Original Research Article

Comparative evaluation of physical and mechanical properties in the radial positions of coconut (*Cocos nucifera)* timber

Abstract:

The study evaluates the physical and mechanical properties variation within coconut timber's radial position (dermal, sub-dermal, core). Properties were studied on the 55-year-old coconut palm from KAU coconut farm Vellanikkara, in Thrissur, district Kerala. The average density of coconut timber measured for three positions was 862.3 kg m^{-3}, 670.8 kg m^{-3} and 287.9 kg m^{-3}, respectively. The average moisture content of coconut timber in the radial position was 15.7 %, 16.6 %, and 17.5 %, respectively. Compressive strength parallel to the grain is 32764.77 kg cm^{-2}, 25591 kg cm^{-2}, 7532.35 kg cm^{-2} and in perpendicular to the grain were found as 46712.42 kg cm^{-2}, 39233.3 kg cm^{-2}, 22353.04 kg cm^{-2}. Hardness at the side and ends of the dermal position is 1207.612 kg and 767.65 kg, respectively. In the sub-dermal position, 1035.7 kg and 750.88 kg, respectively, in core position it is 252.34 kg and 359.31 kg respectively.

Keywords: Physical properties, Mechanical properties, *Cocos nucifera*

INTRODUCTION

The coconut palm (*Cocos nucifera*) is the most important tropical crop under *Arecaceae*. Because of the multi-purpose use of coconut palm, it is often called the "Tree of life." Coconut palm is the most cultivable crop in almost all areas of the Kerala region. It bears food, fuel, cosmetics, and building materials, and it has many other uses. In Kerala, coconut is the inevitable ingredient in foods. Due to the high strength properties of coconut timber, it is used as structural components such as housing components like trusses, purlins, walls, joists, doors, and window frames (Arancon,1997).

The timber of the coconut palm is called ''porcupine wood'' and has a nice-looking, fragmented appearance. Coconut wood has proven to be comparable to conventional wood in durability, sturdiness, and versatility, often at a considerably lower cost. The use of coconut wood as a substitute material for building construction could bring down the cost of housing units.

Physical properties are the key factor in selecting coconut timber for various uses such as

furniture, building materials, cabinet making, construction of the frame, bridge, sporting goods, measuring instruments, musical instruments, particle boards, decorative surfaces, insulating media, etc. (Anon, 1970). Based on the density of the coconut timber, it can be used for loading and non–loaded structural components. Low-density timber is mainly used for non-loading structures, and high-density timbers are used for load-bearing materials.

Mechanical properties resist external forces (static or dynamic load) Sekhar *et al*. (1962); Panshin and De Zeeuw, (1970). These properties are essential in considering the timbers for structural and construction purposes.

Nowadays, people are moving towards urbanization. As the coconut is the major crop in Kerala and the neighboring state, Tamil Nadu's large plantations of the coconut palm are transformed into residential areas that require cutting and efficient utilization of this fallen trunk. Under the pilot project by Coconut Development Board, Kerala has announced a replanting and rejuvenation program. It is aimed to remove the senile and diseased plants by planting a new ones. Efficient disposal of fallen trunks is by converting them into sealable wood products, and it also is an additional source of income for new growers (Anoop *et al.*, 2011). Thus the information of properties makes it more advanced to use coconut timber as wood products. So, the study aims to find out the physical and mechanical properties of timber to assess the coconut timber for structural purposes.

MATERIALS AND METHODS

Coconut palm is collected from the KAU coconut farm of Vellanikkara, Thrissur dist. Kerala. Sample trees were 55 years old and free from knots and other imperfections.

Density:

According to IS 1708: 1986 (ISI,1986) the required sample size for density was 6 cm x 2 cm x 2 cm and for moisture content determination was 2.5 cm x 2 cm x 2 cm. These cut specimens were made by using a plain saw.

A set of six samples were taken from the three radial positions to examine the variations.

