Design of laminated bamboo fishing boat with local cultural heritage using electric motor to support fishing tourism in Pasuruan, East Java

M H N Aliffrananda¹, A R Safaruddin¹, H Supomo¹ and S Regitasyali¹

¹Department of Naval Architecture, Institut Teknologi Sepuluh Nopember, Surabaya, 60111, Indonesia

Abstract. Fishing has been one of the main sources of livelihood in Indonesia, to the point that it gives birth to numerous fishing culture preserved by the locals in the country. However, the development of Indonesia’s fishing tourism is quite slow, despite its identity as an archipelagic state. In attempt to boost the fishing tourism sector, this study proposes a design of a fishing boat with a touch of Pasuruan cultural heritage, a region in East Java. The design is hoped to attract the tourists’ attention by presenting them a local heritage fishing experience. Laminated bamboo is utilised as the boat’s material so it can be recycled as furniture when no longer in use. The boat’s main dimensions are obtained by means of intuitive design method. Technical calculations including the boat’s resistance and propulsion, required power and stability are carried out subsequently. The main dimensions for this boat are: LoA = 8.2 m; B = 1.1 m; H = 0.6 m; and T = 0.42 m. The service speed is set to be 7.5 knots. While the required power to move this boat is around 7.481 kW to power an electrical motor with 25 HP.

1. Introduction
Traditional fishing boats have been part of the Indonesian culture. Not only because of the historical and anthropological value of the nation, these wooden boats are still used up to this day by local fishermen. Despite the technological development in shipbuilding, wood is still mainly used in fishing boats construction. One of the underlying reasons is because wooden ships are relatively cheaper when compared to ships made of steel. It is apparent that wood is one of the highly demanded commodities in Indonesia.

However, a study stated that Indonesia had lost 8.4% of its forest, equivalent to 15 million hectares between 2000 and 2012. Of the 98% forest loss in Indonesia, deforestation occurred in high density forest conservation areas such as in Sumatra, Kalimantan and Sulawesi. The significantly expanding areas reserved for palm oil plantations over the last 20 years is the main cause of forest destruction. Illegal loggings also took part in worsening the deforestation in Indonesia [1]. Wood scarcity began to occur, causing the price of wood to increase. The higher price of wood resulted in an increased production cost for fishing boats and directly threatened the sustainability of the small and medium scale industry (Industri Kecil Menengah), such as the local shipbuilding industry. This condition then triggered multiplier effects on the smallholder shipbuilding industry chain. A substitute material for wood was highly needed. A substitute material for wood was highly needed.

Eventually, it was later found that bamboo could serve as a substitute for wood as the main material used in fishing boat construction, given its positive characteristics such as [2]: its abundance throughout the archipelago, its relatively easy cultivation and preservation nature, rapid growth (15-30 cm/day) [3], its period for construction ≥ 3 years, and its price being relatively cheaper than solid wood with adequate
mechanical properties. Compared to wood which takes decades to harvest and use as the main material for ships, bamboo, on the other hand, only takes about 3-4 years with the same capability for construction.

A survey in East Java [4] found that bamboo is abundant, in terms of species and quantity. There are two types of bamboo that can be used as a ship construction material: Betung Bamboo (Dendrocalamus asper) and Ori Bamboo (Bambusa Arundinacea). Betung bamboo species (Dendrocalamus asper) is spread only in the highlands (350m - 700 m asl) in almost every mountain in Java, while Ori bamboo (Bambusa Arundinacea) is widely distributed in the lowlands (0 – 300 m asl), as seen in Figure 1.

Figure 1 The abundance of Ori bamboo in Indonesia is shown through a) and b) where Ori bamboos are found near rice field [4].

Currently, the construction reliability level of laminated bamboo as ship material has been studied, including its mechanical properties of bamboo and its use in accordance with the classification rules of the Indonesian Classification Bureau (BKI) 2013. A flexural study found that laminated bamboo is very suitable to be used as a fishing boat material, construction wise [4]. Bamboos are also cheap, environmentally friendly, strong, renewable, flexible and sustainable.

Despite the proven capabilities of the laminated bamboo’s mechanical properties, it is important to produce a prototype of a Jukung fishing boat for the purpose of socialization to the local people. This prototype needs to be developed to build the fishermen’s trust in the bamboo laminated construction. With this prototype, it is hoped that the fishermen and the community shipyards will be more than encouraged to opt for laminated bamboo over solid wood.

