49

DERIVATION OF BASIC STRESSES FOR SOME TIMBERS OF SRI LANKA

D. L. Jayanetti

1. Introduction

In Sri Lanka quite a large number of species which could be used for structural purposes are available. But so far, working stresses have not been determined for any of these species. The derivation of safe and efficient working stresses for timber whether solid ,laminated, round, plywood or scantlings, each with its own requirement, has a common starting point, which is the determination of strength properties of clear timber. Since studies have revealed that within species variation exists, samples tested should represent the whole species. For this a direct random sampling method was used to select test specimens.

The test specimens were prepared and tested according to British Standard No. 373 : 1957 — "Methods of testing small, clear specimens of timber". The tests carried out included strength tests as well as two physical tests, namely moisture content and nominal specific gravity (or Basic Density). These properties have been calculated from clear specimens (free from all defects) and the testing time lasts only for few minutes. But in actual practice, structural members are neither free from defects nor are loaded for a few minutes. Therefore, it is obvious that the values obtained from the laboratory tests on small clear specimens cannot be used directly for designing load bearing members.

2. Basic stresses

The basic stress has been defined as "the stress which can safely be sustained by timber containing no strength reducing characteristics".

Since timber is a natural material, it is subject to inherent variability in strength even in clear timber due to numerous influences such as moisture, soil conditions, growing space and age. Hence the values obtained for a given strength property from a number of tests show a significant variation. Due to this variation within the species, a statistical technique has to be adopted to determine the representative values. The method employed involves using the results of tests on small, clear specimens of timber as a basis of determining stresses for ideal structural members and then taking into account the various strength reducing effects encountered in service. The strength reducing factors include moisture content, variability of strength, long duration of loading, size and shape of members, and factor of safety.

3. Moisture content

The strength properties of timber are appreciably affected by the change in moisture content below the fibre saturation point which is around 25 percent. Above this point, there appears to be no change in strength due to increase in moisture content. Below fibre saturation point most strength properties increase with decrease in moisture content. For structural members used in places where the equilibrium moisture content present is relatively high, values obtained for green timber should be used in the computation of design stresses. Although drying results in increases of strength, the member may be affected by shrinkage causing reduction in size, in checking and possibly in degrade. The net gain in strength due to drying may be assumed to offset to some extent by the defects developed during drying and as a result green values are often used as the basis for stresses for solid timber design. Smaller sections where the material is properly dried, graded after drying and used under continuously dry conditions will be an exception. Therefore two exposure conditions will be taken into account namely green and dry. Hence it is permissible to use higher stresses in dry conditions (Table 3) than the green stresses (Table 2).

4. Variability of strength

As mentioned earlier, even within the species, wide variations occur. The probable for timber Timbiri (*Diospyros embryopteris*) is shown in Fig. 1. This is representative of the normal variations in most timbers. When this was statistically analysed, it gave an arithmetic mean of 13600 lb/sqin. and a standard deviation of 1600 lb/sqin With the help of these values, it is possible to draw a theoretical curve superimposing the actual distribution diagram. This curve is called the normal or Gaussian distribution curve. Assuming that the actual distribution follows the theoretical normal distribution, the theory of normal distribution is applied to these experimental results. By this procedure it is possible to estimate the lowest value likely to occur in practice. It is also found that the other properties also tend to follow a normal distribution in this manner. Hence the theory of normal distribution can be applied to the distribution of other strength properties of all timbers. Using this theory, a particular stress value is chosen which is known as the one percent lower probability value or the value below which not more than one in hundred (1 in 100) pieces would be expected to fail under standard test conditions. The theory of normal curve indicated that for one percent of results to be below a certain value is given by—(arithmetic mean — 2.326 times the standard deviation) or approximately (arithmetic mean — 2.33 times the standard deviation).

D. L. Jayanetti, BSc (Eng), MSc, DIC, CEng, MICE, is the Timber Utilisation Research Officer of the Forest Department. He graduated from the University of Ceylon, Peradeniya and pursued post graduate studies in Timber Structures and Technology at the Imperial College of Science and Technology, U.K.

