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PROCESSING

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Revaluation of Structural Properties of Machine Stress Graded Plywoods

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Revaluation of Structural Properties of Machine Stress Graded Plywoods

Prepared for

Forest & Wood Products Australia

by

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Executive Summary

The aim of this project was to relate the strength and stiffness properties of current softwood/hardwood plywood resources from both Australian and New Zealand against the existing published plywood stress grades.
The primary goals for this project were based around the following;

- The plywood standard AS/NZS2269.0:2008 and the timber design standard AS1720. 1:2010 list different grade stresses for the same plywood grades and the designers of plywood structures can choose either standard for the basis of their structural designs. Which set of grade stresses are the most appropriate and should there be any grade stress amendments.
- The plywood standard AS/NZS2269.0:2008 lists three techniques for determination of plywood stress grades, two of which were not in existence when the original plywood strength properties were developed. Thus are the existing plywood grades and strength/stiffness properties still relevant and applicable to the machine stress grading (MSG) approach to grading of plywood for todays softwood and hardwood resource?

Key Recommendations

- The Australian designers of plywood structures should use the characteristic values from AS1720.1:2010.
- The characteristic plywood stresses in AS/NZS2269.0:2008 should either by amended to reflect those in AS1720.1:2010 or deleted leaving AS1720.1:2010 as the only source.
- The planned revision of NZS3603:1993 should be aligned with the AS/NZS4063 series in which normalisation has been discontinued. NZS3603 should also adopt the appropriate plywood grades and characteristic stresses from AS1720.1:2010.
- Consideration should be given to the introduction of lower shear values in AS1720.1:2010 on the proviso that there are no significant impacts on the structural use of plywood and/or the plywood shear test method in AS/NZS2269.1:2008 should be reviewed to improve its ability to produce true shear failures

Impact

With the confirmation of the current grade stresses (apart from shear) in AS 1720.1 it is anticipated that there will be minimal impact on the design use of plywood. Plywood designers should have a renewed confidence in the strength properties of plywood which could reflect in a greater use.

Confirmation that the plywood grade stresses in AS 1720.1:2010 align well with the F8, F11 & F14 plywood resource from both Australia & New Zealand should be of comfort to the plywood producers. This implies that the producers will not have to make significant changes to their plywood production methods.

Disclaimer

The plywood used in this study was selected using a plywood machine stress grader in an effort to understand the effect of machine stress grading plywood on plywood properties. In the report the F rating that has been assigned is that from the machine stress grader, it is not the company branded F ratings. In fact the machine grader sample was made up from a mix of non-structural, downgrade (material with sound bonding), F5, F8 & F11 (company branded) plywood, this was done to maximise the property range within the machine grader sample.

Tables 5 and 6 primarily show the ineffectiveness of machine stress grading plywood. The samples of plywood in Tables 5 & 6 are not representative of company branded product and accordingly the results cannot be interpreted as such.

All the New Zealand plywood used in report was kindly provided from one mill. It is also worth acknowledging that no machine graded softwood plywood is sold in NZ.

The companies producing plywood currently operate under a third party verification scheme and accordingly end users can have confidence that structural plywood will have the properties claimed for it.

Table of Contents

Introduction

The aim of this project was to relate the strength and stiffness properties of current softwood/hardwood plywood resources from both Australian and New Zealand against the existing published plywood stress grades. The current plywood grades in the timber design and plywood standards have been in existence for many years and were originally derived from small, clear sample testing of hardwoods originating from the forest resource of the 1960's or earlier.

The primary goals for this project were based around the following;

- The plywood standard AS/NZS2269.0:2008 and the timber design standard AS1720. 1:2010 list different grade stresses for the same plywood grades and the designers of plywood structures can choose either standard for the basis of their structural designs. Which set of grade stresses are the most appropriate and should there be any grade stress amendments.
- The plywood standard AS/NZS2269.0:2008 lists three techniques for determination of plywood stress grades, two of which were not in existence when the original plywood strength properties were developed. Thus are the existing plywood grades and strength/stiffness properties still relevant and applicable to the machine stress grading (MSG) approach to grading of plywood for todays softwood and hardwood resource?

This project has tested of eight batches of machine graded plywood made up of a mix of Australian produced softwood and hardwood plywood along with New Zealand produced softwood plywood. The plywood F-grades selected for testing are estimated to cover 80-85% of F-grades sold in Australia and 100% of New Zealand..

Methodology

Plywood Sampling

The plywood for this project was selected in conjunction with advice from the EWPAA as follows in Tables 1 & 2.

The plywood was supplied in kind by many of the plywood mills and it was not the intention of this project to evaluate the ability of the individual plywood mills to achieve the grade characteristic properties. Accordingly no reference will be made to the original suppliers of the plywood other than referencing by country, species and machine stress grade. Each batch represents one mill.
The plywood for batches 1, 2, 3, 4, 5, 6 & 8 was selected under the guidance of the EWPAA using the mills plywood machine stress grader. Essentially over the period of one/two days plywood of various grades was taken from stock and passed through the machine stress grader until the required machine rated target grades/thicknesses had been selected.

Table 1: *Plywood sheets received and tested by Scion*

Plywood	**NZ Radiata F11 (Batch 1)**	**NZ Radiata F8 (Batch 2)**	**Australian Radiata F8 (Batch 3)**	**Australian Radiata F11 (Batch 4)**
Number of 12mm sheets			12	12
Number of 15mm sheets	21	17	12	12
Number of 17mm sheets	14	18	10	12
Total Number of sheets to be tested	**35**	**35**	**34**	**36**
Received and tested by	**Scion**	**Scion**	**Scion**	**Scion**

Table 2: *Plywood sheets received and tested by DEEDI*

Plywood	**Australian Slash F11 (Batch 5)**	**Australian Slash F14 (Batch 6)**	**Australian Plantation Hardwood (Batch 7)**	**Australian Hardwood F34 (Batch 8)**
Number of 12mm sheets	18	12		
Number of 15mm sheets	6	12	32/48*	35
Number of 17mm sheets	11	11		
Total Number of sheets to be tested	**35**	**35**	**32/48***	**35**
Received and tested by	**DEEDI**	**DEEDI**	**DEEDI**	**DEEDI**

* 32 compression & Tension tests, 48 bending & shear tests.

Note: The F-grade is that assigned from the machine stress-grader and is not the grade of the input material.

Mechanical Test Methods

1. All the plywood sheets were machined graded at source with the assistance of the EWPAA. The plywood was then supplied to the testing agency. On arrival the machine grading information was recorded and the plywood sheets cut into the test specimens in accordance with AS/NZS2269.1:2008.
2. The bending strength and stiffness specimens were tested to destruction in accordance with AS/NZS2269.1:2008.

3. The tension strength specimens were tested to destruction in accordance with AS/NZS2269.1:2008.
4. The compression strength specimens were tested to destruction in accordance with AS/NZS2269.1:2008.
5. The shear strength specimens were tested to destruction in accordance with AS/NZS2269.1:2008
6. The strength and stiffness data was analysed in accordance with AS/NZS2269.2:2008 and AS/NZS4063.2:2010 using the parametric, log normal method.

Plywood Section Properties

In order to calculate the final strength and stiffness properties the plywood section properties are needed. Tables 3 and 4 show the values used for this project.

***Table 3**: Plywood Bending Section Properties Used.*

				Parallel to 2.4m panel length (Parallel Direction)		Perpendicular to 2.4m panel length (Perpendicular Direction)	
Batch No:	**Plywood Type:**	**Plywood Thickness**	**Source of Section Property values**	**Section Modulus (Z)** (mm^3/mm)	**Moment of Inertia (I)** (mm^4/mm)	**Section Modulus (Z)** (mm^3/mm)	**Moment of Inertia (I)** (mm^4/mm)
1	5 ply	15mm	Manufacturer	28.7	218.2	14.3	73.8
1	5 ply	17mm	Manufacturer	33.3	281.9	20.2	120.2
2	5 ply	15mm	Manufacturer	28.7	218.2	14.3	73.8
2	5 ply	17mm	Manufacturer	33.3	281.9	20.2	120.2
3	12-24-05	12mm	AS/NZS2269.0:2008	19.0	115.0	8.3	33.0
3	15-30-05	15mm	AS/NZS2269.0:2008	29.5	225.0	13.0	65.0
3	17-24-07	17mm	AS/NZS2269.0:2008	33.5	285.0	19.0	120.0
4	12-24-05	12mm	AS/NZS2269.0:2008	19.0	115.0	8.3	33.0
4	15-30-05	15mm	AS/NZS2269.0:2008	29.5	225.0	13.0	65.0
4	17-24-07	17mm	AS/NZS2269.0:2008	33.5	285.0	19.0	120.0
5	12-24-05	12mm	AS/NZS2269.0:2008	19.0	115.0	8.3	33.0
5	15-30-05	15mm	AS/NZS2269.0:2008	29.5	225.0	13.0	65.0
5	17-24-07	17mm	AS/NZS2269.0:2008	33.5	285.0	19.0	120.0
6	12-24-05	12mm	AS/NZS2269.0:2008	19.0	115.0	8.3	33.0
6	15-30-05	15mm	AS/NZS2269.0:2008	29.5	225.0	13.0	65.0
6	17-24-07	17mm	AS/NZS2269.0:2008	33.5	285.0	19.0	120.0
7	-	15mm	DEEDI values*	Plywood manufactured as part of a separate research project, Section properties calculated for each sheet			
8	15-30-05	15mm	AS/NZS2269.0:2008	29.5	225.0	13.0	65.0

* Calculated using the EWPAA software "EZ Calc"

***Table 4**: Plywood Compression/Tension Section Areas Used.*

				Parallel to 2.4m panel length (Parallel Direction)		**Perpendicular to 2.4m panel length (Perpendicular Direction)**	
Batch No:	**Plywood Type:**	**Plywood Thickness**	**Source of Section Property values**	**Number of plies**	**Thickness of plies** (mm)	**Number of plies**	**Thickness of plies** (mm)
1	5 ply	15mm	Manufacturer	3	8.46	2	6.58
1	5 ply	17mm	Manufacturer	3	8.46	2	8.28
2	5 ply	15mm	Manufacturer	3	8.46	2	6.58
2	5 ply	17mm	Manufacturer	3	8.46	2	8.28
3	12-24-05	12mm	AS/NZS2269.0:2008	3	7.20	2	4.80
3	15-30-05	15mm	AS/NZS2269.0:2008	3	9.00	2	6.00
3	17-24-07	17mm	AS/NZS2269.0:2008	4	9.60	3	7.20
4	12-24-05	12mm	AS/NZS2269.0:2008	3	7.20	2	4.80
4	15-30-05	15mm	AS/NZS2269.0:2008	3	9.00	2	6.00
4	17-24-07	17mm	AS/NZS2269.0:2008	4	9.60	3	7.20
5	12-24-05	12mm	AS/NZS2269.0:2008	3	7.20	2	4.80
5	15-30-05	15mm	AS/NZS2269.0:2008	3	9.00	2	6.00
5	17-24-07	17mm	AS/NZS2269.0:2008	4	9.60	3	7.20
6	12-24-05	12mm	AS/NZS2269.0:2008	3	7.20	2	4.80
6	15-30-05	15mm	AS/NZS2269.0:2008	3	9.00	2	6.00
6	17-24-07	17mm	AS/NZS2269.0:2008	4	9.60	3	7.20
7	-	15mm	DEEDI values*	Plywood manufactured as part of a separate research project, Section properties calculated for each sheet			
8	15-30-05	15mm	AS/NZS2269.0:2008	3	9.00	2	6.00

* Calculated using the EWPAA software "EZ Calc"

Results

The characteristic strength and stiffness properties have been calculated using the calculation methods and procedures set out in AS/NZS2269.2:2008 and AS/NZS4063.2:2010 (parametric, log normal method)
Tables 5 and 6 show the characteristic strength and stiffness values by Batch number (plywood sizes combined) with the assigned
(AS1720.1:2010 'F' grade) and the
[AS/NZS2269.0:2008 'F' grade] by test.

