Preliminary investigation on ancient timber structures through microscopic analysis

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***Abstract*— The aim of the study is to identify the wood utilized in the traditional houses built in Uva province of Sri Lanka, constructed using traditional construction technologies. The timber samples were taken out from roof elements such as rafters, wall plates and reapers from three different timber structures located at three different locations constructed during 1960 – 1970 using vernacular timber preservation technics and preservatives. Samples were extracted and adequately prepared for a microscopic investigation to observe the characteristic microscopic anatomical features. Sledge microtome was used for wood sectioning and photomicrographs were obtained by polarized light microscope. The authentic samples and reference microscopic identification keys were employed in order to conclude on the wood species involved. The relative density of the samples was also measured using the maximum moisture content method to verify the identification. Timber samples were identified using vessels, fibers, rays, parenchyma, and other microscopic features. Based on the macro and micro examination of the external and microanatomical features the timber used for rafters, reapers, wall plates were identified as Mango wood which is scientifically known as *Mangifera indica*. The relative density values were in the range of 0.52 – 0.7.**

Keywords—Wood, microscopic analysis, timber structures, wood identification, *Mangifera indica*

I. INTRODUCTION

Remains of traditional edifices are the main sources for a study of the ancient timber architecture of Sri Lanka. Traditional physical evidences cumulate the essence of vernacular technologies with an important historical, aesthetical and technical value resulting from the ingenuity of structures, elegance of shapes, skillfulness of decoration and diversity of finishing techniques employing natural construction materials such as timber and bricks [1-4]. Among them wood is a major utilized versatile material emerge in ancient structures [5,6].

Visual evaluation of these structures, based of its macroscopic features of the heritage structure is not conclusive determining the timber species utilized for construction and to analyze whether the species would have incorporated to resist for timber deterioration during application. In such case identification of wood species becomes, therefore, a compulsory step prior to any intervention [7]. Therefore, a microscopic approach is more reliable as the preliminary stage of the approach to an investigation of the entire timber artifact [8]. A porous, three-dimensional, hygroscopic, interconnecting matrix of cellulose, hemicelluloses, and lignin material can be technically known as wood [10]. The vessels and their walls are composed of cellulose glued together with lignin. The strength properties, appearance, resistance to penetration by water and chemicals, resistance to decay, and many other properties are affected by the characteristics of these fibrous cells and their arrangement [11-13]. The specialized water-conducting cells of hardwoods are literally known as Vessels. The function of hardwood is almost exclusively as mechanical supporting cells. Where the hardwoods consist of a wide variety of axial parenchyma patterns. The rays in hardwoods are structurally more diverse compared to the fibers found in softwoods [14].

In general Wood identification is very momentous for scientists in the fields of forestry, and wood technology and wood engineering as a first step on an investigation. It reveals the cell arrangements and features. Through vast experience features like color odor grain patterns density and hardness can be used to identify wood. But the accuracy depends on the experience of the person and the quality of the expected sample of the particular wood. It's often a challenging mission due to both the diversity of wooden species used throughout vernacular timber structures and the ageing and degradation phenomena affecting the wooden material appearance and sometimes even its structural integrity during its entire service life. The identification will be complicated when the wood sample is a typical, decayed, or insignificant or small in size, often the identification can be incorrect. As per the literature, Examining woods, especially hardwoods, with a 10× to 20× hand lens, greatly improves the accuracy of the identification. Even though the accuracy depends on the experience [15, 16].

Also, the literature states accurate identification requires that the wood be sectioned and examined with a light microscope for a scientific investigation where a 10X objective lens would determine many features of the particular section [17, 18]. Scientists state, simultaneously it is important of the micrographs as well as in identification a reference library of pre-identified authentic samples to which the unknown samples could be compared [19, 20].

Further scientists presents if researches lack collection of a reference library they can additionally refer through indexed reputed books or research journal papers including anatomical descriptions [21]. In addition to these resources, commercially available computer-assisted software or commercial libraries like delta-intkey can be used. At the same time without any physical sectioning, there are few non-destructive advanced techniques, such as X-ray phase-contrast micro-tomography,

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3D-analysis throughout the volume of the wood . Along with all the most used, cost-effective, and readily available technique is the typical wood anatomy imaging techniques that include transmission light microscopy through thin microtome wood sections.

This paper presents a case study of microscopic species identification for three small samples extracted from three selected houses from Uva province constructed during the period of 1960 – 1970 using vernacular timber preservation technics and preservatives.