2. Design Methodology
2.1. Spiral Design
The designing process of a ship is a continuous process, first introduced in 1959, as seen in Figure 2.

Figure 2 Ship design spiral depicted as a continuous cycle [5]
The ship design will undergo continuous correction until the ship’s requirement is completed and is ready to be launched. The stages are divided into Concept Design, Preliminary Design, Contract Design to Detail Design. The ship design is also divided into several main parts, namely: basic design, hull design, hull outfitting design, machinery outfitting, electrical outfitting and miscellaneous.

2.2. Fishing boat
Based on the Regulation of the Ministry of Marine Affairs and Fisheries of the Republic of Indonesia No. 16 in 2010, fishing boat is a special vessel for fishing activities that has a driving force in the form of a paddle, wind, or combustion engine [6]. Fishing boats are a mode of transportation in the sea which plays a vital role for coastal communities whose livelihoods are fishermen. Fishing boats in general are still being built traditionally by following the previous shipbuilding method which tends to be without proper planning even though with the development of shipping technology, every ship construction including fishing boats can be planned according to the demands and needs of the owners.

By maintaining traditional technology in wooden shipbuilding without any planning, the impact on the use of wood is excessive, namely ± 20 to 50 m³ for ships with a keel length of 10 to 20 m. This is a waste of wood raw materials. Meanwhile, the production of teak wood, for example, has experienced a drastic decline due to illegal logging and the time it takes for its reproduction is quite long, which is ± 50 years. Hence, the production cost for one unit of a traditional fishing wooden boat is very high.

Traditional shipbuilding techniques in Indonesia are still fixated on previous ship building experiences without the basis for proper and accurate ship planning and design. Such development process has several shortcomings, including low ship speed in relation to the amount of resistance. This is due to the hull shape is less smooth because of the absence of a lines plan and design plan. Apart of that, the use of rudder is not effective because its position does not align with the propeller and if the size of the rudder is not proportional, it can lead to poor ship maneuverability.

2.3. Jukung fishing boat
The characteristic of these boats is its small size, it is not so wide but long, so it is suitable for in local rivers and swamps. Usually, the Jukung fishing boat is made of solid wood and dredged to get the shape of the desired hull. This will be a waste of wood causing the production of boat to decrease as the wood population decreases. Several types of the Jukung fishing boats include:

2.3.1. Jukung Untul and Jukung Polokan. The Jukung Untul type in Figure 3 has a principal size of 3.50 m long, 0.62 m width and 0.35 m depth, distributed around the areas of Malang, Blitar, Tulungagung, Trenggalek, Pacitan, Tuban, Sampang, Pamekasen, Pasuruan, Probolinggo and Situbondo. The Jukung of the Polokan type in Figure 4 generally has a principal dimension of 8 m long, 0.85 m wide and 0.30 m deep, distributed around areas of Trenggalek, Pacitan, Banyuwangi, Jember and Malang.

![Figure 3 Jukung Untul](image1)

![Figure 4 Jukung Polokan](image2)

2.3.2. Jukung Kunting and Jukung Selentik. The Jukung Kunting type in Figure 5 generally has a principal size of 3.50 m long, 0.50 m width and 0.30 m depth, distributed in Trenggalek and Pacitan. The Jukung Selentik type in Figure 6 generally has a principal size of 8 m long, 0.85 m wide and 0.30 m deep, found in Tuban (Tambakboyo) and Gresik.
2.3.3. *Jukung Banat and Jukung Pandik*. The Jukung Banat type in Figure 7 generally has a principal size of 8 m long, 0.8 m wide and 0.40 m deep, found in Tuban (Tambakboyo) with an almost extinct population condition. The Jukung Pandik type in Figure 8 generally has a principal size of 12 m long, 0.6 m wide and 0.30 m deep, found in Gresik and an almost extinct population condition as well.

2.4. *Bamboo lamination*

2.4.1. *Advantages of laminated bamboo*. Laminated bamboo is one of the most promising and renewable technology for producing future construction materials [7]. A study included the manufacture of laminated bamboo with thin blades followed by tensile and bending tests. In 2011, it was found that the parallel tensile strength of the fibers of *Giganthloa strictus* can reach more than 200 MPa, with MOR flexural strength up to more than 100 MPa, MOE more than 15 GPa. Another study about the strength and possibility of flooring production using a layer of *Phyllosachys edulis* bamboo slats [8] discussed the advantages of bamboo laminated material when compared to the use of solid wood in terms of durability and sustainability.