Tables 7, 8 & 9 list the characteristic plywood design stresses from AS1720.1:2010, AS/NZS2269.0:2008 and NZS3603:1993.

Appendix A, Tables A1 & A2 list the coefficients of variation & 5th percentile data for each test and by batch number.

Table 5: *Summary of AS1720.1:2010 characteristic test results for the combined sample Batches 1, 2, 3 & 4.*

		Characteristic Strength Properties (MPa)			
Strength Property	**Plywood Test Direction**	**NZ Radiata F8 (Batch 1)**	**NZ Radiata F11 (Batch 2)**	**Australian Radiata F8 grade (Batch 3)**	**Australian Radiata F11 grade (Batch 4)**
Bending stiffness	Parallel	9665 (F8) [F8]	10720 (F11) [F11]	8970 (F7) [F7]	10432 (F8) [F8]
Bending stiffness	Perpendicular	10014 (F8) [F8]	9598 (F8) [F8]	11440 (F11) [F11]	10290 (F8) [F8]
Bending strength	Parallel	28.61 (F8) [F8]	33.05 (F11) [F8]	29.36 (F8) [F8]	32.65 (F11) [F8]
Bending strength	Perpendicular	28.60 (F8) [F8]	25.97 (F8) [F8]	33.02 (F11) [F8]	34.00 (F11) [F8]
Tension strength	Parallel	17.43 (F8) [F8]	17.75 (F8) [F8]	19.23 (F11) [F8]	21.30 (F11) [F11]
Tension strength	Perpendicular	14.78 (F7) [F7]	12.26 (F7) [F7]	20.12 (F11) [F11]	14.72 (F7) [F7]
Compression Strength	Parallel	40.05 (F17) [F17]	29.17 (F14) [F11]	31.97 (F14) [F14]	30.66 (F14) [F14]
Compression Strength	Perpendicular	36.92 (F17) [F14]	29.14 (F14) [F11]	35.56 (F14) [F14]	35.23 (F14) [F14]
Shear Strength	Parallel	5.30 (F11) [F11]	5.72 (F14) [F11]	5.48 (F11) [F11]	5.30 (F11) [F11]
Shear Strength	Perpendicular	5.66 (F14) [F11]	6.02 (F17-F34) [F11]	5.74 (F14) [F11]	5.77 (F14) [F11]

(F11) denotes the AS1720.1:2010 grade
[F8] denotes the AS/NZS22669.0:2008 grade

Table 6: *Summary of AS1720.1:2010 characteristic test results for the combined sample. Batches 5, 6, 7 & 8.*

		Characteristic Strength Properties (MPa)			
Strength Property	**Plywood Test Direction**	**Australian Slash F11 grade (Batch 5)**	**Australian Slash F14 grade (Batch 6)**	**Australian Plantation Hardwood (Batch 7)**	**Australian Hardwood F34 (Batch 8)**
Bending stiffness	Parallel	10151 (F8) [F8]	12285 (F14) [F14]	12934 (F14) [F14]	22678 (F34) [F34]
Bending stiffness	Perpendicular	12109 (F14) [F14]	12311 (F14) [F1R4]	13736 (F14) [F14]	21396 (F27) [F27]
Bending strength	Parallel	35.83 (F11) [F11]	44.54 (F14) [F14]	38.20 (F14) [F11]	99.56 (F34) [F27]
Bending strength	Perpendicular	41.36 (F14) [F14]	41.20 (F14) [F14]	40.30 (F14) [F14]	91.11 (F34) [F27]
Tension strength	Parallel	30.34 (F17) [F17]	28.86 (F17) [F14]	30.33 (F17) [F17]	67.13 (F34) [F34]
Tension strength	Perpendicular	23.43 (F14) [F11]	23.12 (F14) [F11]	23.43 (F14) [F11]	52.67 (F27) [F27]
Compression Strength	Parallel	27.30 (F14) [F11]	29.73 (F14) [F11]	34.64 (F14) [F14]	66.85 (F27) [F27]
Compression Strength	Perpendicular	23.31 (F11) [F8]	40.93 (F17) [F17]	43.50 (F17) [F17]	66.6 (F27) [F27]
Shear Strength	Parallel	5.46 (F11) [F11]	5.05 (F11) [F8]	5.91 (F14) [F11]	6.52 (F17-F34) [F14]
Shear Strength	Perpendicular	5.07 (F11) [F8]	5.12 (F11) [F8]	6.01 (F17-F34) [F11]	6.51 (F17-F34) [F14]

(F11) denotes the AS1720.1:2010 grade
[F8] denotes the AS/NZS22669.0:2008 grade

Note:
The batch 7 material was produced by DEEDI using veneers from four species of plantation logs, the plywood was laid-up to suit the objectives of another project, and as such is not directly comparable with production plywood. The test data does however show relativity between the strength results which fit with the other test data collected.

Table 7: *Characteristic stresses for structural plywood (MPa) (Moisture content 15% or less) from AS1720.1:2010*

Stress Grade	Bending f'_b	Tension f'_t	Panel Shear f'_s	Compression in the plane of the sheet f'_c	Bearing Normal to the plane of the sheet f'_p	Modulus of Elasticity E	Modulus of Rigidity G
F 34	90	54	6.0	68	31	21500	1075
F 27	70	45	6.0	55	27	18500	925
F 22	60	36	6.0	45	23	16000	800
F 17	45	27	6.0	36	20	14000	700
F 14	36	22	5.5	27	15	12000	625
F 11	31	18	5.0	22	12	10500	525
F 8	25	15	4.5	20	9.7	9100	455
F 7	20	12	4.2	15	7.7	7900	345

Table 8: *Characteristic stresses for structural plywood (MPa) (Moisture content 15% or less) from AS/NZS2269.0:2008*

Stress Grade	Bending f'_b	Tension f'_t	Panel Shear f'_s	Compression in the plane of the sheet f'_c	Bearing Normal to the plane of the sheet f'_p	Modulus of Elasticity E	Modulus of Rigidity G
F 34	100	60	6.8	75	31	21500	1075
F 27	80	50	6.8	60	27	18500	925
F 22	65	40	6.8	50	23	16000	800
F 17	50	30	6.8	40	20	14000	700
F 14	40	25	6.1	30	15	12000	625
F 11	35	20	5.3	25	12	10500	525
F 8	25	15	4.7	20	9.7	9100	455
F 7	20	12	4.2	15	7.7	7900	345
F 5*	14	9.6	3.8	12		6900	345

** EWPAA Industry Standard F5 grade*

Table 9: *Characteristic stresses for structural plywood (MPa) (Moisture content 15% or less) NZS3603:1993*

Stress grade	Bending f_{pb}	Tension f_{pt}	Panel Shear f_{ps}	Rolling Shear f_{pt}	Compression In the plane of the sheet f_{pc}	Compression normal to the plane of the sheet f_{pp}	Modulus of elasticity E	Modulus of rigidity G
F 22	57.6	34.6	6.0	2.4	43.2	20.4	16000	800
F 17	44.5	26.7	6.0	2.4	33.4	17.3	14000	700
F 14	36.7	22.0	5.4	2.2	27.5	13.6	12000	625
F 11	28.8	17.3	4.7	1.9	21.6	10.7	10500	525
F 8	22.5	13.5	4.2	1.7	16.9	8.6	9100	455

Discussion - Grade stress

In order to understand the relationship between the AS/NZS2269.1:2008 test stiffness and strength properties and the published grade stresses the following figures have been produced.

- Figure 1: Bending stiffness parallel versus bending stiffness perpendicular
- Figure 2: Bending MoE parallel versus Bending Strength parallel
- Figure 3: Bending MoE parallel versus Bending Strength perpendicular
- Figure 4: Bending MoE parallel versus Compression Strength parallel
- Figure 5: Bending MoE parallel versus Compression Strength perpendicular
- Figure 6: Bending MoE parallel versus Tension Strength parallel
- Figure 7: Bending MoE parallel versus Tension Strength perpendicular
- Figure 8: Bending MoE parallel versus Shear Strength parallel
- Figure 9: Bending MoE parallel versus Shear Strength perpendicular

In these figures the characteristic bending stiffness in the parallel direction is used for comparison with the other characteristic stiffness and characteristic strength properties.
The data could be represented by using the bending stiffness in the parallel direction value for the claimed grade against the as tested strength properties. For instance if the plywood was sold as F11 then the bending stiffness in the parallel direction value would be the code value of 10,500MPa (not the as tested value) and the other strength properties would those as tested. This approach would be useful in confirming compliance with standards however for this study the intent was to look at relationships between test properties.

Plotted in these figures are the:

1. Strength and stiffness properties for the plywood batches 1 – 8 (One set of characteristic values per batch).
2. Strength and stiffness properties from 13 Scion client data sets. This information is limited to comparison purposes only, no links can be made to the supplier or the plywood as the raw data remains confidential to the original Scion client.
3. The plywood from batch's 1, 2, 3, 4, 5 & 6 as sorted by the machine stress graded (MSG) parameter (see below).
4. Characteristic strength and stiffness values as taken from AS1720.1:2010.
5. Characteristic strength and stiffness values as taken from AS/NZS2269.0:2008.
6. Characteristic strength and stiffness values as taken from NZS3603:1993.

<u>Plywood machine stress grade re-sort.</u>
The combined data from Batches 1, 2, 3, 4, 5 & 6 MSG was re-sorted by computer using the plywood machine stress grading (MSG) data in conjunction with the mechanical test data. Essentially different MSG grade thresholds were applied and then the corresponding characteristic stiffness and strength were calculated. These calculated values were then compared with required code values for that grade. Further adjustments were made to the thresholds (bearing in mind that any adjustment also affects the grades above and below) as necessary. The aim was to just achieve the stiffness and strength properties for each grade with a primary focus of achieving the bending parallel stiffness.
This resorting reflects the procedures MSG producers could use in practice ie. linking back the QA bending strength and stiffness data back to machine stress graders thresholds (grade cut off points).
The combination of the six batches was only done to provide sufficient data for the analysis to be done, it is accepted that a plywood mill will not be using the combination of raw material in the six batches. However Scion believes for this exercise it shows the potential relationships between the different stiffness and strength properties.

