uses, radiata pine has been considered to be equivalent to Ponderosa pine.

DATA

Sources of data are:

- New Zealand Standard 3603:1993. This lists characteristic stresses for visually graded radiata pine in Engineering and No. 1 Framing graded to NZS 3631.
- National Design Specification for Wood Construction: 1997, American Forest and Paper Association. This lists allowable design stresses (psi, normal load duration) for visually graded lumber of species groups within the USA. Within each group up to 30 grade/size combinations are listed.
- British Standard BS 5268:Part 2: 1984, "Structural Use of Timber". This lists grade stresses (i.e. long term load duration) for a set of strength classes and for various species/grade combinations, both machine and visually graded.
- ISO TC 165 working document N269, "Structural timber – structural classes". This lists a set of 14 strength classes for softwoods and 7 for hardwoods.
- Australian standard AS 1720.1-1997. This lists F-grades which are for either visually or machine graded timber,

and MGP grades which are for machine graded pines only. The two MGP grades (MGP6 and MGP*) proposed by Forest Research are added.

- South African Standard SABS 0162-2:1994 lists stresses for South African Pine grades 5, 7 10 and 14.

Some conversion factors have been applied to bring the data to a common basis which is that of the NZ and Australian data, i.e. MoE is the mean value and bending strength is the lower 5 percentile value determined with 75% confidence. To convert from allowable stress to limit state design, the strength values in the case of the US data have been divided by factor used in their derivation according to ASTM D 2915, (bending or tensile strength 0.475, compressive strength parallel to grain 0.526, shear strength 0.244, compressive strength perpendicular to the grain 0.667). In the case of the UK data the values from Eurocode EN338 were used. For US visual grades a size factor of 1.3 has been applied to the bending stress. The conversion psi to MPa is 1 MPa = 145 psi. Table 1 lists the data from these sources and used for comparison.

DISCUSSION

The UK and ISO strength class systems are not specific as to whether they refer to visually-graded or to machine-graded timber. The Australian F-grade system was initially developed for visually graded hardwoods and was used for all timbers until the MGP system was introduced. Figure 1 compares visually graded radiata and MGP radiata with the US visual grades.

Figure 1 shows:

- Radiata pine has a relatively high strength compared to the others.
- Douglas fir – larch has a high stiffness for its strength.
- Southern pine has exceptionally high strength and stiffness in the top grades.
- The timbers closest to No. 1 Framing radiata are Redwood No. 2 grade Ponderosa No. 1 grade, and Douglas fir – south No. 1 grade.

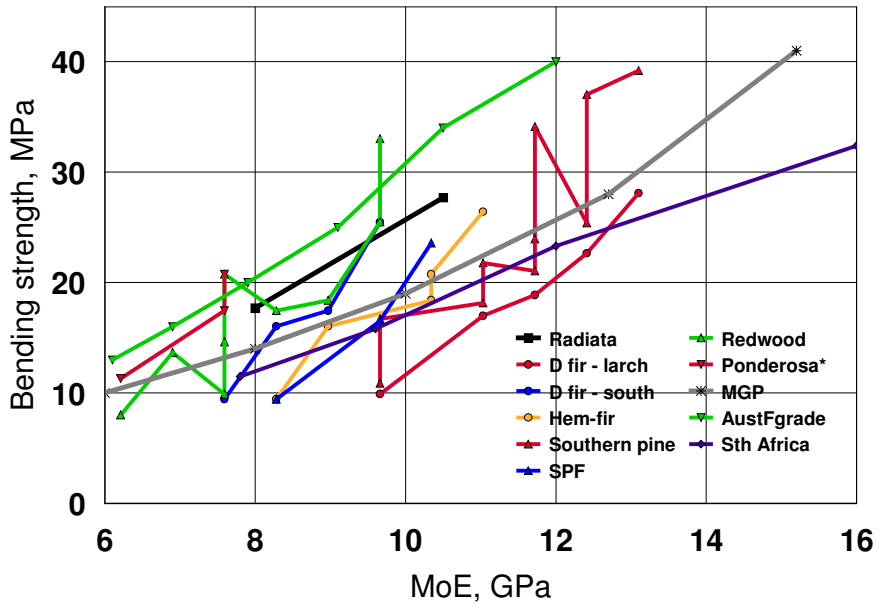

Figure 1. Comparison of visually graded radiata and MGP grades with other visually graded timbers.