Laminated bamboo can also be produced using bamboo fiber or bamboo lumber [9]. This construction also possesses a higher tensile and bending strength when compared to solid teak wood. An initial study in 2015 [4] found that the tensile strength of the laminated blades of *Bambusa*
arundinacea parallel to the fibers reached up to 184 MPa with MOR flexural strength of 84.6 MPa and MOE around 24 GPa. This would be very profitable when used to construct a fishing boat. The direction of tensile and bending stress under study can be described as shown in Figure 9 and Figure 10.

Based on the distribution map, bamboo species and densities can be seen in Figure 11 [10]. Indonesia has a very large density of bamboo species when compared to other countries in the world. This is one of the greatest potentials that bamboo in Indonesia is very abundant in number.

2.4.2. Mechanical properties of bamboo. The mechanical properties of bamboo in general depend on the following factors [11]: The type of bamboo, the age of the bamboo at the time of logging, the moisture (equilibrium moisture content) of the bamboo stems, the part of the bamboo stems used (legs, middle, head), location and distance of used segments (sections of the segment are less resistant to compressive and bending forces). The determination of the mechanical properties of bamboo is based on the prerequisite that the bamboo used in construction is a dry building material with a moisture content of 12%, an equilibrium moisture content at 70% humidity which is considered a reasonable average in tropical climates. In several studies [2], [12] and [13], the mechanical properties of bamboo including tensile strength, compressive strength and shear strength were discussed. In Indonesia, the allowable tensile stress parallel to the direction of the average fiber without mentioning the type of bamboo is 29.4 N/mm², while in Indonesia, the required bending stress is 9.80 N / mm².

3. Building Process

3.1. Design of Jukung Boat

The Jukung ship design that will be used is the Jukung type in the area around Pasuruan-East Java. This Jukung fish boat is redesigned according to local cultural heritage. The initial design (preliminary design) was made based on the main capacity and size of the Jukung. After the main size and capacity were determined, a basic Jukung design was made from laminated bamboo with an output in the form of Lines Plan, Hydrostatic & Bonjean Curves, General Arrangement, Cross Section, Construction Profile and Scantling, according to BKI regulations with local cultural heritage in mind.

3.2. Mold production

This laminated bamboo Jukung fishing boat mold is made according to the Lines Plan design. With the Mold Lofting method, the shape of the mal is obtained at each position of the Jukung ship. The shape of each cross section is then made using multiplex board. The boards were then arranged lengthwise according to its order with the help of markings and were connected to one another with wood. This mold for Jukung boat with laminated bamboo material can be used repeatedly as long as the main dimension of the boat is identical.
3.3. Fabrication of construction components
The fabrication stage is the manufacture of the components of the Jukung boat construction elements, consisting of keel and frame. This fabrication process was made based on the mold of the Jukung boat with laminated bamboo material.

3.4. Assembly and erection
The assembly and erection process of the Jukung prototype consisted of assembling the keel and the frame, continued by installing a shell made from laminated bamboo. After the Jukung body was formed, the left and right outriggers were installed before applying paint and anti-fouling protection to the hull. The next process is the installation of the boat’s electric motor.

3.5. Trial and performance test
After the production has been completed, the next step is to launch the Jukung, followed by trial and performance test to assess the stability of Jukung, maneuvering, speed and resistance of Jukung when operating. The trial and performance data results are presented and socialized to marginalized fishing communities.

4. Results and Discussion
4.1. Design of Jukung Boat
4.1.1. Survey. The survey was carried out in the Sendang Biru area, Malang, a fishery center with a TPI (Fish Auction Place). This survey was carried out to picture an initial view of the design proposed in this study. One of the boats, “Tiga Saudara” shown in Figure 12 had the following main dimensions: 10 m long, 1.1 m wide, 0.75 m high and 30 mm shell thickness.

![Figure 12 Tiga Saudara Jukung Boat](image)

4.1.2. Jukung design process. The process of designing a Jukung fishing boat can be carried out based on the offset value from the “Tiga Saudara” Jukung Boat. The final main dimensions have a slight difference than the “Tiga Saudara” Jukung Boat.

| Parameter            | Dimension | Unit |
|----------------------|-----------|------|
| Length Overall (LOA) | 8.2       | m    |
| Breadth (B)          | 1.1       | m    |
| Depth (H)            | 0.6       | m    |
| Draught (T)          | 0.42      | m    |
| Service Speed (Vs)   | 7.5       | knot |

The first design to be carried out was the Lines Plan design, which was the design of the hull shape of the ship. The Lines Plan design consists of a drawing of the ship’s body plan, which is a cross section of the shape of the hull when viewed from the front. This shape is then projected into a sheer plan and
half breadth plan so that it becomes a Lines Plan from three views (front, top and side). The design of the ship lines plan can be seen in Figure 13.