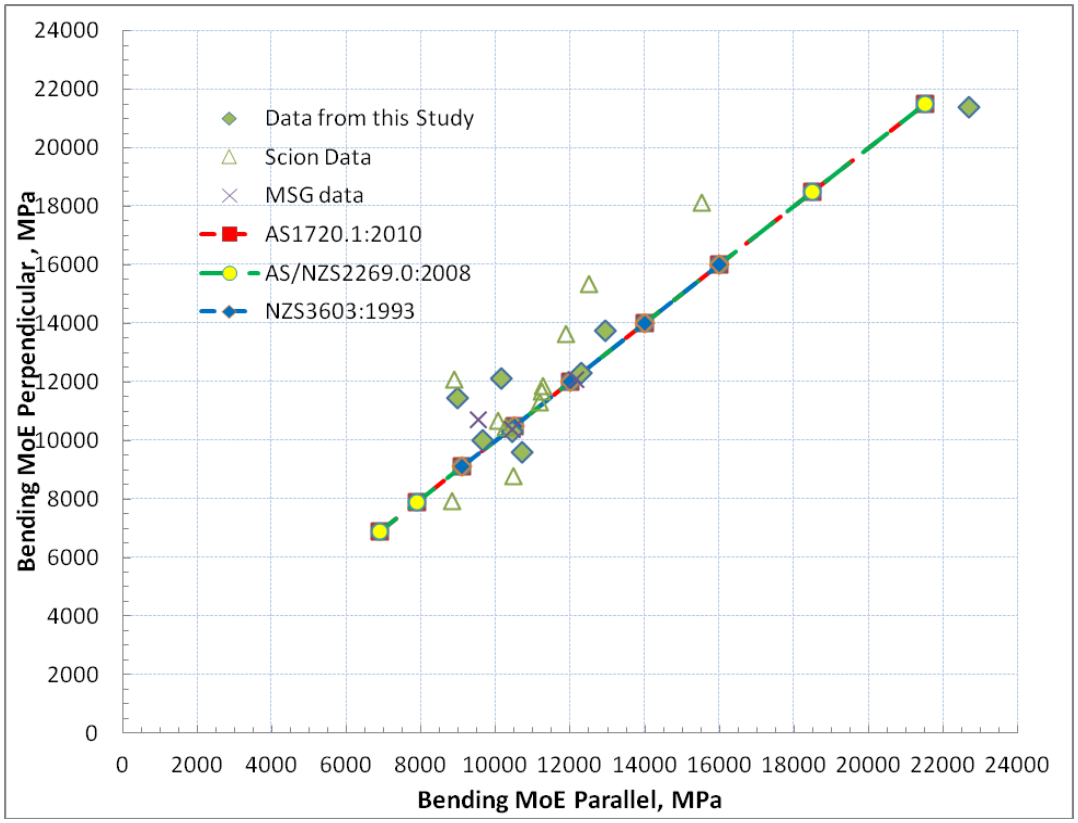

***Figure 1**: Bending MoE parallel vs Bending MoE perpendicular*

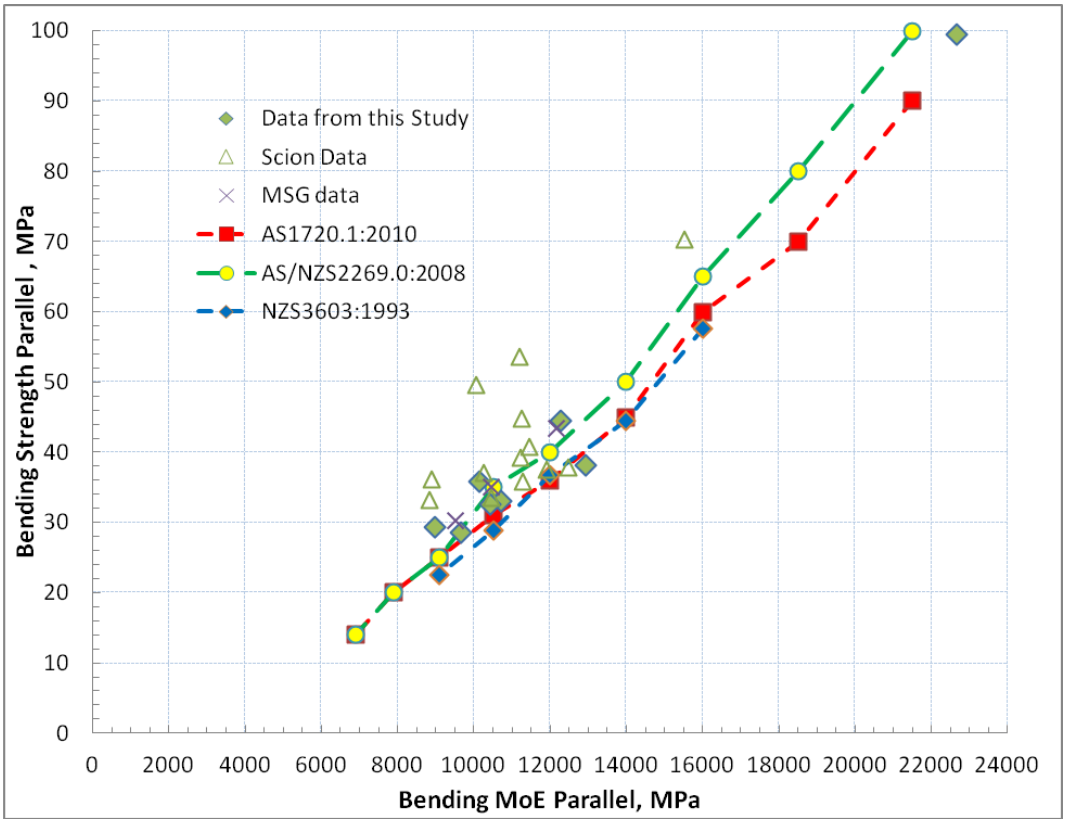

***Figure 2**: Bending MoE parallel vs Bending Strength parallel*

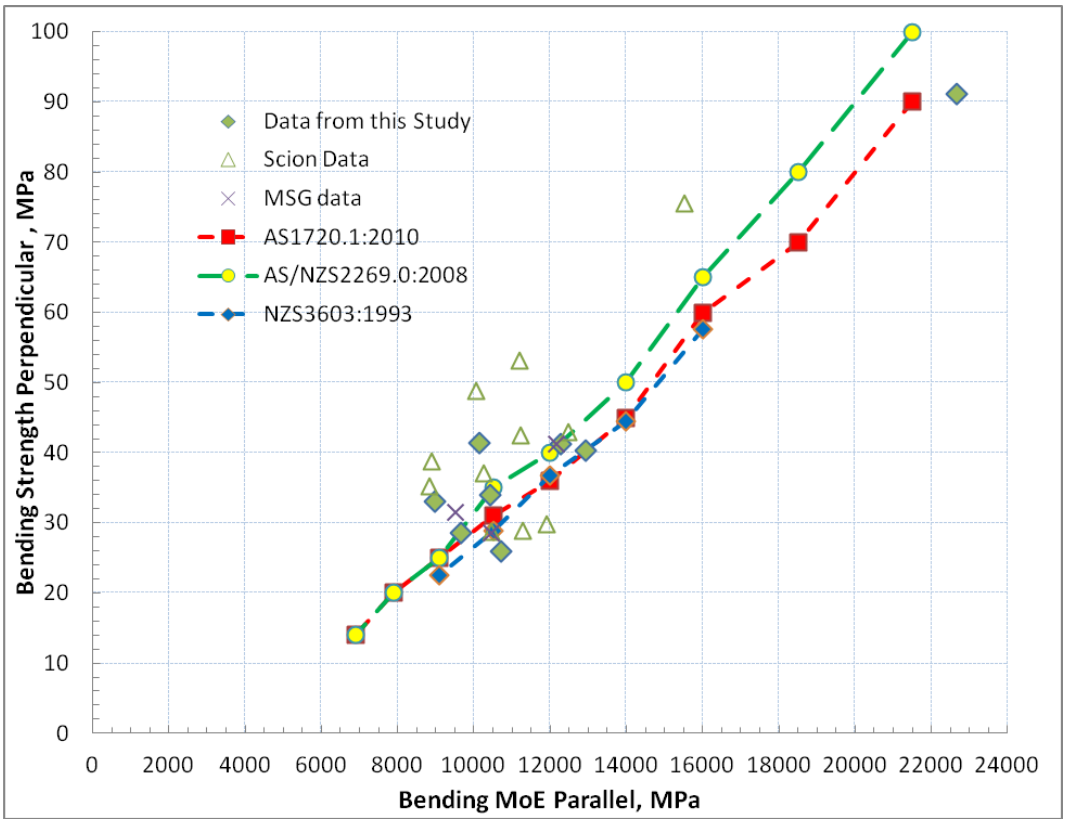

***Figure 3**: Bending MoE parallel vs Bending Strength perpendicular*

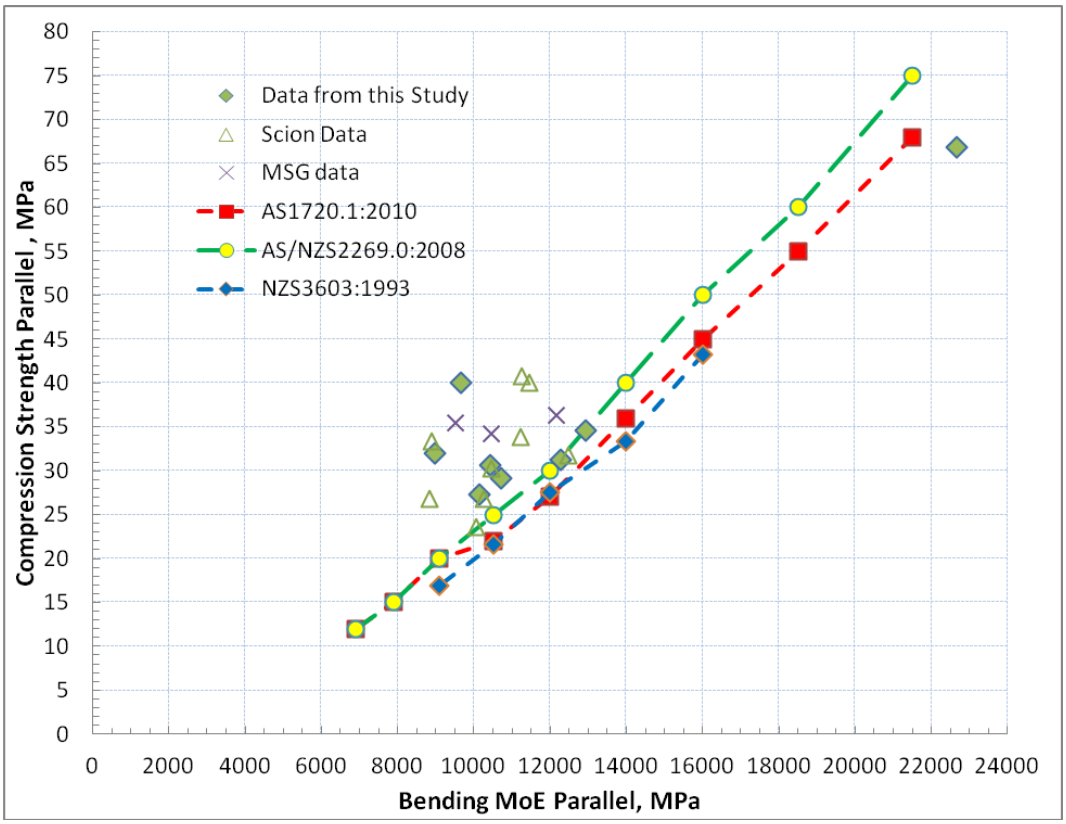

***Figure 4**: Bending MoE parallel vs Compression Strength parallel*

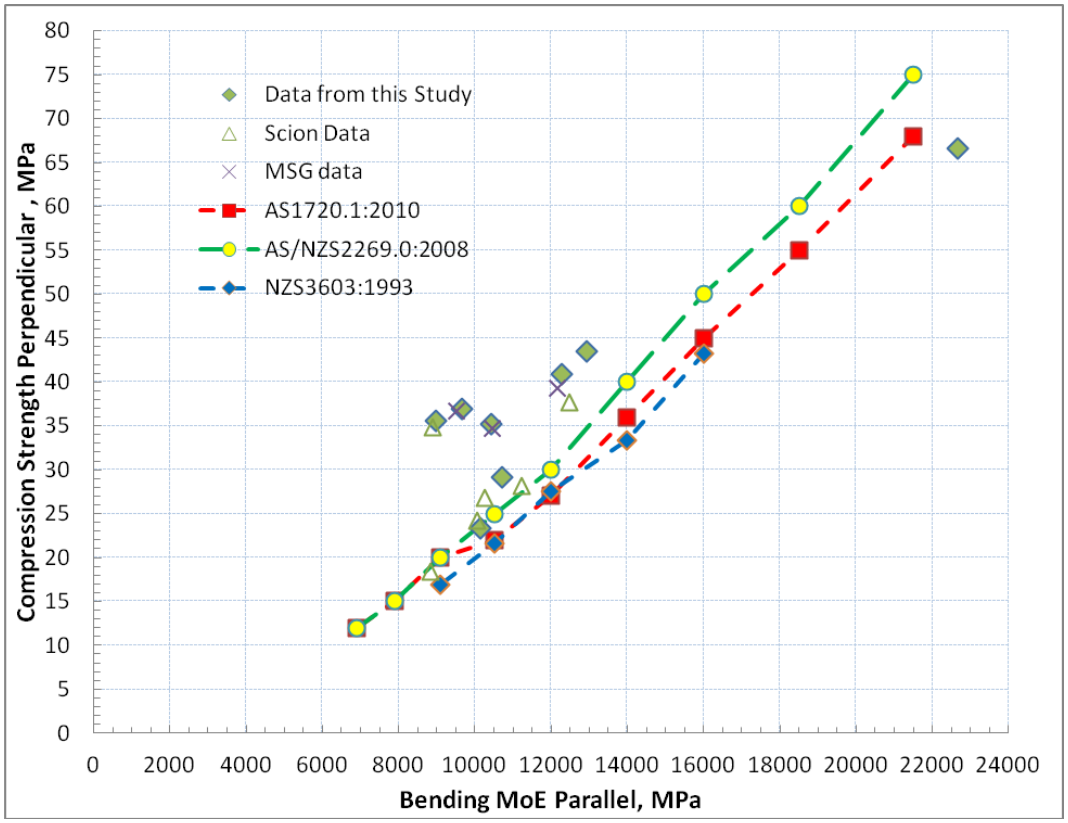

***Figure 5**: Bending MoE parallel vs Compression Strength perpendicular*

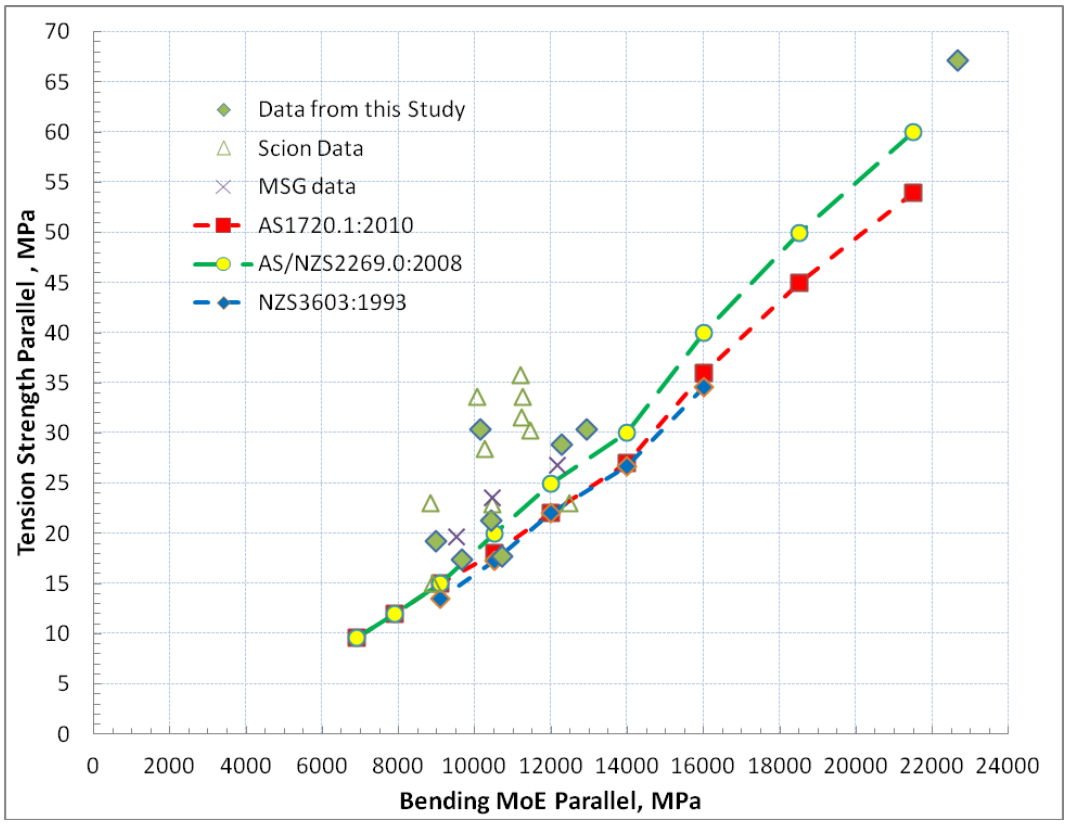

***Figure 6**: Bending MoE parallel vs Tension Strength parallel*

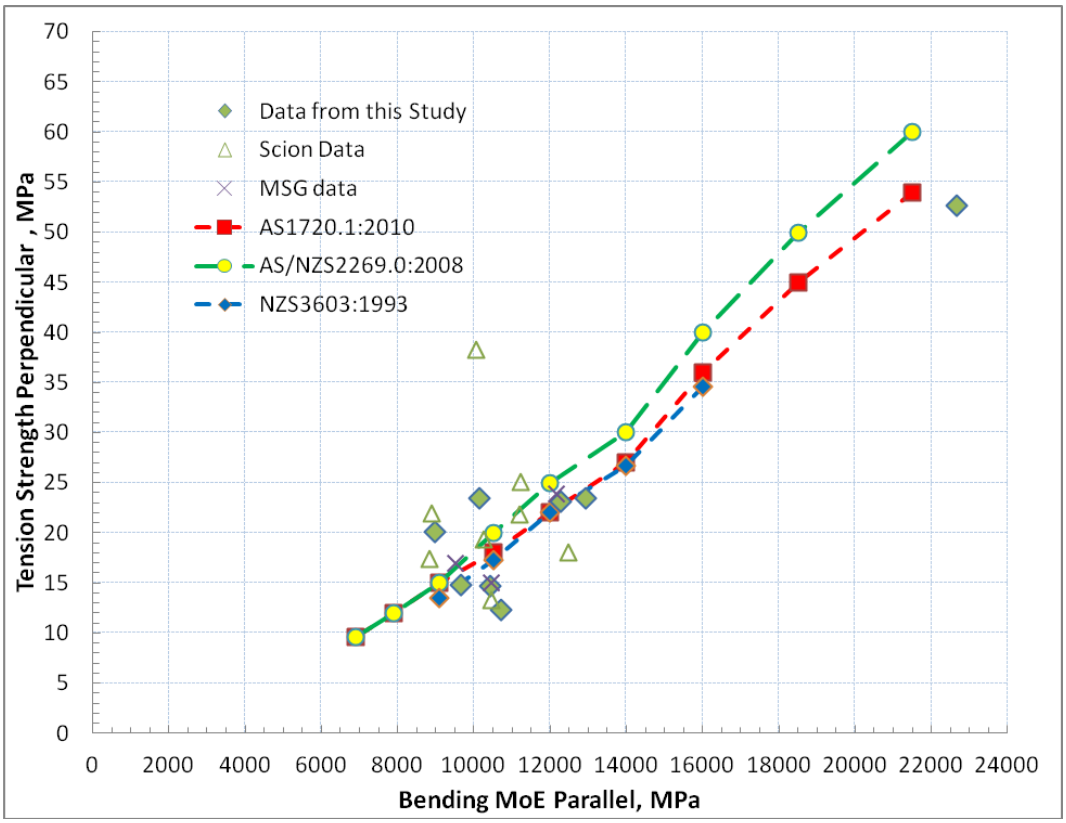

***Figure 7**: Bending MoE parallel vs Tension Strength perpendicular*

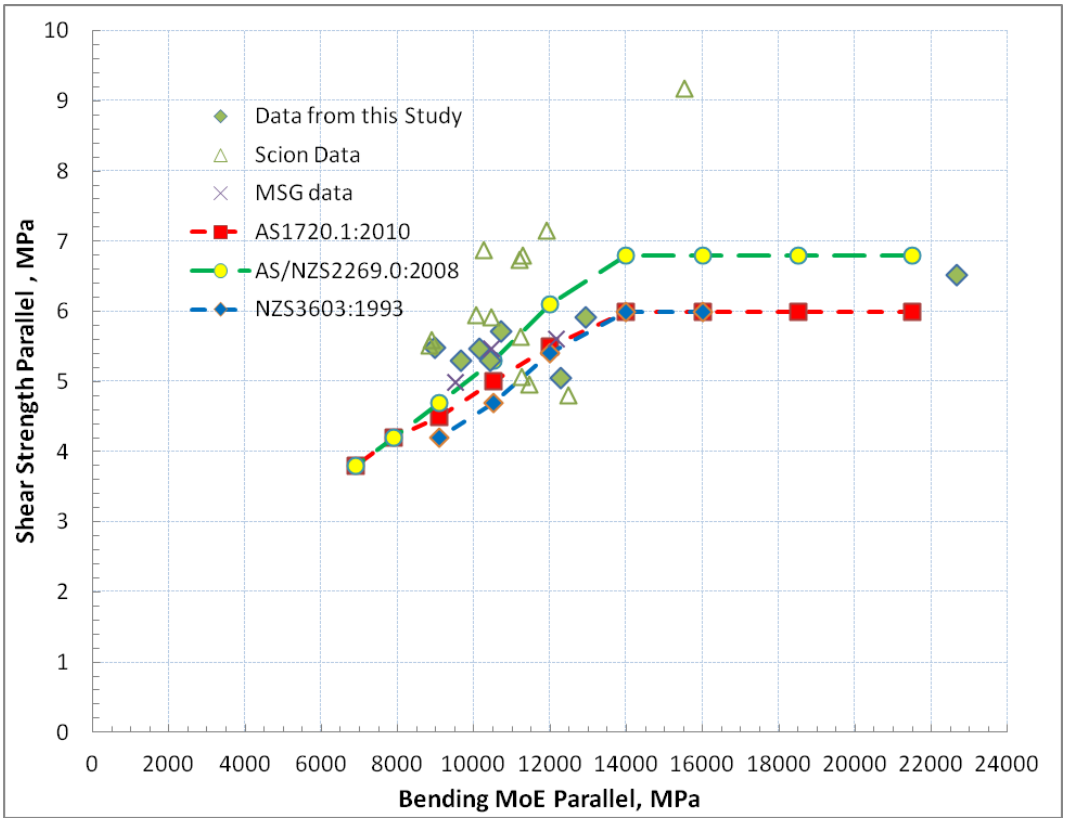

***Figure 8**: Bending MoE parallel vs Shear Strength parallel*

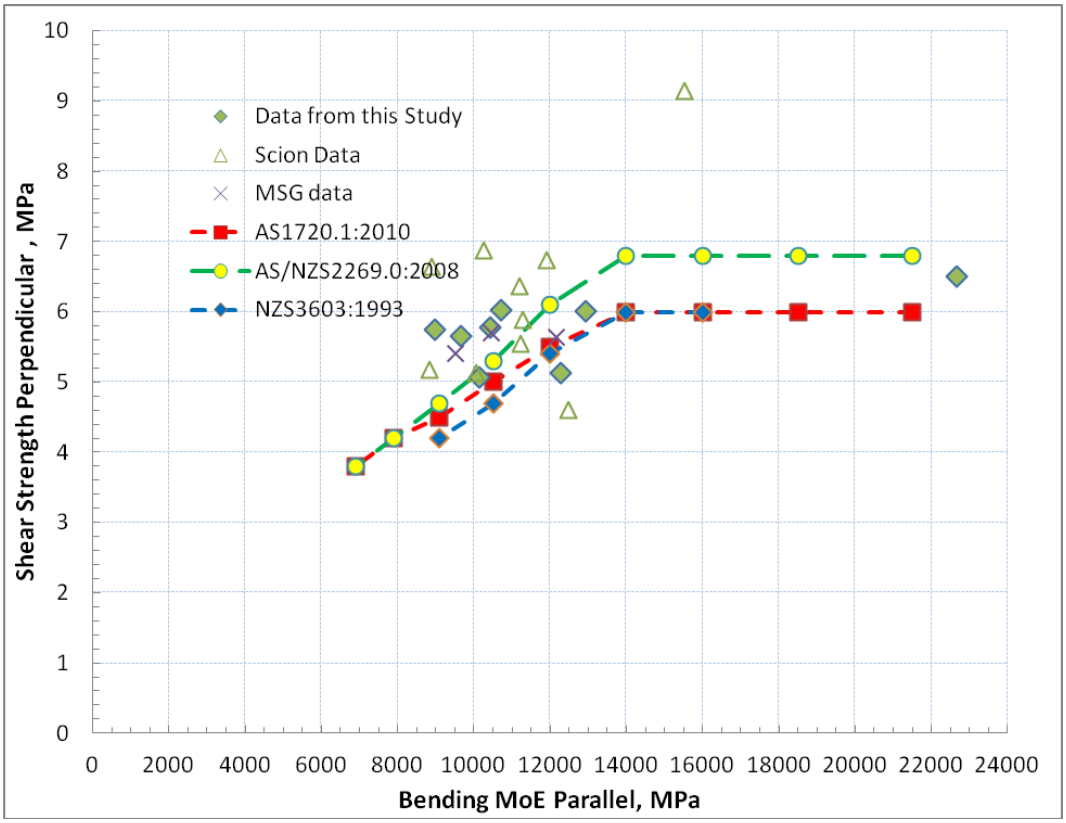

***Figure 9**: Bending MoE parallel vs Shear Strength perpendicular*

Grade Stress Observations

- The characteristic grade stresses are very similar between AS1720.1:2010 and NZS3603:1993. Whereas AS/NZS2269.1:2008 lie above both AS1720.1:2010 and NZS3603:1993.
- It should be noted that AS1720.1:2010 is now aligned with new AS/NZS4063 series in which normalisation has been discontinued which now leaves AS/NZS4063 entirely material related. AS/NZS2269 and NZS3603 are now corresponding not aligned with the new AS/NZS4063 series.

In order to summarise the data shown on Figures 1 – 9 the following Tables 10 – 17 show the number of data points (Batches) falling below the three lines of characteristic plywood stresses ie.. AS1720.1:2010, AS/NZS2269.1:2008 & NZS3603:1993.

Bending stiffness parallel versus bending stiffness perpendicular

