Scientific Study of Physical and Chemical Properties of Elemental Carving for Woodwork Preservation

Zumahiran Kamarudin, Rashidi Othman, Siti Najwa Nazuki

***Abstract:** This study aims to investigate the physical and chemical properties of the woodcarvings that characterize their structural indicator to resist the deterioration. The main objectives of this study are to identify the visual characteristics of the wood components and to examine the physical and chemical properties of the wood that characterize its structural integrity. The researcher conducted a scientific analysis of the selected wood components as specimens using magnification hand lenses (macroscopic method) and microscopic tests to determine the wood characteristics and physical properties. This included to characterize the physical properties of wood surfaces and to observe the types of wood in details via the instruments. The results show that Meranti (Shoreaspp) and Chengal(Neobalanocarpusheimii) woods were used for different types of woodcarving due to their distinctive properties and visual characteristics. Chengal wood which is classified as heavy hardwood has more durable properties as compared to the Light Red Meranti which is classified as light hardwood. Furthermore, fiber structure in Chengal is more compact than those in Meranti. The study suggests that the wood carving made from Chengal provides specialized structure and it has high resistance towards deterioration.*

***Keywords:** Wood carving, wood properties, wood preservation.*

I. INTRODUCTION

Wood carving remains as long-established and long inherited items and wood is the principal material for the fabrication of the Malay traditional woodcarving due to its physical properties. The woodcarving gives particular emphasis on the selection of timber types and the inherent properties of the timber used[1]. Wood from various tropical tree species usually hold various spectrum of colours and textures[2,3]. These include from light soft timbers to very dense dark timbers. As such, timber has inspired the craftsmen of past generations to produce not only the functional wares but intricate carvings. Consequently, it has contributed to the development of the art of Malay wood carving in the Malay Peninsula. In recent years, there has been a burgeoning interest in old woodworks, and in the preservation of them as heritage object. However, the wood components are subject to deterioration due to the hot and humid tropical country like Malaysia. Environmental, biological and physical factors contribute to the deterioration of wood and different wood species have different resistance towards the deterioration effect.

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The main objectives of this study are to identify the visual characteristics of the wood components and to examine the physical and chemical properties of the wood that characterize its structural integrity. This paper has been organized to describe the research method with major scientific analysis through the experimental setup. In the methodology section, the major techniques that were applied are fairly described. This is followed by the discussion on results and findings based on the objectives of the study.

II. WOOD PROPERTIES

Wood species can be categorized into two types which are softwood and hardwood. It can be defined according to it characteristics. According to[4]the terms hardwood and softwood refer to the botanical origins of woods and not to their density or physical hardness. The distinction between hard wood and soft wood is determined by the types of cell found in the secondary xylem. In woody plants, secondary xylem constitutes the major part of a mature stem or root and is formed as the plant expands in girth and builds a ring of new xylem around the original primary xylem tissue. In a trunk of and older branches of a large tree, only the outer secondary xylem (sap wood) serves in water conduction. The structure of cells and the arrangement of this cell into tissue zones reflect their function within the living tree[5]. For example, Chengal is considered the number one wood of Malaysia and it is classified as heavy hardwood[2]. The timber is classified as naturally durable and very resistant to the Malaysia's weather condition. The strength and durability of the timber makes it suitable for various kinds of heavy construction which requires a very little maintenance.

Malaysian timbers have been found to be particularly suitable and widely used, namely flooring, furniture, joinery, building and construction[3].

Woods are categorized for use in different applications. For example, in order to build a reliable roof truss, only woods with acceptable strength such as the Neobalanocarpusheimii or the local name Chengalis suitable for the structure[6]. In the Malay traditional living, Chengal has been commonly used for house and boat building. Different types of woodworks including woodcarving and wood turning also require the wood with strength, lightweight, durability and flexibility. The timber is used either in its natural form or as an engineered wood product (EWP), usually for building products. These products provide improved structural characteristics that have efficient use of wood fibre. Many species of timbers are used in building construction.

This is due to its varying durability and treatability. However, this natural durable species may get exhausted due to environmental factors[7].