Figure 2 compares visually graded radiata and MGP with the stresses assigned to the US machine stress rated (MSR) series.

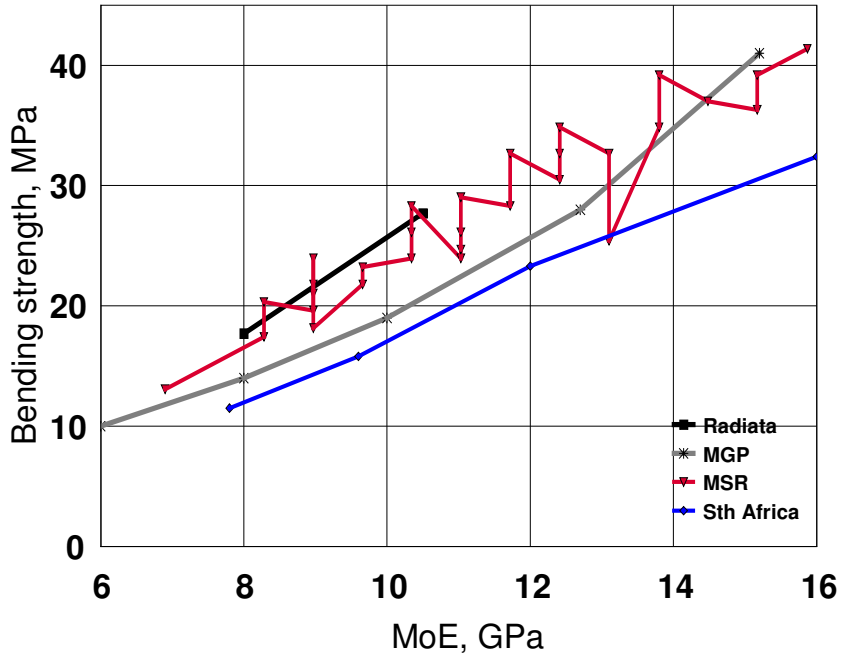

Figure 2. Comparison of radiata pine with the US machine rating system.

Figure 2 shows:

- The MGP system tracks the MSR series reasonably closely but with lower strengths for the same stiffnesses.
- No. 1 Framing radiata equates closest to MSR 1200/1.2. grade..
- Engineering grade radiata equates closest to MSR 1950/1.5 grade.

Figure 3. compares visually graded radiata and the MGP system with the various strength grade systems.

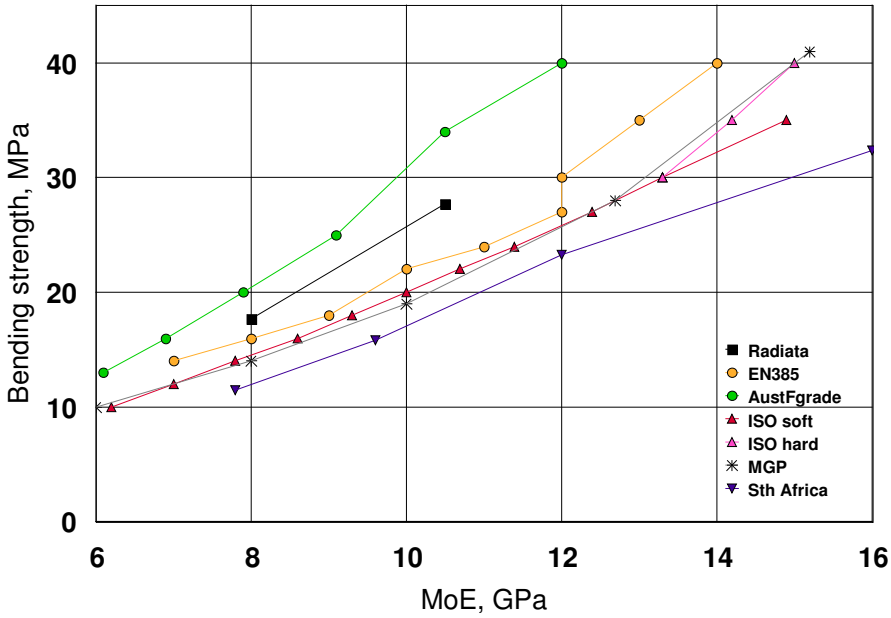

Figure 3. Comparison of radiata pine with various strength class systems.