![Lines Plan of Jukung fishing boat](image)

**Figure 13** Lines plan of Jukung fishing boat shows that the boat has a slender body, enabling it to sail at a high speed.

The Lines Plan were transformed into a 3D computational model as can be seen in Figure 14. The model is made according to the main dimensions, as can be seen in Table 1. Once the dimensions are set, the curvature of each frame is used as a guideline in creating an accurate replica of the boat by using a 3D design software.

![Jukung Fishing Boat 3D Model](image)

**Figure 14** Jukung Fishing Boat 3D Model from perspective view.

Using the 3D model, the hydrostatic analysis of the boat can be obtained directly from the design software. The results are shown in Table 2.
Table 2 Hydrostatic Analysis of Jukung Fishing Boat Prototype

| Parameter                                      | Dimension         |
|------------------------------------------------|------------------|
| Displacement                                   | 1.864 tonnes      |
| Wetted Surface Area (WSA)                      | 9.4 m²           |
| Prismatic coefficient (Cp)                     | 0.685            |
| Block coefficient (Cb)                         | 0.562            |
| Maximum sectional area (Cm)                   | 0.834 m²         |
| Longitudinal Centre of Buoyancy (LCB)         | 3.165 m          |
| Longitudinal Centre of Floatation (LCF)       | 3.312 m          |
| Keel to Buoyancy (KB)                          | 0.256 m          |
| Keel to Metacenter (KM)                        | 11.846 m         |
| Immersion (TPc)                                | 0.066 tonne/cm   |
| Momen Trim (MTc)                               | 0.031 tonne.cm   |
| Hull weight, LCG, TCG and KG                   | 1.968 tonnes     |
| LCG                                            | 3.769 m          |
| TCG                                            | 0 m              |
| KG                                             | 0.404 m          |

When the hydrostatic characteristics of the boat have matched the requirements, the following process include producing a drawing of General Arrangement of the boat as can be seen in Figure 15.

![Figure 15 General arrangement of Jukung fishing boat.](image)

The General Arrangement is drawn using the outlines of the boat acquired from the Lines Plan to depict the interior design of the boat. Prior to planning the General Arrangement, a series of calculation is conducted including the calculation of the required power found to be around 7.481 kW. The result was used in determining the capacity of the electric motor, which was found to be 25 HP, supported by 15 batteries of 12 V 200 Ah. The obtained power can move the boat at a speed of 7.5 knots. It is crucial to ensure that the bamboo hull can withstand the stress it experiences during operation. To achieve this,
the boat’s construction must possess sufficient strength to help support the boat. A series of calculation is done to obtain the adequate construction size to prevent the bamboo hull from experiencing stress beyond its capacity that could lead to deformation during her operation. The calculation was conducted in accordance with [14]. The mechanical properties of the laminated bamboo played an important role in determining the numbers and sizes of the construction elements of the fishing boat. Figure 16 is the layout of the boat’s construction.

![Construction layout of Jukung fishing boat](image)

**Figure 16** Construction profile of Jukung fishing boat.

This Jukung fishing boat only has two side transverses to support the hull, right below the transverse arms of the outrigger. A detailed drawing of the boat’s construction seen from a transverse point of view can be seen in Figure 17 along with its dimensions as listed in Table 3.

![Cross section of Jukung fishing boat](image)

**Figure 17** Cross section of Jukung fishing boat.
Table 3 Construction details of Jukung fishing boat.

| Construction       | Dimension |
|--------------------|-----------|
| Strong beam        | 60 x 60mm |
| Side Transverse    | 60 x 60 mm|
| Outrigger Diameter | 130 mm    |
| Outrigger Arm      | 600 cm    |
| Transverse Outrigger| 80 x 60  |
| Shell              | 37.5 mm   |
| Keel               | 30 mm     |

Another crucial point to be considered is the boat’s stability. The components of the boat’s construction, as well as the hull itself, determine the ability of the boat to turn back to its right position after experiencing an inclination at a certain angle. In this study, the stability analysis is obtained through a simulation using a ship design software.

Figure 18 GZ Curve of Jukung Boat without outriggers.

