

Physical and Mechanical Properties of *Cupressus lusitanica* as a Potential Timber Tree for Sudan

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(Received November 09, 2012; Accepted December 26, 2012)

Abstract— The wood of 20-year-old *Cupressus lusitanica* Mill. from Jebel Marra area Western Sudan was studied to determine its physical and mechanical properties as a potential exotic timber tree. Wood density as basic and on oven-dry density was determined. Bark-to-wood ratio by mass and by volume as well as radial and tangential shrinkage was determined. Static bending tests were carried out and the modulus of rupture MOR and modulus of elasticity MOE were calculated. Impact bending, compression strength parallel to grain, maximum crushing strength as well as shear stress were determined. The obtained results for the mechanical properties were compared with the values for the same cypress species from India and Costa Rica. The results showed that the average value for the oven-dry wood density (513 kg m^{-3}) and the basic density (446.0 kg m^{-3}) were medium but higher than the Indian (434 kg m^{-3}) and Costa Rican cypresses. The average bark-to-wood ratios (7.95% by mass and 5.12% by volume) were in the normal range for tropical softwoods. The MOR ($693.0 \text{ kpa cm}^{-2}$) was lower than that of the Indian cypress ($763.0 \text{ kpa cm}^{-2}$) but higher than for the Costa Rican cypress. The MOE (142.7 kg m^{-2}) indicates good stiffness properties. The compressive strength was higher than for both the Indian and Costa Rican. The shear stress was lower than that of the Indian cypress but similar to Costa Rican. Due to the obtained results the wood of *C. lusitanica* studied could be considered as a medium density structural and general purpose wood.

Index Terms— *Cupressus lusitanica*, Dry density, Basic density, Static bending, Impact bending, Compressive Strength, Shear stress

I. INTRODUCTION

Cupressus lusitanica Mill. (Mexican cypress or East African cypress) is an evergreen coniferous tree. It belongs to the Cupressaceae family [1]. It is indigenous to Central America where it grows at altitudes of 1200-3000m [2]. The tree can reach a height up to 30 meters [3]. The thick bark is reddish-brown, with longitudinal fissures. *C. lusitanica* has been introduced in Sudan as early as 1940 from

Kenya [4]. In the early sixties plantations were made at Beldong, Toron Tonga, Tiena, Barbara, and Kebli forests in Jebel Marra area [5],[6]. The wood of *C. lusitanica* is a medium density wood and used for general construction and furniture. It was reported as good species for pulp and papermaking [7], [8], [9]. Wood varies widely in its composition, structure, and properties. Each wood species with possible commercial importance, therefore, must be carefully studied and analyzed to know its physical, chemical, anatomical, and mechanical properties in relation to the uses intended for [7]. The objective of this study was to find the mechanical utilization potentials of *C. lusitanica* wood and how wood integrated industry can be employed to maximize the economic utilization of plantation forests of Jebel Marra Western Sudan as well as the evaluation of the possible contribution of *C. lusitanica* wood as structural and general purpose timber

II. MATERIALS AND METHODS

The raw material used in this study was wood of 20-year-old *C. lusitanica* (suru) or cypress grown in Jebel Marra Western Sudan. The height of the trees ranged between 18 and 25 meters with an average of 22 meters. Five representative trees were randomly selected, felled, delimbed (branches removal) [10], and cross-cut into logs. Logs of 100cm length were cut (50cm above and 50cm below). The logs were further reduced to different specimens in accordance with the B.S.373; 1957 Standard [11]. Wood density was determined using a water displacement system. The basic density was determined as oven-dry weight / green volume. The oven-dry density was determined as oven-dry weight / oven-dry volume. The wood mechanical properties determinations were carried out in accordance with the British Standard methods for testing small clear specimens of timber (B.S. 373; 1957). The average oven-dry density of wood was measured using standard blocks $2\text{cm} \times 2\text{cm} \times 2\text{cm}$ as shown by the following equation:

$$\text{Oven-dry Density} = \frac{\text{oven-dry weight}}{\text{oven-dry volume}} \text{ (kg m}^{-3}\text{)} \quad [1]$$

$$\text{Basic Density} = \frac{\text{oven-dry weight}}{\text{green (soaked) volume}} \text{ (kg m}^{-3}\text{)} \quad [2]$$