More of the data points lie above the characteristic stiffness (all three standards) line. This indicates that the bending stiffness perpendicular is higher than the bending stiffness parallel.

Bending stiffness parallel versus Bending strength parallel

***Table 10**: Number of data points falling below the characteristic stresses. - Bending Strength parallel*

	AS1720.1:2010	AS/NZS2269.1:2008	NZS3603:1993
Data from this study	1	4	1
Scion Data	1	3	1
MSG data	0	0	0

Bending stiffness parallel versus Bending strength perpendicular

***Table 11**: Number of data points falling below the characteristic stresses - Bending Strength perpendicular*

	AS1720.1:2010	**AS/NZS2269.1:2008**	**NZS3603:1993**
Data from this study	2	3	1
Scion Data	2	2	2
MSG data	1	1	0

Bending stiffness parallel versus Compression strength parallel

***Table 12**: Number of data points falling below the characteristic stresses - Comp Strength parallel*

	AS1720.1:2010	**AS/NZS2269.1:2008**	**NZS3603:1993**
Data from this study	1	1	0
Scion Data	0	1	0
MSG data	0	0	0

Bending stiffness parallel versus Compression strength parallel

***Table 13**: Number of data points falling below the characteristic stresses - Compression Strength perpendicular*

	AS1720.1:2010	**AS/NZS2269.1:2008**	**NZS3603:1993**
Data from this study	2	1	0
Scion Data	0	0	0
MSG data	0	0	0

Bending stiffness parallel versus Tension strength parallel

***Table 14**: Number of data points falling below the characteristic stresses – Tension Strength parallel*

	AS1720.1:2010	**AS/NZS2269.1:2008**	**NZS3603:1993**
Data from this study	0	1	0
Scion Data	0	1	0
MSG data	0	0	0

Bending stiffness parallel versus Tension strength perpendicular

***Table 15**: Number of data points falling below the characteristic stresses – Tension Strength perpendicular*

	AS1720.1:2010	**AS/NZS2269.1:2008**	**NZS3603:1993**