Woodcarving as a woodwork

Wood carving is recognized as a wood-based product that embraces many physical and visual attributes. Usually Malay wood carving stresses on the inherent properties of the types of timber used[1]. Wood from various tropical tree species hold various spectrum of colours and texture from light soft timbers to very dense dark timbers. These distinct characteristics of wood shape the physical properties of wood carving. These distinct characteristics of wood shape the physical properties of wood carving. Each type of woods has character of its own such as the form, pattern and grain and it is this character that determines how it will best be employed in wood carving[8]. Distinctiveness in a piece of carving is associated with the type of timber used. Selection of timber species used in the making of wood carving is based on three criteria including availability of timber, physical characteristics and durability as well as craftsmen's spiritual beliefs toward the timber species[1]. As such carved panels are formed based on the selection, taste and sensitivity of the Malay craftsmen to the wooden materials.

In general, the common wood is Chengal because of its abundance in the lowland dipterocarp forest in the states of Pahang, Terengganu and Kelantan[9]. Inspired by the beauty of the tropical woods, the art of carving is created with distinctive character. As such, the choice of types of wood with visible grains and textures become very importance in most of wood carvings which influence the production of different carving forms. Wood carving as an expression of Malay creativity in visual form is to be found in various forms of objects, which can be categorized as utensils for daily use, weapons, transportation, games of pastimes and architecture. The use of wood in Malay culture is extensive that from a cookies mould, *kris* hilt, sail boats and *congkak* (a traditional game) to wall screens which are all made for accessories of daily uses. A study by[10] has classified woodcarving into three types of form: (1) panel carving, (2) sculptural carving, and (3) lathe carving (Fig. 1).

A

B

C

Fig. 1 A) panel carving, (B) sculptural carving (coconut grater), and (C) lathe carving (three-tier relief newel)

The panel carving is in two-dimensional form that is fitted as part and parcel of building components. It is usually found at timber walls of traditional Malay houses. Meanwhile, a sculptural carving is a three-dimensional carving which refers to wooden tools, home accessories and artifacts. Unlike panel carving, a lathe carving is a piece of wood shaped by a set of chisels and assisted by a lathe machine to rotate the wood. The three principal forms of traditional woodcarvings are ubiquitous in the Malay society. Elemental carving is the most prevalent component due to its visual and physical characteristics.

Preservation of woodcarving

According to[11]preservative method of wood are conducted in order to increase the life of the material and to conserve it as it is very important sources for country. Woods are easily worked materials with tools and machines and it has a very high strength to weight ratio. According to[12], apart from its strength, wood is so elastic that can be used to make it into complex shapes. This include the fabrication of various forms of woodworks, for example woodcarvings. However, the wood components are subject to deterioration due to its organic in nature with the passage of time. Likewise, woodcarving as a natural product can easily deteriorate due to environmental, biological and physical factors. Fluctuating humidity and extremes of temperature can result in physical damage to wood components. Different wood species have different resistance towards the deterioration effect. Preservation of timber against the deteriorating agents requires careful selection of the environment where to use or keep the wood[11]. This environment should be dry and properly protected from rain, wind and direct sun. The physical integrity of wooden objects is protected under this environmental condition.

III. METHODS OF DATA COLLECTION

In order to achieve the aim of the research and objectives of this study, an experimental procedure was adopted for data collection including scientific analyses that were conducted in different stages. This research begins with review of issues related to the craft of wood carving and in relation to its material properties, sustainability issues especially pertaining to the preservation of woodwork.

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Then, the researcher had conducted personal interviews with the selected two Malay woodcarvers from Terengganu, Malaysia apart from observing their works on making woodcarvings. The objectives of the interview were to seek their opinions on the types of wood used for carvings and to determine the visual and physical characteristics of the woodcarvings. Also, the researcher had obtained few samples of elemental woodcarving form the woodcarvers for analysis purpose.

Later, scientific analyses were conducted in wood laboratory to determine the physical and chemical properties of the selected wood carving components from the woodcarvers who have been making the carvings in a range of derivative products and with different types of woods. During this stage of research, a wood expert from a reputable national institution of forestry, was interviewed to obtain information on the wood properties. He is an expert on Malaysian wood and its physical condition. Information obtained through the interviews served as supplementary data for this research. The analysis of the selected wood components (Fig.2) using magnification hand lens method was conducted to determine the wood characteristic and physical properties and to characterize the physical properties of wood surfaces and to observe the types of wood in details via the lens. The researchers had performed scientific test on wood, which involved several steps of scientific analysis on the wood samples.