II. Materials and Methodology

A. Sample collection procedure

The three houses were constructed using hip roof where the wood has been preserved by one of the vernacular timber preservation technics practiced in Sri Lanka; "Fig 1". The decoded information states, village people have practiced to place the sawn timber under paddy field mud for several weeks as a long-term experienced wood preservation technic. The structural elements in roof such as rafters, ridge beam, Hip beam and reapers were collected in three locations in the Badulla District, Uva Province in Sri Lanka.

Three samples per each section (36 total samples) were transported to the pro-green laboratory of Department of Civil Engineering, University of Moratuwa Sri Lanka for macro sample analysis and then to the laboratory in Department of Forestry and Environmental sciences , University of Sri Jayewardenepura Sri Lanka for micro sample analysis.

Fig. 1. The cases selected from Uva Province ,A-Soranathota , a- roof details , B- Mahiyangana b- roof details , C- Silverland Badulla , roof details

B. Macroscopic Observation

This method was based on identification of anatomical features in end grain (cross section) which can be observed with the unassisted eye (naked eye) or with the aid of the magnifying lens

C. Wood Sectioning

20mm x 20 mm x 30 mm sized samples were extracted. Timber samples were soaked in water and left them for one weeks. Radial, Tangential, Transverse sections of 10-15 µm thickness were cut using a sledge microtome (model Leicia SM 2000R) "Fig 3".

Following staining procedure was used to stain the timber section for permanent slide preparation; (chart 1)

Timber sections were stained in safranin using Petri dishes. Sections were then mounted permanently using Canada balsam.

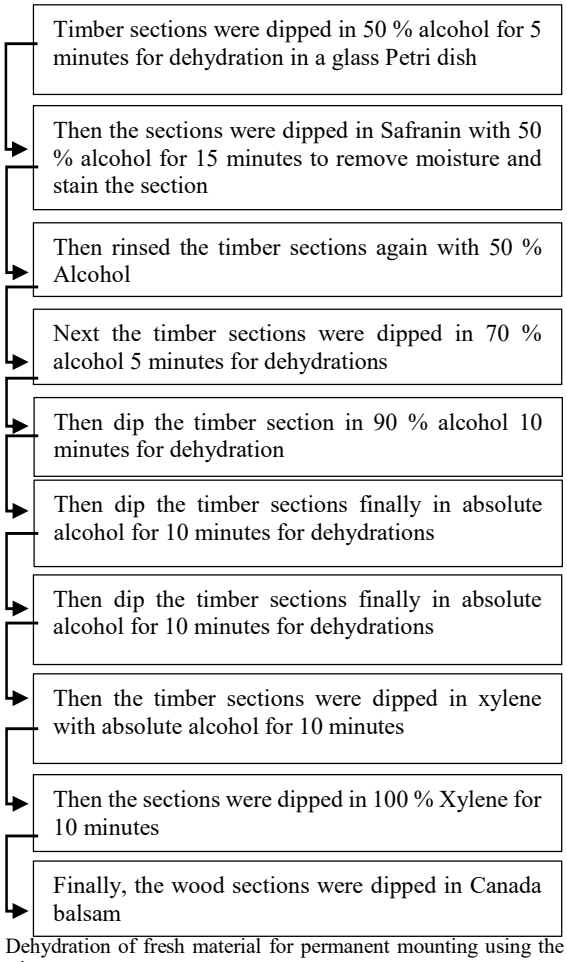


Chart 1 – Dehydration of fresh material for permanent mounting using the stains safranin

D. Microscopic Observation

The permanent slides were prepared from all the samples. Then the slides were observed using a AxioCam Icc 5 – Polarize light microscope.

The observed microscopic features were compared with the authentic sample library images.

Timber samples were identified using anatomical features through comparing with authentic timber samples available in the Department of Forestry and Environmental Science,

University of Sri Jayewardenepura and relevant wood identification data sources (Local and International): “Fig 2”.

Fig. 2. The cases selected from Uva Province ,A-Soranathota , a- roof details , B- Mahiyangana b- roof details , C- Silverland Badulla , roof details

Fig. 3. Some of the sections obtained from the roof .

E. Determining the Specific gravity

Relative density of the Samples was also measured using Maximum Moisture Content Method; “Fig 4”, “Eq. (1)”.

Technically the specific gravity of wood is derived by weight of the oven dry wood divided by the weight of a volume of water equal to the volume of wood under the moisture conditions at test [22].

The specific gravity of the sample was calculated by substitution in the formula:

$$specific\ Gravity = \frac{1}{\{\frac{Mm-Mo}{Mo}+\frac{1}{1.53}\}} \quad (1)$$

Green weight of the samples (Mm), Oven dry weight of the samples 103±2 ° C until a constant weight is obtained (M0). 1.53 is the specific gravity of the wood cell wall substance.

