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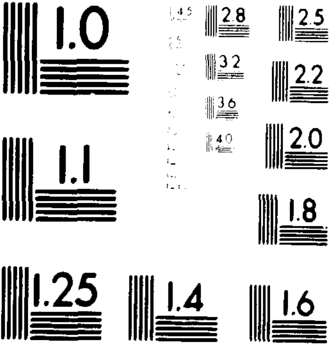

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS
STANDARD REFERENCE MATERIAL 1010a
(ANSI and ISO TEST CHART No. 2)

eturn to Laura Muthsam
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14187
(1 of 3)

STRESS GRADING RULES

for

TROPICAL HARDWOODS

and

CONIFERS.

REVIEW OF EXISTING STRENGTH GROUPING

and

STRENGTH CLASSIFICATION SYSTEMS

3064

Contract between

UNIDO United Nations Industrial Development Organisation

and

TRADA Timber Research And Development Association

January 1984

REVIEW OF EXISTING STRENGTH GROUPING

and

STRENGTH CLASSIFICATION SYSTEMS

INTRODUCTION

In an exercise to make recommendations for a strength grouping system acceptable for international adoption by UNIDO for work in developing countries, a review of existing major strength grouping and strength classification systems in the world was made. From this review, it appears that many countries have either adopted the Australian system of strength groupings or have used it as the basis for developing their own system.

Some of the well known grouping systems such as those used in North America were not discussed in this report as they were mainly concerned with a comparatively small number of softwood species.

Strength grouping

Due to the multiplicity of timber species involved in many countries, it has long been a problem to present structural timber data to the end-user in an appropriate fashion. A technique devised to minimise this problem is grouping. Where the structural species of timber used in a country are easily identifiable, and few in number, it may be appropriate that specific structural design properties be published for each of these species. However, in many countries, numerous species are used and it is not practicable to have long lists of design data. Rather it is preferable to group the timbers and to provide structural design properties for a limited number of strength groups. In general each strength group will cover a large number of species and commercial mixtures of species.

The use of a limited number of strength classifications is of considerable value to the designer as it enables him to specify timber by a strength group rather than by species. This makes it possible to have a wider choice of timbers to select from for any specific design. For the producer it assists in the utilisation of lesser-known species which may be sporadic and regionally limited in their occurrence.

Essentially, grouping for structural purposes means the creation of a preferably small set of hypothetical species so that any timber may be grouped within this set and considered as equivalent to one of the hypothetical species. It has been mentioned by Keating (1982) that it would appear many countries have either adopted the Australian system of strength grouping as described by Pearson (1965) and Kloot (1973) or have used it as the basis for developing their own systems. Some of the countries are Kenya, Tanzania, Nigeria, Papua New Guinea, Fiji, Samoa and Solomon Islands. Of course there are many other systems in use, but most of the well known ones, such as those used in North America, are in the main, concerned with a comparatively small number of softwood species.

Existing Strength Grouping Systems

In preparing this section a considerable amount of information was gathered from publications by W.G. Keating and R.H. Leicester, both from CSIRO Australia and references to their work are given at the end.

In Australia, strength grouping methods have been developed over a period of some 40 years and formalized through a set of building standards (Standards Association of Australia 1979a, 1979b, 1979c, 1980a, 1980b) Information on strength grouping in other countries is given in publications prepared for ISO (Larsen 1978), Africa (Okigbo, unpubl.; Campbell and Malde 1970; Comben 1971; Bolza and Keating 1972; Ward 1974), Malaya (Burgess 1956; Engku Abdul Rahman Bin Chik 1972), Singapore (Singapore Timber Standardisation Committee 1966), Philippines (Espiloy 1978), Indonensia (Suparman Karnasudirdga et al, 1978; Iding Kartasujana and Abdurahim Martawijaya, undated), Laos (Timber Research and Development Association 1976), Papua New Guinea (PNG Department of Forests 1972; Eddowes 1977; undated; Bolza 1975), Fiji (Anon. 1968, 1970), South-east Asia (Bolza and Keating 1981), South America (Berni et al, 1979) and the United Kingdom (Sunley 1979).

a) Australia

The original strength grouping system in Australia was proposed for four strength groups by Langlands and Thomas (1939) in their Handbook of Structural Timber Design. This system was revised and expanded by Pearson (1965) and Kloot (1973) due to the availability of new information and new species. Working back from a set of working stresses developed by Pearson which has now become the basis for a strength classification system, it was then possible to develop the appropriate strength groups. 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 reference 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 series for working stresses and such a choice had also been recommended by the International Organisation for Standardization (ISO) and the Food and Agriculture Organisation (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 mechanical 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.

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	181

* 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 stress-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 2 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 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 appropriate design parameters may be determined.

Because of international agreement on the standard methods of test for small clear specimens, it is possible to utilise data from recognised 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).

In classifying a species from Tables 2 and 3 it is often necessary to decide what to do when the three properties do not all have the same classification. A conservative approach 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.

The assignment of a species to a strength group above the lowest group obtained from individual properties places more emphasis on the modulus of rupture and the modulus of elasticity than on compression strength. The procedure applied is detailed hereunder and summarized in Table 6 and may be any of the numbers 1 to 8 in S1 to S7, or SD1 to SD8. In all other cases, the lowest of the three separate assessments is assigned as the species grouping.

(a) If the lowest group is that obtained from the modulus of rupture, then the overall species strength group may be raised one step above that minimum group only if the modulus of elasticity is in a group at least two steps, and the compression strength in a group at least one step, above the minimum.

(b) If the lowest group is that of the modulus of elasticity, then the overall species strength group may be raised one step above that minimum 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 that minimum.

(c) If the lowest group is that 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 rupture and the modulus of elasticity are in a group at least one step above that minimum.

This leaves those species for which the strength data available are from less than a valid sample, assessed as a minimum of five trees, or is just not available at all. A recent examination by Leicester and Keating (1981) of the relationship between density and modulus of rupture of seasoned timber for 30 species from each of four regions around the world is indicated in Figure 1.

On the basis of this relationship, the following table was constructed to permit a classification to take place. This gives a rather conservative assessment, but at least it does allow those species with limited data to be entered into the system. In the Australian Standard MP 45-1979, Report on Strength Grouping of Timbers, species assessed in this fashion are listed with their strength groups in brackets to indicate the provisional nature of the assessment.

(b) United Kingdom

In the United Kingdom, a system of strength classes for solid timber has been provided for the first time in the British Standard BS 5268 "Code of Practice for the structural use of timber" Part 2 : 1984. The system classifies timbers and species combinations whose grade stresses are similar to one of nine strength classes. The strength classes, which are designated SC1 to SC9 (in ascending order of strength), enable designers to select a suitable class and to use its assigned stress values in structural calculations without making a final choice of timber, species combination or grade. For special cases where it is preferable, the code still gives strength properties for individual timbers and grades. Strength classes SC5 to SC9 form mainly the denser hardwoods and have stresses which progress in a geometrical series.

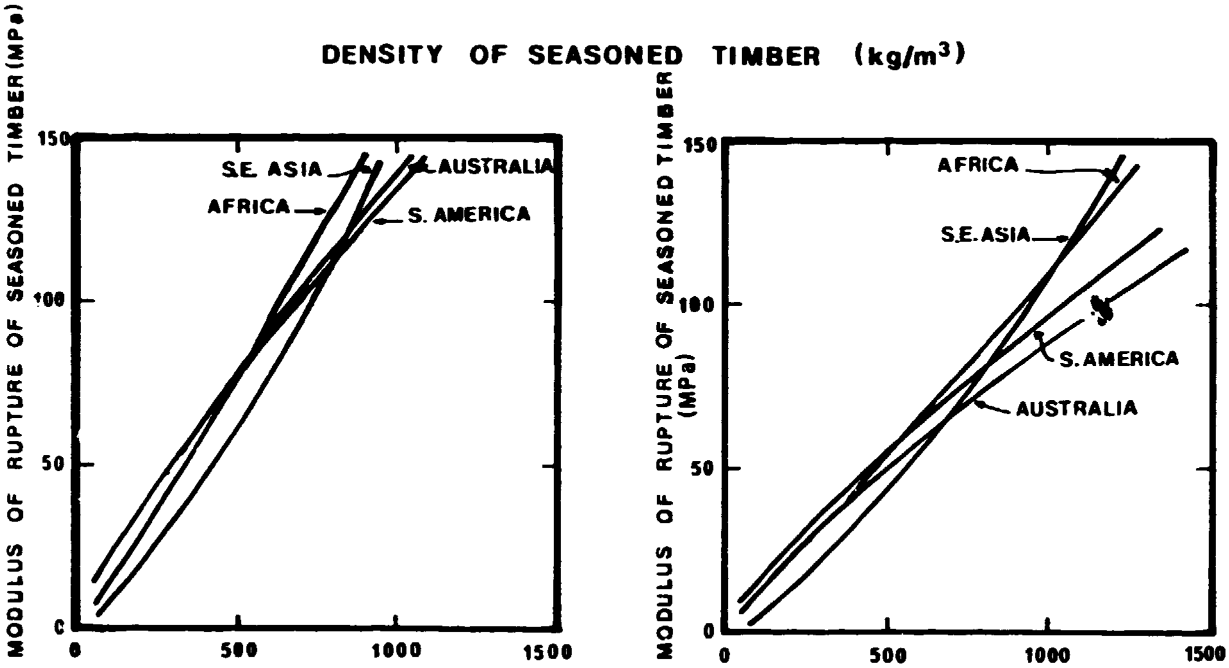

Figure 1: Regression lines for Modulus of rupture versus density of seasoned timber.

