RESEARCH ARTICLE **(Open Access)**

Determination of mechanical properties in Teak wood (Tectona Grandis LF)

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Abstract

The Teak (Tectona Grandis LF) is one of the most important timber in the world, and recently imported in Albania, rightly famous for its fine color, a regular and resistant structure. This study consists in the determination of some of the most important mechanical properties of wood such as MOR, compression strength and wood hardness. After the samples were cut it is done the moisture measurement with the electrical method and resulted that the moisture percentage of the samples were 11.4%. It is calculated the density of wood and the mean value resulted 0.58 g/cm3. The tests for the bending strength are done according ISO 13061-3 at the universal test machine and the sample dimensions (number of samples 40) 2 x 2 x 32 cm with random selection. For the compression tests are cutted (from bending samples) samples with sizes 2 x 2 x 4 cm according ISO 13061-17. The hardness of teak wood is calculated according Brinell according the ISO 6506–1:2005. From all the measurements, resulted that the average compression strength σsh= 44.58 N/mm2. These values compared to the values referred to in the literature, result to be approximate with the values of the compression strength to teak wood originating from the Bali area. The mean value of static bending is MOR =106 MPa, with a st. dev =17.0, that is within reported range. The mean values of Hardness strength are 4,2 kN and 3,80 KN for tangential and radial planes, that are within reported range.

Keywords: Teak; compression strength; MOR, hardness; moisture content.

1. Introduction

Teak wood is used for structural purposes in house constructions as well as in boat and ships. Its growth occurs naturally only in India, Myanmar, the Democratic Republic of Laos and Thailand, and has been naturalized in Java, Indonesia, where it appeared about 400 to 600 years ago [9]. It is prized mostly for its natural durability and high dimensional stability in association with pleasant aesthetics. Some end-user requirements include high heartwood content (at least 85%) and wood density (> 675 kg/m3) and sufficient strength [modulus of rupture (MOR) > 135 N/mm^2 [4]. Indonesia has a long history of growing teak as an exotic plantation. In order to assess if community grown teak plantations there have the required strength properties for those end uses, mechanical strength of wood samples collected from 5 locations were determined. Teak timber used in this study have been cut from Teak plantations community, collected from 5 locations, named Gunungkidul, Wonogiri, Pacistan, Nusa Tenggara eastern and South East Sulawesi. Then samples were taken from the trunks for determining the mechanical and physical characteristics according to the ISO 1975 standard. The strength of the wood of Teak differed between the location. Generally, wood from south-eastern Sulawesi showed a greater mechanical hardness compared to the other four locations. The bending strength of community teak plantations reported in the present study was not inferior to the older trees. Bhat (1997)reported the MOR and MOE of 52 years old trees were 103.6 and 12,985 N/Nm2, respectvely[1]. Teak log normally attains maturity mechanical maturity by 20 & 21 years [2] & [3] which is coincident with the cutting age of mostly community teak plantations in Java. Previous studies on the mechanical properties of Teak wood obtained from a plantation with a senority of 17 years in Java reported that the elastic modulus was 10,729 N/mm2 [6]. An analysis of variance for the mechanical properties reveals that the only factor affected significantly on the mechanical strength of the teak wood was location. The location had profund influence on the structure and anatomy of teak wood. The other factors such as axial positions (butt, middle and top portion of the stem) as well as radial position of sapwood and heartwood did not affect the mechanical strength significantly. As mentioned in the preceding section the wood from South

