Technical and economic analysis on the using of *Hibiscus Tiliaceus* (Waru) and *Boehmeria Nivea* (Rami) fibres for fishing vessel mooring rope

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**Abstract.** Mooring rope of fishing boat made of synthetic fibre materials such as polypropylene or nylon can bring detrimental impacts to the environment as it is arduous to degrade. Natural fibre rope can potentially substitute the commonly-used undegradable mooring line to prevent further chain impacts. This paper aims to technically and economically analyse the tensile strength of mooring ropes made of two natural fibres, *Hybiscus Tiliaceus* (Waru) and *Boehmeria Nivea* (Rami), and to compare them with the former - conventional material manufactured rope. Tensile test, according to ASTM D3822, is performed to measure the tensile strength of the natural fibre ropes twisted into three different diameters (12 mm, 16 mm, 20 mm). Specimens are immersed in seawater for several weeks before testing. As a benchmark, this research examines unimmersed ones. The result shows that immersed Waru fibre ropes with three different diameters are 32.15 MPa, 27.10 MPa, 23.94 MPa, respectively; while for Rami fibre ropes are 37.58 MPa, 29.56 MPa, 24.31 MPa. Waru fibre rope is the most economical one if compared to Rami and synthetic fibre ropes. The manufacturing of mooring rope made of Waru fibres can save 19.4%, 11.5%, and 29.7% for each diameter variation, respectively.

1. Introduction
The use of synthetic fibre as fishing boat mooring ropes is a severe problem in most countries [1] including in Indonesia. The number of fishing boats for marine and public water fisheries in 2016 based on [2] amounted for 726,984 units, consisting of 308,699 vessels without motor, 245,033 onboard motor vessels, and 173,252 engine vessels. It predicts the number will increase due to many new contracts of fishing vessel procurement from the Indonesian government. The more ships built; they need more mooring ropes. In large quantities, the use of this synthetic mooring rope will endanger the environment due to the difficulty to be decomposed [3]. Hence, it will bring severe problems in the long term as well as the impact for human health and well-being, explicitly related to fisheries, heritage and charismatic species, and recreation [4].

Over the years, mooring ropes commonly utilise synthetic material fibres due to technical and economic benefits. Many studies investigated the technical characteristic of these materials for marine application. Weller et al. [5] overviewed the implementation of synthetic mooring ropes for marine renewable energy application. It focused on the mooring system, including crucial information about aspects of specification (performance attributes, classification, and testing) as well as implementation (installation, degradation, maintenance, inspection, and decommissioning). In a similar case, Saidpour and Vaseghi [6] experimentally investigated the termination of heavy-duty polyester mooring rope for
renewable energy construction. It tested the performance of the filament, yarn, strand and the sub-rope. Chevillotte [7] investigated the fatigue characterization of polyamide mooring ropes for floating wind turbine. It aimed to improve understanding of the fatigue mechanism leading to failure. These studies, however, have not explicitly revealed the recycling process of this material which can be difficult due to contamination and the fact that a large number of ropes are still currently being used [8]. Another researcher [9] has initially purposed a study to recycle the mooring ropes from a decommissioned offshore platform. It stressed on the reusing the decommissioned products, but the potential pollution and harms have not been considerably investigated. Based on facts and studies, the synthetic mooring rope for marine application should be reduced.

The effort to reduce the synthetic mooring ropes can be carried out by substituting them with natural fibre manufactured mooring lines which are considered more environmentally friendly. Majority of new natural threads derived from diversified lignocellulosic resources is bark [10]. Not all plant barks have appropriate substances manufactured and applied for natural fibre ropes. The threads as the boat mooring rope materials should have sufficiently high strength, durable, fixed shape (not shrink) and have a smooth surface.

Studies investigating the mechanical properties of possible natural fibre for composites are quite abundant. Some potential natural fibres investigated by researchers are jute, sisal, kenaf, abaca banana, cotton, coir, hemp, and so on [11]. Other potential threads are Boehmeria Nivea and Hibiscus Tiliaceus.