Data from this study	4	5	3
Scion Data	2	3	2
MSG data	1	2	1

Bending stiffness parallel versus Shear strength parallel

***Table 16**: Number of data points falling below the characteristic stresses Shear Strength parallel*

	AS1720.1:2010	**AS/NZS2269.1:2008**	**NZS3603:1993**
Data from this study	1	3	1
Scion Data	2	3	2
MSG data	0	1	0

Bending stiffness parallel versus Shear strength perpendicular

***Table 17**: Number of data points falling below the characteristic stresses – Shear Strength perpendicular*

	AS1720.1:2010	AS/NZS2269.1:2008	NZS3603:1993
Data from this study	1	3	1
Scion Data	1	2	1
MSG data	0	1	0

From Figures 1 - 9 and Tables 10 - 17:

1. The characteristic plywood grade stresses in AS1720.1:2010 appears to provide at better fit then those in AS/NZS2269 with the data. A significant factor is the fact that AS1720.1:2010 is now aligned with new AS/NZS4063 series in which normalisation has been discontinued.
2. Tension strength perpendicular tends to have more data points falling below characteristic plywood grade stresses. This could be associated with a tendency in production to use lower visual grade veneers in the cross bands which then can have a negative impact on tension strength; this also impacts on bending perpendicular strength. In Scions opinion after witnessing a large number of tests this impact does not appear in compression perpendicular or shear perpendicular testing.
3. Potentially the shear grade values for AS1720 could be amended downwards slightly however questions do exist about the shear test itself (see Shear test section in report). Figures 10 & 11 shows a potential revision with Tables 18 & 19 listing the potential shear stresses.