TABLE 6

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

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

TABLE 7

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

(a) Unseasoned Material

Strength Group	S1	S2	S3	S4	S5	S6	S7
Air-dry density at 12 percent moisture content (kg/cbm)	1180	1030	900	800	700	600	500

(b) Seasoned Material

Strength Group	SD1	SD2	SD3	SD4	SD5	SD6	SD7	SD8
Air-dry density at 12 percent moisture content (kg/cbm)	1200	1080	960	840	730	620	520	420

Grade stresses for the dry exposure condition, as defined in BS5268: Part 2 are tabulated for nine strength classes which is given in Table 8. When basing a design on strength classes, the material specification should indicate clearly the strength class required. Conditions arise where it may be advisable to limit choice of material through considerations other than strength. In SC5, both softwoods and hardwoods are combined.

Procedure adopted for softwoods

It was considered that establishing strength class boundaries on the basis of a mathematical progression, results in a system which is inefficient for many of the commonly used species/grades. Because of the wide variety of structural component types, sizes and spans it is also impractical to tie the class boundaries to increments of structural component design. The current (draft) BS5268 is to make the class boundary strength values match the major species/grades used in the UK. Whilst this ensures the most efficient use of these species/grades inevitably others are penalised. However, for those species which can be machine graded, machine settings can be produced which will enable a more efficient approach by grading directly to the strength class boundaries. The strength for species/grades are ranked on the basis of bending strength. Taking into account the strength values of the major species/grades used in the UK, bending stress values of 10.0, 7.5, 5.3, 4.1 and 2.8N/sq.mm. were given for classes SC5 to SC1 respectively. Class values for the other properties were taken from the lowest value for species/grades combinations with bending stress values equal to or greater than the bending value for that class. An exception to this was made where the lowest value of a particular property would have penalised the remaining species/grades in that class too severely. An example of this is the demotion of SS grade British grown spruce to the C2 class because of its low modulus of elasticity values. Species/grades were admitted to a strength class if their bending stress values were equal to or greater than the class value and their values for other properties exceeded 95 per cent of the class values.

For softwoods, there are two visual grades, namely GS -General Structural and SS -Special Structural visually graded to BS4978: 1973 "Timber grades for structural use" and the grade ratios for these two grades are 0.35 and 0.50 of the bending stress respectively.

Procedure adopted for hardwoods

Procedure adopted for strength grouping of hardwoods in BS5268: 1984 is based on the Australian system.

It was noted that the relation between strength properties and dry nominal specific gravity of the species related to the BS5268 hardwoods was very similar to the relationships obtained by the Australians. Due to this close similarity the values given in SAA MP45 would be applicable to the types of tropical hardwood required for inclusion in BS5268. The derivation of basic and grade stresses for BS5268 has been described in detail by Mettem (1981, 1982). Since these stresses were derived using different factors and also due to different assumptions appearing in the code, it would not be appropriate to simply adopt the Australian basic working stresses for hardwood strength classes in the British code.

TABLE 8: GRADE STRESSES AND MODULI OF ELASTICITY FOR STRENGTH CLASSES: FOR THE DRY EXPOSURE CONDITION

Strength class	Bending parallel to grain	Tension parallel to grain	Compression parallel to grain	Compression perpendicular to grain		Shear parallel to grain	Modulus of elasticity		Approximate density
	Grade Stresses						Mean	Minimum	
	(N/sq.mm)	(N/sq.mm)	(N/sq.mm)	(N/sq.mm)	(N/sq.mm)	(N/sq.mm)	(N/sq.mm)	(N/sq.mm)	(kg/cu.mm)
SC1	2.8	2.2	3.5	2.1	1.2	0.46	6800	4500	540
SC2	4.1	2.5	5.3	2.1	1.6	0.66	8000	5000	540
SC3	5.3	3.2	6.8	2.2	2.7	0.67	8800	5800	540
SC4	7.5	4.5	7.9	2.4	1.9	0.71	9900	6600	590
SC5	10.0	6.0	8.7	2.8	2.4	1.00	10700	7100	590/760
SC6	12.5	7.5	12.5	3.8	2.8	1.50	14100	11800	840
SC7	15.0	9.0	14.5	4.4	3.3	1.75	16200	13600	960
SC8	17.5	10.5	16.5	5.2	3.9	2.00	18700	15600	1080
SC9	20.5	12.3	19.5	6.1	4.6	2.25	21600	18000	1200

Preliminary classification values for seasoned (ie 12 percent m.c.) timber and corresponding values for unseasoned material (above saturation point - assumed as an average of 25 percent for timbers of this type) were adjusted for stresses to the dry moisture condition (18 percent). Table 9 shows the final strength classes and their corresponding strength values which after rounding off, appear in Table 8 (BS5268: 1984). The earlier table does not indicate values for tension and shear parallel to the grain. For tension a ratio of 0.6 of the grade stress in bending has been applied and this procedure has been carried through in the case of all the strength class tension stresses. For shear, an ad hoc ranking procedure was applied , listing the hardwoods in ascending order of individual HS grade shear stress (graded to BS5756: 1980) within the classes into which they fell because of other properties and choosing a convenient series in steps of 0.50 or 0.25N/sq.mm.

For tropical hardwoods visually graded to BS5756: 1980 "Specification for tropical hardwoods graded for structural use", there is only one structural grade which is HS (Hardwood Structural) with a grade ratio for bending of 0.67.

(c) Philippines

The strength grouping system developed in the Philippines is very similar to that in Australia where the system 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 (Epsiloy, 1978). However, it was judged that there was no need to cover the same range as the Australian system, so only five groups have been chosen. The advantages of the grouping system according to Epsiloy are:

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

(2) 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 alternative species by specifying that any timber within a given class may be used instead of specifying the timbers by name.

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

(4) 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. The figures quoted are the minimum values of strength class limits for the different properties. These have been derived from the regression equations relating modulus of rupture (MOR) with major strength properties; and from various relationships, sets of strength values of MOR in the preferred number series were assigned to obtain the strength limits of other properties. The results were then rounded off to fit in the suitable series.

TABLE 9

UNROUNDED VALUES OF GRADE STRESSES8 AND MODULI OF ELASTICITY
FOR STRENGTH CLASSES FOR TROPICAL HARDWOODS TO HS GRADE OF BS5756

Strength class **	Strength group +	Bending parallel to grain	Compression parallel to grain	Modulus of elasticity	
				Mean	Minimum
SC5	S5	10.53	10.68	12308	10289
SC6	S4	12.62	12.48	14098	11786
SC7	S3	14.81	14.28	16216	13556
SC8	S2	17.48	16.69	18666	15605
SC9	S1	20.52	19.58	21570	18032

* dry exposure condition
** BS5268: Part 2
\+ SAA MP45: 1979

TABLE 10: MINIMUM STRENGTH CLASS LIMITS FOR

Property	Moisture condition	C1
Modulus of rupture in bending (kg/sq.cm)+	Green 12% MC	800 1250
Modulus of elascicity in bending (1000 kg/sq.cm)	Green 12% MC	130 160
Compression parallel to grain (kg/sq.cm)	Green 12% MC	400 450
Compression perpendicular to grain (kg/sq.cm)	Green 12% MC	900 1135
Shear parallel to grain (kg/sq.cm)	Green 12% MC	100 140
Specific gravity*	Green 12% MC	0.670 0.710

+ 1kg/sq.cm = 0.098 MPa
* Based on weight when oven-dry and volume at test

GROUPING PHILIPPINE TIMBER SPECIES

Class of timber			
C2	C3	C4	C5
630	500	400	315
1000	800	630	500
100	77	60	46
120	95	73	56
305	235	185	140
500	385	300	230
560	255	225	140
900	580	375	245
80	63	50	40
110	85	65	50
0.545	0.450	0.365	0.300
0.560	0.475	0.385	0.315

(d) South America

Five South American countries, Bolivia, Columbia, Ecuador, Peru and Venezuela under the auspices of the Andean Pact have in recent years undertaken a comprehensive testing programme aimed at developing a set of grade rules and a strength grouping system applicable to the region. This was the subject of a detailed report by Centeno (1978). In this the advantages of a strength grouping system are stated as follows:

(i) it permits the introduction of a large number of new, little-used species to the building industry;

(ii) it allows a more homogeneous, balanced and rational exploitation of the forest;

(iii) it allows the limitation or elimination of the vices implicit in the selective exploitation of a few precious species;

(iv) it drastically simplifies the use and commercialization of wood as a construction material.

As a result of the above study, these five countries have agreed on a single visual grading rule for structural hardwood and a strength grouping system comprising three strength groups. The working stresses derived for each strength group were arrived at after taking cognizance of both the results available from small clear testing of 72 species and the testing of approximately 1500 beams of structural size timber representing more than 30 species.

The proposed working stresses for the three strength groups are as given in Table 11. These values are derived by taking the lowest 5th percentile value for the group. The minimum modulus of rupture values are then divided by 2.1 to account for accidental overload and the effect of duration of load; a further reduction of 10 per cent is applied to account for a further size effect. The modulus of elasticity values are the averages taken directly from the tests without further modification.

For a new species to be classified under the proposed system it is recommended that at least 60 beams be tested in third point bending and that the 5th percentile MOR values (modified as above) and the mean MOE values be used to determine the correct strength group by direct comparison with the Table. A species may be allowed in a particular group when these parameters are no more than 10% lower than the values indicated.

