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STRUCTURAL PLYWOOD FROM MALAYSIAN HARDWOODS

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SUMMARY

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Twenty-two Malaysian tropical hardwood species have been categorized into two major structural groups called the Structural I and Structural II based upon specific gravity. Structural II is furtner divided into Strutural IIA and IIB. Species having the lowest Modulus of Elasticity in each group or subgroup are chosen and tested for their mechanical properties. Strength values of each chosen species conservatively represent the strength values of each particular group or subgroup. Preliminary tests on Keruing (Dipterocarpus spp.) and Mersawa (Anisoptera spp.) show that plywoods produced from Malaysian hardwoods are comparable in strength to those plywoods from the United States, Canada and the Scandinavian countries.

This paper is a part of a large scale research to assist in the drawing up of the Malaysian Standard for Structural Plywood.

Keyword: Structural Plywood, Tropical Hardwoods

INTRODUCTION

The timber industry in Malaysia, in general, is already aware of the concept of value added through processing rather than raw log exports. Plywood manufacture in the country is already considered a matured industry whereby the mills are capable of producing high grade panels and veneer sheets with the aid of versatile machineries and skilled workers. Technological advancements in the Far East have helped the country to be at par with many of other plywood manufacturers worldwide. Relatively low labor wages and naturally abundance of raw logs through sustained forest management further put Malaysian plywoods in the competitive edge of the market. The naturally little occurrence of defects in many of the Malaysian species veneers enhance the beauty and strength which make the plywood panels suitable to be used in decorative, structural, utility or any combination of applications.

Generally the Malaysian tropical timbers are divided into four categories: Heavy hardwood, Medium Hardwood, Light Hardwood and Softwood. There are about 57 species from the hardwood categories that are suitable for plywood manufacture, and out of these, 36 species are considered suitable for structural plywood (Wong 1985). Despite the capability of producing high quality structural plywood, many of the mills are still producing and exporting their products only as red-faced plywood or white-faced plywood. In this practice, the species and quality of the core veneer are generally not specified, and this results in plywoods of variable quality and strength properties (Wong, 1985). Therefore most Malaysian plywoods are being considered as normal utility plywood only.

The plywood industry in Malaysia are also geared towards producing plywoods according to the specifications drawn up by the purchasing countries. Therefore it is common for any particular mill to produce plywoods in just about any standard at any time. This does not mean that the products are inferior, but inconsistency in dimensions, species components, tolerance and performance among the mills' products are obvious.

Realizing this fact, many of the mills feel the need to upgrade the commercial value of their products by the support of reliable and consistent strength data which can only be achieved by following a certain specification on the production. Through their association i.e. The Malaysian Plywood Manufacturers Association (MPMA) and The Forest Research Institute of Malaysia (FRIM) they are interested to establish guidelines to develop a form of specification to standardize the plywood manufacture.

The Malaysian Standard (M.S) for Structural Plywood is in the process of being drawn up to guide the mills in producing plywoods that will be acceptable by most, if not all, purchasing countries. Being a developing country, Malaysia has the advantage of not repeating the process of establishing the best method of research as what were done by the developed countries. The British Standard B.S 6566 in grading of veneer is readily adopted to be a part of the M.S for structural plywood. The B.S specification is in many ways more stringent when compared to the American Plywood Association's (APA) Product Standard (PS), and being of mostly high quality, the Malaysian veneers easily comply or exceed the B.S.

To produce a practical and accurate standard, one needs to consider the individual mill capability, production technique change and specific species availability. On the other hand, a large number of strength tests needs to be done to give accurate values that can be confidently accepted by the users.

The steps in the development of the Malaysian Standard for Structural Plywood are as follows:

(1) Standardization of veneer grading that the mills will readily follow.

(2) Categorization of plywood species into structural groups.

(3) Preliminary testing of representative species from each structural group.

(4) Assignment of strength values for each structural group based upon statistical analysis.

(5) Recommendation of standard thicknesses, species structural groups and panel grades to the plywood industry.

(6) Confirmation tests on plywood produced using the recommended parameters.

(7) Draft of the standard to be distributed to the industry, government and professionals for comments.

(8) Publication of the standard after final corrections or amendments.