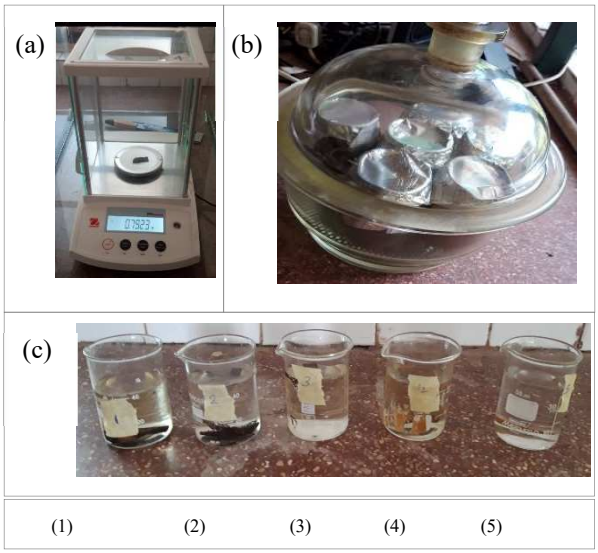


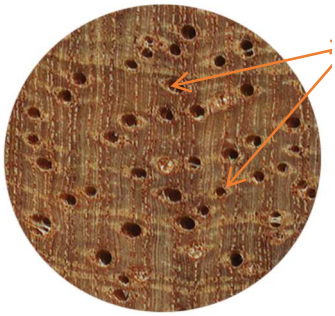
Fig. 4. A-The weight obtained through the digital scale , B- apply pressure C- Timber samples soaked in water

III. RESULTS AND DISCUSSION

A. Macroscopic images and interpretation

Macroscopic observations showed that the growth ring boundaries are distinct or absent; “Fig 5”.

There was no specific color different among the sapwood color and the heartwood color. The outer surface of the elements was darker black in shade.



Diffuse-porous
No specific
Arrangement large to
very large pores seen.

Fig. 5. Mango (end grain 10x)

B. Relative Density

In all the 27 samples in common rafters, Ridge beam, Hip Beam and reapers the relative density values presented in the range of 0.52 – 0. 70.

C. Microscopic Interpretations

The microscopic features presented as follows, “Fig. 6”

- The vessel arrangement of wood is diffuse porous.
- There is no specific pattern in the vessel arrangement. The Axial Parenchyma band are more than three cells wide (Marginal or Seemingly marginal bands.

The helical thickenings (spiral thickening in longitudinal tracheid’s) were absent.

