Utilization of Cocowood for Affordable Engineered Wood Flooring in Sri Lanka

HDS Asoka#, DWK Gayantha and HT Rupasinghe

Faculty of Built Environment and Spatial Sciences, General Sir John Kotelawala Defence University, Sri Lanka

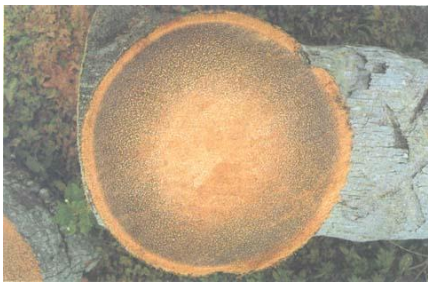
#asokahds@kdu.ac.lk

Abstract – Coconut wood or Cocowood has a long history of being utilized as a building material in Sri Lanka. Cocowood stem has three major parts from the inner core to outer skin such as; low-density wood, medium density wood and high-density wood based on the moisture content and the fibre bundle patterns. Cocowood is mainly used for roof construction and the utilizations are limited for certain lengths where timber logs less than 4'-0" in length are mostly abandoned in factory processes in Sri Lanka. The high-density stem fibre has properties similar to many hardwood timbers which are majorly used for luxury flooring products while the rest of the stems are under-utilized or used as firewood. Even though the utilization of Cocowood for flooring is practised in the international context, it has not been properly adopted in the local context. The objective of this research is to produce an affordable engineering flooring material that minimizes the material wastage of Cocowood by utilizing the medium density Cocowood stem and abandoned short length hard-density Cocowood logs. The research process identified the efficient use of Cocowood and the practical dimensions for an affordable Cocowood flooring material. Experiments resulted in 0'-6"x 0'-48" sized, ¾" thick, glue-lamed, aesthetically pleasing, engineered Cocowood tile that can be utilized as an alternative economic flooring material. The introduced tile is economical compared to the other timber flooring materials available in the current market.

Keywords: *cocowood, building construction, moisture content, density, efficient use, glue-lam, engineered wood, dimensional stability, affordability, colour variation, texture variation*

I. INTRODUCTION

Coconut palm (Cocos nucifera) is an endogenous tree which produce special wood named Cocowood or coconut wood. It is an agricultural crop widely spread throughout the tropics. Economic lifespan of a coconut tree is around 60 years and afterwards the trees are used by saw millers. By that time the dimensions of the tree would be as follows: Maximum Diameter (Butt) - 30cm, Top Diameter - 15cm, Average height - 20m, Gross volume per stem - 0.9m^3 (Killmann, 1996). The anatomical features of Cocowood results non-homogenous distribution of physical properties both over cross-section and height, so is a very non-homogenous raw material. The dry density of the stem fibre decreases towards the centre of the stem and over the height. The higher density wood or hard area (700 Kg/m3) is deposited in the outer periphery of the stem which has properties similar to many hard woods (Bailleres, 2010). Central area of stem consists of low-density wood (<500 Kg/m3) and the area in-between consist of medium density wood (500–700 kg/m3) (Killmann, 1996). Thus, the density rapidly varies approximately by 200Kg/m3 within a 150cm stem radios where approximately 25 % of the millable portion of coconut stem consists of low-density wood.



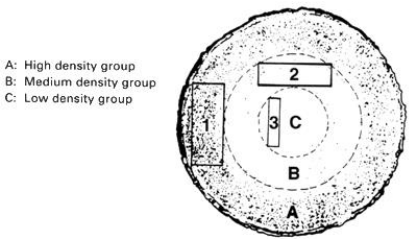


Figure 5: Cross section of coconut palm stem with density zones
Source: Sulc, 1984

The moisture content is high in raw coconut wood compared to exogenous wood. It is negatively correlated with the basic density of coconut wood. The moisture content decreases with increasing basic density and vice versa. The amount of moisture in coconut stem increases with increasing stem height and decreases from the core to the cortex. The moisture content ranges from 50% at the bottom portion to 400% at the top core portion of the stem (Killmann, 1996). According to another research no significant difference in moisture content has been found between periphery and core portion of a 40 years old coconut stem (Rana et al., 2014). The dimensional stability of the wood is determined by its shrinkage or swelling. Shrinkage and swelling cause drying defects such as checks and split. Unlike conventional wood where tangential shrinkage is almost twice the radial shrinkage, the tangential and radial shrinkage of Cocowood are not significantly different (Killmann, 1996). Seasoning is essential for coco timber before using due to this high moisture level. Air drying using an open ended and roofed shed is the most economical practice of seasoning coco timber (Romulo & Arancon, 2009).

