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REGIONAL COCONUT WOOD TRAINING PROGRAMME

DU/RAS/81/110

Technical report: The grading of coconut palm sawn wood*

Prepared for the Governments of the countries participating in the regional project by the United Nations Industrial Development Organization, associated agency of the Food and Agricultural Organization of the United Nations, which acted as executing agency for the United Nations Development Programme

Based on the work of V. K. Sulc, wood technologist

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ABSTRACT

This paper describes the strength grouping and stress grading of commercial timber species. The individual strength groups are determined by limit-values of the following mechanical properties:

1. Modulus of Rupture (bending strength)
2. Modulus of Elasticity (stiffness)
3. Compression parallel to grain (crushing strength)
4. Shear strength (horizontal)
5. Density (specific gravity)

Coconut palm wood strength grouping and stress grading is based on Australian and Philippine systems.

Coconut palm sawn wood intended to be used as construction material has been assigned to appropriate strength groups on the basis of data obtained from standard small and full size specimen tests. The assignment to strength groups is described with tabulated details with its classifition to appropriate stress grade.

The proposed classification of coconut palm sawn wood to stress grades is on the conservative side. Selected material recovered in primary processing will permit classification to a higher level of stress grade due to higher bending values.

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1. STRENGTH GROUPING AND STRESS GRADING OF COCONUT PALM WOOD

Coconut palm wood is a relatively unknown species with considerable potential as a construction material. For this reason, it was necessary to test small clear and full size speciments to assess its properties.

The data obtained were used to assign coconut palm wood to strength groups using the Australian and Philippine strength grouping systems.

It is hoped that such information will have considerable impact on increasing its use in construction and that it will assist in creating a light timber frame construction code and in placing coconut palm wood in the national building standard and the National Structural Code for Building.

The following two chapters have been reproduced with minor alterations from the paper "Review of Timber Strength Grouping Systems" by W. G. Keating, Structures Section, Division of Chemical Technology, CSIRO, Highett, Victoria, Australia presented during the Expert Group Meeting on Timber Stress Grading and Strength Grouping, UNIDO, Vienna, Austria held from 14 to 17 December 1981. (UNIDO document ID/WG.359/4.) This sytem is now the basis of an Australian Standards document, MP45.

2. MOTIVATION FOR GROUPING

The degree of motivation for adopting a classification system based on structural properties varies directly with the number of species that are required to be accommodated. Without grouping, the problems involved are most obvious when it comes to publishing design information. Even if the data on a large number of species from a particular country were available, it is not often feasible to publish the relevant design information in a readily accessible form. This is where the use of grouping techniques makes such data presentation much easier.

The area of building regulations is one where grouping introduces advantages that are of particular value (Leicester, 1981a). Besides the obvious simplification regulations written in terms of groups rather than individual species have tables of design properties incorporated within them that remain fixed. This means that no major change is involved should a new timber be introduced on to the market or an existing one can be re-assessed. In Australia the SSA Timber Framing Code AS 1684 (Standards Association of Australia, 1979b) through a limited set of tables manages to present spans and sizes of all the timber framing members required in domestic housing construction applicable to all grades for several hundred species or species mixtures in a most convenient format.

Even in the case where a single species dominates the timber construction scene, grouping in relation to building regulations is advantageous. The structural properties of populations of timber taken from the same species, particularly with plantation timbers, can vary from one forest location to the next and.can also vary with forest age and silvicultural practices.

Transferring a species, or the production from one area, from one group to another is not nearly as complicated as promulgating a new or additional set of design stresses (Leciester, 1981a).

Internationally an agreed grouping technique could help timber utilization generally and have special relevance to the structural timber trade. The UNIDO Prefabricated Modular Wooden Bridge System is a good example of grouping applied to the world situation as the set of design standards based on eight strength classes is directly applicable for almost any timber in the world. It is not difficult to envisage how other examples of technology transfer in the form of timber design codes and manuals would be possible if an agreed or compatible grouping system for structural timber was in general use. The grouping technique has the following advantages:

(a) Building regulations are concerned with only limited sets of design parameters.

(b) Marketing of structural timber is easier as it is carried out in terms of structural properties rather than be nomination of the species and grading methods.