Nurudin [12] investigated the tensile and bending strength of Hibiscus Tiliaceus fibre in laminated composite to substitute fibreglass reinforced plastic (FRP) for boat hull application. At the same time, in a similar case, Fadhillah et al. [13] examined the tensile strength with different types of resin. Prasetyo et al. [14] studied the effect of soaking on the fibre strength. An experimental tensile strength of this natural fibre composite with different chemical treatment was performed by Prihajatno et al. [15]. Hamidon et al. [16] reviewed the effect of fibre treatment on mechanical properties of kenaf fibre reinforced composites. The mechanical properties Boehmeria nivea (Rami) reinforced polymer composite was carried out by Murali et al. [17]. Lokesh et al. [18] performed a study on mechanical properties of the bamboo fibre-reinforced polymer composite. The effect of fibre length and content on the mechanical behaviour of composites is studied.

Other researchers have investigated the strength and application of natural fibre ropes. An experimental investigation on coconut-fibre rope tensile strength was presented by Ali and Chouw [19]. It tested the tensile strength of this natural fibre rope, considering the rope diameter and pre-treatment. The thinner rope diameter has higher tensile strength than that obtained with the medium and thick one. However, the thick rope has more excellent elongation that captured with the thin and medium strings. Compared to the soaking treatment, the tensile strength and elongation of the lines increased by boiling treatment and decreased by chemical treatment. Ali [20] presents the experimental work on studying the effect of post-tensioned coconut-fibre ropes in controlling uplifts of interlocking blocks in mortar-free concrete construction during seismic loadings. Chokshi et al. [21] predicted the tensile strength of the natural fibre and natural fibre yarn with strain rate variation upshot. The natural fibre used are hemp fibre, sisal fibre and banana fibre while the natural fibre yarn used are flax fibre yarn, bamboo fibre yarn and cotton fibre yarn. The tensile strengths are then predicted using a mathematical model. The tensile strength increases gradually at a lower strain rate and decreases gradually at higher strain rate.

The research of utilising the alternative natural material for marine applications is still scarce. Supomo et al. [22] have initially studied the utilisation of bamboo material for fishing vessel shell due to the scarcity of solid wood, then Supomo et al. [23] have experimentally developed the frame construction study by utilising bamboo material for a small vessel. The other research to find out natural fibre mooring ropes for marine application, especially for small craft vessel, should be investigated. The literature review part has discussed the strength of potential natural fibres for composite applications in terms of mechanical properties and the friendliness for the environment. However, the case for marine application which has unique characteristics should be further studied. This paper presents the experiment of the tensile strength of natural fibres ropes, made of Hibiscus Tiliaceus (Waru) and Boehmeria Nivea (Rami), for mooring fishing vessel application. The results will be examined by the
required minimum standard for fishing vessel mooring rope and compared with the conventional one. The economic comparisons and other added value in term of environmental friendliness of both mooring ropes will also be reviewed.

2. Research Description
The fabrication process of the natural fibre rope begun with obtaining fibre textile yarn by soaking natural fibre barks for several weeks. The multifilament threads are tiny, and the filaments are lightly interlaced or twisted. The small textile yarn elements then were spun into larger rope yarns and finally built into strand and rope [24]. In this study, it used three strands rope with three different diameters of 12 mm, 16 mm, and 20 mm for both fibres, which are manually hand-made twisted. It examined all variation immersed in seawater for five weeks to find out the effect of real environment condition. Eventually, the tensile test was conducted as per ASTM D3822-07 [25] to find out the tensile strength of the ropes and compared with the required minimum strength [26] and the results from other references. Figure 1 and Figure 2 illustrate the rope specimen design with three strands and three different diameters and the rope tensile testing process using a universal testing machine (UTM), respectively.

![Figure 1. Rope specimen design](image1)

![Figure 2. Tensile test of rope specimen using UTM (Capacity 20 tons)](image2)

3. Results and Discussions
Figure 3 depicts the typical stress-strain diagram for both natural fibre ropes. The maximum load, shown as ‘B’ in Figure 3, is used for the ultimate strength calculation, which is divided by the corresponding strain from the curve. The elongation up to peak-load is measured. The figure shows the stress-strain curve has two approximately linear segments (OA and AB) before the maximum load achieved. The twisted imperfection might cause it from the manually hand-made ropes and the unperfect grip to clamp the natural braided fibre before tested. It should be a linear line from OB. Initially, one curled line with the maximum stress ruptured (at point B in Figure 3) and the stress value suddenly dropped to point C. The remaining entwined ropes took the tension load, and the stress started increasing from point C to D to E and then from E to F and finally totally ruptured in point G.
Figure 3. A typical stress-strain relationship for Hibiscus Tiliaceus and Boehremia Nivea-fibre rope