The utilization of coconut tree varies with the height. Average length of the millable log of the tree is 8.4m. The top most part of the stem (from top edge of the millable log up to the level of first nut) has an average length of 6.6m and is considered as unusable as the percentage of low-density wood increases. Thus, that part of the stem is utilized as wood for charcoal and firewood. (Killmann, 1996). Accordingly, 44% of the total length of coconut stem is not used as millable wood.

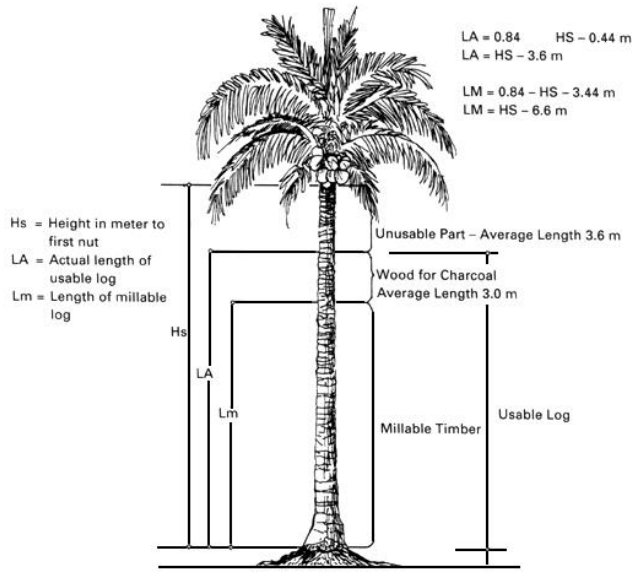


Figure 6: Use of the coconut palm stem
Source: Jensen and Killmann, 1981

One of the primary uses of Cocowood is building construction. In building construction Cocowood is used for making trusses, purlins, walls, joists, doors, windows, wall panelling, and cladding and also as a flooring material. However, around 90% of above mentioned Cocowood end use in building construction require high density and medium density wood materials (Killmann, 1996). As per the literature, approximately 25 % of the coconut stem is not used in building construction due low-density wood. When considering the complete stem of a fully grown 60-year-old coconut tree, overall 54% of Cocowood consist low density portion. Thus, only around 46% of an average coconut stem is possible to be utilized in building construction. Therefore, maximum utilization of this 46% is important to minimize wastage.

Cocowood in local context;

Coconut is a popular agricultural crop in the country. There are three main verities of coconut found in Sri Lanka namely tall (typica), dwarf (nana) and thambili (king coconut - aurantiaca) (Mahindapala, 1989). In Sri Lanka generally after 60 years, palm trees are uprooted (Mahindapala, 1989). As a tropical country Sri Lanka has many historic records proven that Cocowood has been used in many construction works. Coconut can be classified as a "traditional" wood under "non-forest wood resources" group in Sri Lanka. The utilization of coconut timber is increasing in the country as an alternative to solid wood. In fact,

Cocowood is popular as a building material in Sri Lanka in the form of structural members such as rafters, reapers and purlins (Mahindapala, 1989). According to available statistical data from year 1986 to year 1990, 102000m^3 of Cocowood has been utilized in Sri Lanka and had been predicted that it would be around 235000m^3 by year 2020. Therefore, unless the use of coconut wood is developed, the demand will have to be met by imported wood.

Only 20% of the saw log quality Cocowood logs are used mainly for hand-hewn rafters and surplus is likely to be used as fuel wood (Mahindapala, 1989). Thus that 20% has to be the high-density portion of the coconut stem as they are utilized as structural members which need high strength. As aforementioned data, from the 46% of useable middle density and high-density wood available in an average stem, it can be presumed that the remaining 26% of middle density usable wood for construction is underutilized in the local context.

Although Cocowood is popular as structural members in Sri Lanka its utilization as a flooring material is not very common. But it is internationally popular where countries like Australia is manufacturing export quality Cocowood flooring. (Romulo N. Arancon J. , 2009) The aesthetical appearance of the Cocowood created by bundle pattern increases its suitability as a floor finish. According to the data published by Australian centre for agricultural resources high density Cocowood and medium density Cocowood is suitable to manufacture flooring products (Bailleres et al., 2010). Thus, the main objective of this research to incorporate medium density Cocowood for flooring products by maintaining durability and dimensional stability to maximize the underutilized Cocowood and reduce the wastage of Cocowood. The final outcome of this research will serve the purpose of economise coconut wood use and find an alternative to expensive timber flooring.