(c) More flexibility is available to the supplier as the range of species is much wider.

(d) The entry of new lesser-known species onto the market is facilitated.

(e) Trade, both internal and international, in structural timber is simplified.

(f) Technology transfer in the form of timber design codes and manuals is easier.

(g) It is much less expensive in time and material to place a species in a group than it is to develop individual working stresses.

(h) It is possible to group a species, albeit conservatively, based on density measurements alone.

3. EXISTING STRENGTH GROUPING SYSTEMS

3.1 Australia

Strength grouping in Australia has been in operation now for more than forty years. Langlands and Thomas (1939), in their Handbook of Structural Timber Design, proposed for Australian conditions four strength groups. A species was placed in a group according to its species mean values as determined from standard tests on small clear specimens. These strength groups were established when there was little information available about the properties of most Australian species and their successful use was possible only because the limits were not closely defined (Pearson 1965).

The impetus at that time to establish strength groups came, as it does now, from the need to cope with a large number of species, many of which are difficult to identify and many are also marketed as mixtures.

The original Australian strength grouping system was revised and expanded as has been explained by Pearson (1965) and Kloot (1973). Prior to the expansion of the strength groups, made necessary to cope with new information and new species, Pearson developed a set of working stresses that has now become the basis for a strength classification system.

Working back from the set of working stresses, it was then possible to develop the appropriate strength groups. This process is the reverse of the usual procedure for deriving working stresses for an individual species allowing for duration of load, accidental overloads and estimating the 1 per cent probability point.

In the development of this set of stresses, Pearson reported that three decisions were required. Firstly, it was necessary to decide whether the stresses should be in arithmetic or geometric progression. Secondly, a compromise was required on the magnitude of the differences between successive stresses in order to achieve a satisfactory balance between simplicity associated with having only a few groups and the greater efficiency associated with numerous groups. Finally, the actual value of the stresses had to be decided.

Cooper (1953) had shown the merits of a geometric serious for working stresses and such a choice had also been recommended by the International Organization for Standardization (ISO) and the Food and Agriculture Organization (FAO). Accordingly, such a choice was made using a preferred number series with adjacent terms chosen in the ratio of 1.25 to 1 for Modulus of Rupture. This was judged to be the appropriate compromise between simplicity and preciseness. Also, as appeared certain, the Australian visual grading rules then being developed would probably have differences between grades also of 25 per cent. The range of the values chosen was such that it covered all the species likely to be used structurally in Australia.

TABLE 1

DESIGN PROPERTIES FOR SAWN TIMBER, ROUND POLES AND PLYWOOD

Stress* grade	Basic bending strength (MPa)**	Basic tension strength (MPa)	Basic compression strength (MPa)	Modulus of elasticity (MPa)
F34	34.5	20.7	26.0	21 500
F27	27.5	16.5	20.5	18 500
F22	22.0	13.2	16.5	16 000
F17	17.0	10.2	13.0	14 000
F14	14.0	8.4	10.2	12 500
F11	11.0	6.6	8.4	10 500
F8	8.6	5.2	6.6	9 100
F7	6.9	4.1	5.2	7 900
F5	5.5	3.3	4.1	6 900
F4	4.3	2.6	3.3	6 100
F3	3.4	2.1	2.6	5 200
F2	2.8	1.7	2.1	4 500

* The insertion of the letter F before each value in the Table introduces the concept of stress grade. Stress grade is defined as the classification of a piece of timber for structural purposes by means of either visual or mechancial grading to indicate primarily the basic working stress in bending in megapascals for purposes of design and by implication the basic working stresses for other properties normally used in engineering design. For example, a piece of timber with a stress grade of F14 resulting from a certain combination of strength group and visual grade would have a basic working stress in bending of 14 megapascals.

** These values are the result of a soft metric conversion of a preferred series of values in imperial units viz. 5000, 4000, 3200, 2500, 2000, 1600, 1250, 1000, 800, 630, 500, 400 p.s.i., readily recognisable as the R10 series.

Using the set of values decided upon as the basic working stresses in bending, the values of the other properties were determined from regression equations.

From this technique has developed Table 1 (page 5), which is the basis of the current Australian strength classification system.