The samples were kept oven-dry in a hot air oven for 103 ± 2 °C. Oven-dried samples were weighed with an accuracy of 0.001 g in a weighing balance.

- Density was calculated as the following equation.

$$\text{Density} = \frac{\cdot}{\cdot} \quad \text{…….. (Eq 1)}$$

Where,

W= oven-dry weight, kg

V= Volume of the sample at test, m^3

Moisture content:

❖ The percentage of moisture content was calculated as the following equation.

$$\frac{w1}{w1-w0} \text{x } 100 \text{ …...…….(Eq 2)}$$

Where,

w_1 - Weight of sample at test in g

w_0 - oven dry weight of sample in g

Mechanical properties:

Mechanical properties such as compressive strength(parallel and perpendicular to the grain) and hardness were tested using an automatic Universal Testing Machine (UTM- Shimadzu 100 KN). These tests were conducted at the central wood testing laboratory, The Rubber Board, Kottayam.

According to IS 1708: 1986 (ISI,1986), the sample size required for various mechanical properties testing is as follows. Compressive strength parallel to the grain (8 cm x 2 cm x 2 cm), Compressive strength perpendicular to grain (10 cm x 2 cm x 2 cm), and Hardness test (15 cm x 5 cm x 5 cm).

RESULTS AND DISCUSSION

Density:

The density at the three radial positions varies greatly (Fig:1). The highest mean density was at the dermal position (862.27 kg m^{-3}) and the lowest at the core (central) position (287.94 kg m^{-3}) (Table 1).

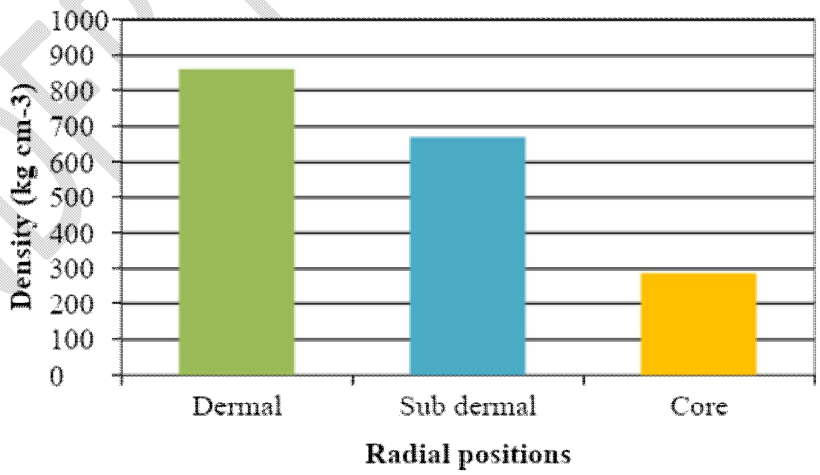

Fig:1 Density variation at three radial positions

Table: 1 Density and moisture content variation at three radial positions

SL.NO	Radial position	Density (kg m^{-3})	Moisture content %
1	Dermal	862.27 (25.59)	15.559 (0252)
2	Sub-Dermal	670.75 (87.88)	16.58 (0.198)
3	Core	287.94 (14.89)	17.28 (0.432)

Note: Values in the parenthesis show standard deviation. Significant within radial positions at 5% level.

Moisture content:

The moisture content was different among the radial position (Fig 2). The moisture content ranges from 15.7 % to 17.5 % (Table:1). The highest moisture content was at the central core position, and thus it is not suitable for making load-bearing structural components. There is a significant moisture content variation among the three radial positions of coconut timber.