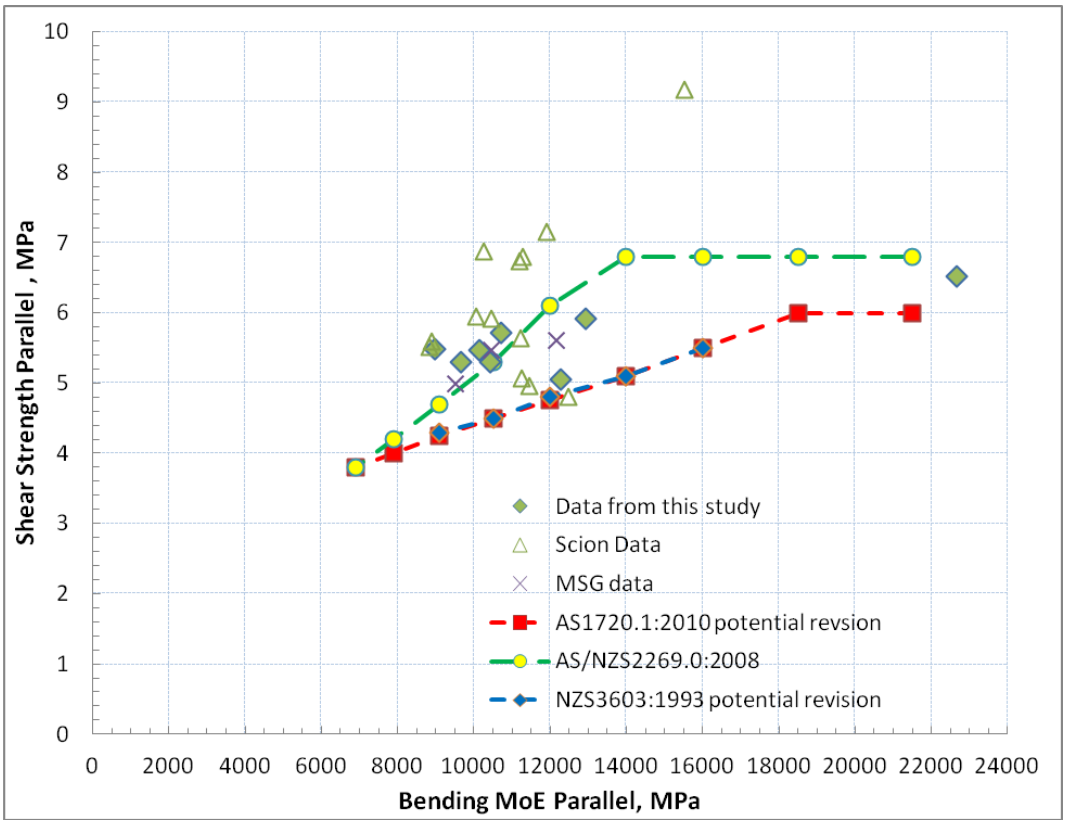

***Figure 10**: Bending MoE parallel vs Shear Strength parallel revision*

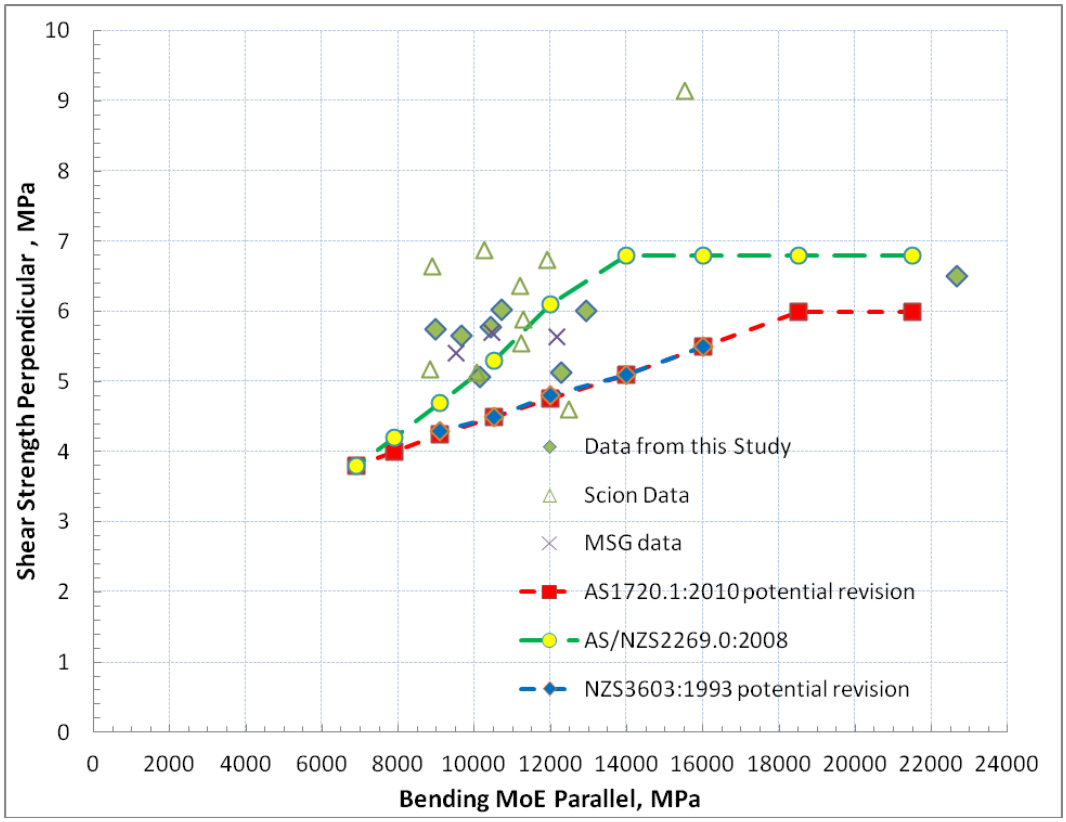

***Figure 11**: Bending MoE parallel vs Shear Strength perpendicular revision*

***Table 18:** Characteristic stresses for structural plywood (MPa)- Revision (Moisture content 15% or less) from AS1720.1:2010*

Stress Grade	Bending f'_b	Tension f'_t	Current Panel Shear	Proposed Panel Shear f'_s	Compression in the plane of the sheet f'_c	Bearing Normal to the plane of the sheet f'_p	Modulus of Elasticity E	Modulus of Rigidity G
F 34	90	54	6.0	6.0	68	31	21500	1075
F 27	70	45	6.0	6.0	55	27	18500	925
F 22	60	36	6.0	5.5	45	23	16000	800
F 17	45	27	6.0	5.1	36	20	14000	700
F 14	36	22	5.5	4.8	27	15	12000	625
F 11	31	18	5.0	4.5	22	12	10500	525
F 8	25	15	4.5	4.3	20	9.7	9100	455
F 7	20	12	4.2	4.0	15	7.7	7900	345

(Revised shear stresses shown highlighted)

Table 19: *Characteristic stresses for structural plywood (MPa) -Revision (Moisture content 15% or less) NZS3603:1993*

Stress grade	**Bending** f_{pb}	**Tension** f_{pt}	**Current Panel Shear** f_{ps}	**Proposed Panel Shear** f_{ps}	**Rolling Shear** f_{pt}	**Compression** **In the plane of the sheet** f_{pc}	**Compression** **normal to the plane of the sheet** f_{pp}	**Modulus of elasticity** ***E***	**Modulus of rigidity** ***G***
F 22	57.6	34.6	6.0	5.5	2.4	43.2	20.4	16000	800
F 17	44.5	26.7	6.0	5.1	2.4	33.4	17.3	14000	700
F 14	36.7	22.0	5.4	4.8	2.2	27.5	13.6	12000	625
F 11	28.8	17.3	4.7	4.5	1.9	21.6	10.7	10500	525
F 8	22.5	13.5	4.2	4.3	1.7	16.9	8.6	9100	455

(Revised shear stresses shown highlighted)

Prior to any revision of grade stresses the use of the new stresses should be tested in the market via a design study to review the impact on the use of plywood in structures. For instance will the reduced stresses now make some plywood designs less economic?

Discussion - Shear Testing

The plywood shear method in AS/NZS2269.1:2008 requires 200x85 plywood specimens to which steel rails are bolted each side and then tested, as Figure 12

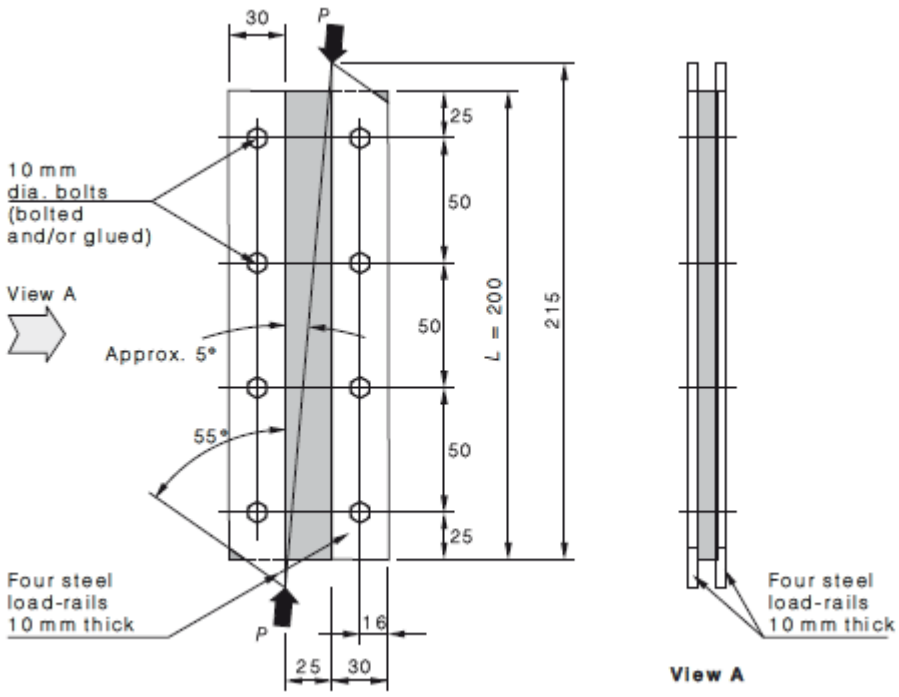

Figure 12: *Plywood Shear test configuration*

On undertaking this shear testing Scion consistently observes that the maximum test load is not always associated with a shear failure but often related to a bolt bearing failure (Figure 13). In Figure 13 the specimen on the left has generated a shear failure whereas the specimen on the right has produced a bolt bearing failure. The concern is that if the method was improved to always generate a shear failure then the calculated shear stresses could also be improved. It is suggested that this issue be directed to the relevant AS/NZS plywood standards committee.

This data should further be interrogated to examine the numbers of bolt bearing failures with their failure loads versus true shear failures this would further develop and refine this issue. However this work was outside the original scope of this project.

A topic for further discussion from this study is:

Should the AS1720 characteristic shear stresses be amended to suit the test data or should the test method be amended to improve the failure shear stresses?

***Figure 13**: Plywood shear test specimens after test.*

Discussion - Machine Stress Grading Relationships

The plywood machine stress grader grades whole sheets of plywood by measuring bending stiffness along in the parallel direction (parallel to the 2.4m sheet length.) by applying load and measuring the resultant deflection. Figure 14 shows a plywood machine stress grader.

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***Figure 14**: Plywood machine stress grader.*

In order to investigate the ability of plywood machine stress grading the data has been pooled to cover the plywood grades F8, F11 and F14, this range reflects that which could be expected to be produced from a radiata pine or slash pine plywood operation.

The following Figures 15 – 24 show the relationship between the whole sheet bending parallel MoE (the plywood machine stress grader value) and the ten AS/NZS2269 plywood strength and stiffness properties, Table 20 lists the regression coefficients.