3.1 Tensile Strength

Table 1 shows the experimental results of natural fibre ropes through tensile testing. Five specimens determine the average value of results for Waru fibre rope and Rami fibre rope as per ASTM D3822-07 [25]. From Table 1, Rami fibre rope has higher ultimate tensile strength than that of Waru fibre rope for all diameters. This higher strength occurred because Ramie fibre has higher hemicellulose content compare to Waru fibre. The hemicellulose content affects the bonding strength of the fibre element, which also increase the tensile strength of natural fibre [27]. It shows that the bigger the diameter, the lower the tensile strength of the ropes. As the rope diameter decrease from 20 mm to 12 mm, the bond strength increases from around 23 MPa to 28 MPa for Waru fibre rope and up to 36 MPa for Ramie fibre rope. The thicker rope diameter requires higher pull-out load than the thinner one. However, due to an increased diameter size, the interfacial surface area increases, causing reduced bond strength. The previous research supports that fibre coconut ropes tested with the different diameters decreased tensile strength for smaller diameter [19].

The immersion treatment slightly increases the tensile strength for both natural fibre ropes. The slight additional strength value is around 0.8% up to 2.3% for both. Seawater consists of mild alkalinity, which could eliminate the hemicellulose and lignin of the fibre [28]. Based on previous research, the alkaline substance can change the Waru fibres surface becomes clear, fibril and rougher, which eventually increase the tensile strength of the rope [29]. It may impact the Rami fibre rope also in the same way.

Table 1. Experimental tensile testing results for both fibre ropes

| Experimental Results | Immersion treatment | Diameter (mm) | Hibiscus Tiliaceus Rope | Boehremia Nivea Rope |
|----------------------|---------------------|---------------|------------------------|---------------------|
|                      | No                  | 12            | 31.87                  | 37.25               |
|                      |                     | 16            | 26.58                  | 29.03               |
|                      |                     | 20            | 23.67                  | 23.76               |
|                      | Yes                 | 12            | 32.15                  | 37.58               |
|                      |                     | 16            | 27.10                  | 29.56               |
|                      |                     | 20            | 23.94                  | 24.31               |
| Tensile Strength (MPa) | No                  | 12            | 95.00                  | 102.00              |
|                      |                     | 16            | 96.33                  | 105.00              |
|                      |                     | 20            | 100.67                 | 112.00              |
|                      | Yes                 | 12            | 96.00                  | 104.00              |
|                      |                     | 16            | 99.00                  | 109.00              |
|                      |                     | 20            | 106.00                 | 119.33              |
| Elongation at peak load (%) | No                  | 12            | 33.55                  | 36.52               |
|                      |                     | 16            | 27.59                  | 27.65               |
|                      |                     | 20            | 23.52                  | 21.21               |
|                      | Yes                 | 12            | 33.49                  | 36.14               |
|                      |                     | 16            | 27.37                  | 27.12               |
|                      |                     | 20            | 22.59                  | 20.37               |

Figure 4 depicts the tensile strength of natural fibre ropes made of Waru fibre and Rami fibre as well as the synthetic fibre ropes compared with the minimum requirement from bureau classification of Indonesia (BKI) [26]. At a glance, both natural fibre ropes fulfil the minimum requirement from Indonesian bureau classification rule for fishing vessel. However, the values of the tensile strength in all diameters are still below the synthetic fibre ropes. Fibre rope made of nylon synthetic has higher tensile strength than that made of polypropylene mono and multifilament ropes [24]. This rope has better
mechanical properties if compared with natural fibre ropes (Waru & Rami). Tensile strength comparison amongst natural, nylon and polypropylene fibre lines are 1: 1.69-2.13: 1.15-1.7, respectively.

3.2 Strain and Modulus of Elasticity
The graph, in Figure 3, shows the strain value of the experiment obtained by dividing the elongation at peak load with the initial essential length of the rope. Concerning the previous explanation, the strength of the natural fibre ropes decreases in line with the increasing of the rope diameter. On the contrary, the elongation measurement on peak load is in vice versa. The elongation of all-natural fibre ropes is higher following the thicker rope diameter. As presented in Figure 5, the elongation at peak-load for Rami fibre rope, in general, is above Waru fibre rope at all diameter size.