During the course of the testing programme it was observed that basic density was a good indication of strength and as a consequence basic density is now proposed as a method of positioning a species in a group on a preliminary basis. The limits selected taking a conservative approach were as given in Table 12.

An interesting approach taken in the development of the single visual grading rule was that the limits set on size and location of defects should permit an average mill to produce 50-60% of acceptable structural material. The remainder of the mill output would normally be suitable for non-structural applications in housing such as sheathing and joinery.

TABLE 11

PROPOSED WORKING STRESSES (kg/cbm)* (Centeno, 1978)

Group	F. Flexure	Fc Comp. Para.	Ft Tens. Para.	Fp Comp. Perp.	Fv Shear Beams	Fv Shear Joints	E Modulus of Elasticity Eo.5	E Modulus of Elasticity Eo.05
A	220	170	160	60	20	25	140	110
B	170	130	120	45	16	20	120	95
C	130	100	90	30	12	15	90	70

* 1 kg/cbm = 0.098 MPa

TABLE 12
LIMITS FOR BASIC DENSITY (gm/cbm)
FOR EACH STRENGTH GROUP

Group	Basic Density *
A	0.76 and above
B	0.60 - 0.75
C	0.44 - 0.59

As a consequence to the acceptance of the above system, a Timber Construction Manual has been produced and industry has expanded as is evidenced by the establishment of nine factories producing prefabricated houses in the five countries concerned and the construction of a wood/cement panel plant in Ecuador. It is noteworthy that the various governments support the rules and are incorporating them into the relevant building codes.

The incentives for the Andean Pact countries to develop a stress grading and grouping syste, was the assistance it would provide in overcoming the serious housing shortages, the need to utilize a valuable resource and the need to create employment.

(e) Mexico

In Mexico (Davalos, 1981), development of a simplified set of grading rules is close to being finalised. The 50 PINUS species in use throughout the country have for convenience been treated as a single species group. A large in-grade testing programme (5000 full-sized pieces) is in progress to determine the appropriate working stresses for the two grades of structural timber considered necessary. Up until now, North American grading rules have been used but their validity has been queried prompting the above testing programme.

The proposed grading rules have been framed so that, on average, mill output would be 30 per cent in the top grade, 40 per cent into the second grade with the remainder going into non-structural applications. If this break-down can be reflected throughout the country there would be sufficient production to fulfill the needs of the local market.

The tentative design values based on the tests to date for the two suggested grades of pine are given in Table 13.

Investigations are also under way in an attempt to obviate the need for visual grading. A TRU-grader has been purchased from South Africa and is currently being evaluated in the field.

(f) Malaysia

In Malaysia it is usual to market timber in parcels of mixed species of similar properties under one trade name. These species are often indistinguishable from one another.

At present the system of strength grouping adopted in Malaysia is to place structural timbers into four strength groups denoted by A, B, C and D in order of decreasing compressive strength (Burgess, 1956). In deciding the position of the timber in the group, bending strength had also been considered. When these strength groups were established little information was available on the properties of some Malysian timbers and the working stresses were based on the weakest species in a particular group.

The placing of the species in the group is determined by their green and dry basic stresses. By necessity the minimum basic and grade stresses for the weakest species will determine the basic and grade stresses for the group. Tables 14 and 15 give the green and dry basic and grade stresses for the strength groups respectively. The timber is graded according to the "Malayan Grading Rules for Sawn Hardwood Timber".

TABLE 13

TENTATIVE DESIGN VALUES FOR MEXICAN PINE (kg/cbm) *

Grade	Bending		Mean M of E x 10cu
	Single	Load sharing	
A	140	160	115
B	80	90	90

* 1 kg/cbm = 0.098 MPa

TABLE 14

GREEN STRESSES AND MODULI OF ELASTICITY FOR MALAYSIAN STRENGTH GROUPS
(Stresses and moduli expressed in lbf/in sq.)

Strength Group	Grade	Bending and tension parallel to grain	Compression parallel to grain	Compression perpendicular to grain	Shear parallel to grain	Modulus of elasticity	
						Mean	Minimum
A	Basic	3 000	2 500	250	400	2 000 000	1 250 000
	Select	2 400	2 000	210	280		
	Standard	1 850	1 550	200	220		
	Common	1 500	1 250	180	180		
B	Basic	2 500	2 000	150	300	1 600 000	900 000
	Select	2 000	1 600	120	210		
	Standard	1 500	1 250	120	160		
	Common	1 250	1 000	110	130		
C	Basic	1 800	1 400	100	200	1 300 000	750 000
	Select	1 400	1 100	85	140		
	Standard	1 100	850	80	110		
	Common	900	700	75	90		
D	Basic	1 100	950	60	200	830 000	450 000
	Select	850	750	50	140		
	Standard	650	550	45	110		
	Common	550	470	40	90		

TABLE 15

DRY STRESSES AND MODULI OF ELASTICITY FOR MALAYSIAN STRENGTH GROUPS
(Stresses and moduli expressed in lbf/in sq.)

Strength Group	Grade	Bending and tension parallel to grain	Compression parallel to grain	Compression perpendicular to grain	Shear parallel to grain	Modulus of Elasticity	
						Mean	Minimum
A	Basic	3 660	3 230	280	470	2 140 00	1 400 000
	Select	2 900	2 550	230	330		
	Standard	2 300	2 000	220	260		
	Common	1 800	1 600	210	210		
B	Basic	2 880	2 330	180	310	1 700 000	950 000
	Select	2 300	1 850	150	220		
	Standard	1 800	1 450	140	170		
	Common	1 400	1 150	130	130		
C	Basic	2 100	1 600	110	210	1 350 000	600 000
	Select	1 650	1 250	90	150		
	Standard	1 300	1 000	80	110		
	Common	1 050	800	80	90		
D	Basic	1 400	1 200	90	200	950 000	450 000
	Select	1 100	950	75	140		
	Standard	800	750	70	110		
	Common	700	600	65	90		

TABLE 16

DENSITY CLASSIFICTION FOR TIMBER

density class	minimum characteristic value of density (kg/cbm)
D 800	780
D 600	630
D 500	500
D 400	400
D 300	300

For design purposes, 5-percentiles related to density classes are given in Table 2.

(g) International Standards Organisation

Working group (WGI)of the International Standards Organisation Technical Committee (ISO TC/165) has produced a draft on Structural Grouping of Timber. This will incorporate the strength classifications given in the Timber Design Code which has been produced by CIB Working Group (W18) on timber structures.

Basis for grouping

The following are the two factors that will be used for grouping of timber with respect to its structural properties.

(i) Grouping based on the density of dry clear wood

(ii) Grouping based on the structural properties of stress graded timber elements containing natural defects

ISO system adopted in the Working Group (WGI 1983) is stated in terms of characteristic values that can (if desired) be measured directly by simple laboratory tests. Consequently this type of system has the potential to remain invariant and the characteristic values chosen for the above document are five percentile values.

Structural configurations have been deferred for each characteristic value because of the variability introduced by the occurrences of natural defects.

Table 16 shows the minimum acceptable characteristic values of density for timber classified according to the density. For design purposes 5-percentiles related to density classes are given in Table 17.

The target 5-percentile values of the structural properties of solid timber classified according to grade are given in the Table 18. If the measured property profiles do not line up exactly with the values shown in Table 18, then the classification rules given in Table 4 should be applied.

Classification into grade classes

In the application of Table 19 to classify stress graded solid timber the structural properties of the timber may be determined directly by the methods described in the ISO draft standard ISO/TC165 N688 "Timber Structures: Solid Timber in Structural Sizes: Determination of some Physical and Mechanical Properties"; or the properties may be assessed through indirect methods based on correlations with other structural characteristics. In all cases, the properties to be used for classification purposes are assessed with at least 75 per cent confidence.

NOTATION

D800, ..., D300	- density classes
Eo	- Modulus of elasticity chracteristic value
fm	- bending strength paralle to the grain, characteristic value
fc,o	- compression strength parallel to ghe grain, characteristic value
fc,90	- compression strength perpendicular to the grain, characteristic value
ft,o	- tension strength parallel to the grain, characteristic value
ft,90	- tension strength perpendicular to the grain, characteristic value
fv	- shear strength in beams, characteristic value
fvj	- local shear strength for design of joint details, characteristic value
T75, ..., T5	- grade classes for solid timber and poles.

TABLE 17

CHARACTERISTIC VALUES RELATED TO DENSITY CLASS

density class	5-percentiles, MPa					
	green timber			dry timber (characteristic values)		
	ft,90	fc,90	fv,j	ft,90	fc,90	fv,j
D800	1.10	6.8	10.0	0.65	10.1	15.0
D600	0.85	4.5	7.0	0.50	6.8	10.0
D500	0.65	3.0	4.5	0.40	4.5	7.0
D300	0.40	1.3	2.0	0.25	2.0	3.0

TABLE 18

CHARACTERISTC VALUES RELATED TO GRADE CLASS, FOR SOLID TIMBER

grade class	5-percentiles (MPa)				
	fm	ft,0	f,,0	fv	Eo
T75	75.0	54.0	52.0	5.2	12,200
T60	60.0	44.0	43.0	4.6	10,600
T48	48.0	34.0	36.0	4.0	9,300
T38	38.0	26.0	30.0	3.5	8,100
T30	30.0	20.0	25.0	3.5	7,000
T24	24.0	15.5	21.0	2.6	6,100
T19	19.0	11.8	17.5	2.3	5,300
T15	15.0	9.1	14.5	2.0	4,600
T12	12.0	7.0	12.0	1.7	4,000
T10	9.5	5.4	10.0	1.5	3,500
T8	7.5	4.1	8.4	1.3	3,000
T6	6.0	3.2	7.0	1.1	2,600
T5	5.0	2.5	5.8	1.0	2,300

EO,mean = 1.4 EO

Gmean = 0.095 Eo

TABLE 19

CLASSIFICATION RULES FOR GRADE CLASSES

Preliminary grade classification for each design parameter				resultant assigned grade class for the timber
fm	ft,0	fc,0	Eo,mean	
T	T	T	T	T
T	T	T-1	T+1	T
T+1	T	T-1	T-1	T

T+1 denotes one grade class higher than T

Other countries

There are several other countries, such as Papua New Guinea, Solomon Islands, Fiji, etc., that have strength grouping systems similar to or based on the Australian system. In Tanzania, a strength grouping system with seven groups (A to G) has been in existence since 1970. (Cambell & Malde, 1970). Timber Research and Development Association (TRADA), UK in connection with a wood working project sponsored by UNIDO in 1976 drew up a strength grouping system with 3 groups for Laos timbers and a set of stress grading rules having only one grade equivalent 63 percent of the basic bending stress (air dry).