Figure 3 shows that:

- The Australian F-grade system has a much higher strength-for-stiffness ratio than all the others. This will be due to the fact that it is based on hardwood data.
- The MGP system tracks very closely with the ISO system.
- No. 1 Framing radiata is closest to C16 in the EN 338 system.

Table 1. List of characteristic stresses for various softwoods.

								Factor		
Species	**Grade**	**MoE**	**5%ile MoR**	**Comp. parl.**	**Tension parl.**	**Shear in beams**	**Compr. perp.**	**ASD/ LSD**	**size Fb**	**metric/ imperial**
		GPa	**MPa**	**MPa**	**MPa**	**MPa**	**MPa**			
Radiata	# 1F	8.00	17.7	20.9	10.6	3.8	8.9			
Radiata	Eng	10.50	27.7	25.7	16.5	3.8	8.9			
D fir - larch	SS	13.10	28.10	24.52	18.87	2.69	6.46	0.475	1.3	1/145
D fir - larch	#1+	12.41	22.65	22.35	15.1	2.69	6.46	0.475	1.3	1/145
D fir - larch	#1	11.72	18.87	21.63	12.74	2.69	6.46	0.475	1.3	1/145
D fir - larch	#2	11.03	16.99	19.47	10.85	2.69	6.46	0.475	1.3	1/145
D fir - larch	#3	9.66	9.91	11.18	6.13	2.69	6.46	0.475	1.3	1/145
D fir - south	SS	9.66	25.48	23.08	19.99	2.54	5.37	0.475	1.3	1/145
D fir - south	#1	8.97	17.46	20.91	11.32	2.54	5.37	0.475	1.3	1/145
D fir - south	#2	8.28	16.04	19.47	9.91	2.54	5.37	0.475	1.3	1/145
D fir - south	#3	7.59	9.44	11.18	5.66	2.54	5.37	0.475	1.3	1/145
Hem-fir	SS	11.03	26.42	21.63	17.45	2.11	4.19	0.475	1.3	1/145
Hem-fir	#1+	10.34	20.76	19.47	13.68	2.11	4.19	0.475	1.3	1/145
Hem-fir	#1	10.34	18.40	19.47	11.8	2.11	4.19	0.475	1.3	1/145
Hem-fir	#2	8.97	16.04	18.75	9.91	2.11	4.19	0.475	1.3	1/145
Hem-fir	#3	8.28	9.44	10.46	5.66	2.11	4.19	0.475	1.3	1/145
So. pine	HD SS	13.10	39.20	28.19	28.24	2.54	6.82	0.475		1/145
So. pine	SS	12.41	37.02	26.22	26.36	2.54	5.84	0.475		1/145
So. pine	HD #1	12.41	25.41	24.91	22.6	2.54	6.82	0.475		1/145
So. pine	LD SS	11.72	34.12	24.26	17.89	2.54	4.96	0.475		1/145
So. pine	#1	11.72	23.96	22.94	16.94	2.54	5.84	0.475		1/145
So. pine	HD #2	11.72	21.05	22.94	15.06	2.54	6.82	0.475		1/145
So. pine	LD #1	11.03	21.78	20.98	14.59	2.54	4.96	0.475		1/145
So. pine	#2	11.03	18.15	20.98	13.65	2.54	5.84	0.475		1/145
So. pine	LD #2	9.66	16.70	19.67	12.71	2.54	4.96	0.475		1/145
So. pine	#3	9.66	10.89	12.13	8	2.54	5.84	0.475		1/145
SPF	SS	10.34	23.59	20.19	13.21	1.98	4.39	0.475	1.3	1/145
SPF	# 1&2	9.66	16.52	16.59	8.49	1.98	4.39	0.475	1.3	1/145
SPF	#3	8.28	9.44	9.37	4.72	1.98	4.39	0.475	1.3	1/145
Redwood	Clear	9.66	33.03	26.68	18.87	4.1	6.72	0.475	1.3	1/145
Redwood	SS	9.66	25.48	14.42	15.1	2.26	6.72	0.475	1.3	1/145
Redwood	#1	8.97	18.40	17.31	10.85	2.26	6.72	0.475	1.3	1/145
Redwood	#2	8.28	17.46	13.7	9.91	2.26	6.72	0.475	1.3	1/145
Redwood	SS fast	7.59	20.76	15.86	11.8	2.26	4.39	0.475	1.3	1/145
Redwood	#1 fast	7.59	14.63	12.98	8.49	2.26	4.39	0.475	1.3	1/145
Redwood	#3	7.59	9.91	7.93	5.66	2.26	6.72	0.475	1.3	1/145
Redwood	#2 fast	6.90	13.68	10.1	8.02	2.26	4.39	0.475	1.3	1/145
Redwood	#3 fast	6.21	8.02	5.77	4.72	2.26	4.39	0.475	1.3	1/145
Ponderosa*	SS	7.59	20.76	10.82	13.68	1.84	5.53	0.475	1.3	1/145
Ponderosa*	#1	7.59	17.46	9.01	9.44	1.84	5.53	0.475	1.3	1/145
Ponderosa*	#2	6.21	11.32	5.77	5.66	1.84	5.53	0.475	1.3	1/145