Meanwhile, the immersion treatment slightly increased the elongation values for all diameters. It means that the seawater substance may upgrade a little additional toughness of both natural ropes as the tensile strength increase coupled with the elongation. However, this research needs further work to reveal the longevity of the natural fibre ropes in marine condition for a longer duration.

![Graph showing tensile strength and elongation of natural fibres](image-url)

**Figure 4.** Tensile strength comparisons of natural fibre rope (Rami and Waru) with synthetic ropes and minimum requirement Indonesian bureau classification (BKI)

![Graph showing elongation comparison](image-url)

**Figure 5.** Elongation comparisons of natural fibre rope with two different treatment

In general, the elongation of synthetic fibre ropes is minimal compared with the Waru and Rami natural fibre ropes. A conventional 3-stand line made of nylon fibre with circle diameter ¾ inch (19
mm) is about 8%. The higher the diameter, for example, 1½ inch (38 mm) has more excellent elongation, which is about 15% in the breaking load strength [24]. It points out that although synthetic fibre rope has higher tensile strength than the natural one, it is considerably more brittle in compared with the natural fibre rope from Waru and Rami.

The stress-strain diagram slop determines the Modulus of Elasticity (MOE). As presented in Table 1, the MOE value of both Waru and Rami fibre ropes are ranging from around 21 GPa up to 36 GPa. The same crossed diameter has a relatively similar value of MOE. The thicker the crossed diameter of the rope, the MOE is relatively lower if compared to the thinner one. Comparing with the synthetic fibre ropes, the value of MOE of Waru and Rami fibre ropes are relatively smaller. Based on a reference from [24], the MOE of synthetic fibre ropes is ranging from 50 GPa to 100 GPa. It is due to the bonding characteristic of synthetic fibre yarns which are relatively more durable than the natural fibre yarns.

### 3.3 Economic Analysis of Fishing Boat Natural Fibre Mooring Ropes

As state in rules for fishing vessel section 18 [26], this vessel can use fibre rope made of natural or synthetic fibres. It also provides the minimum strength and recommended length of mooring lines required. Indonesia Bureau Classification (BKI) [30] suggested a minimum of four pieces of ropes, where two of four should have a minimum length of approximately two times. Hence, the total length of mooring rope recommended by BKI for diameters 12 mm, 16 mm, and 20 mm are 45 metres, 65 metres and 85 metres respectively. Table 2 presents the detailed breakdown of the mooring rope total length for the fishing vessel.

| The diameter of fishing boat mooring rope (mm) | Number (pieces) | Length 1 mooring rope with length L (m) | Length 1 mooring rope with length 2L (m) | The total length of mooring rope (m) |
|-----------------------------------------------|-----------------|----------------------------------------|----------------------------------------|-----------------------------------|
| 12                                           | 4               | 7.5                                    | 15                                     | 45                                |
| 16                                           | 4               | 10.83                                  | 21.67                                  | 65                                |
| 20                                           | 4               | 14.16                                  | 28.33                                  | 85                                |

#### 3.3.1 Material cost

Once the required length of mooring rope is determined, the unit cost, price and economic comparison with the synthetic fibre rope for fishing vessel mooring can be estimated. The cost of production consists of material costs, labour costs, and expense costs [31]. The material to produce natural fibre rope consists of direct material which is the natural fibres itself and the indirect content such as supporting material to fabricate the mooring lines. Labour and expenses costs include direct and indirect costs/expenses. Labour cost estimations are determined from the direct labour based on the number of workers and the duration time spent to manufacture the natural fibre into ropes. Lastly, the approximation of the overhead costs, which may consist of electricity for machines, the water and other components can be measured.