As described above, the species mean values for clear material for each strength group for the critical properties were developed for green and dry timber and are shown in Tables 2 and 3 respectively.

TABLE 2

PRELIMINARY CLASSIFICATION VALUES FOR UNSEASONED* TIMBER

Property	Minimum species mean						
	S1	S2	S3	S4	S5	S6	S7
Modulus of rupture (MPa)	103	86	73	62	52	43	36
Modulus of elasticity (MPa)	16300	14200	12400	10700	9100	7900	6900
Maximum crushing strength (MPa)	52	43	36	31	26	22	18

*As measured or estimated at a moisture content above fibre saturation point.

TABLE 3

PRELIMINARY CLASSIFICATION VALUES FOR SEASONED* TIMBER

Property	Minimum species mean							
	SD1	SD2	SD3	SD4	SD5	SD6	SD7	SD8
Modulus of rupture (MPa)	150	130	110	94	78	65	55	45
Modulus of elasticity (MPa)	21500	18500	16000	14000	12500	10500	9100	7900
Maximum crushing strength (MPa)	80	70	61	54	47	41	36	30

*As measured or adjusted to a moisture content of 12 percent.

TABLE 4
RELATIONSHIP BETWEEN STRENGTH GROUP, VISUAL GRADE AND STRESS GRADE FOR GREEN TIMBER

Visual grade*		Stress grade						
Nomenclature	% strength of clear material	S1	S2	S3	S4	S5	S6	S7
Structural grade No.1	75	F27	F22	F17	F14	F11	F8	F7
Structural grade No.2	60	F22	F17	F14	F11	F8	F7	F5
Structural grade No.3	48	F17	F14	F11	F8	F7	F5	F4
Structural grade No.4	38	F14	F11	F8	F7	F5	F4	F3

* Australian Standard AS 2082-1977, Visually stess-graded hardwood for structural purposes; and AS 1648-1974, Visually stress-graded cypress pine for structural purposes.

Note the interlocking effect (diagonal line) reducing a possible 28 stress grades to 10.

TABLE 5

RELATIONSHIP BETWEEN STRENGTH GROUP, VISUAL GRADE AND STRESS GRADE FOR SEASONED TIMBER

Visual grade*		Stress grade							
Nomenclature	% Strength of clear material	SD1	SD2	SD3	SD4	SD5	SD6	SD7	SD8
Structural grade No.1	75		F34	F27	F22	F17	F14	F11	F8
Structural grade No.2	60	F34	F27	F22	F17	F14	F11	F8	F7
Structural grade No.3	48	F27	F22	F17	F14	F11	F8	F7	F5
Structural grade No.4	38	F22	F17	F14	F11	F8	F7	F5	F4

* Australian Standard AS 2082-1977, Visually stress-graded hardwood for structural purposes; AS 2099-1977, Visually stress-graded seasoned Australian grown softwood (conifers) for structural purposes (excluding radiata pine and cypress pine); AS 1490-1973, Visually stress-graded radiata pine for structural purposes; and AS 1648-1974, Visually stress-graded cypress pine for structural purposes.

By use of Tables 2 and 3, every species that had been or was capable of being properly sampled and tested by standard methods using small clear specimens may be strength grouped. Once strength grouped, commercial pieces of that species can, following visual grading, be allocated a stress grade by reference to Tables 4 and 5.

From Table 1 the apprcpriate design parameters may be determined.

Because of international agreement on the standard methods of test for small clear specimens, it is possible to utilize data from recognized laboratories anywhere in the world to place any species into a strength group. This has been done for 700 African (Bolza and Keating, 1972), 190 South American (Berni et al., 1979) and 362 South-East Asian species (Keating and Bolza, 1982).

One assessment that is often required in classifying a species from Tables 2 and 3 (Page 6) is what to do when the three properties do not all have the same classification. A conservative apprcach would be to assign the species to the lowest group indicated from the individual properties. This must apply for many combinations, but there are several for which raising the overall species strength group one step above the lowest assessment is deemed justified.

Positive strength classification is based on individual critical properties which are:

Modulus of Rupture

Modulus of Elasticity

Compression strength parallel to grain

whose values are first classified spearately by comparing the species' mean values for the above-listed properties for each group in Tables 2 and 3.