DEVELOPMENT OF THE MALAYSIAN STANDARD FOR STRUCTURAL PLYWOOD

Categorization of Species

Preliminarily, indicative tests to assess the strength of Malaysian structural plywood were planned to be performed on some selected species. But the multitude of species and species combination that could be used to produce any particular thickness of plywood led to the idea of categorizing the

Fig. 1: **CATEGORIZATION OF MALAYSIAN TIMBER SPECIES BY SPECIFIC GRAVITY AND RANKING BY MODULUS OF ELASTICITY**

STRUCTURAL I
(S.G 0.55-0.75)

	MOE N/mm^2
Kasai (Pometia spp.)	(2,200)
Simpoh (Dillenia grandiflora)	(2,080)
Balau, Red (Shorea spp.)	(1,990)
Gerutu (Parashorea spp.)	(1,920)
Kapur (Dryobalanops spp.)	(1,910)
Keruing (Dipterocarpus spp.)	(1,480)

STRUCTURAL II
(S.G 0.40-0.59)

IIA	MOE N/mm^2
Merawan (Hopea spp.)	(2,180)
Mengkulang (Heritiera spp.)	(1,990)
Mempisang (Monocarpia marginalis)	(1,880)
Meranti, White (Shorea spp.)	(1,840)
Bintangor (Calophyllum spp.)	(1,750)
Melantai (Shorea macroptera)	(1,640)
Kedundong (Canarium spp.)	(1,600)

IIB	MOE N/mm^2
Melunak (Pentace triptera)	(1,530)
Meranti, Yellow (Shorea spp.)	(1,520)
Kungkur (Pithecellobium confertum)	(l,510)
Meranti, Dark Red (Shorea spp.)	(1,470)
Nyatoh (Palaquim)	(1,420)*
Meranti, Light Red (Shorea spp.)	(1,350)*
Mersawa (Anisoptera spp.)	(1,340)
Durian (Durio oxyleyanus)	(1,250) *
Machang (Mangifera)	(970)

* Limited to species having S.G of 0.41

species into groups before the testing program was started.

Out of the thirty-six species that were recommended as suitable and moderately suitable for structural plywood, twenty-two species were chosen after considerations were made on their availability and practicality to be processed. These species were then categorized based upon their specific gravity into two major groups called the Structural I and Structural II (Fig. 1). The species in each group were then arranged from top to bottom according to their decreasing Modulus of Elasticity. Six common species were classed under Structural I and the rest in Structural II. Because of having relatively large number of species Structural II was further subdivided into two subgroups called the Structural IIA and Structural IIB.

One species from each group or subgroup was taken as the representative species to be tested. Keruing was taken to represent the Structural I group while Kedondong was taken to represent the Structural IIA group.

For Structural IIB, even though Machang was the weakest, it was thought that either Light Red Meranti or Mersawa should represent the subgroup since each contains variety of subspecies in addition to being the more common species processed in the mills.

These species ie. Keruing, Kedondong and Light Red Meranti or Mersawa were to be tested for their strength properties, and being in the weakest end of their appropriate groups, their strength would conservatively be representing the strength of the other species in the group.

TEST METHODS

For the purpose of establishing basic strength data seven mechanical testings were planned to be performed on the plywood samples. The tests were performed on small clear specimens to the methods stipulated in the American Society for Testing and Materials standards (Anon. 1988). The tests were as follows:-

Static Bending	-	ASTM D3043
Compression	-	ASTM D3501
Tension	-	ASTM D3500
Panel Shear	-	ASTM D2719
Rolling Shear	-	ASTM D2718

Shear Modulus - ASTM D3044

Toughness - ASTM D3499

The veneers for the panels to be tested were graded by the B.S 6566 method of veneer grading whereby veneers of Grade-E denotes the best grade with virtually no defects.

First four tests of the above were completed for the Keruing Grade-E and Mersawa Grade-E, 4.8mm 3-ply, plywoods at this stage. These tests were for both face grain parallel to span or force and face grain perpendicular to span or force where applicable.

RESULTS

The mean ultimate values of Mersawa Grade-E and Keruing Grade-E are as shown in Table 1.

Generally, Keruing plywoods which were having higher specific: gravity (S.G 0.72) were stronger than Mersawa (S.G 0.56) in all of the mechanical tests.

The strength of all the plywoods, regardless of their species, were higher when tested with the face grain parallel to direction of force or span as compared to face grain perpendicular to direction of force or span.

In static bending test, the extreme fiber stress or Modulus of Rupture (MOR) of Keruing was about 30% larger than Mersawa for both directions of face grain. When strength under static bending was compared between face grain directions, the MOR for face grain parallel to span was three times higher than MOR for face grain perpendicular to the span, and this was true for both species. The plywoods was also stiffer by about 17 to 18 times when force was introduced parallel instead of perpendicular to the face grain.