Fig. 2 Wood carving specimens in form of ventilation panel for identification of physical properties

The scientific analyses on the samples of Chengal and Meranti wood were conducted in the Wood Anatomy Laboratory. The analysis was done to identify the wood types and its properties. The laboratory tests took many days to get the result and a lab officer from the institution had assisted the researcher during the test. Two types of analysis involved are; 1) macroscopic method, a process of identification of wood using hand lens and, 2) microscopic method, a process of identification of wood and its properties through many steps of laboratory works.

Macroscopic and microscopic test for identification of wood properties

Simple equipment was required to conduct the macroscopic method of wood identification. These included a sharp pocket knife and a10x magnification hand lens (Fig. 3). The wood identification of the transverse surface is possible only on a clearly cut-surface. The wood samples should be consisting of three sections which are cross section, tangent and wood radial.

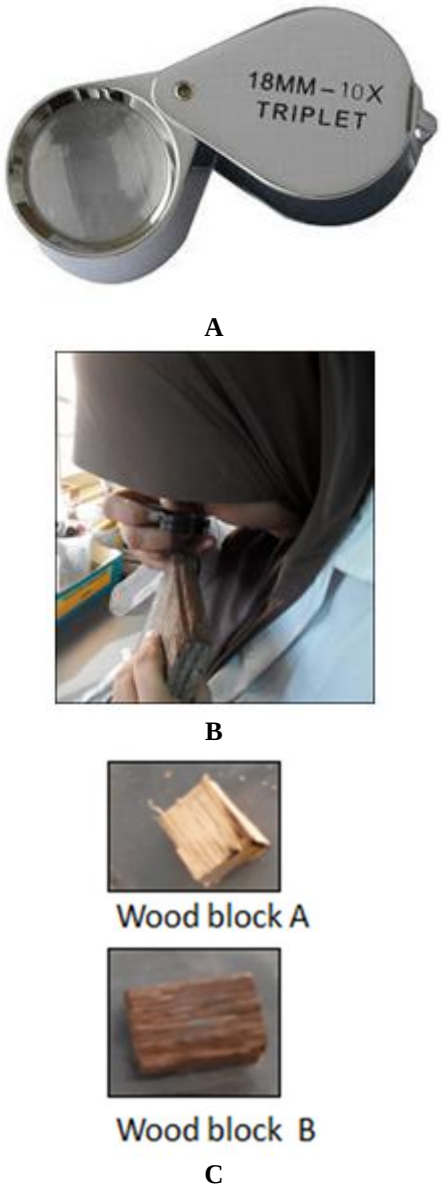

Fig. 3 A) 10x magnification Hand lens, B) examination of wood under lens, C) wood samples of Chengal and Meranti

The section was prepared by cutting the wood samples with a sharp pocket knife. The cut surface was examined under a lens; holding the lens close to the eye and bringing the exposed section into focus. The sample of wood was examined under natural light.

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The sample was analyzed in a very dry condition because the structural features can be more clearly seen. Microscopic anatomy of the wood using microscopic method was conducted for more specific identification on wood. The test was conducted to characterize the physical properties of wood surfaces and to observe the wood structure in details via microscopic magnification. The researcher had analyzed two types of wood samples; the wood sample A was taken from the Meranti wood and wood sample B was taken from Chengal wood. As found through physical observation, wood A had some deterioration defect as compared to the wood B. The test was essential to identify the wood species and its properties.

First process in this test is softening and wood embedding. The wood samples need to be cut into a cubic shape with dimension 1cm x 1cm. The cubic shape ensures that the transversal sections, radial section and tangential of wood section are clearly seen. Then the wood samples were put into two beakers with labels by samples A and B. The wood samples were boiled to remove all the airs contain. The wood samples that sink show that all the air had been removed. The blocks also need to be boiled to make it soft and easily handle during sectioning process. The boil duration is depending on the density of wood. If the wood has high density, the boil process will take a longer time. The wood sample A took 3 days for boiling process while wood sample B took 4 weeks for boiling process. Distilled water was used during this boiling process (Fig. 4).