3.1.1 Positive strength classification based on the combination of properties

When all three above-listed properties in green or seasoned condition have the same classification, the species is assigned to that "S" (green) or "SD" (air dry) group. When the three listed properties do not have all the same classification, a conservative approach would be to assign the species to the lowest group obtained from the individual properties. There is justification using the overall species' strength group one step above the lowest assessment.

The assignment of a species to a strength group one step above the lowest group from individual properties gives more emphasis on Modulus of Rupture and Modulus of Elasticity than on compression strength (crushing strength).

(a) When the lowest group is obtained from Modulus of Rupture, then the overall species' strength group may be raised one step above the minimum group, only if the Modulus of Elasticity is in group at least two steps and compression strength at least one step above the minimum.

(b) When the lowest group is obtained from Modulus of Elasticity, then the overall species' strength may be raised one step above the minimum group, only if the Modulus of Rupture is in a group at least two steps and the compression strength in a group at least one step above the minimum.

(c) When the lowest group is obtained from the compression strength, then the overall species' strength group may be raised one step above the minimum, only if both the Modulus of Elasticity and Rupture are in the group at least one step above the minimum.

Table 6 (page 11) summarizes the procedure that is followed indicating that more emphasis is placed on Modulus of Rupture and Modulus of Elasticity than on compression strength.

TABLE 6

COMBINATIONS OF PRELIMINARY CLASSIFICATION THAT PERMIT THE OVERALL STRENGTH GROUP ASSESSMENT TO BE ONE STEP ABOVE THE LOWEST IN THE COMBINATION

Preliminary classification based on -			Assessed S or SD strength group
Modulus of rupture	Modulus of elasticity	Maximum crushing strength	
x	x	x + 1	x
x	x - 2	x - 1	x - 1
x	x + 2	x + 1	x + 1

Note: Strength group x - 1 is stronger than strength group x, e.g., if strength group S4 is denoted by x then strength group S3 is denoted by x - 1.

Example:

If the lowest strength group is obtained from Modulus of Rupture as a dominant parameter,

Then:

If the given species mean unseasoned wood properties values are:

Modulus of Rupture 58 MPa then it is assigned to Group S5 (see Table 2, page 6) and denoted as "x".

Modulus of Elasticity 8,500 MPa then it is assigned to Group S6 and denoted as "x + 1".

Maximum crushing strength 27 MPa then it is assigned to Group S5 and denoted as "x".

Then:

As Modulus of Elasticity is one group lower than S6 and maximum crushing strength is in the same group S5, the given species is classified to group S5. See paragraph "Positive strength classification based on the combination of properties" (page 9).

TABLES 7a & 7b

MINIMUM AIR DENSITY VALUES FROM 5 OR MORE TREES FOR ASSIGNING SPECIES TO STRENGTH GROUPS IN THE ABSENCE OF ADEQUATE STRENGTH DATA.

(a) Unseasoned Material - Green (Moisture Content above 30%)

Strength Group	S1	S2	S3	S4	S5	S6	S7
Air dry density* at 12% MC (kg/m^3)	1180	1030	900	800	700	600	500

(b) Seasoned Material - Air Dry (Moisture Content - approximately 12%)

Strength Group	SD1	SD2	SD3	SD4	SD5	SD6	SD7	SD8
Air dry density* at 12% MC (kg/m^3)	1200	1080	960	840	730	620	520	420

3.1.2 Extension of the grouping technique

(a) Joints

It has been found that grouping is also a very useful technique in developing the basic loads applicable to metal fasteners (Mack, 1978). When revised, the Australian Timber Engineering Code will be using the following classification system based on basic and air-dry density as shown in Table 8.

TABLE 8

PROPOSED MINIMUM DENSITY FOR JOINT STRENGTH GROUPS

Green timber		Seasoned timber	
Group	Basic density (kg/m^3)	Group	Air-dry density* (kg/m^3)
J1	750	JD1	940
J2	600	JD2	750
J3	475	JD3	600
J4	380	JD4	475

* Density at 12% moisture content after reconditioning.