According to Figure 18, the design is shown to have good stability according to its maximum value of GZ, which equals to 0.086 m at 54.5° and its GM₀ value, which equals to 0.103 m. GZ is the length of a righting arm that is needed to return the boat to its equilibrium state when it experiences inclination at a degree. GM is the distance between the center of gravity to an imaginary point of intersection, between the extension of vertical line through the center of buoyancy and a vertical line through the new center of buoyancy when the ship is inclined, also known as the metacentric height.

4.2. Mold production and assembly
The first step to produce a Jukung fishing boat is to make a mold. This mold is made using a multiplex material for its properties that tend to be stronger than ordinary plywood. In addition, multiplex is relatively cheaper and relatively easier to shape than solid wood. The multiplex had the following sizes: 1220 mm wide, 2400 mm long, and 9 mm thick. This multiplex is then cut into shape using a CNC cutting machine as shown in Figure 19, Figure 20, and Figure 21 which is located at the Protomodel Laboratory, Department of Product Design, ITS. The multiplex is cut according to the Lines Plan. There are 20 stations that had to be molded on the multiplex, hence the cutting process chosen to
make this Jukung fishing boat is CNC cutting due to its ability to cut in a fast rate while maintaining its cutting accuracy.

![Figure 19 Mould production out of multiplex using cutting machine CNC.](image)

**Figure 19** Mould production out of multiplex using cutting machine CNC.

![Figure 20 Mould production out of multiplex using cutting machine CNC for multiple stations.](image)

**Figure 20** Mould production out of multiplex using cutting machine CNC for multiple stations.

![Figure 21 Post-cutting of a station of Jukung fishing boat mould.](image)

**Figure 21** Post-cutting of a station of Jukung fishing boat mould.

The subsequent step is to assemble the mold lengthwise of the boat. This series of molds must be placed in the order they are stationed. In addition, the ship molds must be arranged in reverse as in
Figure 22. This was done to simplify the erection process of the Jukung fishing boat. These molds are assembled on straight solid wood to ensure alignment between each mold. The height of each mold must also be adjusted according to the sheer height.

![Figure 22](image-url)

**Figure 22 Assembly of Jukung fishing boat mould in reverse order.**

4.3. Fabrication of construction components

The bamboos in use need to be fabricated before being assembled and erected into a ship. The bamboos used for ship construction components are Ori bamboo and Betung bamboo which are 1.5 - 2 years old, at this age the bamboo is ripe and ready to be cut down. Logged bamboo is then broken into several strips and cut into 2 meters long, to maintain its alignment. These 2 meters long bamboo strips must be flattened on all four sides (top, bottom, right and left) prior to being laminated. The alignment of the four sides of the bamboo slats is done using a planner machine.

![Figure 23](image-url)

**Figure 23 Flattening of bamboo strips using a planner machine.**

The bamboo flattening process as shown in Figure 23, is carried out until the entire bamboo surface is flat on all four sides. Apart from being flat on some sides, bamboo must also be clean from the outer skin to maintain the effectiveness of the gluing process.

4.4. Finishing of Jukung Fishing Boat

After undergoing previous steps, the laminated bamboos of the Jukung fishing boat are assembled. The results can be seen in Figure 24 and Figure 25.
Figure 24 Side a) and front b) view of the Jukung fishing boat after assembly process without the outriggers, as they are still a work in progress at the moment.

Figure 25 For the finishing touch, the boat’s surface is refined by rubbing sandpaper to its construction and applying gel coat to prevent the bamboo from absorbing water as seen in a). Gel coat can also benefit as an exterior shield to keep the bamboo in place even when it experiences crack. It adds aesthetic values to the boat as seen in b).
5. Conclusion
A half complete design and production of a Jukung fishing boat has been conducted as elaborated. Bamboo as the main material of the boat offers more benefits than regular wood. Bamboo is cheaper, as well as more abundant than wood and is found to have similar strength as regular wood. The following were found in this study:
1. The result of this study can be used as a solution to increase the number of Jukung fishing boat owned by marginal fishermen based on a number of reasons:
   a. Laminated bamboo Jukung fishing boat is a sustainable and easily made construction,
   b. It is relatively cheaper than wooden fishing boat for marginalized fishermen,
   c. Bamboo is abundant in Indonesia in terms of species and quantity in Indonesia,
   d. This study can solve the lack of new technology implementation among local fishermen by means of maintaining the local cultural heritage.
2. The main dimensions of the Jukung fishing boat prototype are as listed in Table 1.
3. The results of technical analysis are as follows:
   a. Hydrostatic calculations as listed in Table 2.
   b. Resistance calculations found that the resistance of the Jukung fishing boat is 738.41 N.
   c. Power calculation. With the value of the resistance found, the power required to move the boat can be determined. With a 30% efficiency, the required power is found to be 9.497 kW.
   d. Machinery specification. Using the obtained required power, a 25 HP electrical motor was chosen in order to move the ship with a service speed of 7.5 knots.

