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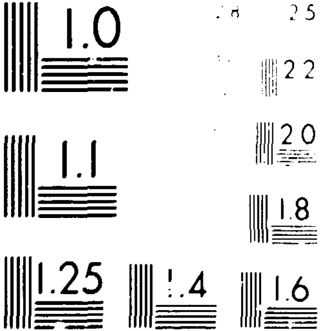
UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org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PROBLEMS - AND SOME SUGGESTIONS - IN THE IDENTIFICATION OF APPROPRIATE STRESS GRADING TECHNIQUES FOR DEVELOPING COUNTRIES*

by

C. J. Mettem**

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** Head, Materials Section, Engineering Department, Timber Research and Development Association; Hughenden Valley, High Wycombe, Buckinghamshire, UK.

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INTRODUCTION

The need for stress grading pre-supposes the use of timber in situations where its strength and stiffness matters. UNIDO is dedicated to the promotion of development through industrialization. This is achieved by fostering appropriate technologies, bearing in mind conditions in often very poor countries. The first British Standard rules for stress grading were published in 1941 when in Britain timber was a very scarce commodity indeed, and they were said on the title page to be 'For purposes where the stresses in timber are known', acknowledging that stress grading would only be for certain uses. It is important not to lose sight of this today.

There may well be situations, for example in disaster relief operations, or projects aimed at providing simple improvements on essentially traditional skills and crafts of construction, where stress grading is unaffordable or inappropriate. Under such circumstances, grading rules may nevertheless provide useful guidance in eliminating a small proportion of completely unacceptable pieces of wood from the general supply, although common sense and local tradition are likely to prove an equal or better guide.

When low-cost housing, simple trusses, prefabricated buildings and bridges are being designed and implemented in developing countries, materials must be selected only at the level of discrimination strictly necessary, at the same time selection must be efficient to avoid waste of valuable resources.

This paper and the accompanying discussion considers the application of the principles of

(a) Visual grading

(b) Mechanical grading

to address the needs of developing countries, attempting to assure as rational a use of resources as possible, bearing in mind the principles and design requirements discussed earlier (Mettem, 1981).

VISUAL STRESS GRADING

It is suggested that certain essentials of a suitable visual stress grading system are as follows:

(1) The system must employ easily understood principles, since stress grading entails application of common sense and judgement, and these cannot be applied unless the principle is evident. Possible principles appear to be

  (i) knot diameter rules, or surface measurement
  (ii) knot area ratio rules

(2) It must be easy to apply. Users should be able to put the principles into practice, recognising the features described in the rules when confronted with the wood and being able to decide whether or not individual pieces pass the limits. Although training is an essential aspect of industrial development, it often has to be undertaken in a limited or less than ideal way.

(3) The rules should leave as little as possible open to interpretation and should be capable of being checked by re-inspection.

Some points which should be considered are as follows. Firstly, to what extent do the rules need to vary, or to have enlarged scope in comparison with existing models in order to cope with the spectrum of timbers viewed internationally? Timbers which must be graded include:

(i) softwoods, both indigenous and plantation
(ii) hardwoods of tropical rain forest
(iii) timbers of montane and savannah trees, often of very mixed species or intractable woods
(iv) plantation hardwoods.

All of these present their own peculiar characteristics which must be taken into account in an international set or sets of grading rules. Furthermore they are liable to indicate differing strength ratios, bringing us to the problem of the number of visual grades required. The following two thoughts must be paramount:

Economic use of resources ◄—► Simplification

Unfortunately they are not completely compatible - the simplest system would be to have <u>one</u> grade of structural timber, plus rejects!

Recent trends have been towards reduction in the number of grades provided in each set of rules. For example BS 4978 provides for only two grades of softwood in Britain, whilst BS 5756 deals with a single grade of tropical hardwood. Centeno (1978) has found a single structural grade sufficient in the Andean Pact countries, whilst it is understood that Davalos (1981) is working towards two grades of pine in Mexico. As discussed earlier however, there is a need in international development work to cover material of widely ranging qualities, from knotty, distorted softwood taken from immature plantation trees, up to clear, straight grained tropical rainforest hardwoods.

The virtues of general purpose versus specific end use grading rules have been discussed and it is assumed that the former are highly desirable, although there are instances in work for developing countries where the latter might have a place.

Although grouping and stress grading have been dealt with separately on the meeting agenda, they are interdependent as far as structural design is concerned. It has been shown that whilst it is a relatively simple matter to group timbers according to established criteria based on small clear properties, the achievement of an internationally acceptable strength class system for work in developing countries is a worthy and difficult goal. A step towards introduction of an international strength class system has been taken by the inclusion of standard classes in the CIB Structural Timber Design Code, TABLE 1. It is the intention of CIB-W18 that their Code should be presented to ISO/TC 165 - Timber Structures as the basis for a Draft Intenational Standard.