(b) Poles

From Tables 4 and 5 (pages 7-8) it can be seen that if the product under consideration had only one visual grade and one moisture condition then a much simplified new table would be possible. This is the case with poles if they are graded to the Australian Standard.

On the basis of a large pole testing programme carried out by the Commonwealth Scientific and Industrial Research Organization (Boyd, 1962) poles from mature trees are considered to be in a single grade, the next above 75 per cent grade. As poles are normally regarded as unseasoned, then Table 4 (page 7) leads to Table 9 below.

TABLE 9

CORRESPONDENCE BETWEEN STRENGTH GROUP AND STRESS GRADE FOR ROUNDED TIMBERS GRADED TO AS 2209-1979

Strength group	Stress grade
S1	F34
S2	F27
S3	F22
S4	F17
S5	F14
S6	F11
S7	F8

NOTE: The equivalence expressed is based on the assumption that poles or logs are from mature trees.

3.2 Philippines

In the Philippines a system has been developed that is very similar to the Australian strength grouping system in that it is based on the results of small clear tests and adopts a preferred number progression with an interval of 1.25 between the base numbers (Espiloy, 1977). However, it was judged that there was no need to cover the same range so only five groups have been chosen. The advantages of the grouping system according to Espiloy, are:

(a) Each member species within a class can substitute for the other, thus in a way overcoming the problem of supply.

(b) The traditional bias against the lesser known species is easily overcome when these are grouped together with the more common species. Hence, this system will help engineers and architects familiarize themselves with alternate species by specifying that any timber within a given class may be used instead of specifying the timbers by name.

(c) It will overcome the problem that is usually encountered in identifying sawn timber of similar physical strength characteristics.

(d) Grouping will simplify design and specification procedure and thus facilitate the formulation of a comprehensive building code for structures using solid wood. The grouping scheme will form a rational series that will fit closely with timber grades. With this system only a few sets of working stresses are adequate to cover the proposed strength classes and grades of timber.

The limiting average values for classifying a species into one of the strength classes, C1 to C5, are given in Table 10 (page 15).

TABLE 10

MINIMUM STRENGTH-CLASS LIMITS FOR GROUPING PHILIPPINE TIMBER SPECIES

Property	Moisture condi-tion	Class of timber				
		C1	C2	C3	C4	C5
Modulus of rupture in bending (MPa)*	Green	78.4	61.7	49.0	39.2	30.9
	12% MC	122.5	98.0	78.4	61.7	49.0
Modulus of elasticity in bending (MPa)	Green	12740	9880	7546	5880	4508
	12% MC	15680	11760	9310	7154	5488
Compression parallel to grain (MPa)	Green	39.2	29.9	23.0	18.1	13.7
	12% MC	63.7	49.0	37.7	29.4	22.5
Compression perpendicular to grain (MPa)	Green	8.82	5.49	2.5	2.21	1.37
	12% MC	13.2	8.82	5.68	3.68	2.4
Shear parallel to grain (MPa)	Green	9.8	7.8	6.17	4.9	3.92
	12% MC	13.7	10.8	8.33	6.37	4.9
Specific gravity	Green	0.870	0.545	0.450	0.365	0.300
	12% MC	0.710	0.580	0.475	0.385	0.315

* Based on weight when oven-dry and volume at test.

4. COCONUT PALM WOOD CLASSIFICATION

4.1 Australian strength grouping system

Standard small specimens

Moisture condition: Unseasoned

TABLE 11

STANDARD SPECIMEN ULTIMATE MEAN VALUE

Density group	Modulus of rupture	Modulus of elasticity	Compression // to grain	Strength group
kg/m^3	MPa	MPa	MPa	
600 and above	86	10857	49	S3
400 to 599	53	6880	31	S6

Density group 600 kg/m^3 and above:

Modulus of Rupture	86 MPa	is assigned to S2
Modulus of Elasticity	10856 MPa	is assigned to S4
Maximum crushing strength	49 MPa	is assigned to S2

(See Table 2, page 6)

Group strength is determined as follows:

(Table 6 and positive strength classification based on combination of properties, page 11).

Modulus of Rupture = x - 2
Modulus of Elasticity = x
Maximum crushing strength = x - 2

Therefore, assigned to Stress Group S3.