Table 1 (cont). List of characteristic stresses for various softwoods.

								Factor		
Species	**Grade**	**MoE**	**5%ile MoR**	**Comp. parl.**	**Tension parl.**	**Shear in beams**	**Compr. perp.**	**ASD/ LSD**	**size Fb**	**metric/ imperial**
		GPa	**MPa**	**MPa**	**MPa**	**MPa**	**MPa**			
MSR	900/1.0	6.90	13.07	13.77	5.08			0.475	1	1/145
MSR	1200/1.2	8.28	17.42	18.36	8.71			0.475	1	1/145
MSR	1400/1.2	8.28	20.33	20.98	11.62			0.475	1	1/145
MSR	1350/1.3	8.97	19.60	20.98	10.89	same	same	0.475	1	1/145
MSR	1450/1.3	8.97	21.05	21.31	11.62			0.475	1	1/145
MSR	1500/1.3	8.97	21.78	21.63	13.07	as	as	0.475	1	1/145
MSR	1650/1.3	8.97	23.96	22.29	14.81			0.475	1	1/145
MSR	1250/1.4	8.97	18.15	19.34	11.62	those	those	0.475	1	1/145
MSR	1500/1.4	9.66	21.78	21.63	13.07			0.475	1	1/145
MSR	1600/1.4	9.66	23.23	21.96	13.79	for	for	0.475	1	1/145
MSR	1650/1.5	10.34	23.96	22.29	14.81			0.475	1	1/145
MSR	1800/1.5	10.34	26.13	22.94	18.87	#2	#2	0.475	1	1/145
MSR	1950/1.5	10.34	28.31	23.6	19.96			0.475	1	1/145
MSR	1650/1.6	11.03	23.96	22.29	17.06	visual	visual	0.475	1	1/145
MSR	1700/1.6	11.03	24.68	22.62	17.06			0.475	1	1/145
MSR	1800/1.6	11.03	26.13	22.94	17.06	grade	grade	0.475	1	1/145
MSR	2000/1.6	11.03	29.04	23.93	18.87			0.475	1	1/145
MSR	1950/1.7	11.72	28.31	23.6	19.96	timber	timber	0.475	1	1/145
MSR	2250/1.7	11.72	32.67	25.24	25.41			0.475	1	1/145
MSR	2100/1.8	12.41	30.49	24.58	22.87	of	of	0.475	1	1/145
MSR	2250/1.8	12.41	32.67	25.24	25.41			0.475	1	1/145
MSR	2400/1.8	12.41	34.85	25.89	27.95	the	the	0.475	1	1/145
MSR	2250/1.9	13.10	32.67	25.24	25.41			0.475	1	1/145
MSR	1750/2.0	13.10	25.41	22.62	16.33	spp	spp	0.475	1	1/145
MSR	2400/2.0	13.80	34.85	25.89	27.95			0.475	1	1/145
MSR	2700/2.0	13.80	39.20	27.53	26.13			0.475	1	1/145
MSR	2550/2.1	14.48	37.02	29.5	29.76			0.475	1	1/145
MSR	2500/2.2	15.17	36.30	26.22	25.41			0.475	1	1/145
MSR	2700/2.2	15.17	39.20	27.53	31.22			0.475	1	1/145
MSR	2850/2.3	15.87	41.38	28.19	33.39			0.475	1	1/145
MSR	3000/2.4	16.55	43.56	28.84	34.85			0.475	1	1/145
EN338	C14	7	14	4.3	8	1.7	4.3			
EN335	C16	8	16	4.6	10	1.8	4.6			
EN338	C18	9	18	4.8	11	2.0	4.8			
EN338	C22	10	22	5.1	13	2.4	5.1			
EN338	C24	11	24	5.3	14	2.5	5.3			
EN338	C27	12	27	5.6	16	2.8	5.6			
EN338	C30	12	30	5.7	18	3.0	5.7			
EN338	C35	13	35	6.0	21	3.4	6.0			
EN338	C40	14	40	6.3	24	3.8	6.3			
Aust Fgrade	F4	6.10	13	9.7	6.5	1.5	7.7			
Aust Fgrade	F5	6.90	16	12	8.2	1.8	7.7			
Aust Fgrade	F7	7.90	20	15	10	2.1	9.7			
Aust Fgrade	F8	9.10	25	20	13	2.5	9.7			
Aust Fgrade	F11	10.50	34	25	17	3.1	12			
Aust Fgrade	F14	12.00	40	30	21	3.7	12			