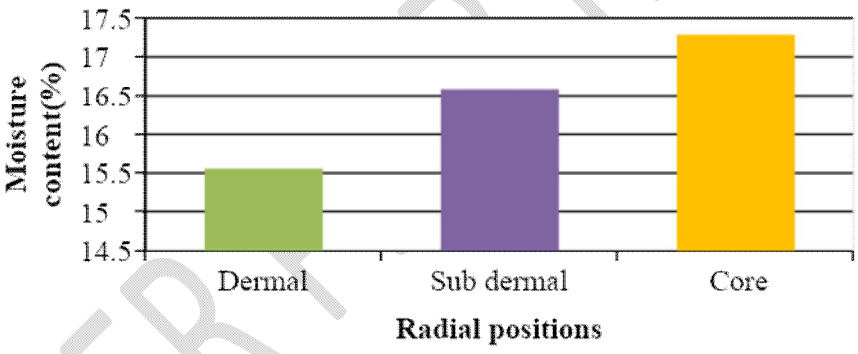

Fig:2 Moisture content variation at three radial positions

Mechanical properties:

1) Compressive strength

The palm's compressive strength (parallel to the grain and perpendicular to the grain) varies within the radial position. The highest strength is in the dermal position in both cases, i.e., 32764.77 kg cm^{-2} (Table 2) and 46712.42 kg cm^{-2} (Table 3). Figure 4 & 5 shows the variation of compressive stress (parallel and perpendicular to the grain) between the radial positions.

Table : 2 Compression paralel to the grain in between the radial position

SL.NO	Radial	CS at LP	CSat ML	MOE	ML

	poaition	(kg cm^{-2})	(kg cm^{-2})	(kg cm^{-2})	kg
1	Dermal	576.3 (15.5)	668.98 (21.42)	32764.77 (5539.46)	2706.7 (86.71)
2	Sub-Dermal	364 (62.59)	470.65 (59.48)	25591 (5691.85	1885 (238.58)
3	Core	119.18 (27.25)	152.07 (40.8)	7532.35 (208.96)	612.58 (166.1)

Note: Values in the parenthesis show standard deviation. Significant within radial positions at 5% level.

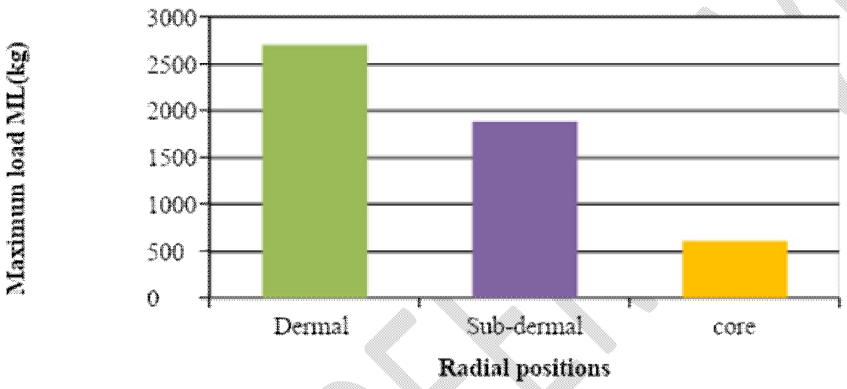

Fig:3 Variations of ML for compression parallel to the grain between the three radial positions

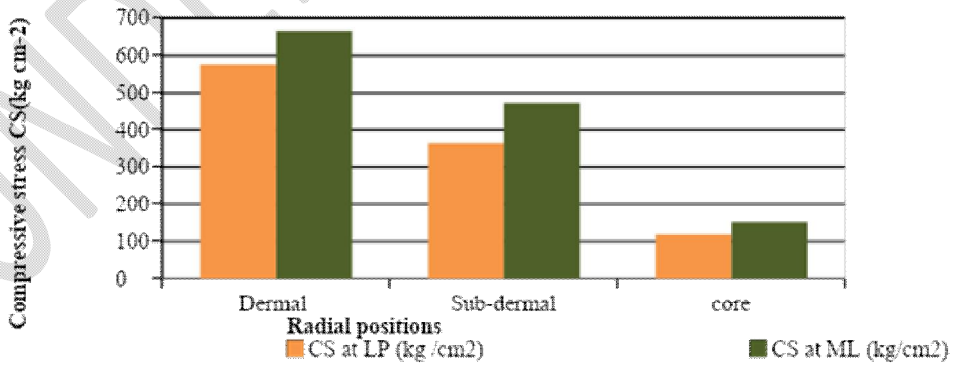

Fig:4 Compression perpendicular to the grain in between radial position of coconut timber