In other developed countries such as Canada, USA, etc. grouping techniques are used for a small number of species and they are mainly for softwoods.

In considering a fundamental system for bringing timbers into strength groups on the basis of their small clear properties, the Australian system detailed in SAA MP 45 is well documented and established, has been applied to a large range of timbers from many parts including less developed countries, and is fully appropriate to UNIDO's requirements. It is therefore the obvious choice.

Stresses published in design codes to form the basis of permissible values for design differ from the properties associated with small clear strength groups. Most industrialized timber-using countries and quite a number of less-developed countries have national stress grading rules. Sets of simplified model rules for tropical hardwoods and for conifers have also been proposed within the scope of this project. Such rules should form the basis of future UNIDO field projects, and also possibly further developments in the form of guidance documents.

The terms used for the 'safe working stress' values published in codes differ, unfortunately, according to the country considered. Those to be mentioned in this section dealing with recommendations are the 'grade stresses' as defined in BS 5268, Part 2, 1984 and the 'stress grades' given in AS 172, SAA Timber Engineering Code. It is recommended that design in accordance with either of these codes, or their successors in the light of revisions, should be encouraged when experts and consulting organisations are engaged by UNIDO in future timber projects.

Occasions may arise when special local considerations suggest the use of other design recommendations. These might for example be those given in the Junta del Acuerdo de Cartagena (Andean Pact) timber design manual or the US National Design Specification for Wood Construction. Both of these examples are thoroughly applicable to the types of timber enginering design that might be considered in UNIDO projects. Unfortunately however the basis of the classifications and species combinations which they contain are so different from the systems discussed under British and Australian standards that they must remain separate options rather than documents whose good features can be isolated and brought into special use in UNIDO projects. They are either used in their entirety or not at all. Nor can it be recommended at this stage that international developments such as the timber design code which has been produced by the CIB Working Group W18, or the ISO TC/165 draft recommendations on strength grouping are sufficiently mature or prescriptive documents to enable them to be used in in projects in less developed countries where only scant information on the performance of the materials available may be to hand.

The recommendation to use either the British or the Australian code may seem insuffficiently decisive, but this is not in fact the case, since as explained elsewhere, if the basic strength group of a timber is known according to the methodology of SAA MP 45, then either strength class stresses according to BS 5268, or 'grade stresses' according to AS 1720 can be determined. This will be particularly easy if the recommended UNIDO simplified grading rules are adopted in work for the organisation, in which case the procedures explained elsewhere in the papers relating to this project will be followed. If it is a matter of indifference whether the Australian or the British code be adopted for a particular project, then it is recommended the latter be chosen, since the system is simpler, relating only to five strength groups, and having only nine classes, rather than seven groups and twelve stress grades in the Australian case.

ACKNOWLEDGEMENT

In preparing this document, a great deal of information was extracted from the paper published by Keating, W.G. (1982). Review of Timber Strength Grouping Systems, Expert Group Meeting on Timber Stress Grading and Strength Grouping, UNIDO, Vienna, Austria.

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(2 of 3)

STRESS GRADING RULES

for

TROPICAL WOODS

and

CONIFERS

RECOMMENDATIONS FOR NATIONAL TRAINING PROGRAMMES AND QUALITY ASSURANCE

Contract between

UNIDO United Nations Industrial Development Organisation

and

TRADA Timber Research and Development Association

January 1984

MODEL GRADING RULES FOR TROPICAL TIMBER - RECOMMENDATIONS FOR NATIONAL TRAINING PROGRAMMES AND FOR QUALITY ASSURANCE

The adoption by a country of the model rules for the stress grading of tropical timber will need to be followed by two further steps for the implementation of these rules to achieve the objectives intended.

1) A programme of information and encouragement to specifiers and users to adopt stress graded timber in their construction projects

2) The training of stress graders and continuing surveillance of their grading so that users will have a reliable supply of properly graded timber available to them.

This paper concerns the second of these activities. It is considerably influenced by TRADA's own experience of responsibility for both training and quality assurance in the United Kingdom but does not blindly follow TRADA's UK practice.

The dependable quality of visually stress graded sawn timber can be assured by:

1) correct training and initial certification of graders

2) continuing re-examination of graders as to their competence

3) quality control of the grading process exercised by the producing company

4) independent surveillance of the quality of grading of the company's output

A question to which different countries may find different answers is that of responsibility for the various activities described in this paper.

This paper presumes the establishment of an Inspection Agency which will provide a team of inspectors who will carry out the essential activities of periodically re-examining graders as to their competence and carrying out random or batch inspections on a sampling basis. Inspectors should preferably be certificated graders with experience of commercial grading, but this will be difficult to ensure in the early days of the agency's operations. It is strongly recommended that senior inspectors from this team should act as examiners for the initial examination of graders and it is suggested that inspectors should be available to producing companies who would otherwise have difficulty in arranging for the internal quality control of their graders' work. It is possible also that inspectors could provide a commercial grading service in appropriate circumstances provided that their inspection function has priority. This grading service would be particularly useful and economical in the early days of stress grading in any country.

The question of who should provide training is a very open one. Most countries will have existing colleges or institutes which could provide such training and it is thought that it would normally be cost effective to use suitable existing establishments. The effectiveness of this training can be coordinated on a national basis by the use of senior inspectors from the Inspection Agency as examiners. The examiners should liaise with training staff to ensure nationally consistent standards, and more specifically, the suitability of timber stocks used for examination purposes. It would of course be possible for the Inspection Agency itself to provide training.

Inspection Agencies are likely to be national agencies though it is possible that they should be based on smaller areas such as States or convenient geographical areas, in which case their activities should be coordinated by a committee established on a federal or national basis.

It is important to appreciate that grading is a production process. The grader is not an inspector checking on the quality of a prior process. He is himself carrying out a process that has not previously been carried out. For this reason the graders activities need to be the subject of internal quality control and this is the reason for the inclusion of 3) above.

Since it will generally be the companies that make potential graders available for training, and since it is companies that have to take commercial responsibility for the quality of their production, it seems logical that the governmental or quasi-governmental agency responsible for the surveillance of timber grading should deal with the companies rather than with graders individually. This recommendation also has the merit of reducing quite considerably the bureaucratic process involved.

The general framework of the overall training and quality assurance process is accordingly seen as follows:

a) potential graders are made available by companies for training along with other personnel who need to appreciate the grading process, the training being carried out by an appropriate college or institute.

b) all personnel taking the training course are examined at the end of the course and receive a personal certificate if they are successful in passing the examination. Copies of the certificate are passed to the company and the quality assurance agency.

c) companies register with the Inspection Agency those personnel intended to be active graders and provide these graders with the status and practical recognition that their new duties justify. Only certificated graders should be allowed to grade constructional timber.

d) companies arrange internal procedures to monitor the performance of their graders and may make use of agency inspectors to assist this process. It is suggested that any such assistance should be provided at cost to the company whether or not other agency activities are partly or wholly charged to companies,

e) the Inspection Agency will arrange for the periodic re-examination of all registered graders by their inspectors

f) procedures should be established for companies to inform the Inspection Agency when timber being supplied to official contracts will be available for batch inspection or when there has been release or despatch of stress graded stocks for sale for general constructional use.

A problem associated with the surveillance of visual grading is that there are strong commercial pressures not to carry graded stocks and for individual requirements to be graded on demand. For this reason it may be very likely that inspectors will find few stocks on which to make random checks when visiting companies. For this reason emphasis is placed on both the re-examination of graders as to their competence and on the notification to the agency of the availability of quantities of graded timber for inspection. The agency may decide whether or not to carry out an inspection of any particular quantity of timber that has been notified to them. The notification of small quantities of graded timber may be excused.

Where grading is being carried out at the original sawmill, rather than at some depot or elsewhere, it is more likely that the stress grading of constructional sizes will be carried out regardless of the availability of orders and prior to the allocation of timber to specific orders. It may be possible to encourage the stress grading of all such appropriate specific sizes by generally excusing such companies from batch inspection procedures in favour of the periodic random unannounced inspection of graded stocks by agency inspectors.

Training

Most stress grading experience has been in the context of softwoods and the combined effect of the profusion of knots and the small diameter of many softwood logs results in grading rules having to be comparatively complex in order to deal adequately with the problem of the reduction of strength due to knots. The same problem is met in the case of coniferous timbers grown in tropical countries and also in the case of plantation grown hardwoods such as the eucalypts which may be harvested as soon as they reach a size providing a reasonable yield of construction timber.