Similarly, for seasoned timber:

Moisture condition: Seasoned

TABLE 12

STANDARD SPECIMEN ULTIMATE MEAN VALUE

Density group	Modulus of rupture	Modulus of elasticity	Compression // to grain	Strength group
kg/m³	MPa	MPa	MPa	
600 and above	104	11414	57	SD5
400 to 599	63	7116	38	SD8

4.2 Philippine strength grouping system

The Philippine grouping system has no provision for the strength classification based on the combination of properties. Usually more emphasis is given to the value of Modulus of Rupture and Modulus of Elasticity than the values of compressions. The system is intended for use with results from testing small clear specimens, hence the following are indicative only of strength class.

Classification of the coconut palm wood

Moisture condition: Green

Density group: 600 kg/m^3 and above

TABLE 13

FULL SIZE SPECIMEN (STATIC TEST ONLY, OTHER PROPERTIES OBTAINED FROM THE STANDARD TEST) CLASSIFIED TO MINIMUM STRENGTH CLASS LIMITS

Property	Type of Test	Ultimate Mean Value in MPa	Class of Wood	Moisture Condition
Modulus of rupture	Full size	54.5	C2	22%*
Modulus of elasticity	Full size	10760	C3	22%*
Compression // to grain	Standard	49.0	C1	Green
Compression ⊥ to grain	Standard	8.3	C2	Green
Shear // to grain	Standard	10.4	C3	Green
Specific gravity .70 g/cm^3	-	-	C2	-

* Partly dry not adjusted to green condition.

Density group 600 kg/m^3 and above could be assigned to C2 based on the value of Modulus of Elasticity or to C3 which is based on the value of Modulus of Rupture. The final classification depends on which properties are considered. See Table 10 (page 15).

Density group: 400 to 599 kg/m^3

TABLE 14

FULL SIZE SPECIMEN (STATIC TEST ONLY, OTHER PROPERTIES OBTAINED FROM THE STANDARD TEST) CLASSIFIED TO MINIMUM STRENGTH CLASS LIMITS

Property	Type of Test	Ultimate Mean Value in MPa	Class of Wood	Moisture Condition
Modulus of rupture	Full size	35.10	C5	22%
Modulus of elasticity	Full size	7020	C4	22%
Compression // to grain	Standard	31.00	C2	Green
Compression ⊥ to grain	Standard	2.85	C3	Green
Shear // to grain	Standard	6.15	C4	Green
Specific gravity .50 g/cm^3	-	-	C2	-

Density group 400 to 599 kg/m^3 could be classified to class C4 based on the value of Modulus of Elasticity or to class C5 based on the value of Modulus of Rupture.

Moisture condition: Air dry

Density group: 600 kg/m^3 and above

TABLE 15

AIR DRY STANDARD SMALL SPECIMEN VALUE CLASSIFIED TO MINIMUM STRENGTH CLASS LIMITS

Property	Type of Test	Ultimate Mean Value in MPa	Class of Wood	Moisture Condition
Modulus of rupture	Standard	104.00	C2	12%
Modulus of elasticity	Standard	11414	C2	12%
Compression // to grain	Standard	57.00	C2	12%
Compression ⊥ to grain	Standard	9.03	C2	12%
Shear // to grain	Standard	13.39	C2	12%
Specific gravity .70 g/cm^3	-	-	C2	-

Density group 600 kg/m^3 and above could be classified to C2.

Density group: 400 to 599 kg/m^3

TABLE 16

AIR DRY STANDARD SMALL SPECIMEN VALUE CLASSIFIED TO MINIMUM STRENGTH CLASS LIMITS

Property	Type of Test	Ultimate Mean Value in MPa	Class of Wood	Moisture Condition
Modulus of rupture	Standard	63.00		12%
Modulus of elasticity	Standard	7116	C4	12%
Compression // to grain	Standard	38.00	C3	12%
Compression ⊥ to grain	Standard	3.42	C5	12%
Shear // to grain	Standard	7.96	C4	12%
Specific gravity .49 g/cm^3	-	-	C4	-

Density group 400 to 599 kg/m^3 could be classified to C4.