Furthermore, the following recommendations can be considered in further research following this study:
1. Perform assembly and erection of all components of the Jukung fishing boat construction made of laminated bamboo,
2. Conduct economic judgment analysis on the construction of the Jukung fishing boat made of laminated bamboo,
3. Hold an educative socialization of the results of innovative laminated bamboo Jukung fishing boat prototype to marginalized fishermen, including the manufacturing methods and sea trials.

References
[1] M. C. Hansen et al., “High-resolution global maps of 21st-century forest cover change,” Science (80-. ), vol. 342, no. 6160, pp. 850–853, 2013, doi: 10.1126/science.1244693.
[2] Morisco, “Pemberdayaan Bambu untuk Kesejahteraan Rakyat dan Kelestarian Lingkungan,” 2006.
[3] S. Cao, J. D. Wang, H. S. Chen, and D. R. Chen, “Progress of marine biofouling and antifouling technologies,” Chinese Sci. Bull., vol. 56, no. 7, pp. 598–612, 2011, doi: 10.1007/s11434-010-4158-4.
[4] H. Supomo, D. Manfaat, and A. Zubaydi, “Flexural strength analysis of laminated bamboo slats (Bambusa Arundinacea) for constructing a small fishing boat shells,” Trans. R. Inst. Nav. Archit. Part B Int. J. Small Cr. Technol., vol. 157, no. Part B1, pp. 23–31, 2015, doi: 10.3940/nma.ijsct.2015.bl.167.
[5] W. T. Pribadi, S. I. Wahidi, and I. Baihaqi, “Manajemen Produksi Kapal,” no. 5 M, 2018.
[6] A. . Fallis, “Peraturan Menteri Kelautan dan Perikanan Republik Indonesia Nomor PER.16/MEN/2010,” J. Chem. Inf. Model., vol. 53, no. 9, pp. 1689–1699, 2013.
[7] C. S. Verma and V. M. Chariar, “Development of layered laminate bamboo composite and their mechanical properties,” Compos. Part B Eng., vol. 43, no. 3, pp. 1063–1069, 2012, doi: 10.1016/j.compositesb.2011.11.065.
[8] C. H. Lee, M. J. Chung, C. H. Lin, and T. H. Yang, “Effects of layered structure on the physical and mechanical properties of laminated moso bamboo (Phyllosachys edulis) flooring,” Constr. Build. Mater., vol. 28, no. 1, pp. 31–35, 2012, doi: 10.1016/j.conbuildmat.2011.08.038.
[9] C. A. Fuentes et al., “Wetting behaviour and surface properties of technical bamboo fibres,”
[10] N. Bystriakova, V. Kapos, C. Stapleton, and I. Lysenko, “Bamboo biodiversity: Information for planning conservation and,” 2003.

[11] I. Suprijanto, Rusli, and D. Kusmawan, “Standardisasi Bambu Laminasi Sebagai Alternatif Pengganti Kayu Kontruksi,” Pros. PPI Stand. 2009, no. November, p. hal 1-23, 2009.

[12] K. Janssen, J.J., Boughton, G., Adkoli, N. S., Ranjan, M.P., Sastry, C. B., Ganapathy, P. M., Ramanuja Rao, I., V., Ghavami, K., Ravindran, Bamboo as an engineering material, no. 1991. Ottawa, Canada: International Development Research Centre, 1991.

[13] S. Handayani, “Pengujuan Sifat Mekanik Bambu (Metode Pengawetan Dengan Boraks),” Penguji. Sifat Mek. Bambu (Metode Pengawetan Dengan Boraks), vol. 9, no. 1, pp. 43–53, 2009, doi: 10.15294/jtsp.v9i1.6921.

[14] Biro Klasifikasi Indonesia, Volume vii rules for small vessel up to 24 m 2013 edition biro klasifikasi indonesia, vol. VII. Jakarta: Biro Klasifikasi Indonesia, 2013.