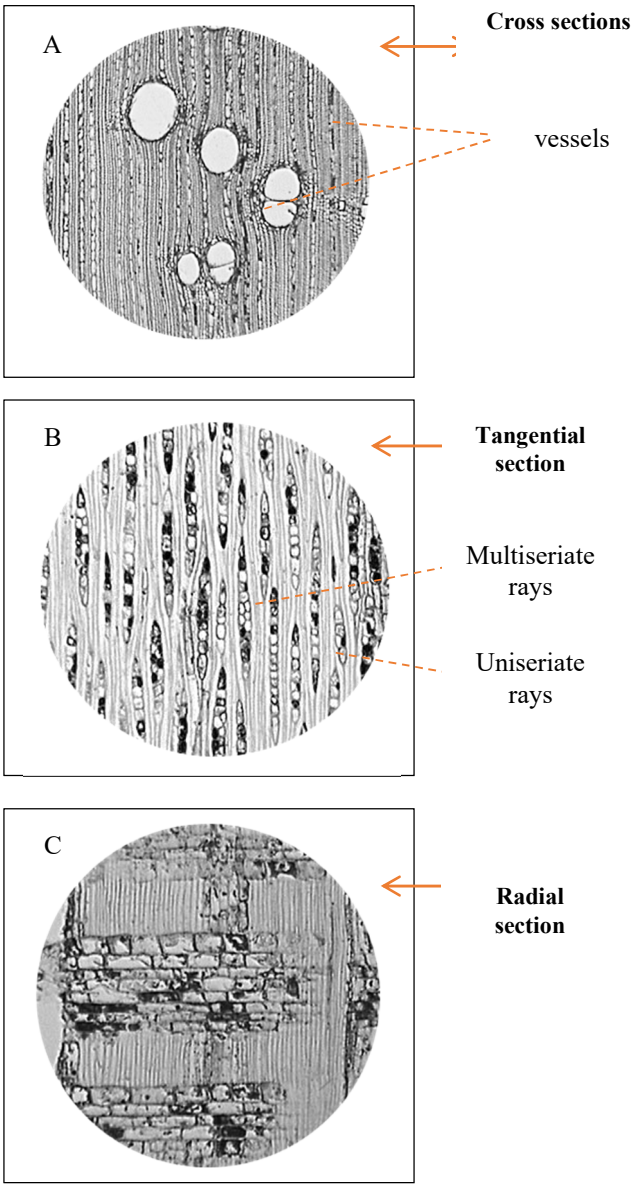


Fig. 6. A-Transverse section , B- Tangiantial section , C- Radial Section

- Tyloses were commonly available. The thickness of the fiber walls gradually increases, while the very thick fiber walls are visible in the latewood region; Figure 6.
- Axial Parenchyma in marginal bands are visible as strands (2-8 cells). Uniformed sized rays with an absent of Aggregate rays.
- Perforation plates are simple.
- Vessel-ray pits with reduced borders or apparently simple.
- Helical thickenings were absent.
- Tyloses were present also thin walled.
- Dark reddish brown deposits present.
- Fibres of medium wall thickness was visibly seen .
- Fibre pits restricted to radial walls, simple to minutely bordered.
- The Fibres was non-septate.
- The tangential section presented multiseriate rays and also uniseriate rays.
- Heterocellular rays are present.
- Intercellular canals are absent.

IV. TIMBER IDENTIFICATION

As per the above features of the macroscopic and microscopic observations, the samples were identified as *Mangifera indica* timber belongs to the family of Anacardiaceae. The geographic distribution of mango trees within the Sri Lankan context lies all around the country. They are mostly found in the home gardens.

Macroscopic observations show that the growth ring boundaries are distinct or absent. There was no specific color difference between the sapwood color and the heartwood color. The relative density values presented as 0.52 – 0.74.

The preservation technique might have an influence on the outer surface color of the wood was in a very darker shade diverging from the light to golden brown natural wood color.

V. CONCLUSION

This paper presents wood identification as a preliminary investigation of the vernacular timber preservation technique practiced in Sri Lanka. Three cases were selected, from Uva province and timber samples were obtained from the roof elements [23-26]. Wood anatomy imaging techniques had included microscopy through thin microtome sections.

The study has identified the wood used for the roof as Mango wood that is scientifically known as *Mangifera indica* belongs to the family of Anacardiaceae. Reference to the timber classification published by state timber cooperation in Sri Lanka, *Mangifera indica* wood falls under Class III category.

It is significant to identify mango wood because at present mango wood seems to be the only wood heavily used for furniture manufacturing as for its low durable fact where is highly prone to insects. But the as per the visual observation of the three houses and the roof elements it still exists in an acceptable better condition including a service life of 30 to 40 years.

So, the Authors recommend considering this as a preliminary investigation on the preservation technic and further investigation on the preservation technic reference to its chemical analysis and mechanical performance for future use as mango wood could be considered as a sustainable construction wood if we can utilize the exited timber preservation in Sri Lanka.

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REFERENCES

[1] M. S. Mendis, R. U. Halwatura, D. R. K. Somadeva, R. A. Jayasinghe, and M. Gunawardana, “Influence of timber grain

distribution on orientation of saw cuts during application: Reference to heritage structures in Sri Lanka," *Case Stud. Constr. Mater.*, vol. 11, p. e00237, 2019.

[2] M. S. Mendis and R. U. Halwatura, "Decoding the societal transitions on environmental innovation under vernacular timber construction practice in Sri lanka," in *2019 From Innovation to Impact (FITI)*, pp. 1–6, 2019.

[3] M. S. Mendis, M. Rajapaksha, and R. U. Halwatura, "Unleashing the Potentials of Traditional Construction Technique in Bio-climatic Building Designs: A Case of Ambalam, Sri Lanka," *Int. J. Environ. Sci. Dev.*, vol. 11, no. 6, 2020.

[4] M.S., Mendis, R.U., Halwatura, D.R.K Somadevaa.,2018. Investigation on the Significance of Design Elements of Timber with Respect to Architectural and Structural Engineering Aspects: Review on Ambalam in Sri Lanka. *Asian Studies International Journal,* ISSN: 2279-1949,28

[5] D. M. P. Sudeshika, M. S. Mendis, and R. U. Halwatura, "Investigation on the Mechanical Property Variation on Timber Caused Due to the Thermal and Chemical Modification," in 2020 *Moratuwa Engineering Research Conference (MERCon)*, 2020, pp. 78–83.

[6] D. M. P. Sudeshika, M. S. Mendis, and R. U. Halwatura, "A study on most abundantly utilized timber for structural application in Sri Lanka," *12th FARU international research conference, Sri Lanka*, Dec. 2019, pp. 107–114

[7] M. Riggio, D. D'Ayala, M. A. Parisi, and C. Tardini, "Assessment of heritage timber structures: Review of standards, guidelines and procedures," *J. Cult. Herit.*, vol. 31, pp. 220–235, 2018.