East Sulawesi had greater percentage of heartwood than other locations which contributed to the differences in mechanical strength. As previously mentioned, the wood from south-eastern Sulawesi had a higher percentage of heartwood than other sites, which also affects the variability of mechanical strength. Physical properties assessed in many studies consist of wood specific gravity, shrinkage and swelling. The three factors included in the study are: the location of Teak wood taken from the plantations, radial position and three levels axial positions (but, middle and the top portion). Teak logs from five locations relatively had thesame physical characteristics. The highest wood specific gravity was found in teak wood coming from South East Sulawesi. The oven dried wood specific gravity of teak wood from this area was 0.69 and decreased slightly when it was measured in air dry condition. On the other hand, the lowest specific gravity was wood obtained in Nusa Tenggara eastern. Another result on shrinking abilities was taken from the teak trees from south-eastern Sulawesi. They were lower than the shrinkage values of Teak Drum from Java (Gunung Kidul, Wonogiri and Pacitan). Early wood shrinkage studies from a 17-year-old plantation in Java reported that radial shrinkage was 2.19%, while tangential shrinkage was 3.55% [6]. Shrinkage behavior of teak wood from community plantations agrees with the universal rule of shrinkage and swelling. The highest shrinkage value from the green condition to oven dried state was at the tangential direction, followed by radial direction and the lowest was at the longitudinal direction. The tangential direction shrinkage was almost twice radial shrinkage. The shrinkage value of the studied Teak samples is lower than the values reported by a similar study using trunks cut from a 20-year plantation in Thailand, where the resulting radial and tangential contraction values were respectively 4.1% and 10.7% [7]. Other published data ranged from 2.5% to 3.0% in the radius direction and 3.4% to 5.8% in the tangential direction [8]. While the values from the trunks taken in Java and eastern Indonesia were within the above mentioned limits. Factors that influence wood resistance. For the same sample we can obtain different values of mechanical characteristics in function of material conditions. In general we can say that the temperature rise corresponds to the reduction of strength and the timely prolongation of wood exposure to an elevated temperature (eg thermal wood treatment) can lead to negative effects on material strength. Generally, the changes of mechanical strength decrease by increasing the moisture content of wood and vice versa, such that the maximum of mechanical strength appears to be for oven-dry state while the minimum strength for the green state [5]. The annual growth ring width essentially affects resistance through density. For example, for Pinus sylvestris, with the annual ring width increasing from 1 to 5 mm, σsh decreases from 480 to 420 (kg/cm2). Generally they tend to aggravate the mechanical characteristics and sample s compactness. This study consists in the determination of some of the most important mechanical properties of wood such as MOR, compression strength and hardness in the teak samples taken from the teak wood of Bali region.

2. Material and Methods

This study consists in the determination of some of the most important mechanical properties of wood such as MOR, compression strength and wood hardness. The teak boards considered in this study originates from Bali, Indonesia. To perform mechanical tests it is necessary to determine the moisture content of the wood according ISO 13061-1. After sampling, their moisture content was initially measured by the electric method. In the case of our samples, average moisture content was 11.4%. It is calculated the density of wood according the ISO 13061-2 with the formula d=M/V (g/cm^3). The tests for the bending strength are done according ISO 13061-3. Sample dimensions are 2 x 2 x 32 cm and they are taken from random boards. Number of samples is 40. Modulus of Rupture MOR-Reflects the maximum load carrying capacity of a sample in bending and is proportional to maximum moment borne by the sample. To calculate the maximum bending strength, referred as Modulus of Rupture MOR we use the maximum load, P max

$$\sigma_{max} = MR = 1.5\frac{P_{max}\, l}{bd^2}$$

Where *P* is the load in N,

l span of the test specimen (24 cm),

b width of the specimen (2 cm),

d depth of the specimen (2 cm).

For determination of compression strength, the samples (40 pieces) were cutted from the bending samples with 2x2x4 cm size according to ISO 13061-17. The sample is placed with parallel oriented grain with the direction of load, the direction corresponding to the height of the sample 4 cm.From mechanical testing machine the values of the failure loads regarding to tests performed over 30 samples were obtained.

Fig 1. Tests carried out in laboratory to measure failure load during compression parallel to the grain

The method specified by the standard ISO 13061-17 was applied to measure the compression strength parallel to the grain. Specimens 2x2 cm in cross section and 3-6 cm in length were loaded gradually by a steadily increasing force F, up to a dry and harsh noise was heard. At the same time occurs even the reduction of load, which together with the noise indicate the failure of the specimen's material. The compression strength parallel to the grain σ_{sh0} was calculated in N/mm^2 by means of formula:

$$\sigma_{sh_0} = \frac{F_u}{A} \quad \left(N / mm^2\right)$$

where F_u is the failure load in N
A is the cross-section of specimen in mm^2 (around 400 mm^2).
The signature "σ0" indicates respectively the compression load as well as the angle between the load's direction and the direction of the grain, which in our case is 0º). The mechanical tests about the hardness Brinell hardness HB (N/mm2) of wood are done according the ISO 6506–1:2005. The aplied force according the wood density of Teak is 1000 N. The ball was loaded and reloaded in tangential and radial section of samples for 20 sec and the time of retention of the maximal load was 30 sec. The samples were cut in dimensions of 40 × 40 x 40 mm. Brinell hardness HB (N/mm2) is given by Eq.

$$HB = \frac{2F}{\pi D(D-\sqrt{D^2-d^2})}$$

where F (N) is applied load (1000 N),
D (mm) the diameter of the steel ball (10mm)
d (mm) the diameter of indentation.