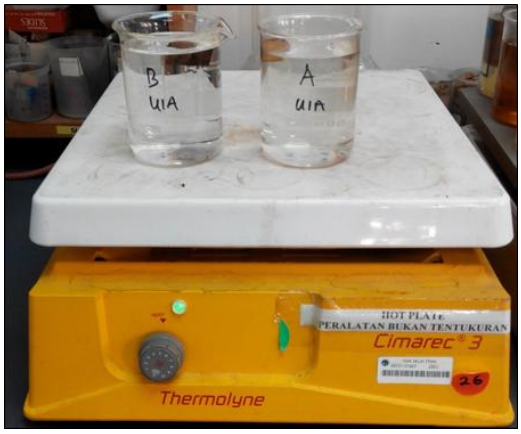


Fig. 4 Wood samples during boiling process

Fig. 5 Wood samples after boiling process

The second process that involved in this test is wood sectioning. Three petri dishes were prepared for wood section with labels (Fig. 6). These dishes were filled up with spirit that acts as mounting medium for temporal storage for hours or days. Spirit solution also serves as lubricant during the sliding process and this process used sliding microtome. The thickness of wood section must be between 20 to 30 micrometers. Wood section slices that are more than 30 micrometers may affect the anatomy characteristics that may causes the image could not clearly be seen through microscope. The wood section must consist of transversal sections, radial section and tangential of wood section.

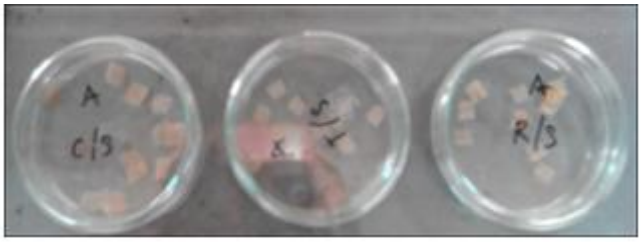
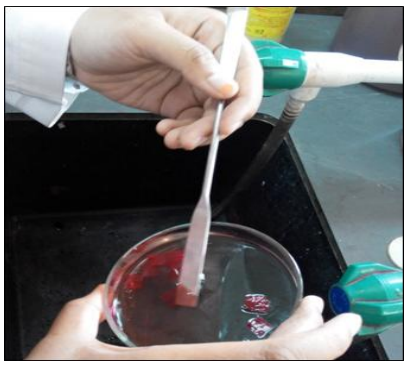


Fig. 6 Three petri dishes contain of wood slice samples

The third process for this test is staining the wood section. Safran in solution was dropped into 3 petri dishes as shown in Figure7A. The lignin in wood section usually absorbsthis solution. The wood sections were soaked in the solution for 5 minutes. Then, the wood sections were rinsed using distilled water for 3 times after soaked. Next, the wood sections were rinse using ethanol for 3 times to make sure all the impurities were removed. Later, the clove solution was dropped onto the wood section in petri dishes before putting the section on PVC strips (Fig. 7C). The clove solution was used to act as air bubble remover.

A



B

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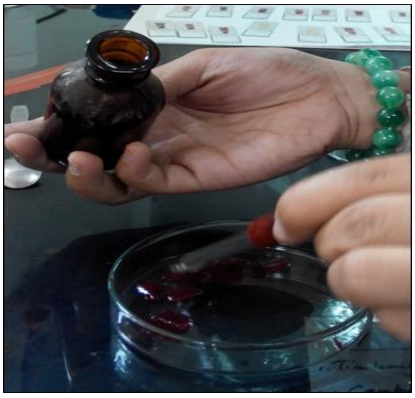


C

Fig. 7A) Dropping a Safran in solution onto wood slides, B) rinse the wood slides, C) drop a clove solution onto wood slides

The final process in this test was transferring and labeling the wood section slices. The slices section needs to be transferred onto glass slide and four glass sections were needed for each wood samples. The slides section must be arranged according to it flow and in vertical lines; 1) transversal sections, 2) tangential of wood section, 3) radial section (Fig. 8). The arrangement can be confirmed by using microscope.

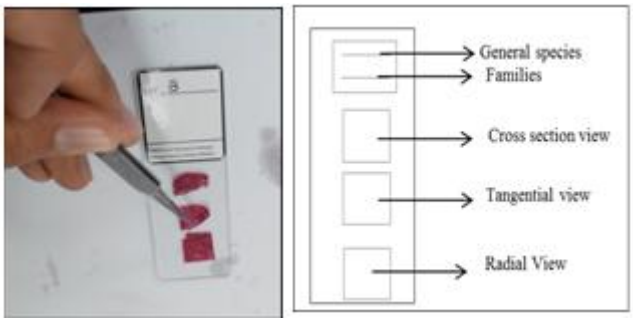


Fig. 8 a) Transferring the slides onto a glass slide, b) arrangements of wood slide on A glass slide

Fig. 9 Microscopic used in checking the correct position of slides

Canada balsam acts as embedding resin for the section. Cover slip was pressed onto the wood section and all the air bubble inside the glass slides need to be removed as illustrated in the figure.