[8] M.-C. Timar, L. Gurau, M. Porojan, and E. Beldean, "Microscopic identification of wood species an important step in furniture conservation," *Eur. J. Sci. Theol.*, vol. 9, no. 4, pp. 243–252, 2013.

[9] M. Romagnolj, M. Sarlatto, F. Terranova, E. Bizzarrj, and S. Cesettj, "Wood identification in the Cappella Palatina ceiling (12th century) in Palermo (Sicily, Italy)," *Iawa J.*, vol. 28, no. 2, pp. 109–124, 2007.

[10] D. Dissanayake, M. S. Mendis, G. Y. Jayasinghe, and R. U. Halwatura, "Possible Cellular Structural and Chemical Changes of Timber Under Water," 2018.

[11] D. Dissanayake, M. S. Mendis, G. Y. Jayasinghe, and R. U. Halwatura, "Utilization of Sustainable Timber Materials for Innovative Green Building Solutions," 2019.

[12] "9th_YSF_Symposium_Proceedings_2020.pdf." Accessed: Dec. 11, 2020. [Online]. Available: http://www.nastec.gov.lk/files/ysf_proceeding/9th_YSF_Symposium_Proceedings_2020.pdf#page=45.

[13] J. Panshin and C. De Zeeuw, Textbook of wood technology. Part 1. Formation, anatomy, and properties of wood. McGraw-Hill, New York, USA, 1980.

[14] R. B. Hoadley, *Identifying wood: accurate results with simple tools*. Taunton Press, 1990.

[15] J. C. Tardif and F. Conciatori, "Microscopic examination of wood: Sample preparation and techniques for light microscopy," in Plant microtechniques and protocols, Springer,, pp. 373–415,2015

[16] E. A. Wheeler and P. Baas, "Wood identification-a review," *IAWA J.*, vol. 19, no. 3, pp. 241–264, 1998.

[17] R. B. Miller and P. Détienne, Major timber trees of Guyana: wood anatomy. 2001.

[18] "Wood species analysis of traditional hand-operated spinning wheels from Central Europe in: IAWA Journal Volume 40 Issue 1 (2019)." https://brill.com/view/journals/iawa/40/1/article-p92_7.xml (accessed Dec. 11, 2020).

[19] E. W. J. Phillips, "The Identification of Coniferous Woods by their Microscopic Structure," *Bot. J. Linn. Soc.*, vol. 52, no. 343, pp. 259–320, Apr. 1941, doi: 10.1111/j.1095-8339.1941.tb01390.x.

[20] "Computer-assisted timber identification based on features extracted from microscopic wood sections in: IAWA Journal Volume 41 Issue 4 (2020)."

[21] M.-C. Timar, L. Gurau, M. Porojan, and E. Beldean, "MICROSCOPIC IDENTIFICATION OF WOOD SPECIES AN IMPORTANT STEP IN FURNITURE CONSERVATION," *Eur. J. Sci. Theol.*, p. 10, 2013.

[22] D. M. Smith, "Maximum moisture content method for determining specific gravity of small wood samples," 1954.

[23] MS Mendis, R Arooz, RU Halwatura "Being Tectonic: Social Innovation Through Mud-concrete (MC) Technology" ,*in 2019* From *Innovation to Impact (FITI),* pp. 1–5,2019.

[24] Dissanayake, D. M. N. A., Mendis, M. S., Jayasinghe, G. Y., & Halwatura, R. U. A study on chemical insertion and physical property changes of sunken timber; Terminalia arjuna along with river water in Sri Lanka. *IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT)e-ISSN: 2319-2402,p- ISSN: 2319-2399.Volume 14, Issue 1 Ser. II (January. 2020),* PP 54-69

[25] D.M.N.A.Dissanayake, G.Y.Jayasinghe ,M.S.Mendis, R.U.Halwatura "Investigation on Chemical insertion and physical property changes of sunken timber; Terminalia arjuna along with River water in Sri Lanka", *International Symposium on Agriculture and Environment , young Graduates' Forum* , pp.20. 2019

[26] M. S. Mendis and S. Jayasignhe , Non-verbal communicative aspects of verandah in "walauwa" under uva province: a case study, *"Sustainability for people - envisaging multi-disciplinary solution": Proceedings of the 11th International Conference of Faculty of Architecture Research Unit (FARU), University of Moratuwa, Sri Lanka, ,* pp. 440–447, 2018