Table : 3 Compression perpendicular to the grain in between the radial position

SL.NO	Radial position	CS at LP (kg cm-2)	CS at 2.5 mm kg cm-2	MOE kg cm-2	Load at 2.5 mm kg
1	Dermal	557.54 (90.92)	718.64 (137.68)	46712.42 (1035.34)	2878.42 (550.92)
2	Sub-dermal	40128 (64.5)	519.02 (70.59)	39233.3 (2973.41)	2078.2 (282.59)
3	Core	286.2 (34.95)	342.42 (42.67)	22353..04 (2032.8)	1372.96 (171.21)

Note: Values in the parenthesis show standard deviation. Significant within radial positions at 5% level.

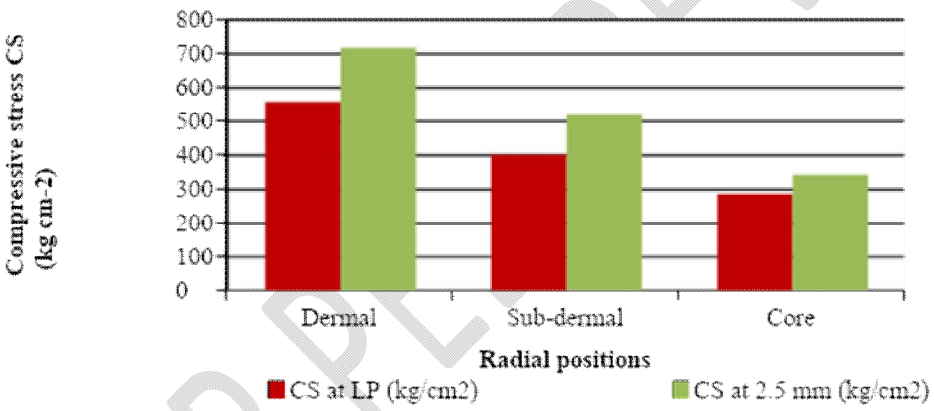

Fig:5 Compression perpendicular to the grain in between radial positions

2) Hardness

The resistance to the indentation (hardness) is more for the dermal position (1207.61 kg, 767.65 kg) and is lesser for the core position (252.587 kg, 359.31 kg) on both sides and ends of coconut timber (Table 4).

Table:4 Hardness at the radial position

SL.NO	Radial position	Hardness	
		Side (kg)	End(kg)
1	Dermal	1207..612 (82.746)	767.65 (224.69)
2	Sub-dermal	1035.7 (61.782)	750.88 (78.43)
3	Core	252.587 (164.69)	359.31 (50.65)

Note: Values in the parenthesis show standard deviation. Significant within radial positions at

5% level.