For this reason separate grading rules are supplied for tropical hardwoods and conifers, the main distinction being the treatment of knots which can be simpler in the case of tropical hardwoods (excluding plantation grown hardwoods as indicated above).

In both cases the rules are based on a surface measurement approach to knots as opposed to the so called knot area ratio method. This choice results in grading rules that will seem simpler to most people and the result of this decision is likely to be a greater examination pass rate rather than a reduction in the time taken for training.

The rules for tropical hardwoods are significantly simpler as regards knots since these are of limited occurrence in trees from natural forests. On the other hand interlocked grain is a problem in many tropical hardwoods species since this can be confused with slope of grain.

Obviously, the time required for training courses will depend to a considerable extent on the levels of intelligence and ability of those chosen for training. This will vary from country to country and the availability of suitable jobs for higher educated people in rural areas is likely to be a key factor. TRADA agrees with the findings of the Expert Group Meeting in December 1981 that trainees should have had practical experience in a sawmill and that a minimum educational level shoud be satisfied. Alternatively, a suitable aptitude test might be developed to screen people who might not benefit from training.

Broadly, it is TRADA opinion that the simplest requirement, namely to grade tropical hardwoods species from natural forests, could be achieved within a full six day working week in the most favourable of circumstances. The rules for coniferous timbers would require the equivalent of two to three weeks. The Expert Group were thinking in terms of 5 - 6 weeks and it may be found in some circumstances that this length of time will be needed. However, it is TRADA's recommendation that no course should be of more than 3 weeks duration unless problems are found.

Training at TRADA is normally of two weeks duration and it has always been found convenient in the circumstances of the UK to provide a lapse of four to eight weeks between the two weeks of the training course. It is thought to be quite practicable but marginally less satisfactory to provide the training in two consecutive weeks.

An exam should be held on the last day of every course and this should be partly written and partly practical. The written part of the examination is more appropriate to the establishment of the candidate's essential understanding of grading, while the practical part of the examination establishes his ability to put this understanding into practice. A purely practical examination is likely to favour those candidates with good short-term memory who may be able to achieve a pass without having an essential understanding of the principles.

The syllabus and the timetable of the training should be made to suit the requirements of those who are intended to be active company graders, though many others in the timber and construction industries who require a good working knowledge of grading should find the course useful for their needs also. There will probably also be benefit to be obtained from a short appreciation course for management and sales personnel but in this case there is no need for an examination at the end of the course and there should be no question of any certificate being granted.

The syllabus of a full course should be along the following lines:

1) Assembly and administrative introduction

2) Wood, the material and its mechanical properties; recognition of species

3) Background to stress grading

4) Introduction to the grading rules appropriate to the course

5) Defects other than knots and their measurement and assessment (in the case of tropical hardwoods interlocked grain will need special attention and the rules regarding brittleheart may need mention)

6) Practical exercises on defects other than knots

7) Knots, the different types (this need only be quite brief in the context only of tropical hardwoods from the natural forest)

8) The measurement and assessment of different types of knot

9) Practical exercises on knots

10) Introduction to the two different grade rules

11) General grade rules

12) Practical exercises on General grades

13) The Special grade rules

14) Practical exercises on Special grades

If the course is split into two separate periods of time then this is the point at which there should be a review of stress grading techniques and an individual check of comprehension prior to the break. After the break there should be a recapitulation of theory and practical techniques and then:

15) Practical exercises in groups

16) Practical exercises as individual graders

17) Mock examination

18) Examination

Instruction should be restricted to the circumstances appropriate to each situation. For example, there should be no training given in the grading of conifers if these are not available commercially to the companies employing the graders. The syllabus and duration of a course will need to be related to the circumstances, and need be no longer than these circumstances dictate.

Practical experience shows that it is not possible to organise successful courses on the basis of timber stocks generally to be found in timber yards with little or no selection. Timber for training purposes needs to be carefully chosen to illustrate the principles involved and the examination stock should be selected so as to avoid ambiguous results. The selection of these stocks is time consuming and cannot be seen to be practical in the context of a single course to be held at a sawmill or similar venue where repeat courses in the foreseeable future are unlikely. This is a serious logistical constraint and leads TRADA to question the opinion of the Expert Group that courses should be held at sawmills. It might of course be possible for a college or institute to run courses at a conveniently located sawmill rather than at their own premises, but the idea of running courses at a number of mills to minimise travel and to suit the convenience of the industry has to face this problem of suitable timber stocks.

Periodic re-examination of graders

It is considered that graders should be re-examined periodically as to their competence even when considerable quantities of the graders' work may be subject to random or batch inspections. While it may be argued that a grader who produces results that satisfy regular inspections need not be the subject of any further check, this re-examination is not solely to check on the competence of a grader but is intended to help the grader retain that competence. Constructive criticism may be provided in circumstances where no commercial consequences are involved as would be the case where a random or batch inspection was being carried out. The possibility of over-grading and its economic consequences may be kept in check.

Internal quality control

Companies should be recommended to keep the work of their graders under surveillance in between random or batch inspections carried out by agency inspectors. Where a grader's work is the subject of a recent or substantial batch inspection then it should be possible to excuse him a corresponding amount of internal quality control procedure. This internal quality control will be most important where comparatively small quantities of graded timber are being produced and visits from agency inspectors may be relatively infrequent.

This internal quality control is particularly important since the cost burden of agency inspection should be capable of being reduced if producing companies' own quality control is found to justify a relaxation of the level of inspection. It is much healthier for the industry to produce satisfactory quality on the basis of their own high standards of control.

Internal quality control is not too difficult where several graders operate at the same company since programmes of cross-checking can readily be devised, particularly if this can be done under the surveillance of a more senior grader. Where a company has only one grader on site then it should be possible for arrangements to be made with the Inspection Agency for supplementary visits to be made on an informal basis.

It is suggested in the next section that account should be taken of a company's internal quality control procedures when determining the overall level of surveillance to be applied. It is very important that any such internal quality control shall be properly documented and the records of inspections kept available for examination by the agency inspector. Only in these circumstances should the Agency give any credit to internal quality control procedures such as would reduce the amount of external surveillance considered to be adequate.

It should be emphasised that the Inspection Agency itself must institute and maintain quality control of its own inspectors' operations.

Independent surveillance

The problem of providing independent surveillance of visual stress grading is made more difficult by the fact that there are many reasons why companies may not maintain stocks of stress graded timber on site, preferring to grade on ad hoc basis to satisfy requirements. Typically this will be the last process to be carried out on a batch of timber prior to despatch and the chances of a random unannounced visit by an agency inspector coinciding with the availability of graded stock on site may be quite small.

On the other hand a sawmill producing substantial quantities of constructional sizes and grades of sawn timber may find it worthwhile to grade all such material on a grading chain and to accept as a matter of small consequence that some proportion of this material will be sold in circumstances which do not strictly require the provision of stress graded timber.

In these latter circumstances it is comparatively easy to arrange for random unannounced visits by agency inspectors several times a year with the full expectation that their will be graded material on site for them to examine. In the former case arrangements have to be more complex and it is probably necessary for companies to inform the inspection agency of the coming availability of batches of timber for official contracts or for supply into stockholdings of stress graded timber that may be held by the sawmills customers.

It is difficult to make positive proposals for any particular situation until the facts are known regarding the demand for stress graded sawn timber from the mill concerned and the way in which the sawmill intends to respond.

The overall quality assurance effort as a company will be a combination of random unannounced surveillance and batch inspections by agency inspectors together with the documented internal quality control procedures carried out by the company. Bearing in mind that the throughput of stress graded sawn timber may vary considerably from one sawmill to another it should be the duty of the Inspection Agency to ensure that the burden of inspection should fall on each company on an equitable basis. The programme of visits to each company should be tailored to suit the variety and throughput of timber graded by that company.

Disciplinary action will need to be taken by the Inspection Agency in respect of incompetence, carelessness or worse on the part of graders, and of inadequate supervision or quality control on the part of companies. In some cases poor company attitudes to quality assurance may lead to bad grading or misuse of stamps. The action that may be taken would include official warnings leading to additional inspection which should be charged to companies, suspension of graders or companies till appropriate remedial action has been taken, and in the worst of cases complete withdrawal of grading rights.

If the Inspection Agency has the statutory right to do so, it may arrange inspection of graded timber on construction sites, and may in any case agree with companies that batch inspection at site may in some cases be more convenient than at the sawmill. There could also be collaboration between the Agency and the building control authorities to arrange some sampling of quality on site or to follow up reports of poor quality timber received.

STRESS GRADING RULES

for

TROPICAL WOODS

and

CONIFERS

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(3 of 3)

EVALUATION OF RESPONSES TO QUESTIONNAIRE
ON STRESS GRADING AND STRENGTH GROUPING
RESEARCH AND DEVELOPMENT ACTIVITIES

Contract between

UNIDO United Nations Industrial Development Organisation

and

TRADA Timber Research and Development Association

EVALUATION OF RESPONSES TO QUESTIONNAIRE
ON STRESS GRADING AND STRENGTH GROUPING
RESEARCH AND DEVELOPMENT ACTIVITIES

INTRODUCTION

An outcome of an Expert Group Meeting on Timber Stress Grading and Strength Grouping* was the circulation of a questionnaire on research and development activities within this field. The purpose was to gather information on current projects of this type in which forest products laboratories, research associations, universities, trade associations and other bodies are involved. The objectives of the projects revealed by the questionnaire would be identified, technical details summarised, and further information on codes and standards would be given.