Comparing species to species for compression and tension tests, Keruing had maximum stresses that were between 26 to 32% higher than Mersawa when force was acted parallel to the face grain, and about 34 to 40% higher than Mersawa for force acted perpendicular to the face grain.

Under compression test alone, the maximum compressive stress in the direction parallel to face grain was higher by about 87 to 99% than the other direction for both species. While for tension test, the tensile strength in direction of the face grain was about 42 to 50% higher than tensile strength perpendicular to the face grain.

Table 1: Mean ultimate strength of 4.8mm 3-ply plywood

TEST	MERSAWA Grade-E		KERUING Grade-E	
	Direction of force to face grain or span			
	parallel	perpendi-cular	parallel	perpendi-cular
Static Bending				
MC %	11.60 (0.267)	11.23 (0.31)	11.73 (0.22)	11.5 (0.195)
SG	0.562 (0.0203)	0.557 (0.0151)	0.734 (0.0185)	0.716 (0.0233)
MOR N/mm^2	66.81 (6.68)	15.71 (2.59)	89.6 (6.78)	20.86 (3.66)
MOE N/mm^2	11,484.75 (1259.8)	639.16 (99.14)	15,083.5 (1034.8)	762.1 (144.2)
Compression				
MC %	11.13 (0.243)	11.31 (0.552)	11.56 (0.187)	11.55 (0.290)
SG	0.564 (0.0202)	0.552 (0.0176)	0.729 (0.018)	0.70 (0.020)
Max. Comp. Stress N/mm^2	25.35 (2.530)	12.73 (1.293)	33.51 (2.106)	17.93 (2.504)
MOE N/mm^2	3346.7 (710.5)	2071.41 (445.65)	5720.5 (965.2)	2499.8 (995.39)
Tension				
MC %	13.40 (0.163)	13.45 (0.1996)	13.17 (0.154)	13.23 (0.183)
SG	0.56 (0.017)	0.548 (0.0187)	0.72 (0.017)	0.701 (0.023)
Max. Tensile Stress N/mm^2	51.87 (8.26)	34.61 (6.34)	65.59 (9.59)	46.27 (9.08)
MOE	6675.4 (1130.2)	3917.5 (465.2)	9462.5 (2186.9)	5954 (1144.8)
Panel Shear				
MC %	9.75 (0.968)		10.32 (0.648)	
SG	0.561 (0.017)		0.720 (0.0186)	
Max. Shear Stress	7.595 (1.359)		7.988 (1.449)	

Note: Standard Deviation in parentheses

Only small difference was observed between Keruing and Mersawa when they were tested for their shear through the thickness strength. Panel shear strength for Keruing was about 7.988 N/mm^2 while Mersawa was 7.595 N/mm^2.

The deviation in strength values when force was acted perpendicular to face grain or span was usually high and could vary by as much as 20% around the mean value, and this was particularly true for the tensile strength test. Defects that might exist in the core could have affected the strength and caused the variation.

The variations in moisture content and specific gravity of the samples tested for every test were small except for panel shear test. Due to their irregular shape and size, the samples for panel shear test had to be conditioned in a bigger conditioning room where the relative humidity was difficult to control. The large variation in the R.H had caused large variation also to the moisture content of the samples. Nevertheless, the variation was only in the region of 6 to 10%.

DETERMINATION OF BASIC STRESSES

For the purpose of comparison between Malaysian hardwood plywood with other plywoods from different countries, the mean ultimate values in Table 1 were reduced to their basic stresses and moduli values. Due to lack of other research on Malaysian plywoods, the method of determining basic stresses for solid wood as stipulated in Malaysian Forest Service, Trade Leaflet No. 37 was adopted (Engku 1980).

Identical to solid wood, the definition for basic stress of plywood is "the stress which can safely be permanently sustained by plywood containing no strength reducing characteristics". The modification factors used were for the variability of strength and factor of safety.

To account for the variability of strength, the following probabilities and formulae were used:

Property	Probability	Formula
Bending	1 in 100	$\bar{x}$ - 2.33 S.D
Compression	1 in 100	$\bar{x}$ - 2.33 S.D
Panel shear	1 in 100	$\bar{x}$ - 2.33 S.D
Tension	1 in 100	$\bar{x}$ - 2.33 S.D

Factors of safety to account for items such as accidental overloading, errors in design assumptions, and mistakes in analysis and fabrication were as follows:

Property	Factor of Safety
Bending	2.5
Compression	1.5
Panel shear	2.5
Tension	2.5

The basic stresses for Mersawa Grade-E and Keruing Grade-E plywoods are as in Table 2.