Compression strength parallel to the grain was carried out using specimens of 2cmx2cmx6cm. The test was carried on a Losenhausenwerk universal testing machine. The maximum crushing strength (p_{\max}) was calculated by dividing the load to failure by the cross-sectional area of the specimen as shown by the following equation:

$$\text{Comp // grain} = \frac{P(\max)}{A} \text{ (kpa m}^{-2}\text{)} \quad [3]$$

$P(w_{\max})$ = is the maximum load at
Break point (kpa)

A = the area of cross-section of specimen (cm^2)

For both static bending and impact bending determination the size of the test specimen was 2x2x30cm. The test specimens were supported over a span of 28cm. on the roller bearings. The load was applied to the center of the beam and the loading head was descending at a constant speed of 0.01mm/second. The machine used for static bending test was the Hounsfield tensometer while for impact bending a small Hutt-Turner machine was used. The Modulus of rupture (MOR) and the modulus of elasticity (MOE) were calculated as follows:

$$\text{MOR, kpa cm}^{-2} = \frac{3PL}{2bh^2} \quad [4]$$

$$\text{MOE, kpa cm}^{-2} = \frac{PL^3}{4\Delta bh^3} \quad [5]$$

Where,

P = load in kg at the limit of proportionality,

L = span of the test specimen in cm,

h = depth of the test specimen in cm,

b = width of the test specimen in cm,

Δ = deflection at the limit of proportionality in cm.

The shear stress parallel to the grain test was carried on 2-cm cubes using the Hounsfield tensometer, Maintained at a constant rate of crosshead movement of 0.01mm/second. The radial and tangential apparent average shearing stresses were calculated as follows:

$$\text{A.A. S. S., kpa cm}^{-2} = \frac{p}{bh} \quad [6]$$

Where:

p = maximum load in kpa causing shear.

b = width of the test specimen in cm.

h = depth of the test specimen in cm.

All test pieces were completely free from defects including knots, splits, wane, resin pockets, bark or cross grain. Any samples showing defects were rejected from the test. All test specimens were conditioned at 12% moisture content for all

mechanical tests. The results obtained were compared with those of 20 to 30-year-old cypress wood from India and 10-year-old cypress wood from Costa Rica.

III. RESULTS AND DISCUSSION

The mean values for physical properties of *C. lusitanica* from Western Sudan, India (studied by Shukla [12]), and Costa Rica (studied by Moya [13]) are shown in **Table 1**. The average values for basic density of wood from the three different regions (446.0 kg m^{-3} , 434.0 kg m^{-3} , and 430.0 kg m^{-3} respectively) are nearer to each other and they are in the normal range for tropical softwoods. The average basic density for the saturated wood specimens was lower than the oven-dry density for the same wood species and that was due to the bigger volume of specimens at the fiber saturation point. Since the wood density is a characteristic of wood that affects the properties of the manufactured products, it could be taken as a reasonably reliable indicator of the wood strength and ease of working. The average values of bark-to wood ratio for the Sudanese cypress both by mass and by volume (7.95 and 5.12 respectively) were in the normal range for tropical softwoods. The bark-to- wood ratio for the Sudanese cypress was also nearer to that of the Costa Rican cypress while the tangential and volumetric shrinkage for the Costa Rican cypress were lower than for the Sudanese cypress. According to these physical properties, the Sudanese cypress wood could be classified as a medium density pulpwood and structural timber with moderate strength properties.