The results of the questionnaire would be evaluated by an organisation briefed by UNIDO to draw up a standard framework for stress grading rules for developing countries. The organisation would also be required further to consult with earlier participants and new contacts.

This report provides the evaluation, carried out by TRADA in accordance with the terms of reference.

* UNIDO, Vienna International Centre, 14-17 December, 1981.

FORMAT OF QUESTIONNAIRE

The actual form of the questionnaire which was circulated is shown in Appendix I and the responses to the questionnaire in Appendix II. It is hoped that much of the questionnaire is self-explanatory, certainly the quality and quantity of replies received was impressive. Although the section on Building Standards was intended for developing countries only, many of the replies from industrialized countries also gave useful information on these. The final 'catch-all' question - "Have we asked the right questions" - gave scope for some respondents to fill the gaps.

RESUME OF REPLIES

In the following resumes, initials or brief titles of responding organisations are cross-referred by number to the full list given in Appendix II.

Current projects, obectives and further details

CTIB(1) report research on spruce (Picea excelsa) grown in Belgium. They are studying the relation between anatomic characteristics, structural defects and mechanical properties. The first steps will entail visual grading, but mechanical and other more sophisticated methods will follow. Their objectives are to develop a set of grading rules for Belgian softwoods and to improve the use of timber through closer relations between grading and end purpose.

This is a 2 to 4 year project, commencing in the latter part of 1982 and involving 4 or 5 people.

The University of Toronto (2) replied with details of two projects. One, a two man-year project, concerns the tensile strength and stiffness of poplar woods in structural sizes, whilst the other concerns the use of tropical hardwoods in the Andean Pact group of countries. The project aimed at developing models for tensile strength and stiffness of temperate hardwoods is intended to influence future visual and mechanical rules for these, with special reference to their possible use in laminated beams. In the South American project, correlations between strength, stiffness and grade-permitted defects are being examined, special emphasis being placed on the need to sort heterogeneous tropical hardwoods into stiffness categories.

The Forest Products Laboratory, Finalnd (5), is continuing work on approval of the Finnograder stress grading machine. Grade stresses are to correspond with those of existing visual grades and the machine will possibly grade to BS 4978 or other relevant codes.

The Forest Products Department of the Institute for Industrial Research and Standards (Ireland) (6) reports three projects. One is accumulating a data bank on the strength properties of Irish timber, objectives being the establishment of permissible design stresses and evolution of a viable grading system.
Start: 1979 End: 1985 Manpower: 1 Professional and 1 Technician per annum.

The second project is attempting to develop an inexpensive small output mechanical grader suitable for sawmills, merchants and manufacturers in Ireland.
Start: 1982 End: 1982 Manpower: 2 Professional and 4 Technicians.

The third is a project involving machine grading and the derivation of design stresses for scaffold boards.

In addition to these projects a number of quality control programmes are being successfully operated.

The Technical University of Munich (4) is co-operating in a national research programme entitled, "Structural safety and reliability, deelopment of probability-based safety concepts". This involves the effect of stress grading and strength grouping on the reliability of glulam components. A research proposal entitled, "Optimisation of stress grading including the number of strength classes and grade units" has also been submitted to the Commission of European Communities. Results are intended to be applied to visual and mechanical grading of glulam laminations.

The Institute of Applied Science and Technology (Nigeria) (10) reports a sawmill project where grading forms part of the wider objectives of improving sawmill performance. Results will be applicable to visual grading and special use material.
Start: 1981 End: 1983
Manpower: 3 men

The Italian Federation of Wood, Cork, Furniture and Furnishing Industries (8) indicates that it has no specific projects underway but aims to introduce and experiment with the FAO-ECE stress-grading standard.

At Warsaw Agricultural University (12) recent projects have included research into the mechanical properties of visual stress-graded coniferous sawn timber for structural use in Poland, and visual and mechanical methods of stress grading timber in small sizes (18-32mm thick) for structural use. They are also currently conducting projects on visual methods of stress grading coniferous sawn timber greater than 100mm thick and on mechanical methods of stress grading coniferous sawn timber less than 25mm thick and 100mm wide. These projects partly include the physical principles of mechanical grading, e.g. sonic methods and hardness based methods.

The Royal Institute of Technology (Sweden) (14) currently has three projects underway. One is investigating tolerances in practical grading (visual and by machine), their influence on permissible stresses and relation to grading conditions, whilst others consider the international unification of stress grading rules and grading rules for special uses such as glulam.

Colorado State University (15) reports two relevant projects. The first is attempting to develop a reliability-based design procedure for wood transmission structures, whilst the second is endeavouring to predict the tensile strength of wood containing defects such as cross-grain knots and checks by developing a suitable mathematical model.

The Forest Research Institute (New Zealand)(18) currently has two projects under way on grading. The first is evaluating visually graded Radiata Pine via the 'in-grade' approach developed by Borg Madsen. A report is anticipated in June 1983. The second is evaluating proof testing as a grading method.
End: December 1983 Manpower: 1 man year.

Finally, the Wood Technology Institute (Poland) (16) has a series of projects underway, both of a fundamental and applied nature. These have the objective of implementing mechanical strength grading of sawn timber in Poland and securing an international certificate for a mechanical sorter of the ITD-DKT-3 type developed at the Institute. It is also hoped that this work will create a basis for changes in Polish standards PN-82/D-94021 and PN-81/D-03150. The Institute is also co-operating in an EEC and Finland project "Strength indices of construction sawn timber, effect of defects on these indices and mechanical strength classification of sawn timber".

BUILDING STANDARDS

Replies relating to building standards were received from various countries (not only developing countries). For completeness all such replies received are included.

CTIB (Belgium)(1) states that in Belgium a limited number of technical specifications covering the structural use of timber exist and these are applied only on a contractual basis.

A new edition of the Danish Code of Practice on the structural use of timber is in print. Formulated on the strength grouping concept, it utilises four of the groups mentioned in the CIB-W18 structural timber design code (Danish Building Research Institute)(3).

The Technical University of Munich (4) list three relevant German standards -
DIN 1052 Timber structures, design and construction
DIN 1074 Timber bridges, design and construction
DIN 4074 Building timber for wood building components, quality conditions for converted building timber (softwood)

Such German DIN standards are usually used in Italy, although the FAO-ECE standard concerning stress grading has recently been adopted as a national standard there. (Italian Federation of wood, cork, furniture and furnishing industries)(8). Building Research Station (Israel)(7) indicates that no standards exist for the use of timber in structures or for stress grading in Israel. All its structural timber is imported and is selected for use by craftsmen. A formwork code does exist which refers to timber.

Delft Technical University (Holland)(9) states that the Dutch building standard NEN 3852:Timber Structures is currently being revised to a probabilistic basis.

Information on the various Polish standards was provided by Warsaw Agricultural University(12), Building Joinery Research and Development Centre(13) and Wood Technology Institute(16). These are as follows:-

Polish Standard PN-82/0-94021: Stress graded coniferous sawn timber for structural use (25-100mm thick)

Polish Standard PN-81/0-03150: Timber structures. Design rules. (Design based on limit states is partial safety factor for loads and materials.)

The Canadian building standard CSA 086: Code and Engineering Design in wood is currently beng revised and will appear in 1983 in a limited state design format. Timber frame houses do not have to be designed to this code but rather to Part 9 of the National Building Code of Canada - a prescriptive code including span tables, etc.: (Council of Forest Industries of British Columbia - Canada)(17).

The Institute of Applied Science and Technology (Nigeria)(10) states that building standard NCP 23: The Use of Wood in Building Construction is used in their country. This is formulated on a deterministic basis.

The Forest Research Institute of New Zealand states that two building standards are in operation. The standard for light frame timber construction (NZS 3604) is a descriptive code based on deterministic principles, whilst the standard for structural timber design (NZS 3603) is formulated on a deterministic basis. Although the possibility of revising this code to a limit states design format has been discussed no real enthusiasm seems to exist at present.

Finally, the Norwegian Technical Institute(4) indicates that stress grading standard NS 3080 is used in Norway.

OTHER COMMENTS

The final part of the questionnaire was an "open-ended" question which invited additional questions or comments to be made about the relevance and content of the questionnaire. These comments are summarised below:-

Mr. Saarelainen(5) stated that a system which relates 5 percentiles for a series of grading rules from structural tests to small clear specimen values would be both simple and efficient for a limited number of species. However, since the small clear approach can be used for guidance only, if there are many species groups and visual grades of these a stress classification system might be convenient.

UNIDO was cautioned by Prof. Keenan(2) to review the findings of the Andean Pact workers before becoming committed to developing strength related grading rules for tropical hardwoods. Earlier he stated that it was likely that grading rules for tropical hardwoods should relate primarily to stiffness and secondly to strength.

Dr.-Ing. Glos(4) stresses the importance of investigating the scientific background of stress grading and strength grouping in addition to technical and commercial aspects based on presently used grading principles. He states that there is some evidence that better predictors or combinations of predictors are available than those used at present.

Prof. Kuipers(9) was unclear as to what the questionnaire wanted to know. He also raised the question, "What is going to happen in Europe with the ECE grades? Will they be used and by which countries?" He would also like to know the definite strength - not allowable strength characteristics. A better relationship with CIB-W18 was recommended.

Prof. Madsen(19) feels that it is extremely important to grade so that the proposed ISO system of strength grades will be followed. He states that grading rules should be developed to obtain the stresses in the proposed strength classification system.