3. Results and Discussion

The mean value of static bending is MOR =106 MPa, with a st. dev =17.0, that is within reported range. From the tests the average compression strength of Teak wood resulted σsh= 44.58 N/mm^2, with a standard deviation. 4.19. Data of results were elaborated using EXCEL. The mean values of Hardness strength are 4,2 kN and 3,80 KN for tangential and radial planes, that are within reported range. The mechanical properties of Teak determinated in this study are shown in Table 1.

Table 1. Some physical and mechanical properties of Teak samples

MC (%)	Density (g/cm^3)	MOR (MPa)	Compression (N/mm^2)	Hardness (kN)	
				Tangential	Radial
11.4	**0.58**	**106**	**44.58**	**4.2**	**3.80**
(1.2)	(0.04)	(16.0)	(4.19)	(0.81)	(0.9)

Note: The bold figures are the mean values and the figures in parenthesis are the standard deviation

Table 2. Comparison of the mechanical properties from our tests with the reported range values from other studies

Properties	Samples Values	Reported range	Remarks
MOR (MPa)	106	85 - 106	Within range
Compression strength (N/mm^2)	44.58	47 - 60	Lower
Hardness (kN) Tangential	4.2	3.73 - 4.51	Within range
Hardness (kN) Radial	3.8	3.73 - 4.51	Within range

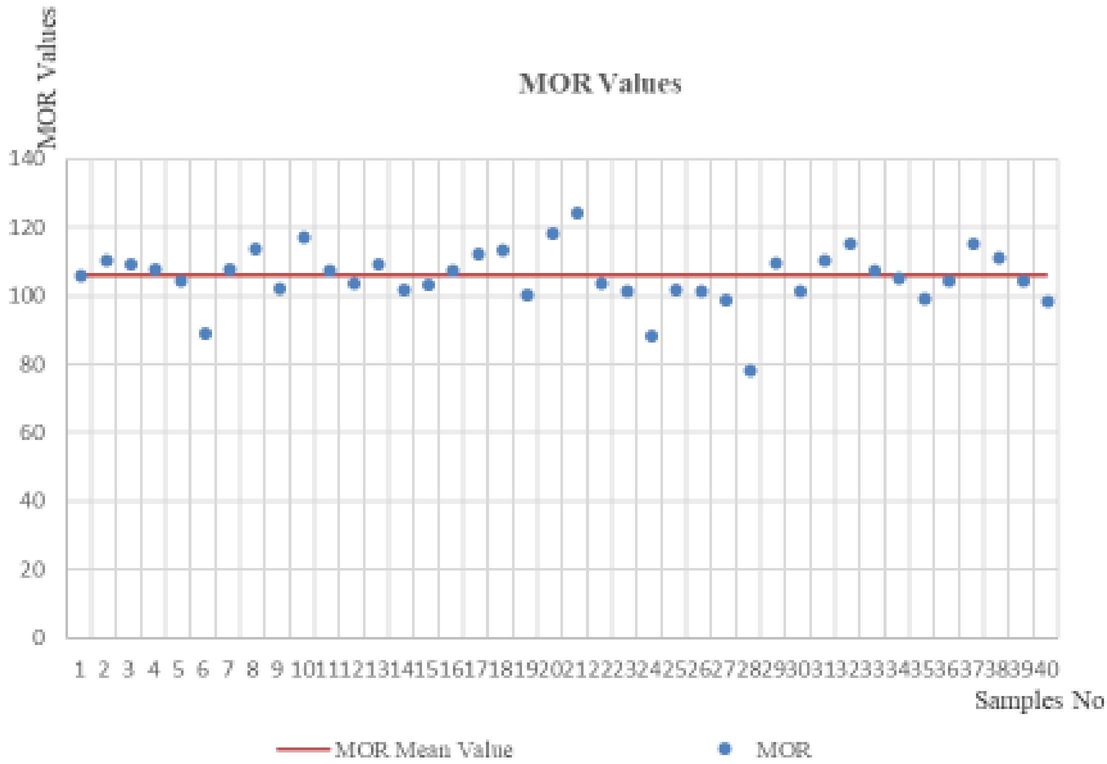

Figure 2. The Modul of Rupture values.