Table 1 (cont). List of characteristic stresses for various softwoods.

								Factor		
Species	**Grade**	**MoE**	**5%ile MoR**	**Comp. parl.**	**Tension parl.**	**Shear in beams**	**Compr. perp.**	**ASD/ LSD**	**size Fb**	**metric/ imperial**
		GPa	**MPa**	**MPa**	**MPa**	**MPa**	**MPa**			
ISO soft	S10	6.20	10	18	6	2.7	5			
ISO soft	S12	7.00	12	19	7	3	5.2			
ISO soft	S14	7.80	14	20	8	3.4	5.4			
ISO soft	S16	8.60	16	20	10	3.7	5.5			
ISO soft	S18	9.30	18	21	11	4	5.7			
ISO soft	S20	10.00	20	22	12	4.4	5.9			
ISO soft	S22	10.70	22	23	13	4.7	6.1			
ISO soft	S24	11.40	24	24	14	5	6.3			
ISO soft	S27	12.40	27	26	16	5.5	6.5			
ISO soft	S30	13.30	30	27	18	6	6.8			
ISO soft	S35	14.90	35	30	21	6.8	7.3			
ISO soft	S40	16.30	40	32	24	7.6	7.7			
ISO soft	S45	17.70	45	34	27	8.5	8.2			
ISO soft	S50	19.10	50	37	30	9.3	8.6			
ISO hard	H30	13.30	30	24	18	4.5	8.6			
ISO hard	H35	14.20	35	28	21	4.7	9.6			
ISO hard	H40	15.00	40	32	24	4.8	10.6			
ISO hard	H50	16.70	50	40	30	5.1	12.5			
ISO hard	H60	18.40	60	48	36	5.4	14.5			
ISO hard	H70	20.10	70	56	42	5.7	16.4			
ISO hard	H80	21.80	80	64	48	6.1	18.4			
MGP	6	6.00	10	16	4	2.5	8.9			
MGP	8	8.00	14	20	6.3	4	8.9			
MGP	10	10.00	19	24	8.9	5	12			
MGP	12	12.70	28	29	15	6.5	12			
MGP	15	15.20	41	35	23	9.1	12			
Sth African	5	11.50	7.80	16.4	6.7	1.6	4.7			
Sth African	7	15.80	9.60	20.7	10.0	5.0	6.7			
Sth African	10	23.30	12.00	23.8	13.3	2.9	9.1			
Sth African	14	32.40	16.00	23.1	19.1	4.0	12.9			

* Ponderosa only in 5” x 5” and larger sizes