Summarising this section dealing with visual stress grading and grouping, the following is an outline for further discussion:

Groups It is suggested for a UNIDO brief that their documents should retain references to the Australian system for grouping, based on minimum standard strength classifications for small clear specimens. When large numbers of species have to be grouped, the decision as to where to place boundaries inevitably becomes somewhat arbitrary. The Australian system already has international repute through the publications of Bolza and others, covering a great range of timbers and world regions.

Grades Three grades having nominal ratios of 38%, 43%, 60% are proffered as an initial suggestion. Visual grading rules would be agreed that would serve the need for international work in developing countries. Included in the document of rules would be the recommendation that the lower two grades are envisaged mainly for softwoods, whilst the high grade is principally for hardwoods of the tropical rainforest type. Other hardwoods would probably be caught by the two upper grades. However the measurements of characteristics and the grade requirements for all three grades should be written to embrace all types of timber likely to be encountered.

Strength Classes It is recommended that both the small clear and the structural sized approach to stress derivations should be retained. The nominal grade ratios suggested above would only have actual meaning as grade ratios for small clear methods. Nevertheless it should be possible, and indeed an attempt must be made, to agree and draw up a strength class table. It is suggested that this should give characteristic values and mean moduli of elasticity, similarly to the provisional table given by the CIB code. Agreement on such values should be sought as a first step. It will then be necessary to reduce the target 5th % ile values to grade stresses for design. This step involves difficult decisions about marrying the small clear and structural sized test answers, as well as what to adopt from other timber codes when designing for UNIDO projects (for example, should one adopt the best from each and draft a UNIDO code; expect experts and engineers in developing countries to use their own codes or try to follow other international developments such as the CIB?).

MACHINE STRESS GRADING

In considering machine stress grading for a developing country or region, it should first be questioned whether it is appropriate at all. This remark is not intended as a slight upon the technical competence of those working in such areas, rather it stems from a consideration of the timber technology background necessary to initiate and maintain a satisfactory programme.

Machine stress grading cannot substitute visual stress grading, it is an adjunct. Both methods applied satisfactorily can produce good results and should be equally acceptable to specifiers and official bodies. Machine grading can have certain advantages, such as efficiency of utilization of the resource, and potential improvements in quality assurance. Several reasons may be given however for regarding machine grading as a successor to visual methods in a new region, and some are as follows:

A prerequisite when setting up grading schemes is information on the mechanical behaviour of the timbers or species combinations occurring in the region concerned and reasons have been given for the need to examine this in relation to the actual in-grade characteristics present in typical qualities of structural - sized pieces. These characteristics themselves must be measured and recorded in research and development programmes using the same basic techniques as are needed in commercial visual grading. Furthermore, in standards dealing with machine grading it is usual to include additional visual grading requirements for the pieces passed by the machine. Acceptance of the concepts of stress grading by producers, specifiers and official agencies is also desirable before the more sophisticated demands of machine grading and its accompanying control procedures are introduced.

Amongst the questions to be considered when suggesting the introduction of machine grading are whether or not there exists an experienced, independent or official timber research organisation which can support the introduction and implementation of machine grading. Actual day-to-day control may be vested in a more general standards organisation or control authority, but experience has shown the need for considerable technical back-up. Once introduced, machine grading brings continual demands for new information, modified settings for varying sizes and grades, as well as advice on quality monitoring, developments to keep abreast of code changes and so on.

Assuming that machine stress grading is contemplated, the next consideration will be the choice of principle used to link the strength - stiffness characteristics of the timber population to be graded with the desired grade stresses for use in design. This choice will also directly introduce the question of how settings are to be derived for the particular type of machine or machines proposed. Both the principles and the actual mechanics of machine grading are discussed in UNIDO Document ID/WG.359/3, (Mettem 1981).

Simplified grading based on strength - stiffness principles can be used to supplement visual grading. This tends to be an unpopular suggestion with both machine and visual graders. Advocates of full mechanical grading programmes view simplified methods with suspicion - after all if the process can be simplified, why use expensive equipment - and will not the simplified concepts reduce standards of quality assurance? Those who recommend the relatively simple procedures of visual grading on the other hand, argue that if these are properly carried out, then no additional checking process is necessary, it can only add cost and threaten to cause unwarranted rejection of material.

The first type of argument, that in favour only of full mechanical grading, can be countered especially in the case of developing countries by pointing out that the more sophisticated methods generally demand high volumes of production and investment in other parts of the construction process. Simplified methods on the other hand are by their very nature more appropriate to smaller scale slower operations. This is a 'horses for courses' type of argument.