Finally, Prof. Dr. Babicki(16) raises the question,"Why does mechanical strength grading of sawn timber not find its proper place with sawn timber producers and users?" He feels that one of the reasons is the divergence of results from different authors investigating a relationship between modulus of elasticity and strength. He states that the solution of these problems is the responsibility of science.

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The reference numbers (1) to (19) mentioned in the text correspond to the numbers in the questionnaire in which the following references were provided:

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UNIDO

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

QUESTIONNAIRE ON STRESS GRADING AND STRENGTH GROUPING RESEARCH AND DEVELOPMENT ACTIVITIES

Please feel free to interpret the following questions as you think appropriate and give such additional information as you think may be of benefit, attaching reports and unpublished information to the answer sheets as necessary.

(1) TITLES, ADDRESS

As well as ensuring that we have the correct title and address of your organization and names of persons concerned with stress grading and strength grouping projects, please give details of any organizations with whom you are collaborating. Indicate any international liaisons which you have already formed and the extent to which the work is being shared.

(2) PROJECTS CURRENT

What are your projects? Please give titles or very brief descriptions of current or recent projects on stress grading or strength grouping, with which you are concerned. Indicate start date, duration and effort e.g. in terms of man-years, if possible.

(3) OBJECTIVES OF PROJECTS

What are their objectives? Indicate whether for example the work is aimed at replacing or improving existing grading rules; introducing rules for the first time; or changing current grading concepts completely. Are the grading rules intended for implementation in your own country or internationally? In either case please give references to relevant standards, codes of practice or regulations. Give similar information, if relevant, on work on strength groups.

(4) FURTHER TECHNICAL DETAILS

Please give us further details. Do your stress grading projects include work of a fundamental nature? Will the results be applied in

visual grading?

mechanical grading?

special use material, e.g. scaffold boards?

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(5) BUILDING STANDARDS (Developing Countries only)

What building standards or codes of practice are now in effect which cover the structural use of timber in construction? Are they deterministic or based on limit state design (or partial safety factors)? Are they being or will they be revised to a probabilistic basis?

In your view are they now biased against the use of timber as a structural material? Briefly, how?

(6) REFERENCES

Unless already covered above, please give references to relevant publications, reports, technical notes, proceedings, etc.

(7) HAVE WE ASKED THE RIGHT QUESTIONS?

It is very difficult in compiling a questionnaire on such a broad and technical subject to foresee what information will be the most useful, and we should welcome comments, additional notes, information about the work of others, etc.

NOTE: A limited number of the background documents listed in Annex III of the report are available on request.

Responses to questionnaire on Stress Grading and Strength Grouping

Appendix II

NAME & ADDRESS OF ORGANISATION	COLLABORATING ORGANISATIONS
Mr. E. Sauvage Centre Technique de l'Industrie du Bois Chaussee d'Alsemberg 830 Belgium	I.W.O.N.L.-De Crayerstraat 6, Brussels Prof. J. Schalck-Rijks-Universiteit Gent Mr. E. Clicheroux-Admin.des Eaux et Forets Grecon - Hannover, W. Germany
Prof. F.J. Keenan University of Toronto 203 College Street Toronto, Ontario, M5S 1A1 Canada *Under negotiation at time of writing	Andean Group Countries of South America Int.Dev.Res.Centre - Ottawa, Canada Dept.of Forest Prod. - Kasetsart Univ. Thailand Div.of Struct.Eng. - Asian Inst.of Tech. Thailand Standards & Ind.Res.Inst.of Malaysia Faculty of Forestry, Univ.Pertanian Malaysia Ministry of Energy & Mines - Govt.of Costa Rica* Inst.of Standards & Ind.Res. - Paraguay*
Prof. H.J. Larsen Danish Building Research Inst. SBI.Postboks 119, DK-2970 Horsholm, Denmark	
Dr.Ing.Peter Glos Lehrstual fur Baukonstruktion Und. Holzbau, Arcisstrasse 21 Technische Universitat 8000 Munchen, 2 Federal Republic of Germany	Contacts with most of the leading research institutions

SECTION 1

CURRENT PROJECTS RELEVANT TO STRESS GRADING, ETC.	OBJECTIVES OF PROJECTS
Research on home grown spruce (Picea excelsa). Relation between anatomic Characteristics, Structural Defects & Mechanical Properties. Start: End '82 for 2-4 yrs. (4 to 5 men)	Try to develop a set of grading rules for Belgian Softwoods. Aim to optimise the use of timber through closer relation between grading & usage. (Implementation basically related to Belgium)
(a) Tensile strength & stiffness of poplar lumber (2 man-years) (b) Utilization of Tropical hardwoods as building materials in the Andean group countries of S.America Publications likely to be ready in 1983 (c) Other projects Currently developing projects in this Field in Malaysia, Thailand, Paraguay, Bolivia & Canada	(a) Develop models for tensile strength & stiffness (b) Study correlations between strength stiffness & grade permitted defects for tropical hardwoods
As Chairman of ISO/TC165 involved with Dr. Leicester's project. No activities regarding stress grading, etc. at Danish Building Research Inst.	
(a) Co-operation in national research programme strucutral safety & reliability, development of probability based safety concepts. Involving the effect of stress grading & strength grouping on the reliability of glulam components. (continuing to end '84 - 2 man-years/year) (b) Optimisation of stress grading including the number of strength classes & grade limits Research proposal submitted to CIC.	(b) Better utilisation of the quality of home grown timber - to select & use high quality material more efficiently & to increase the amount of available structural timber by increasing the yield within structural grades by developing & applying a more efficient stress grading method.

SECTION 2

QUESTION (4) FURTHER TECHNICAL DETAILS	QUESTION 5 BUILDING STANDARDS (DEVELOPING COUNTRIES ONLY)
Fundamental work with visual grading a first step, leading to mechanical grading & possibly more sophisticated methods. Interest in the industrial production of timber construction prefab houses, glulam beams.	Some technical specifications in Belgium covering structural use of timber. These are applied only on a contractual basis. Cover roof construction, floors, windows, doors etc.
(a) Results will influence visual & mechanical grading rules for hardwoods to be used as laminating stock for glulam beams. (Applicable to CSA glulam standards & relevant to structural use of hardwoods internationally.) (b) Likely that grading rules for tropical hardwoods should relate primarily to stiffness & secondly to stength.	
	New edition of Danish Code of Practice on structural use of timber in print. Formulated on the strength grouping cocept. Only 4 of the groups mentioned in CIB-W18 Struct.Timber Design Code are included.
(b) The results are intended to be applied to visual and mechanical grading of glulam laminations (boards).	DIN 1052 Timber structures, design & construction DIN 1074 Timber bridges, design & construction DIN 4074 Building timber for wood building components, quality conditions for converted building timber (softwood).

SECTION 1

Not yet available	None
	Re: Question (3) (b) UNIDO is cautioned to review the findings of the Andean pact workers before becoming committed to developing strength-related grading rules for tropical hardwoods.
Glos, P. & Heimeshoff (1982): Capabilities & limitations of stress grading laminae for glulam structures (in German) Glos, P. & Th Michel (1982): The strength distn. of timber as dependant on stress grading efficiency (Paper presented to IUFRO). Glos, P. (1982): Machine stress grading of sawn lumber state of the art - comparison of different methods (in German) Glos, P. & Schultz (1980): State of the art & prospects for machine stress grading (in German).	Important to investigate the scientific background of stress grading & strength grouping in addition to technical & commercial aspects based on presently used grading principles. There is some evidence that there are better predictors (or combinations of predictors, resp.) available than those used at present.

SECTION 2

Mr. Urho Saarelainen Research Officer Technical Research Centre of Finland Timber Laboratory/PTA SF-02150 Espoo 15, Finland	Mr. J. [illegible] Mr. E. [illegible] Mr. A. [illegible] - Finnish Sawmill Owners Assoc., Fabianinkata 29C, SF0-00100 Helsinki 10
Mr. P.R. Colclough - Head Forest Products Dept. Inst.for Industrial Research & Standards Ballymun Road Dublin 9, Rep. of Ireland	P.R.L.(U.K.) - (Curry/Tory/Fewell) For. Prod. Lab., Madison, USA (Galligan/Greene/Murphy/Gerhardts). Univ.of British Columbia, Canada - (Prof. Madsen) For.Prod.Lab., Sweden - (Dr. B. Noren) N.T.R.I. South Africa - (Brynt/Ges) CSIRO, Australia - (Dr. Leicester) For.Res.Inst., New Zealand - (E.Walford) Centre Technique du Bois, France - (Crubile) T.N.O., Holland - (A.Van der Velden) T.R.C., Finland (Saarelainen)
[illegible]. H. Korin Head of Testing Dept., Building Research Station Techion Res. & Dev. Foundn. Haifa 32000, Israel	Israeli Standard Institution Tel Aviv Israel
Mr. G.U. Marchi Federazione Italianiana Inds. Del Legno Federlegno I-20090 Segrarte (Mi) S. Felice VII/24, Italy	Federlegno-Arredo 1-20145 Milano via Mascheroni 19
Prof. J. Kuipers Stevin Laboratory Stevinweg 1 NL-Delft 8 The Netherlands	Stichting Centrum Hovt. (Onderzoerkcommissie OCA) Naaren

SECTION 1

Mr. D.E. Lucas Institute of Applied Science & Technology Univ. of Ibadan Nigeria	Forest Products Res. Laboratory, Nigeria