Table 2: Basic Stresses for 4.8 mm 3-ply Malaysian Plywood

TEST	Mersawa Grade-E		Keruing Grade-E	
	Direction of force to face grain or span			
	parallel	perpendicular	parallel	perpendicular
Static Bending				
MOR (N/mm^2)	20.50	3.87	29.52	4.93
MOE* (N/mm^2)	11,484.75	639.16	15,083.50	762.10
Compression				
Max. Compressive Stress (N/mm^2)	12.97	6.48	19.07	8.06
Tension				
Max. Tensile Stress (N/mm^2)	13.05	7.94	17.30	10.05
Panel Shear				
Max. Shear Stress (N/mm^2)	1.77		1.84	

Note:MOE is taken as the mathematical mean

Table 3: Basic stress for plywoods from various countries

TEST	U.S PSI-74** (C-C STRESS GRADE) (8 mm 3 ply)		FINNISH BIRCH** (SANDED) (6.5 mm 5 ply)		CANADIAN DOUGLAS FIR** (Select and sheating grades) (7.5 mm 3 ply)	
	Direction of force to face grain or span					
	Parallel	Perpendicular	Parallel	Perpendicular	Parallel	Perpendicular
Static Bending						
MOR (N/mm^2)	11.4	3.50	19.0	9.79	11.6	2.78
MOE (N/mm^2)	10,750	900	10.750	4,000	12,350	850
Compression						
Max. Compressive Stress (N/mm^2)	7.63	3.97	8.95	5.63	7.99	3.22
Tension						
Max. Tensile Stress (N/mm^2)	5.22	3.20	14.9	7.79	5.13	2.14
Panel Shear						
Max. Shear Stress (N/mm^2)	1.73		3.51		1.82	

** extracted from BS 5268: Part 2: 1984

Note: Due to the different plywood thicknesses and grades, testing procedures, factors of safety and analysis theories (either full area or parallel ply theorem) amongst the countries, the values in Table 2 and 3 are only for strength and moduli indication of the plywoods and cannot be directly compared without proper balancing and judgement.

Table 3 shows the basic stresses for plywoods from other countries. Direct comparison between stress and modulus values from these countries cannot be done directly due to the different plywood thicknesses and grades, testing procedures, factors of safety and analysis theories. Australia and the U.S.A use the 'parallel ply theorem' for their analyses while U.K uses the 'full area' method. For the purpose of this paper the 'full area' method was adopted because it was quite impossible to get final thicknesses of the veneer plies after the cold pressing and hot pressing of the panel. However, these values are the indication of strength for Malaysian plywood at least for the 4.8 mm 3-ply construction. Strength data for other thicknesses and construction will be made by the use of the formulae already developed and will be confirmed by extra testings in the next level of this study.

Undoubtedly the modification factors used in deriving the basic stresses are necessarily conservative at this primary stage. A more refined basic stresses for Malaysian plywoods could be produced in the near future when modifications factors are derived by further researches on Malaysian plywoods.

CONCLUSION

Plywoods produced by Malaysian mills are of high quality but suffers downpricing due to lack of supporting data on strength and moduli. The Malaysian Standard for Structural Plywood is being drawn up to guide the local industry, and perhaps any plywood industry from the tropical region, into producing more consistent products that would gain confidence from the purchasing country.

Preliminary tests have shown that the Malaysian species currently used for plywood manufacture do have comparable or of even better strength than the plywoods made by other countries where the production of plywood is already standardized. The basic stresses presented here are conservative due to the still primary steps undertaken in the research on Malaysian plywoods.

The principal tests for Keruing and Mersawa have already given the indication of strength for the proposed Structural I and Structural IIB grades respectively. Even though the samples prepared for the testings were of one species panels, the manufacturers are not demanded to do same to acquire the basic strength for a particular strength group. They are free to mix species in the lay-up and the basic strength of the panel will be dictated by the weakest species. Although the weakest species would uneconomically to a certain extent be the single degrading factor to the other stronger species, the plywood panel could be confidently said to have the minimum strength for the particular strength group.

Secondary test for these plywood are ongoing and will later complement the tabulation of strength data for these structural grade plywoods. When more data are gathered it can be seen that being normally of hardwoods and naturally less occurrence of defects, the Malaysian plywoods are of superior strength compared to the softwood plywoods.

Thus, when further tests are completed, a practical and logical specification for production of Malaysian structural plywood including the basic strength data for the final product made to that specification would possibly be drawn up, and the already saleable Malaysian plywood can be accepted for structural use confidently.

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