***Table 20**: R^2 regression coefficients*

Measured Property	Predicted AS/NZS2269 Property	Regression Coefficients R^2
Whole Sheet MoE	Bending MoE parallel	0.4199
Whole Sheet MoE	Bending MoE perpendicular	0.0699
Whole Sheet MoE	Bending strength parallel	0.1808
Whole Sheet MoE	Bending strength perpendicular	0.0820
Whole Sheet MoE	Compression strength parallel	0.1798
Whole Sheet MoE	Compression strength perpendicular	0.0520
Whole Sheet MoE	Tension strength parallel	0.2985
Whole Sheet MoE	Tension strength perpendicular	0.1822
Whole Sheet MoE	Shear strength parallel	0.0235
Whole Sheet MoE	Shear strength perpendicular	0.1193

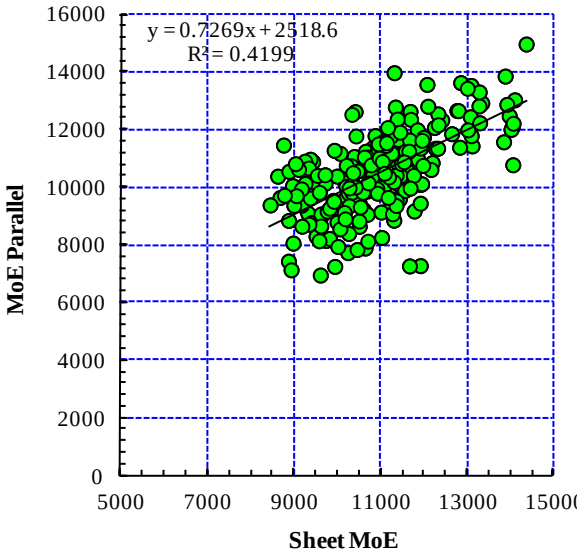


Figure 15: *Sheet MoE vs MoE parallel*

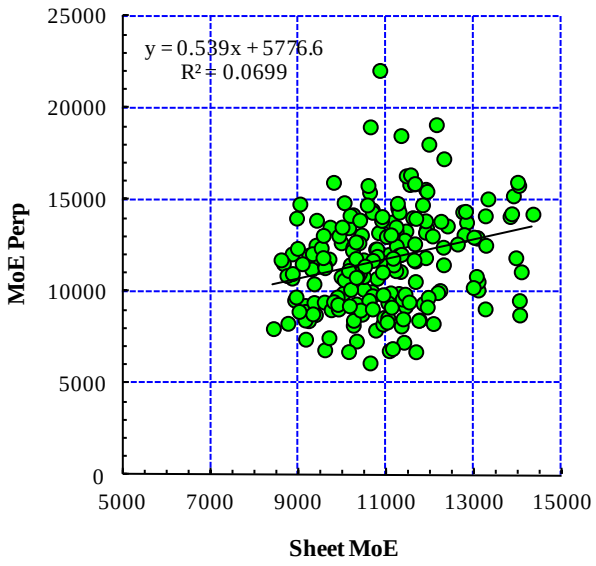


Figure 16: *Sheet MoE vs MoE perpendicular*

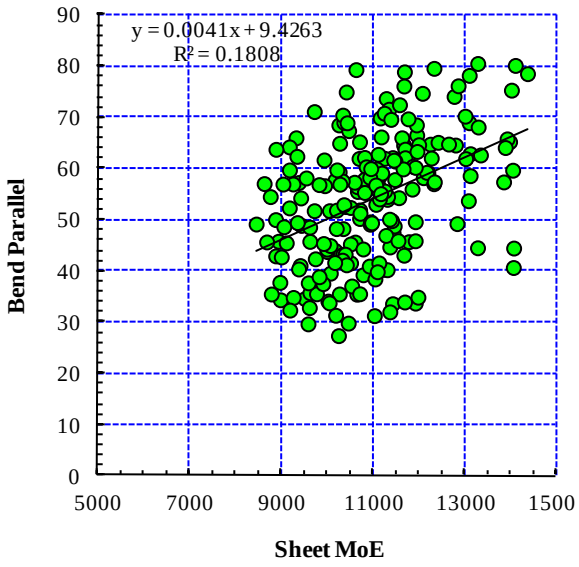


Figure 17: *Sheet MoE vs Bending parallel*

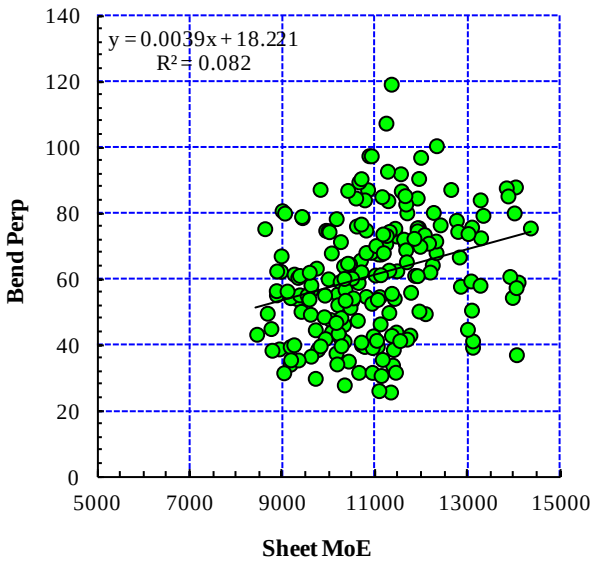


Figure 18: *Sheet MoE vs Bending perpendicular*

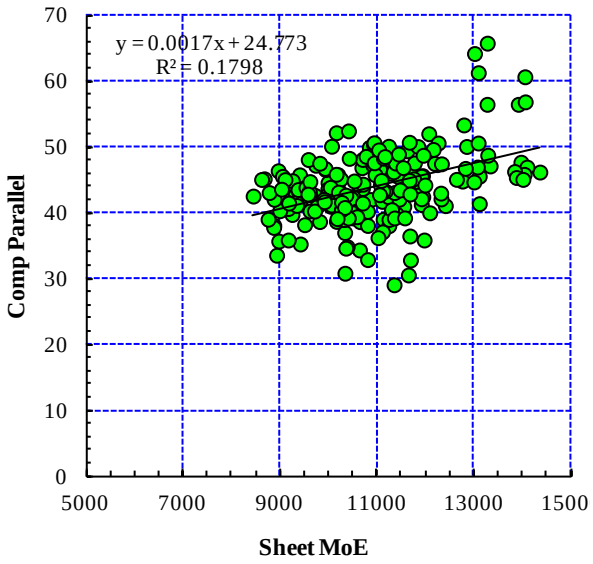


Figure 19: *Sheet MoE vs Comp parallel*

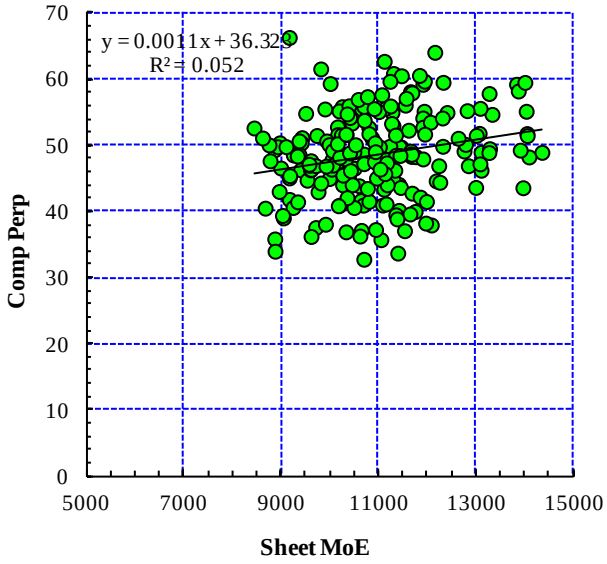


Figure 20: *Sheet MoE vs Comp perpendicular*

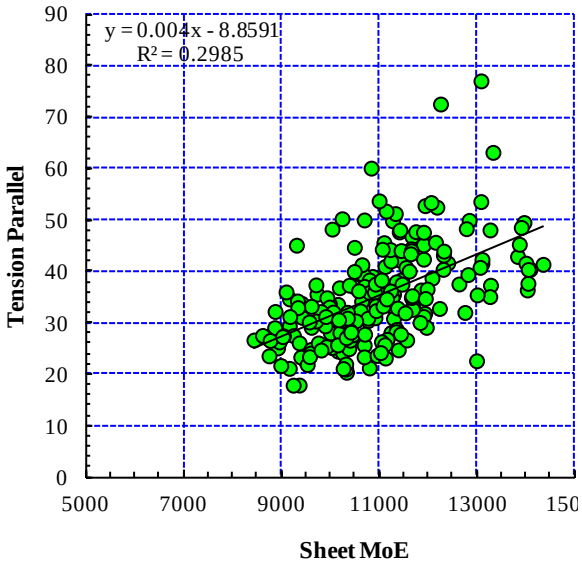


Figure 21: *Sheet MoE vs Tension parallel*

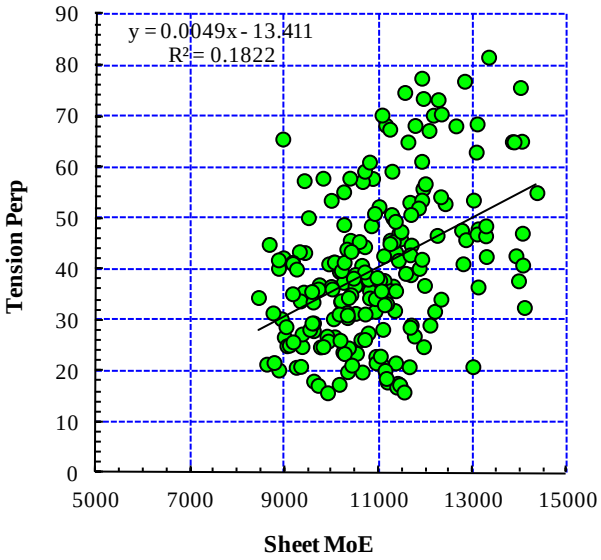
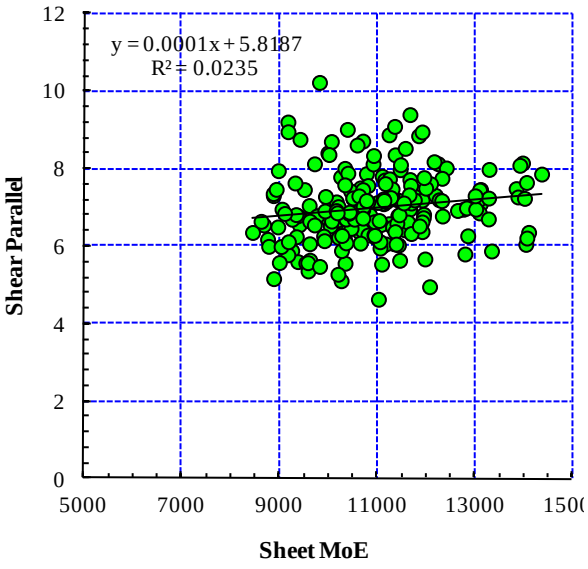


Figure 22: *Sheet MoE vs Tension perpendicular*



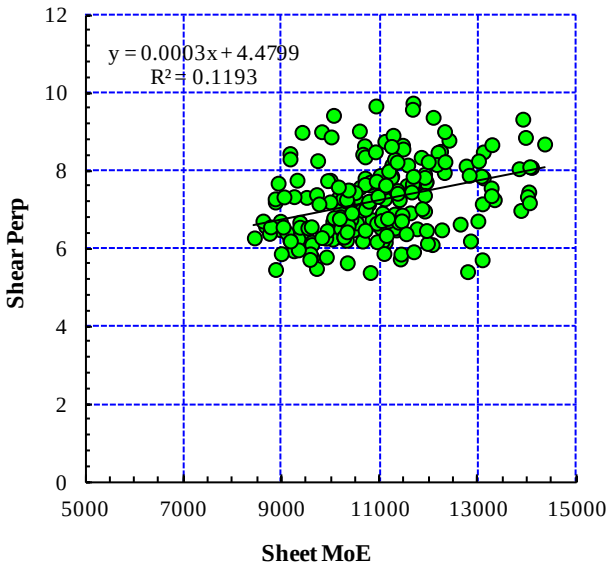


Figure 23: *Sheet MoE vs Shear parallel*

Figure 24: *Sheet MoE vs Shear perpendicular*

Machine stress grading observations

The only significant relationship that exists is between the sheet MoE and bending MoE in the parallel direction only. This could reasonably be expected as both measurements are addressing the same property. The relationships to other nine properties are very weak if apparent at all.