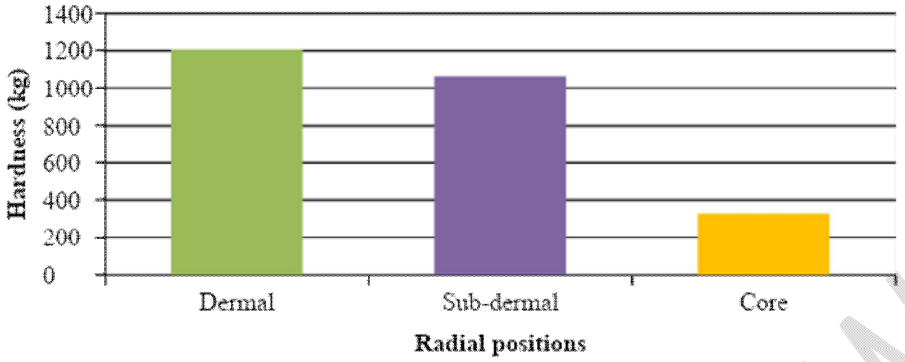

Fig:6 Hardness at the sides of radial position

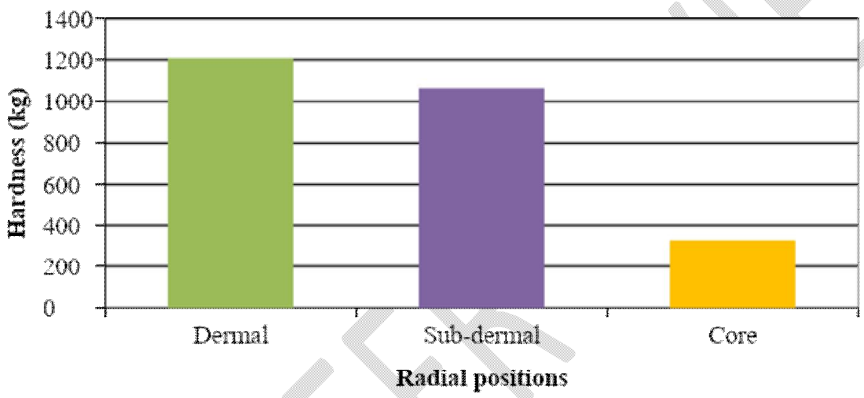

Fig:7 Hardness at the ends of radial position

CONCLUSION

The density of coconut timber at the radial positions was 862.3 kg m^{-3}, 670.8 kg m^{-3} and 287.9 kg m^{-3}. The moisture content measured 15.7 %, 16.6 %, and 17.5 %. Compressive strength parallel to the grain was 32764.77 kg-cm^{-2}, 25591 kg cm^{-2}, 7532.35 kg-cm^{-2} and compressive strength perpendicular to the grain was found to be 46712.42 kg-cm^{-2}, 39233.3 kg-cm^{-2}, 22353.04 kg-cm^{-2}. Hardness for dermal position (1207.612 kg, 767.65 kg), sub-dermal (1035.7 kg, 750.88 kg), core (359.31 kg). Further studies are required to find out other properties. This study focuses on the usage of coconut timber for structural purposes.

REFERENCES

Arancon, R. N. Jr. 1997. *Asia Pacific Forestry Sector Outlook; Focus On Coconut Wood*. Asia Pacific Forestry Outlook Study Series No.APFSOS/WP/23, Forestry Police and Planning Division, Food and Agriculture Organization, Rome, 39p.

Arancon, R. N. Jr. 2009. *The Situation and Prospects for the Utilization of Coconut wood in*

Asia and the Pacific. Asia-Pacific Forestry Sector Outlook Study II Serie No. APFSOS

II/WP/2009/15, Regional Office for Asia and Pacific, Food and Agriculture Organization, Bangkok, 45p.

Anon. (1970). Indian Forest Utilization, Forest Research Institute, and Colleges, Dhera Dun, India,1:179-185.

Anoop, E. V. *et al.* (2011). Processing and utilization of coconut wood in Kerala', *J. Indian Acad. of Wood Sci.* 8(2): 76–79.

Panshin, A. J. and Zeeuw, C. D. 1970. *Textbook of Wood Technology: Structure, Identification, Uses, and Properties of the Commercial Woods of the United States and Canada* (3rd Ed.). Mc- Graw-Hill: New York, 705p.

Sekhar, A., Rawat, B., and Bhartari, R. 1962. Strength of bamboos *(Bambusa. nutans). Indian For.* 88(1): 67-73.

M. N. Rana, A. K. Das and M. Ashaduzzaman (2015). Physical and mechanical properties of the coconut palm (*Cocos nucifera*) stem. *Bangladesh J. Sci. Ind. Res.* 50(1): 39-46.