II. METHODOLOGY

As mentioned the experimental research was conducted with the aim of utilising the underutilized medium density Cocowood and to reduce the wastage in Cocowood industry, aiming a product development; Cocowood flooring, which is economically feasible in local context. Main objective of the product development process was to utilize the existing cocowood related technology, techniques and machinery in the local industry.

A. Selection of materials and primary processing

For the study, 50 number of fallen trees with an average length of 60' were selected which are ready to process for timber. The top most part of trees of approx. 16.4' average length were removed due to the high proportion of low density wood. The rest approx. 49.2' long usable logs were bucked in to 8', 7', 6' and less than 5' Lengths. All logs were counted and measured after bucking. In the sawmill selected logs less than length of 5' were processed into 2"X4" lumbers by standard sawmilling equipment as 2"x4" is the common timber size of Cocowood which are used as rafters in roof construction. Afterwards a visual grading was done on physical defect and colour by an experienced timber technician to select medium density and high density lumber out of the lot.

B. Construction of The Flooring Material

Once sorting the lumber based on density they were dipped in a boron-based wood preservative commonly available in market as the preservative chemical to avoid stains and moulds as accelerated drying was not utilized in the process. The used preservative is a water born preservative suitable for timber use for internal applications. Boron is poisonous to wood-boring insects and wood-destroying fungi but safe for human (Romulo and Arancon, 2009). Lumber was dipped for 02 to 03 minutes in the Boron solution and stacked 04 to 05 weeks following the standard stacking methods to avoid boards contacting with the ground or direct sunlight, either before or after dipping.

Process of air drying was done in an open sided roofed shed. Since the product development was aimed to be an economical flooring material for the local market air drying alone was identified to be sufficient. Air-drying in tropical environments can achieve moisture contents between 15% and 18% because of the ambient conditions. This moisture content is proved to be feasible for non-airconditioned environments (Bailleres et al., 2010). Therefore, logs were kept inside a protected shed for air drying and the moisture content was monitored using resistant meter until 15% moisture content was achieved which took six weeks.

C. Construction of Timber Floor Tile

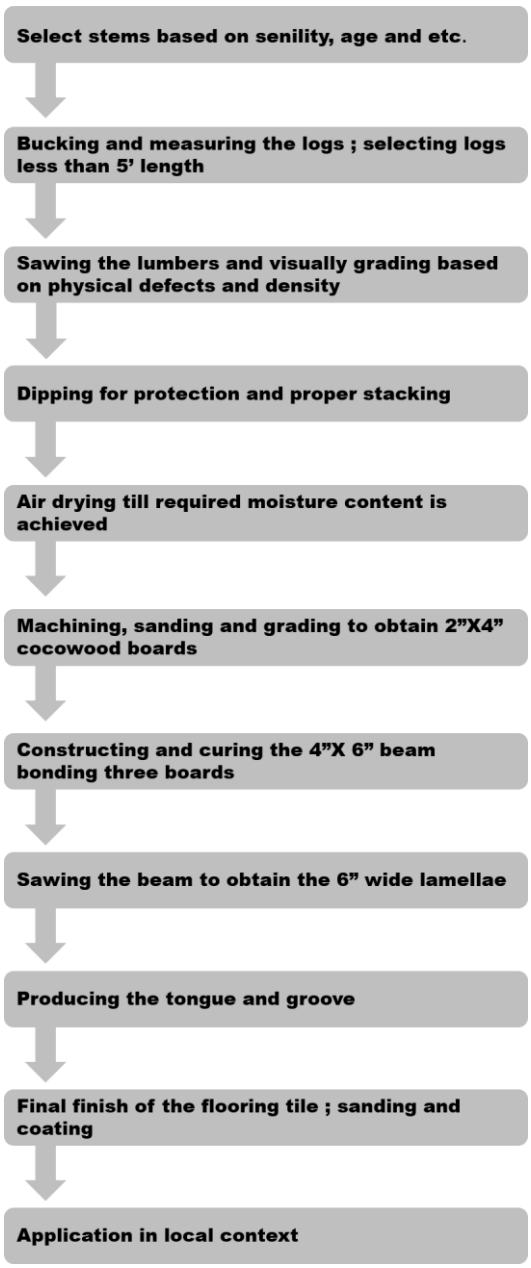


Figure 7: Production process followed in developing the Cocowood floor tile in local context

Seasoned 2"x4" Timber sections were glued using epoxy wood adhesive in the way that high-density lumber and low-density lumber are placed in alternate rows to produce a 6"x 4" beam (figure 4). This method is called as glue lamination or glue-lam. This method prevents the deformation of the final product due to case hardening and improve the dimensional stability. Further, this alternative use of high and medium density lumber influences the appearance of the tile by creating a visual variance which otherwise is monotonous.