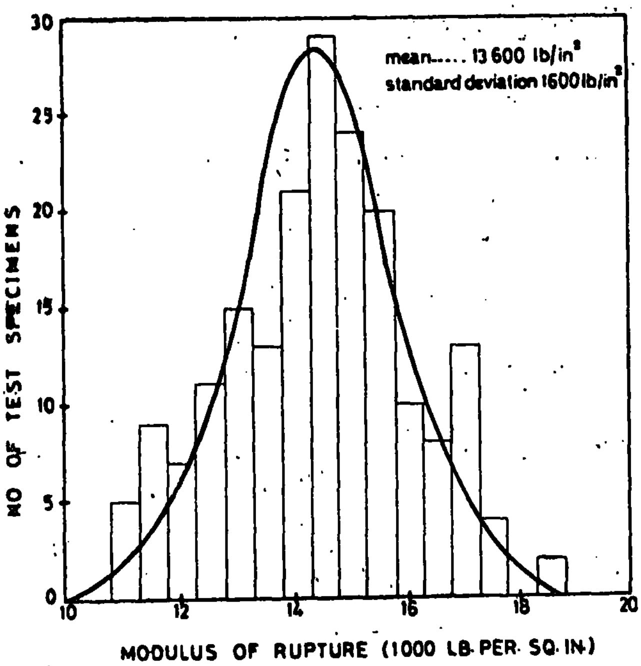

Fig. 1 Frequency distribution of modulus of rupture (adjusted to 15% moisture content) of Timbiri (Diospyros Embryopteris)

5. Duration of loading

It has been found that the duration of loading influences the magnitude of load required to cause failure. Standard strength values for timber are based on tests of 5 to 10 minutes duration. But in actual practice this is not so. It was found by Wood (1960) and Pearson, Kloot and Boyd (1958) that the long-term load strength to be at a stress level of 56 percent which means that a member is able to carry a load indefinitely provided the stress is not more than 56 percent (or 9/16) of the ultimate stress obtained from laboratory short duration tests. Therefore a reduction factor of 9/16 is applied to allow for the effect of long time loading which is a compensating provision made for loads applied for short periods.

6. Safety factor

The above reduction factor is combined with another reduction factor called the safety factor which is assumed to compensate for small accidental overloads, errors in design assumptions and defects in workmanship. This is taken as 80 percent (or 4/5). The magnitude of these reduction factors cannot be determined in a scientifically precise manner, as these are dependent upon limited information available on laboratory test specimens, instead of actual structural members. Use of these factors has been found to be satisfactory by past experience over the long periods of time.

7. Methods of determining basic stresses

The basic stress for each species and property is obtained by determining a statistically estimated minimum which is based on the test results of small clear specimens and dividing by a reduction factor given in Table I (Booth and Reece, 1967).

TABLE I

Property	*Probability determining minimum*	*Reduction factor*
Bending	1 in 100	2.25
Compression parallel to the grain ...	1 in 100	1.40
Compression perpendicular to the grain	1 in 40	1.20
Shear parallel to the grain	1 in 100	2.25
Mean modulus of elasticity	—	1.00
Minimum modulus of elasticity ...	1 in 100	1.00

It will be seen that these reduction factors are not the same for each property. For example, the strength property compression parallel to grain is not affected by the shape and size of specimen and also by the defects to the same extent as in bending. In addition the ratio of limit of proportionality to ultimate strength is about 25 percent greater in compression parallel to grain than it is in bending. Based on the above facts a smaller reduction factor of 1.40 is used for the derivation of basic compression stress parallel to grain as compared to 2.25 used for derivation of bending stress.

In the case of modulus of elasticity two values are given a minimum and a mean. The mean value of the strength property is used for calculation of deflections where a number of members act in unison and minimum value is used for individual members where a deflection limitation is specified.

Though the tensile strength of clear timber has a higher value than bending strength, a basic stress equivalent to bending is generally used for tension parallel to the grain because the defects have a considerable influence on tensile strength and the higher reduction factor has to be applied before use in that case.

8. Relationship between green stresses and dry stresses

It was mentioned earlier that the strength of timber is influenced by its moisture content and that when the member remains in a dry condition, it is permissible to use higher stresses than green stresses. A mathematical formula has been derived by Wilson (1932) to determine the strength values at various moisture contents below fibre saturation points and it is expressed by—

$$\log S = \log S_p + k\ (M_p - M)$$

Where S is the strength corresponding to a moisture content M, and S_p and M_p are the strength and moisture content respectively at the fibre saturation point, K being a constant.