This can be explained as follows:

- For bending stiffness the stiffness properties of the long band veneers and the cross band veneers are usually not linked in anyway. It is not uncommon for the cross band veneers to be of a lower visual grade and /or lower stiffness grade..
- A measurement of bending stiffness can have a strong relationship with strength when the wood samples are small, clear and straight grained. However strength is commonly governed by grain angle and direction, this occurs primarily around knots. Figure 25 shows the relationship between plywood bending stiffness and plywood bending strength in the parallel direction as taken from the same AS/NZS2269 test specimens. This is the theoretical best case relationship and generates an R^2 of only 0.4323. Taking this theoretical best relationship it becomes possible to explain the poor relationship between sheet MoE and the other eight strength properties.

Looking at the MSG data points in Figure 1-9 (three data points only) appears to show the MSG grading better achieving all characteristic strength properties. The author believes this apparent trend just reflects the fact that higher stiffness grade plywood has higher strength properties as seen in the plywood characteristic design values (AS1720.1:2010)

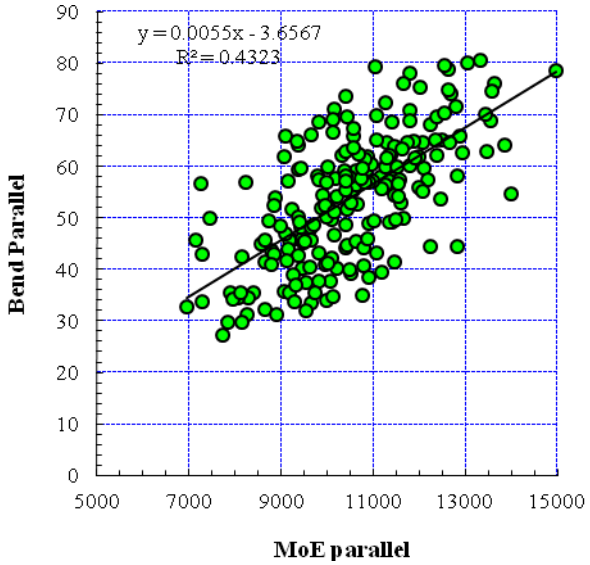


***Figure 25**: Same test specimen Bending MoE parallel vs Bending Strength parallel*

Conclusions

- The plywood characteristic grade stresses in AS1720.1:2010 provide a better fit with the data from this study & Scion test data then those in AS/NZS2269.0:2008. The primary factor in this, is that AS1720.1:2010 is now aligned with new AS/NZS4063 series in which normalisation has been discontinued whilst AS2269.0:2008 is out of step with the new AS/NZS4063 series.
- Ultimately the plywood stresses in the New Zealand timber structures standard NZS3603 should be aligned with those in AS1720.1:2010.
- Potential exists to amend the characteristic shear grade values in AS1720.1:2010 as the both the data from this study & Scion test data indicate some difficulty in achieving the required grade stresses. However concern exists whether the shear test method in AS/NZS2269 can reliably and consistently produce a true shear failure. With the current shear test method on observation of other Scion shear testing a true shear does not always occur with the specimens failing on occasions in bolt bearing first.
- When plywood sheets are machine stress graded along the parallel direction the only significant AS/NZS2269 mechanical test relationship in with the bending stiffness in the parallel direction. The relationships to the other nine AS/NZS2269 mechanical test properties are very low if apparent at all in some cases. The properties in the parallel direction are not always linked to the properties in the perpendicular direction as in Scion observations there is a tendency on occasions in production to use lower visual grade veneers in the cross bands. This can have a negative effect on the perpendicular properties without adversely affecting the parallel properties.

Recommendations

1. The Australian designers of plywood structures should use the characteristic values from AS1720.1:2010.
2. The characteristic plywood stresses in AS/NZS2269.0:2008 should either by amended to reflect those in AS1720.1:2010 or deleted leaving AS1720.1:2010 as the only source.
3. The planned revision of NZS3603:1993 should be aligned with the AS/NZS4063 series in which normalisation has been discontinued. NZS3603 should also adopt the appropriate plywood grades and characteristic stresses from AS1720.1:2010
4. Consideration should be given to the introduction of lower shear values in AS1720.1:2010 on the proviso that there are no significant impacts on the structural use of plywood.
5. The plywood shear test method in AS/NZS2269.1:2008 should be reviewed to improve its ability to produce true shear failures.

References

AS/NZS 2269.0:2008, Plywood—Structural Part 0: Specifications. Standards Australia/Standards New Zealand.

AS/NZS 2269.1:2008, Plywood—Structural Part 1: Determination of structural properties—Test methods. Standards Australia/Standards New Zealand.

AS/NZS 2269.2:2007, Plywood—Structural Part 2: Determination of structural properties—Evaluation methods. Standards Australia/Standards New Zealand

AS/NZS4063.1:2010, Characterization of structural timber Part 1: Test methods. Standards Australia.

AS1720.1:2010, Timber structures Part 1: Design methods. Standards Australia.

NZS3603:1993 Timber Structures Standard, Standard New Zealand

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- The support of the plywood mills in facilitating the collection and supply of the plywood test sheets both in Australia and New Zealand

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Appendix A

Table A1: *Summary of AS1720.1:2010 test results for the combined sample Batches 1, 2, 3 & 4.*

		Characteristic Strength Properties (MPa)			
Strength Property	**Plywood Test Direction**	**NZ Radiata F8 (Batch 1)**	**NZ Radiata F11 (Batch 2)**	**Australian Radiata F8 grade (Batch 3)**	**Australian Radiata F11 grade (Batch 4)**
Bending stiffness	Parallel	9665 (10.3%) [8056]	10720 (10.8%) [8849]	8970 (11.7%) [7277]	10432 (11.7%) [8470]
Bending stiffness	Perpendicular	10014 (17.9%) [7255]	9598 (16.1%) [7182]	11440 (19.3%) [8198]	10290 (25.9%) [7427]
Bending strength	Parallel	28.61 (21.9%) [29.88]	33.05 (23.8%) [34.63]	29.36 (23.3%) [30.77]	32.65 (23.3%) [34.18]
Bending strength	Perpendicular	28.60 (26.1%) [30.45]	25.97 (26.9%) [27.91]	33.02 27.0%) [35.60]	34.00 (30.7%) [38.30]
Tension strength	Parallel	17.43 (21.5%) [17.96]	17.75 (20.5%) [18.25]	19.23 (24.8%) [19.92]	21.30 (23.0%) [21.99]
Tension strength	Perpendicular	14.78 (31.0%) [16.41]	12.26 (32.4%) [13.85]	20.12 (31.3%) [22.46]	14.72 (39.9%) [18.30]
Compression Strength	Parallel	40.05 (5.8%) [38.89]	29.17 (13.9%) [31.18]	31.97 (11.2%) [33.07]	30.66 (13.1%) [32.44]
Compression Strength	Perpendicular	36.92 (10.2%) [37.75]	29.14 (17.2%) [30.13]	35.56 (14.1%) [38.11]	35.23 (15.2%) [36.28]
Shear Strength	Parallel	5.30 (8.6%) [5.32]	5.72 (8.2%) [5.70]	5.48 (15.3%) [5.65]	5.30 (15.6%) [5.47]
Shear Strength	Perpendicular	5.66 (6.9%) [5.56]	6.02 (6.8%) [5.92]	5.74 (11.6%) [5.97]	5.77 (12.5%) [6.06]

(10.3%) denotes Coefficient of Variation
[9680] denotes 5^{th} percentile

Table A2: *Summary of AS1720.1:2010 test results for the combined sample. Batches 5, 6, 7 & 8.*

		Characteristic Strength Properties (MPa)			
Strength Property	**Plywood Test Direction**	**Australian Slash F11 grade (Batch 5)**	**Australian Slash F14 grade (Batch 6)**	**Australian Plantation Hardwood (Batch 7)**	**Australian Hardwood F34 (Batch 8)**
Bending stiffness	Parallel	10151 (12.0%) [8199]	12285 (7.5%) [10759]	12934 (-) [-]	22678 (11.7%) [18407]
Bending stiffness	Perpendicular	12109 (21.7%) [8710]	12311 (19.5%) [8821]	13736 (-) [-]	21396 (15.7%) [16141]
Bending strength	Parallel	35.83 (21.6%) [37.40]	44.54 (17.1%) [46.07]	38.20 (-) [-]	99.56 (11.9%) [103.84]
Bending strength	Perpendicular	41.36 (25.3%) [43.75]	41.20 (24.0%) [43.21]	40.30 (F-) [-]	91.11 (17.5%) [94.31]
Tension strength	Parallel	30.34 (17.5%) [31.08]	28.86 (22.0%) [29.76]	30.33 (-) [-]	67.13 (20.7%) [69.10]
Tension strength	Perpendicular	23.43 (30.7%) [25.93]	23.12 (32.4%) [26.12]	23.43 (-) [-]	52.67 (31.5%) [59.02]
Compression Strength	Parallel	27.30 (14.4%) [29.38]	29.73 (19.7%) [30.92]	34.64 (-) [-]	66.85 (9.4%) [67.65]
Compression Strength	Perpendicular	23.31 (25.6%) [24.71]	40.93 (10.6%) [42.06]	43.50 (-) [-]	66.6 (11.6%) [69.34]
Shear Strength	Parallel	5.46 (9.3%) [5.52]	5.05 (12.6%) [5.31]	5.91 (-) [-]	6.52 (11.1%) [6.74]
Shear Strength	Perpendicular	5.07 (13.5%) [5.39]	5.12 (14.7%) [5.53]	6.01 (-) [-]	6.51 (10.5%) [6.68]

(10.3%) denotes Coefficient of Variation
[9680] denotes 5th percentile

Note:
The batch 7 material was produced by DEEDI using veneers from four species of plantation logs, the plywood was laid-up to suit the objectives of another project, and as such is not directly comparable with production plywood. Hence the Coefficient of Variation and 5th percentile data has not been included.