Based on the technology and machinery available in the current industry the thickness of the beam was limited to 6". This was due to the reason that the possible maximum depth of the sawing table blade is 6". Glued boards were kept for 08 hours to ensure adhesion. After 08 hours glued timber beams were cut along its longitudinal axis in to in to ¾" thick timber tiles to obtain 05 tiles of equal thickness.

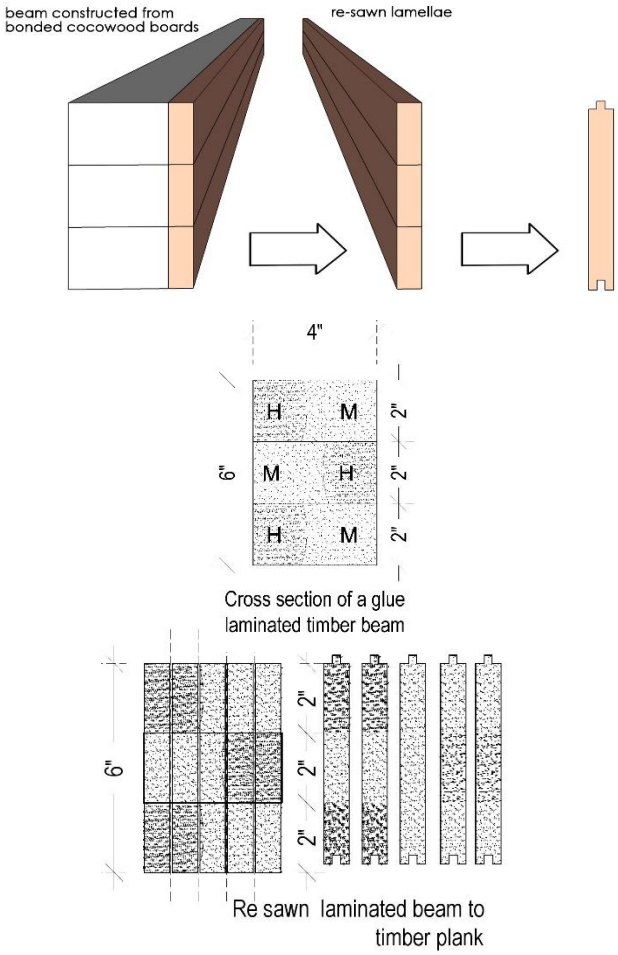


Figure 8: Constructing the Cocowood tiles

The thickness was decided based on the minimum wastage requirement and recommended minimum thickness. Afterwards those ¾" thick timber planks were trimmed in to a 4' of lengths. One engineered timber tile consists of 02 high density timber pieces and one medium density timber piece or vice versa. The final size of the engineered timber plank is 6"x48" and ¾" in thickness. Subsequently tongue and

groove joints were made on each engineered timber tile.

Surface Finishing

Wood planks were sanded to get the smooth finish following the standard sanding procedure. One coat of wood stain and three coats of water-based wood top coats were applied to get the desired finish (Figure 5).

Cost comparison

Market Prices of a leaner foot of 2"x3" Cocowood lumber of 8'-0" 18'-0" and less than 5' lengths were recorded based of 05 large scale sawmills. Manufacturing cost of the Cocowood tile flooring was calculated and compared with the market prices of conventional hardwood flooring and parquet flooring to determine the economic feasibility and maximum utilization of manufactured product.

Figure 9: Processing of Cocowood tile

III. RESULTS AND DISCUSSION

Using the measurements of 45'-0" long usable logs taken by 50 selected coconut trees, the length comparison of different log lengths produced by an average coconut tree was calculated and given in the table 01. 13% Log length is less than 5'0" according to the results.