5. STRESS GRADE CLASSIFICATION OF COCONUT PALM WOOD

The following stress grade classification is based on the Australian strength and stress grading.

As has been described before, the coconut palm sawn wood is divided into three density groups from which higher density group (BD 600 kg/m^3 and above) and medium density group (BD 400 to 599 kg/m^3) are usable as construction materials. A third group (BD below 400 kg/m^3) is not recommended as a structural material.

The following tables are arranged by density groups and represent mean values obtained from the standard and full size specimen tests:

Unseasoned (green) standard small specimens	Tables 17 and 18
Seasoned (air dry) standard small specimens	Tables 19 and 20

5.1 Description of terms used in the tables

Unit stress

Unit stress is determined from the average ultimate values obtained from a test data as described in section "Standard small specimens test" (page 16).

Unit stress or as sometimes called "basic stress" represents a stress value of a piece of wood free o. any strength reducing characteristics.

Basic working stress or stress grade

Basic working stress is a classification of a piece of wood to be used as a construction material with adjusted stress value to permissible defect (strength reducing characteric) allowed in the particular stress grade. E.g., basic working stress grade 75 is a value of the unit stress reduced by 25 per cent in a piece of wood that contains defects liable to reduce its strength up to 25 per cent. In grade 60, unit stress is reduced by 40 per cent, etc.

Strength ratio

The reducing factor 25 or 40 per cent, etc., is called strength ratio and can be defined as the ratio of basic working stress or stress grade to unit stress.

Australian stress grade classification system for a structural wood omits the use of a grade description as Grade 75, Grade 60 or select standard, etc.

The stress grade is designated by description as "F11" or "F8" or "F5", etc., which indicates that with such grade of wood the basic working stress in bending in minimum 11 or 8 or 5 MPa (megapascal). See Table 1 (page 5).

5.2 Application to coconut palm construction wood

Stress grade classification:

TABLE 17

STANDARD SMALL CLEAR SPECIMEN DATA
GREEN COCONUT PALM WOOD DENSITY GROUP 600 KG/M^3 AND ABOVE
ULTIMATE MEAN VALUE, UNIT STRESS AND BASIC WORKING STRESS GRADE 75 IN MPa

	Bending and Tension // to grain	Compression // to grain	Compression ⊥ to grain (CSLP)*	Shear		Modulus of elasticity	
				in beams	in joints	Mean	Minimum
Ultimate Test Value table 1	86.00	49.00	8.30	10.04 1/		10857	8466
Unit Stress	25.67	20.62	6.26	2.35	3.0	10857	8466
B.W.S.** Grade 75	19.25	15.46	6.26	1.76	3.0	10857	8466

Coconut palm wood has relatively low Modulus of Elasticity as compared with bending stress. Therefore, conservative choice has been taken in stress grade classification.

Bending stress value for basic working stress grade 75 - (19.25 MPa) permit to be assigned to F11.

Modulus of Elasticity value 10857 MPa is assigned to stress grade F11. See Table 1 (page 5).

1/ Standard deviation 2.04
* Crushing strength at limit of proportionality
** Basic working stress grade 75 (75 per cent strength of clear material)

TABLE 18

STANDARD SMALL SPECIMEN DATA
GREEN COCONUT PALM WOOD DENSITY GROUP 400 TO 599 KG/M^3
ULTIMATE MEAN VALUE, UNIT STRESS AND BASIC WORKING STRESS GRADE 75 IN MPa

	Bending and Tension // to grain	Compression // to grain	Compression ⊥ to grain (CSLP)*	Shear in beams	Shear in joints	Modulus of elasticity Mean	Modulus of elasticity Minimum
Ultimate Test Value table 1	53.00	31.00	2.85	6.15		6880	4423
Unit Stress	11.33	9.12	2.14	1.38	1.73	6880	4423
B.W.S.** Grade 75	8.49	6.84	2.14	1.04	1.73	6880	4423

The bending stress value will permit Grade 75 to be assigned to F7. Modulus of Elasticity value is slightly below F5, therefore recommended classification is stress grade F5.