Q2	Q3
Approval of stress grading machine - Finnograder - started 1975 with the prototype - continued in 1979 with MK II - total effort 2 man-years	(1) Verifying machine parameters - repeatability, consistency, etc. (2) Correlation of machine parameters with stress values. (3) Formulation of stress prediction model - grade stresses to correspond to those of existing usual grades, possibility to grade BS 4978 or other relevant grades. (4) Strength group not applicable as such - machines grade to target stress.
(a) Data bank on strength properties of Irish Timber. Objective to establish permissible design stresses, and evolve a viable grading system. Start: 1979; End: 1985; Manpower - 1 professional & 1 technician per annum. (b) Objective to develop an inexpensive small output mechanical grader for sawmills, merchants & manufacturers in Ireland. It would be a "one" grade machine, eg Yes/No. Start: 1982; End: 1983; Manpower 2 professional & 4 technicians (c) Scaffold Boards. Project commencing involving machine grading & derivation of design stresses for scaffold boards.	
None	
None	Aim is to introduce & experiment with the FAO-ECE stress grading standard
None	

SECTION 2

Q2	Q3
(a) Sawmill project - Production quality studies. Start: 1981; End: 1983 - 3 men	Grading is only part of this, wider objectives are to improve sawmill performance

Q4	Q5
(Same as question 3)	
Quality control programmes successfully operated in: (1) Timber in housing - monitoring of wood & wood products in new housing. (2) Roof trusses (3) Visual stress grading - monitoring & training (4) Machine stress grading - monitoring of approved mechanical stress grading machines	
At the moment there is no stress grading practice in Israel and timber for structural purposes is selected by craftsmen.	No standards for the use of timber for structures for stress grading. There is formwork code which refers to timber.
Stress grding regulations will be used for visual grading & for calculations in timber. structures & glulam	Have adopted the FAO-ECE Standard concerning the stress grading as a national standard (Norma UNI) usually use DIN standard from German practice.
	New 3852 Timber Structures is in revision to a probabilistic basis.
Results applied to visual grading and special use material	NEP2: The use of wood in building construction. This is on a deterministic basis and will not be revised to a probabilistic basis yet. It is meant to remove the bias against the structural use of timber.

SECTION 1

Q6	Q7
None	A System which relates 5 percentiles for a series of grading rules from structural tests to small clear specimen values would be simple & efficient for a limited number of species. However, since the small clear approach can be used for guidance only, if there are many species groups & visual grades of these a stress classification system might be convenient.
	Because of its special characteristics eg fast grown, visual grading to BS 4978 gives poor yields for Irish Timber studies have shown mechanical grading is much more satisfactory
	Israel imports all its structural timber
	Not clear what you want to know. What is going to happen in Europe with the ECE-grades? Will they be used & by which countries? What are the definite strength - not allowable strength characteristics? A better relationship with CIB-W18 is recommended.
	Yes, I think you have asked the right question.

SECTION 2

Mr. L. Morkred Norsk Treteknisk Institutet Box 337, Blindern Oslo 3, Norway	The Swedish Wood Research Institute The Technical Research Centre Finland
Mr. S. Dzbenski Expert on Wood-working Industries Warsaw Agricultural Univ Warsaw, Poland	Institut of Wood Technology - Poland Research & Development Centre of Timber Industry - Poland Polish Stress Grading Cttee. of ECE-UN-Geneva British Stress Grading Assoc.- Wicnes Suomen Tasavallan ja Keskiwaisen Taloudellisen Avun Neuvoston Yaters-Tyokomissio - Finland.
Prof. W. Kozynski Centralny Osrodek Badawczo Rozwojowy Przemyslu Stolarki Budowlanej 05-200 Wolomin ul Laskowa 4, Poland	Mr. S. Dzbebnski - Warsaw Agricultural Univ. Prof. M. Wnuk - Institute of Wood Technology
Prof. B. Thunell Royal Inst.of Technology Wood Technology & Processing S-100 44, Stockholm, Sweden Stockholm, Sweden	
Dr. Jozsef Bodig Prof. of Wood Science & Civil Eng. Dept.of Forest & Wood Sciences Colorado, USA	Mr. R.A. Sa'Ribeiro - Forest Products Res.Centre, Manaus, Brazil Mr. C.B.S. Lisboa - Forest Prod.Lab. Brazil Mr. R. Mutuku - Univ.of Nairobi, Kenya Mr. R.L. Sotelo - Laciteno - Inireb, Mexico Mr. G.S. Somfalvi - Univ.of Forestry & Wood Technology, Hungary

SECTION 1

Q2	Q3
None	
Recent projects: (a) Mechanical properties of visual stress-grading coniferous sawn timber for structural use in Poland (b) Visual & mechanical method of stress grading timber in small sizes (19.32mm thick) for structural use Current projects: (a) Visual methods of stress grading of coniferous sawn timber more than 100mm thick (b) Mechanical methods of stress grading of coniferous sawn timber less than 25mm thick and 100mm wide.	
Collaboration with M. Dzbenski's projects	
(a) Tolerances in practical grading, visual and by machine; their influence on permissible stresses and relation to grading conditions. (Species, speed, light, etc.) (b) International unification of stress grading rules. (c) Grading rules for special uses such as glulam.	
Two projects with implications to lumber grading: (a) Reliability - based design of wood transmission pole structures (b) Tensile strength of wood containing defects.	(a) To develop a reliability-based design procedure for wood transmission structures. (b) To develop a mathematical model to predict the strength and stiffenss of wood in tension containing cross-grain, knots & checks.

SECTION 2

Q4	Q5
Mechanical grading is planned for but not being used yet.	Stress grading standard [illegible] NS 30[illegible]
These projects partly include physical principles of mechanical grading, eg. sonic methods & hardness based methods. We do not specify detailed use of timber.	Polish standard PN-82/D-94021 stress graded coniferous sawn timber for structural use (25-100mm thick).
	Polish standard PN-81/B-03150: Timber structures, design rules, design is based on the limit status & partial safety factors for loads & materials.
(a) The project on reliability-based design is both fundamental & applied. (b) The tension project is a fundamental study	

SECTION 1

Dzbenski, W.: Mechanical methods of lumber stress grading in Poland. (In Polish)
Dzbenski, W.: Testing methods of structural timber quality (in Polish)
Dzbenski, W.: Attempts of implementing ultrasonic measurement technique in stress grading of structural timber. (In German)
12 References included in total.

None

Reports from Swedish Forest Products Research Laboratory, Royal Institute of Technology,
Svensk Byggnorm 67
(The Swedish Building Code)

Bodig, J. & Troxell, H.E.: Mechanical Stress-rating of Engelman spruce.
Bodig, J.: Comments on the mechanical stress-rating of Western Canadian species.
11 References provided

SECTION 2

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SECTION 1

	Q2	Q3
	Co-operation in [illegible] and Finland project "Strength indices of construction sawn timber, effect of defects on these indices & mechanised strength classification of sawn timber" Own projects:- (1) Testing of prototype device for mechanical strength grading of sawn timber (End 1984) (2) Research on theoretical foundations of mechanical strength grading (End 1984). (3) Determination of relationship between mod.of elast. in bending & bending, compressive & tensile strengths of pine sawn timber (End 1984) (4) Development of standards as a basis of standard subsystem for mechanical strength grading (End 1984) (5) Investigation of economic relations concerned with the application of mechanical strength grading (End 1983) (6) Effect of visual charcteristics of softwood sawn over 100mm thick on its strength properties (End 1984)	Objective to implement mechanical strength grading of sawn timber & obtain an international certificate for mechanical sorter of ITT-ORT-3 type developed at the Institute. Also to create a basis for changes in the standards listed in question (5).
	No specific projects at present working closely with FORINTEK on their various lumber projects. Investigations envisaged in 1983. (Details not yet available.)	
	(a) In-grade evaluation of visually graded radiata pine (Report due June 1983) (b) Proof test grading (1 man year - End 1983.)	(1) Determine the properties of Radiata pine when graded to overseas standards (both visually & mechanically) (2) Monitor the properties of graded timber as they are affected by site, forest management & sawing patterns. (3) Evaluate proof testing as a grading method.

SECTION 2

04	05
Subjects listed under item 1-[illegible] are related to mechanical sawn timber grading based on mod. of elast. measurements in bending. Investigations 2 & 3 are of a fundamental character.	PN-82/D-94021 - Softwood sawn timber graded by means of strength method. PN-81/B-03150 -Constructions made of wood & wood-based material statical calculations & design materials.
	CSA O86 - Code of engineering design in wood (Currently being revised & will apper in 1983 in a limit state design format.) Timber frame houses do not have to be designed to CSA O86 but rather to Part 9 of the National Building Code of Canada - A prescriptive code including span tables, etc.
(a) The in-grade approach developed by Borg Madsen has been used in several NZ mills	NZS3604 - Standard for light frame timber construction (descriptive code based on deterministic principles.) NZS3603 -Standard for structural timber design - deterministic. No great enthusiasm in NZ for limit states design format.

SECTION 1

[illegible], T. & [illegible], [illegible]: Method and device for non-destructive strength grading of constr. sawn timber.

7 References provided

[illegible] should also contain a question:-

"Why mechanical strength grading of sawn timber does not find a proper interest of saw timber producers & users?"

It seems that one of the reasons is the divergence of results from different authors investigating a relationship between mod. of elasticity & strength. The solution of these problems is the responsibility of science.

Proceedings of the Seminar on Stress Graded Timber, held in Rotorua, May 1979

Have recently been concerned with removing the restriction on rate of growth from Japanese grading rules. This was successful.

SECTION 2

Important to grade so that the proposed ISO system of strength grades will be followed. Should develop grading rules to [illegible] stresses in the [illegible] strength classification system.