Table 01: different log lengths produced by an average coconut tree

Log length	% of total length of the log
Less than 5'	13%
5'-0"- 10'-0'	28%
10'-0"- 15'-0'	42%
15'-0"- 18'-0"	27%

Price of a linear foot of 2"x4" coconut timber for different length were compared and given in the table 02. According to the table 02 the price of a 2"X4" coco wood lumber increases by 20 LKR per every additional linear foot of a specific length.

Table 02: Price comparison of 2"x4" Cocowood timber for different lengths

Log length	Price per 1ft. (LKR)
Less than 5'	70.00
6'-0"	100.00
8'-0"	140.00
10'-0"	180.00
12'-0"	220.00
14'-0"	260.00

Manufacturing cost breakdown of 05 number of ¾" tk. 4'-0" x 0'-6" engineered coconut timber tiles is given in the table 03.

Table 03: Manufacturing cost breakdown of 05 number of ¾" tk. 4'-0" x 0'-6" engineered coconut timber tiles

Description	unit	Rate (LKR)	Total (LKR)
4'-0"X4"X2" coconut wood lumber	12ft.	70 per ft.	840.00
Epoxy resin glue lamination	4sq.ft	38	152.00
Preservative treatment	0.2l	150 per litre	28.50
One coat of water base wood stain	8sqft	8 per sq.ft	64.00
three coats of water base top coat	8sqft	17 per sq.ft	136.00
Labour and equipment		100	825.00
			Rs.2045.50

According to the aforementioned figures the manufacturing cost for 05 number of ¾" thick 6"X4'-0" engineered coconut wood tile is 2045.50 LKR. So, the cost per square foot of coconut wood flooring tile is 204.55 LKR. Based on the market

survey, installation cost of the conventional hardwood flooring system was found as LKR.250.00 per sq.ft. The rate calculated to Cocowood flooring system introduced through the research is considerably lower than the conventional hardwood flooring. Based on this data, the rate for supply and installation cost of laminated Cocowood flooring system is LKR.454.00 per sq.ft with added 25% of profit margin referring the rule of thumb in current market. Based on these figures price comparison of the coconut wood laminated tile with other hardwood flooring systems is in table 04.

Table 04: Price comparison of the coconut wood laminated tile with other hardwood flooring systems

Cocowood	Burma teak hardwood	Burma teak parquet	Local teak hardwood	Local teak laminated
Rs.566	Rs.2250	Rs.1750	Rs.1650	Rs.950

IV. CONCLUSION

The research was conducted to construct an affordable engineered timber floor tile using under-utilized local Cocowood stem. Thus, 0'-6"x 0'-48" sized, ¾" thick, gluelamed, aesthetically pleasing, engineered Cocowood tile was produced using short length (less than 5'-0") Cocowood logs combining high density and medium density Cocowood lumber. Cocowood logs less than 5'-0" lengths are not utilized in the industry as shorter lengths are not adequate to get the required roof spans. Thus, offcuts of the Cocowood logs which got shorter lengths (less than 5'-0") have no economic value in the market. Further, medium density Cocowood is not utilized for structural timber members and rarely used for other purposes in Sri Lankan building industry. Therefore, the under-utilized medium-density Cocowood was combined with offcut high density Cocowood to manufacture the engineered Cocowood floor tile through the research process. Standard methods of timber floor installation were used for the installation of the Cocowood tile as well. Adopting a unique installation method was not in the scope of the research. Dimensional stability of the tile was expected by Alternate combination of medium density wood and high-density wood. The developed product and the findings of the research indicated following advantages in economical, sustainable and architectural point of views;

- Economical with reduced cost compared to local teak laminated timber flooring solutions as the tile is engineered by an underutilized parts of coconut stem.
- sustainable due to utilization of probable waste of the coconut wood; 13% of usable wood from the coconut stem is under-utilized due to medium density and short length.
- Aesthetically pleasing than monotonous colour and texture of conventional Cocowood as colour and texture variation of the engineered tile due to batch variation of timber and alternate fibre bundle pattern of medium density wood and high-density wood.
- Available for mass production as coconut is an agricultural crop, a forestry wood and abundance of underutilized parts of coconut stem in local context.
- Potential for exporting due the demand from foreign market

Further studies;

The mechanical properties and the durability of the tile has to be measured in further researches. Mass production possibility of this product and potential of exporting should be analysed further. Moreover, it is needed to further research on maximizing the utilization of Cocowood as flooring and to further economize the product by reducing the costs by developing the Cocowood floor tile combining a different base material suitable for local context and bonding the Cocowood as the top lamellae instead of homogenous Cocowood tile.

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