Lastly, the glass slides of wood section need to be kept in the oven for drying process. It took 2 to 3 days until it got really dry. The temperature is 60 Celsius.

Scientific analysis on moisture content in the wood samples

The moisture content in the wood is defined as the weight of water in wood given as a percentage of oven dry weight. The significant of this analysis is to determine moisture contents in two different types of wood. Also, to identify types of wood that has a high amount of moisture content. Lastly, to investigate the relationship between the amounts of moisture contain with the growth of deterioration agents such as fungi and insects. First step in this test was to prepare the wood samples in block form in size of 1cm x 1cm x1cm and label it according to the types of wood (Fig.10). The volume for each of the wooden blocks need to be measured using length x width x height. The weight for each wooden block needs to be measured by using weight measure machine (Fig.10).

Fig. 10 Wood block samples with label, and each block was measured for its weight

In equation form, moisture content (MC) and wood density are expressed as followed.

Moisture Content (MC) = Weight before dry – Weight after dry

The last step for this test was to keep the wooden blocks in an oven for 48 hours to absorb moisture content in the woods.

The oven temperature is 103 Celsius. All wooden blocks need to be measured for its weight and volume again to get the reading of final moisture content (MC o).

IV. RESULTS AND DISCUSSION

There are two types of wood analysis, namely macroscopic and microscopic that have been conducted in order to achieve all the objectives and aim of the research. The objectives of this research are to identify the physical characteristics of the wood components and to examine the physical and chemical properties of the wood that characterize its structural integrity. The analyses were conducted to identify the properties of the wood samples. Results of these wood analyses are explained in the following paragraphs.

Physical characteristics and properties of the wood components

A total of two different types of wood were analyzed to identify the types of wood, its classification and wood structure. It is important to obtain the data because some of the wood deterioration is related to the wood properties. The result indicates that wood sample A is identified as Light Red Meranti (Dipterocarpaccac) and its scientific name is Shoreaalbida. The wood is classified as Light Hardwood. The general characteristic of Meranti wood is the sapwood which is lighter in colour, and the heartwood is pale to mid red-brown. The texture for Light Red Meranti is coarse but even and usually is interlocked producing stripe figure on the radial surface. There is a growth ring in it. Meanwhile, sample wood B is identified as Chengal Wood and its scientific name is Neobalanocarpusheimii. It is classified as heavy hardwood. The general characteristic of Chengal wood are the sapwood is well defined and the heartwood is in light yellow-brown with a distinct greenish tinge, darkening on exposure to dark purple- brown or rust red. The texture for Chengal wood is fine, even and medium in texture. The grain is interlocked and the growth ray is absent.

Vessel is another characteristic of the wood. It is a tube-like series of water-conducting cells (with bordered pits) which are axially joined by perforation plates in the cell end walls. From the test that has been conducted, sizes of vessel for Meranti wood has simple perforation and in moderate size and the number of vessel cell is few. It is diffused but with a tendency to be aligned in short. Intercellular cell for Meranti is vertical canals in concentric series, distinct to the naked eye on both the cross-section and longitudinal sections. While the size of vessel for Chengal is in medium size, predominantly solitary and others in radial pairs or short multiples with evenly distributed. It is also filled with teloses. The cross section for both types of wood (Fig. 11 and Fig 12).