TABLE 19

STANDARD SMALL CLEAR SPECIMEN DATA
AIR DRY COCONUT PALM WOOD DENSITY GROUP 600 KG/M^3
ULTIMATE MEAN VALUE, UNIT STRESS AND BASIC WORKING STRESS GRADE 75 IN MPa

	Bending and Tension // to grain	Compression // to grain	Compression ⊥ to grain (CSLP)*	Shear in beams	Shear in joints	Modulus of elasticity Mean	Modulus of elasticity Minimum
Ultimate Test Value table 1	104.00	57.00	9.03	13.39 1/		11414	8258
Unit Stress	29.91	27.19	6.77	3.03	3.87	11414	8258
B.W.S.** Grade 75	22.43	20.39	6.77	2.27	2.90	11414	8258

1/ Standard deviation 2.04
* Crushing strength at limit of proportionality
** Basic working stress grade 75 (75 per cent strength of clear material)

The air dry standard test of coconut palm wood has high value of bending stress and relatively low Modulus of Elasticity. The recommended assignment is to stress grade F11 which represents Modulus of Elasticity value.

TABLE 20

STANDARD SMALL CLEAR SPECIMEN DATA
AIR DRY COCONUT PALM WOOD DENSITY GROUP 400 TO 599 G/M^3
ULTIMATE MEAN VALUE, UNIT STRESS AND BASIC WORKING STRESS GRADE 75 IN MPa

	Bending and Tension // to grain	Compression // to grain	Compression ⊥ to grain (CSLP)*	Shear		Modulus of elasticity	
				in beams	in joints	Mean	Minimum
Ultimate Test Value table 1	63.00	38.00	3.42	7.96		7116	4902
Unit Stress	13.60	12.48	2.56	2.18	2.78	7116	4902
B.W.S.** Grade 75	10.20	9.36	2.56	1.64	2.08	7116	4902

The value of bending stress will permit assignment to stress grade F8. Modulus of Elasticity value is assigned to F5. Recommended classification is to stress grade F5.

* Crushing strength at limit of proportionality
** Basic working stress grade 75 (75 per cent strength of clear material)

5.3 Classification of coconut palm construction wood for joint design

In general, strength group classification of different species for a joint design correlates closely with the basic density of wood due to the close correlation between desntiy of wood and its corresponding strength properties

Coconut palm sawn wood intended for construction wood and classified to density group:

600 kg/m^3 and above is proposed to be assigned to	J3
400 to 599 kg/m^3 is proposed to be assigned to	J4

NOTE: Conservative classification to the above joint groups could be the subject of further review. Using density as a guide, classification could be higher, namely, J2 and J3 respectively.

Wood species of basic density below 400 kg/m^3 are not recommended for construction use and consequently fabrication of joints. The same rule applies to coconut palm wood.

6. CONCLUSIONS

The considerable variation in the physical and mechanical properties of coconut palm wood made the conclusive classification to stress grade difficult. The proposed stress grade classification is more o less on the conservative side.

The data obtained from the full size specimen test is recommended to be used in preference to data obtained from the small specimen test:

Density group 600 kg/m^3 and above graded to basic working stress 75 is recommended to be classified to F11.

Density group 400 to 599 kg/m^3 grade to basic working stress 75 is recommended to be classified to F5.

The above stress grades value apply to green (unseasoned) wood which is usually used and recommended for light framing construction purposes.

Air dry or kiln dry coconut palm construction wood

For special designs such as laminated exposed beams, it is necessary to season wood to the required moisture content. Particular care should be taken when making structural glued joints.

It is recommended that classification based on stress grade should be used in the same way as for unseasoned wood.

In many coconut palm growing countries, the average equilibrium moisture content (EMC) is relatively high (in the Philippines EMC fluctuates between 14 to 17 per cent). The fibre saturation point is lower for coconut palm wood than for most of the conventional timbers, and has been estimated to be between 21 and 24 per cent depending on the specific gravity. Therefore, there is a smaller difference between saturation point and the moisture content of wood in service.

The proposed stress grade for the higher density group 600 kg/m^3 and above could be supplemented by special limited stress grade F14 if the wood is obtained from the butt section of fully mature and selected palms. and if MOE is not the limiting factor in use.

7. REFERENCES

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