TABLE 2

Green Stresses (expressed in lb/in²)

NOTE: These stresses apply to timber having a moisture content exceeding 15%

SPECIES — Common Name	Botanical Name	Bending and tension parallel to the grain	Compression parallel to the grain	Compression perpendicular to the grain	Shear parallel to the grain	Modulus of Elasticity — Mean	Modulus of Elasticity — Minimum
Arridda (S)	Campnosperma zeylanica	1800	1400	250	220	1.05×10^6	0.60×10^6
Burutha (S), Mutirai (T), Satinwood (E)	Chloroxylon swietenia ...	3300	2400	600	500	1.75×10^6	1.10×10^6
Etamba (S), Kaddu Ma (T)	Mangifera indica ...	2600	1900	500	350	1.50×10^6	1.0×10^6
Hora (S)	Dipterocarpus zeylanicus	2550	1750	500	360	1.65×10^6	1.05×10^6
Kataboda (S), Mullupilaka (T) ...	Cullenia ceylanica ...	2800	2150	550	220	1.40×10^6	0.90×10^6
Kos (S), Pila (T), Jak (E)	Artocarpus heterophyllus	2700	2000	550	320	1.5×10^6	0.95×10^6
Rubberwood (Boron Treated) (E) ...	Hevea brasiliensis ...	2400	1700	600	500	1.1×10^6	0.8×10^6
Tekka (S), Teak (E)	Tectona grandis ...	3200	2200	550	310	1.5×10^6	1.0×10^6
Timbiri (S), Panichchai (T)	Diospyros embryopteris	2400	1650	500	330	1.2×10^6	0.85×10^6
Welang (S), Vinanku (T)	Pterospermum canascens	2700	2100	600	500	1.5×10^6	0.95×10^6

S — Sinhala T — Tamil E — English

TABLE 3

Dry Stresses (expressed in lb/in²)

NOTE: These stresses apply to timber having a moisture content not exceeding 15%

SPECIES — Common Name*	Approx. density at 15% moisture content (lb/ft³)	Bending and Tension parallel to the grain	Compression parallel to the grain	Compression perpendicular to the grain	Shear parallel to the grain	Modulus of Elasticity — Mean	Modulus of Elasticity — Minimum
Aridda	30	2200	1900	380	250	1.20×10^6	0.65×10^6
Burutha	60	4200	3200	950	650	2.0×10^6	1.25×10^6
Etamba	37	3200	2600	750	500	1.75×10^6	1.15×10^6
Hora	52	3200	2500	700	500	2.9×10^6	1.2×10^6
Kataboda	37	3500	3000	900	250	1.6×10^6	1.0×10^6
Kos	38	3300	2800	900	380	1.7×10^6	1.0×10^6
Rubber Wood (Boron Treated) ...	46	3000	2400	850	600	1.25×10^6	0.9×10^6
Tekka	44	3900	3200	800	380	1.8×10^6	1.15×10^6
Timbiri	47	3000	2400	600	400	1.45×10^6	1.0×10^6
Welang	38	3400	3000	900	620	1.8×10^6	1.1×10^6

* Refer to Table 2 for other common names and botanical names.

References

1. British Standards Institution (1957), *Testing Small Clear Specimens of Timber*, B.S. 373 : 1957, B.S.I London.
2. Booth, L. G. and Reece, P. O. (1967), *The Structural Use of Timber*, SPON, London.
3. Pearson, R. G., Kloot, N. H. and Boyd, J. D. (1958) *Timber Engineering Design Handbook*, Commonwealth Scientific and Industrial Research Organisation, Melbourne.
4. Wilson, T. R. C. (1932), *Strength-Moisture Relations for Wood*, Tech. Bull., U.S. Dept. Agriculture, No. 282.
5. Wood, C. W. (1960), *Relation of Strength of Wood to Duration of Load*, United States Forest Products Laboratory Report, No. 1916.

(Refer page 29 for Sinhala Summary)