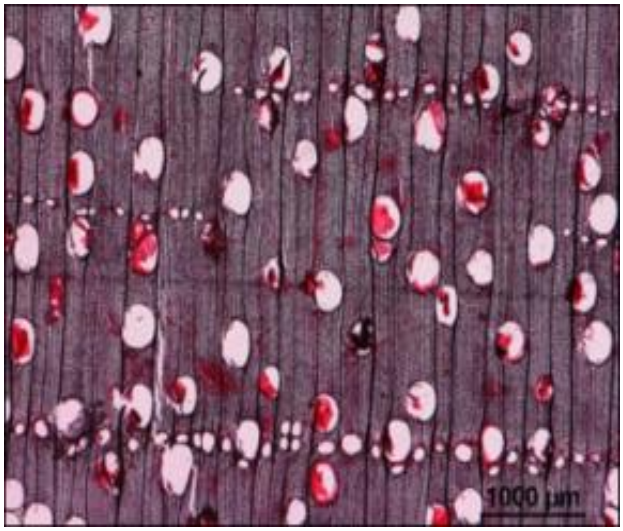


Fig. 11 Wood cross section for Meranti showing the wood fiber, vessel wood, and intercellular cell

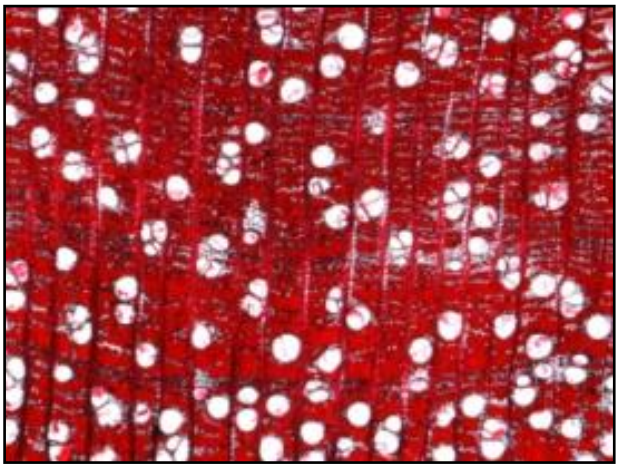
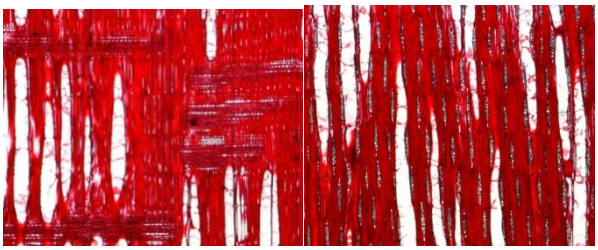


Fig. 12 Wood cross section for Chengal, showing the wood fiber, vessel wood, and intercellular cell

Ray structures for Meranti wood are medium in size and it is visible to the naked on cross-section; it is fairly conspicuous on a radial surface. The arrangement of ray is tendency to irregularly story with the fiber and appearing as indistinct ripple marks. Wood fiber for the wood is small bordered pits that is present on radial walls but not very conspicuous. While ray structure for Chengal wood is moderately fine and inconspicuous on a radial surface. Images of tangent section for both types of wood (Fig. 13).

A



B

Fig. 13 Radial and tangent structure of A) Meranti, and B) Chengal

Ray homogeneous can be seen on radial structure of Meranti wood. It is in medium to fine size. Ray homogeneous also is defined as composition of wood cells. For Chengal wood, the rays and axial parenchyma are storied and axial resin canals in more or less continuous and are absent in some specimens. Crystal is often present in square ray cells and silica grains are absent. Image of radial section for both types of wood (Fig. 13).

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The results give a correct identification of wood types and it properties through the structure image. Based on this identification and its analysis, Chengal is naturally durable and have high resistance towards termite attacks and fungi infestation based on its properties[13]. These properties characterize its structural integrity.

Moisture content in the two different types of wood

After completing the test on wood identification, the moisture content of Meranti and Chengal wood were analyzed. These analyses were repeated for 3 times to get the final result. The results of moisture content in the two different types of wood samples are highlighted in Table 1 and Table 2.

Table. 1 Result on moisture content test in wood sample A (Meranti)

Sample Label	Weight before oven (M_I)	Weight after oven (M_0	Moisture content (MC)
A_1	6.59	5.89	11.9
A_2	5.81	5.17	12.4
A_3	6.05	5.41	11.6

Table. 2 Result on moisture content test in wood sample B (Chengal)

Sample Label	Weight before oven (M_I)	Weight after oven (M_0	Moisture content (MC)
B_1	28.18	25.11	12
B_2	28.0	24.94	12.3
B_3	27.12	24.17	12.2

The results show that the level of moisture in Chengal wood is higher than Meranti wood. Wood with higher moisture content has more strength in its structure. The surface of wood is more stable and not too dry. Fiber structure in Chengal is more compact than those in Meranti. Fiber wood in Meranti have many pores and less compact (Fig. 10).