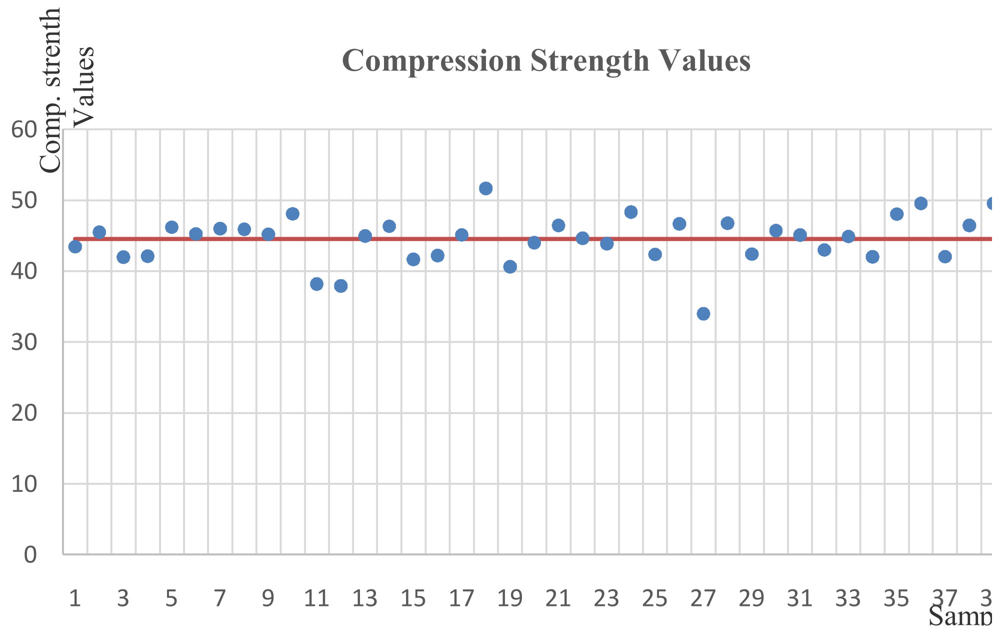

Figure 3. Compression strength values.

Some physical and mechanical properties of the Teak samples from the tests in our study, with means and standard deviations are summariezed in Table 1. The average Moisture Content of the samples was 11.4 % and the average density is 0.58 g/cm3. The Table 2 gives the comparison between the tests values and the Reported Range from the other studies.

4. Conclusions

From the tests on the Teak sample we have these conclusions:

- The mean value of static bending is MOR =106 MPa, with a st. dev =17,0, that is within reported range.
- The mean compression strength parallel to the grain of Teak wood imported by Bali is σsh= 44.58 N/mm2.
- These values compared to the values referred into the literature, result to be comparable with the values of the compression strength of teak wood originating from E. Nusa Tenggara area 46 N/mm². This value is lower than reported range.
- The mean values of Hardness strength are 4,2 kN and 3,80 KN for tangential and radial planes, that are within reported range.

5. References

1. Bhat KM. **Managing teak plantations for superior quality timber**. In: Basha, S., Mohanan, C. and Sankar, S. (eds.). Teak. Proceedings of the International Teak Symposium, India, 2-4 December, 1991. Kerala Forest Department and Kerala Forest Research Institute. 1997 pp. 28-31.
2. Bhat KM. **Timber quality of teak from managed plantations of the topics with special reference to Indian plantations.** Bois et Foret des Tropiques 2000 263:6-16.
3. Bhat KM, Priya PB, Rugmini P. **Wood characterisation of juvenile wood in teak**. Wood Science and Technology 2001 34:517-532.
4. Eko B. Hardiyanto TA, Prayitno. **Present Utilization of Small-Diameter Teak Log from Community Teak Plantations in Java and Eastern Indonesia** 2008
5. Lato. E – Quku D. **Studim druri** – Struktura makroskopike dhe vetitë fizike mekanike të llojit
6. Putro AM. and Sutjipto, A. H. **The influence of age and axial position on physical and mechanical properties of thinned teakwood. F**aculty of Forestry GMU, Yogyakarta (unpublished) 1989. 98p.
7. Ruksasupaya,B., Kruesuwanwes, S., and Buranasheep, S. **Mechanical properties of teak wood** (Tectona grandis Linn.f) from plantation grown logs. 1995
8. Trockenbrodt, G. and Jouse, J.
9. **Woodproperties and utilisation potential of plantation teak (Tectona grandis) in Malaysia:** a critical review. Journal of Tropical Forest Products 1999 5:58-70.
10. Troup, R.S. **The silviculture of Indian trees** Vol. II, Clarendon Press, Oxford. 1921pp. 697-769.