The mean values of strength properties are shown in **Table 2**. The average value for modulus of rupture (MOR) for the Sudanese cypress (693.0 kPa cm^{-2}) was lower than the Indian (763.0 kPa cm^{-2}) [12] and higher than the Costa Rican (576.0 kPa cm^{-2}). The lower value for the Costa Rican [13] cypress shows the effect of age on the strength properties of wood. The modulus of elasticity (MOE) for the Sudanese cypress was higher than the Indian cypress [12]. The MOR and the MOE are important parameters for the use of wood as a structural material. MOR is an indication of bending strength of a board or structural element and MOE is an indication of stiffness. The results showed that the MOR for the Sudanese cypress (776.00 kPa cm^{-2}) was higher than that for the Indian (763.00 kPa cm^{-2}) which means higher stiffness, and as it is expected the reverse was true for the MOE (142.7 kPa cm^{-2}) but was also higher than the Indian cypress which has shown only 87.9 kPa cm^{-2} . This indicates that both the ease with which the wood can be bent and the percentage of strength it retains after bending are of medium range like other *Cupressus* species [14]. This also proves that the greater the stiffness the less the deflection of the beam under load [15]. The impact bending as a measure for toughness of timber has shown a reasonable average height of drop (79.00 cm) this is good at resistance to suddenly applied loads.

This indicates good toughness which is important when considering the wood for sports equipment and handles of striking tools but the best and suitable use is for roofing and flooring where moderate impact strength is very important. The results for compression strength parallel to grain were higher than that of the Indian cypress where the maximum crushing strength reached 477.00 kPa cm⁻² with an average of

421.00 kPa cm⁻² compared to 319.00 kPa cm⁻² of that of Indian cypress (**Table 3**). This is good for poles, posts, and trusses. The radial and tangential shear stress (101.50 kPa cm⁻² and 114.00 kPa cm⁻² respectively) results were both lower than those of the Indian cypress and higher than those of Costa Rica (**Table 4**).

Table 1
Physical Properties of *Cupressus lusitanica* wood from Western Sudan, India, and Costa Rica.

Origin	Sudan	India Shukla [12]	Costa Rica Moya [13]
Properties	Mean	Mean	Mean
Oven-dry density kg m ⁻³	513.00	-	-
Basic density kg m ⁻³	446.00	434.00	430.00
Bark- to-wood ratio by mass %	7.95	-	7.12
Bark- to-wood ratio by volume %	5.12	-	-
Radial shrinkage %	3.20	-	3.24
Tangential shrinkage (T) %	5.80	-	4.42
Volumetric shrinkage (R) %	8.20	-	7.29
Ratio of shrinkage T/R	1.81		1.36

Table 2
Average basic density, static bending, and impact bending for *C. lusitanica* Wood from Western Sudan compared with the same species from India and Costa Rica.

Origin	Western Sudan			India Shukla [12]	Costa Rica Moya [13]
Properties	Mean	Minimum	Maximum	Mean	Mean
Basic density kg m ⁻³	446.0	414.0	478.0	434.0	430.0
Static Bending					
Modulus of rupture, kPa cm ⁻²	693.0	485.30	776.00	763.00	576.00
Modulus of elasticity, MPa cm ⁻²	142.7	98.8	178.4	87.9	76.0
Impact Bending					
Maximum height of drop, cm	79.00	73.70	86.4	-	-

Table 3
Compression strength parallel to grain for Sudanese *C lusitanica* wood from Western Sudan compared with the same species from India and Costa Rica.

Origin	Western Sudan			India cypress Shukla [12]	Costa Rica Moya [13]
	Mean	minimum	maximum		
Maximum crushing stress, KPa cm ⁻²	421.00	392.00	477.00	319.00	143.00

Table 4

Shear stress for Sudanese cypress (*C. lusitanica*) wood from Western Sudan compared with The Indian and Costa Rican cypresses.

Origin	Western Sudan			India Shukla [12]	Costa Rica Moya [13]
	Mean	Minimum	Maximum		
Radial, kPa cm ⁻²	101.50	96.00	112.00	108.00	101.00
Tangential, kPa cm ⁻²	114.00	101.00	124.00	119.00	94.00

IV. CONCLUSIONS

From the obtained results and based on the physical and mechanical properties, cypress wood from Western Sudan could be considered as medium density exotic softwood of good strength properties mainly in the modulus of rupture and compression parallel to grain. The test results proved that this Sudanese cypress has medium-to-tough durable, and good

Quality wood compared with the same cypress from India and Costa Rica. Therefore, it could be used in many applications such as building constructions in the form of trusses, beams, headers, and poles. The impact bending result showed that it is also suitable for roofing, flooring, where moderate impact strength is very important. Due to its medium density, the Sudanese cypress wood could be used for veneer production and decorative purposes.

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