Result on calculating volume and density of wood

Based on the wood moisture content test, the density for wood samples had been calculated and the unit of wood density is in kilogram per volume meter (Kgm-3). The result is presented in Table 3.

Table. 3 Result of wood density test in two types of wood

Samples wood A		Samples wood B	
Sample label	Density	Sample label	Density
A_1	0.032 Kgm^{-3}	B_1	0.09 Kgm^{-3}
A_2	0.031Kgm^{-3}	B_2	0.1 Kgm^{-3}
A_3	0.03 Kgm^{-3}	B_3	0.09 Kgm^{-3}

Based on the density calculation as shown in table 3, it appears that wood samples B have a high density while wood sample A have a lower density. According to[14], wood with high density was more resistant than the wood with lower density that to subterranean termite attack. This suggests that Chengal wood that are used for woodcarvings have a minimal effect from deterioration. This type of wood has a high density that is highly resistant towards deterioration agents such as termites. While the woodcarvings made from Meranti have a high tendency towards deterioration because they are made from wood that have low density. Chengal wood has more strength and resistance towards deterioration factors as compared to Meranti wood because it has high moisture content and density.

The characteristics and physical properties of the wood components

The results indicate that Chengal wood is classified as heavy hardwood and Light Red Meranti is classified as light hardwood. General characteristic of Chengal wood are the texture of wood is fine, even and medium in texture and the grain is interlocked, whereas, the texture for light Red Meranti is coarse but even and usually interlocked producing stripe figure on the radial surface. Also, fiber structure in Chengal is more compact than those in Meranti. Fiber wood in Meranti have many pores and less compact. However, the terms hardwood and softwood refer to the botanical origins of woods and not to their density or physical hardness[2]. The structure of hardwoods is much more complex. There is also a lot of variation from one species of tree to another in hardwoods. Hardwoods contain vessel elements, or pores[15]. If pores are present, the wood is a hardwood.

Chengal-based wood carving has distinctive physical characteristics and has more strength in its structure thus distinguished it from those found in Meranti-based wood carving. The study found that Chengal-based wood carving has distinctive physical and chemical characteristics thus distinguished it from those found in Meranti-based wood carving.

The identification of the properties of the wood components through analysis is necessary to find out especially the relationship between wood properties and wood sustainability. As noted by NorhaizaNoordin, "Chengal-based wood carving is naturally very durable and can last for hundreds of years without substantial change". Hardwood is a durable material and would last indefinitely[1] as it does not deteriorate spontaneously[2]. Woodcarving made from Chengal usually has slight treatment but has not gone into polishing so that a person can feel, look and smell the material in its natural form as much as possible. This carving is about the materiality of timber. Chengal is classified as a hardwood, hence the wood carving made from this type of wood provides specialized structure and it has high resistance towards deterioration.

Findings from the research suggest that wood carvings made from Chengal are naturally durable on its properties. This suggests that because of this reason, a good number of wood carving collection from the carvers are made from hardwood and they are under upkeep and are less vulnerable to physical decay.

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As such, the research findings suggest that the tangible heritage value also relies on the type and characteristic properties of timber used for the wood carvings apart from its visual beauty. The concept of 'sustainability' in relation to traditional crafts and craftsmanship is strongly connected to environmental and cultural concerns[16]. In short, the study suggests the visual and physical characteristics of the carving components characterize their cultural heritage values. These characteristics determine the distinctiveness of the components that has become the key determinants to their heritage attributes resulting to significant pieces of work.

V. CONCLUSION

In this paper, a scientific study of the wood properties for recognition of tropical wood species based on scientific analyses has been presented. The study was objectively conducted to identify the visual characteristics of the wood components and to examine the physical and chemical properties of the wood that characterize its structural integrity. The study found that the different types of wood especially Meranti and Chengal were used for the fabrication of the carving components because of their distinctive physical properties that characterize their integrity. Elemental woodcarvings made from Meranti have a high tendency towards deterioration because they are made from wood that have low density. Chengal wood has more strength and resistance towards deterioration factors as compared to Meranti wood because it has high moisture content and density. The results and findings of the study are useful research outcome and would help in developing a method for preserving the Malay traditional wood carving craftsmanship as cultural heritage.

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