The point of view of the confirmed visual grader is harder to contradict, especially as the writer, and probably many readers of this have been parties to a conspiracy! The truth is that at the best, even under carefully controlled laboratory conditions and slow and patient measurement, knot area ratio alone is not a particularly good predictor of bending strength in softwoods. Difficulties of practical assessment of sloping grain, the chief defect which one must try to assess visually in tropical rain forest hardwoods, are also formidable.

It should be acknowledged therefore, that combined visual and mechanical methods may well be the best choice of stress grading technique, especially in developing areas. Provision should be made in projects aimed at establishing such methods to ensure the proper balance between economy of use of the resource (reasonable grade yields for e[illegible]e) and adequate safety and serviceability in use.

Dealing with machine stress grading in summary, the following points are outlined for further discussion:

(1) Is machine grading feasible in the region concerned? Technical feasibility and supply of machines, spares and servicing facilities are obviously important, but equally so is the existence of an organisation or organisations capable of providing initial data and continuing advice and support.

(2) Machine grading programmes can be set up on the basis of a species-by-species approach (this includes modest degrees of grouping, where several similar species are amalgamated) or on a very general basis. The latter is

usually regarded by timber engineering specialists as being technically inefficient, but as the rewards of grouping are so great to timber producers and specifiers alike, methods should continually be sought to improve the compromise between efficiency and generality.

(3) Simplified grading methods, using combined visual assessment and stiffness testing are recommended for special consideration in developing countries. Possible reasons for their rejection in industrialized countries have been suggested, and analysis of these may help to produce improvements.

TABLE 1 - Extract from CIB - Structural Timber Design Code

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Characteristic values and mean elastic moduli, in MPa *Provisional*

		SC6	SC8	SC10	SC12	SC15	SC19
Characteristic values							
Bending	f_m	6.0	7.5	9.5	12	15	19
Tension parallel to grain	$f_{t,0}$	3.6	4.5	5.7	7.2	9.0	11.5
Tension perpendicular to grain	$f_{t,90}$	0.22	0.26	0.30	0.38	0.45	0.55
Compression parallel to grain	$f_{c,0}$	5.7	7.0	9.0	11.5	14	18
Compression perpendicular to grain	$f_{c,90}$	1.8	2.2	2.9	3.6	4.5	5.7
Shear parallel to grain *	f_v	0.9	1.05	1.2	1.5	1.8	2.2
Modulus of elasticity	E_0	3900	4100	4400	4800	5250	5850
Mean values							
Modulus of elasticity, parallel	$E_{0,mean}$	5200	5500	5900	6400	7000	7800
Modulus of elasticity, perpendicular	$E_{90,mean}$	210	230	250	270	290	330
Shear modulus	G_{mean}	320	340	370	400	440	490

		SC24	SC30	SC38	SC48	SC60	SC75
Characteristic values							
Bending	f_m	24	30	38	48	60	75
Tension parallel to grain	$f_{t,0}$	15	18	23	29	36	45
Tension perpendicular to grain	$f_{t,90}$	0.68	0.82	1.0	1.3	1.6	1.9
Compression parallel to grain	$f_{c,0}$	23	29	36	45	57	70
Compression perpendicular to grain	$f_{c,90}$	7.2	9.0	11.5	14.5	18.0	22.5
Shear parallel to grain *	f_v	2.7	3.3	4.1	5.1	6.3	7.8
Modulus of elasticity	E_0	6600	7500	8600	10100	12000	14250
Mean values							
Modulus of elasticity, parallel	$E_{0,mean}$	8800	10000	11500	13500	16000	19000
Modulus of elasticity, perpendicular	$E_{90,mean}$	370	420	480	560	670	790
Shear modulus	G_{mean}	550	630	720	840	1000	1190

* Rolling shear strength may [illegible]med to be $f_v/2$.

4.1.1 Standard strength classes

In this code the following standard strength classes are used for solid sawn and round timber: SC6, SC8, SC10, SC12, SC15, SC19, SC24, SC30, SC38, SC48, SC60, and SC75.

For the standard strength classes the strength and stiffness values given in table 4.1.1 are assumed.

A given grade can be assigned to one of the standard strength classes if the characteristic bending strength f_m is not less than the value given in table 4.1.1, and if the characteristic compression strength $f_{c,0}$, shear strength f_v and the mean modulus of elasticity $E_{0,mean}$ are not less than 95 per cent of the tabulated values.

The specification of standard strength classes does not prevent the use of other strength and stiffness values for individual species and grades.

Annex 4.1 contains a survey of which national grades can be assumed to satisfy the requirements of the different standard grades. (In preparation).

Annex 4.2 contains strength and stiffness values for a number of the most important structural species and grades e.g. for European redwood/whitewood graded according to UN/ECE Recommended standard for stress grading of coniferous sawn timber (Supplement 2 to Volume XXX of the Timber Bulletin for Europe, 1977).

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