In this study, it predicts that the manufacturing process of mooring ropes produced in an industrial scaled or mass production—a year cost calculation. The target production in a year is assumed based on manual productivity (data experiment) which is enhanced eight times faster by using technological advancement. Thus, the material cost needed in a year can be estimated, and then the direct material cost in a year can be determined. The direct material cost consists of direct fibre yarn material, transport cost and the indirect cost, which is assumed about 5% of total direct material cost. The transport costs for both are different due to different stowage capacity and the limitation of truck capacity/trip, which is only 15 tons. After the total material cost is estimated, then it is divided by the effectivity ratio of both natural fibres for each different diameter. The cost/meter for each diameter and each natural fibre ropes can be determined. To provide a more precise illustration, (Table 6). Table 3 and Table 4 show the detailed step calculation to illustrate the material cost per unit length.
3.3.2 Labour cost

The compositions of labour costs are direct labour costs and indirect labour costs. In this case, it assumes that the mooring rope industry has three rope twisted machines which each machine are operated by two workers and three helpers + 1 additional helper as a general service in the workshop. Meanwhile, the indirect cost includes the chief director, manager for production and sales, supervisors, administrative staff and security staff. For more detail, Table 5 illustrates the labour cost estimation in a year for the mass production process of the natural fibre ropes. The production rope in a year is estimated from multiplying the upgraded productivity with the available man-hours in a year, which is 300 days in a year with eight working hours in a day, times the total direct worker man-hours/year. The length of the produced ropes in a year can be estimated. Finally, the total cost of the labour cost each length unit can be determined (Table 6).

**Table 3. Target production capacity per year and the material cost/unit meter**

| Diameter (mm) | Effectivity Ratio (meter/kg) | Produced rope (m/year) | Need of fibre rope (ton/year) | Cost/meter (IDR/meter) |
|--------------|-------------------------------|------------------------|------------------------------|------------------------|
|              | Rami fibre                    | Waru fibre             | Rami fibre rope              | Waru fibre rope        |
| 12           | 6.00                          | 14.55                  | 2,163,380.28                | 360.56                | 148.73                |
| 16           | 3.38                          | 8.18                   | 1,536,000.00                | 455.11                | 187.73                |
| 20           | 2.16                          | 5.24                   | 930,909.09                  | 430.98                | 177.78                |

**Table 4. Calculation of direct material cost/year and per unit kilogram of fibre**

| Direct material cost | Fibre Yarn needed (ton/year) | Cost/unit yarn (IDR/ton) | Number of trip | Cost/unit transport (IDR/trip) | Material + transport (Million IDR/year) | *Indirect cost (5%) (Million IDR/year) | Direct Material Cost (Million IDR/year) | Cost of material/kg (IDR/kg) |
|---------------------|-------------------------------|--------------------------|----------------|-------------------------------|----------------------------------------|----------------------------------------|----------------------------------------|-----------------------------|
| Rami fibre          | 1,246.65                      | 90,000,000               | 83.00          | 1,500,000                    | 112,323.08                             | 5,616.15                              | 117,939.24                            | 94,604.86                   |
| Waru fibre          | 514.24                        | 10,000,000               | 34             | 1,500,000                    | 5,193.44                               | 259.67                                | 5,453.11                              | 10,604.13                   |

Notes: Exchange rate is USD 1.0 = IDR 14,225

**Table 5. Labour cost estimation in a year**

| Cost Item            | Number | Total Mhrs/year | Rate/hours (IDR/h) | Total Direct Cost (IDR) |
|----------------------|--------|-----------------|--------------------|------------------------|
| Direct Labour Cost   |        |                 |                    |                        |
| Workers              | 6      | 14,400          | 31,250.00          | 2,700,000,000.00       |
| Helpers              | 10     | 24,000          | 21,875.00          | 5,250,000,000.00       |
| Total Mhrs/year      | 38,400 |                 |                    | 7,950,000,000.00       |

Indirect labour cost

| Cost Item        | Number | Duration (month) | A monthly rate ( IDR) | Total Indirect labour cost ( IDR) |
|------------------|--------|------------------|-----------------------|----------------------------------|
| Main Director    | 1      | 12               | 25,000,000.00         | 300,000,000.00                   |
| Manager          | 2      | 12               | 10,000,000.00         | 240,000,000.00                   |
| Supervisor       | 2      | 12               | 7,500,000.00          | 180,000,000.00                   |
| Admin Staff      | 2      | 12               | 5,000,000.00          | 120,000,000.00                   |
| Security staff   | 2      | 12               | 4,000,000.00          | 96,000,000.00                    |
| Sub-total II     |        |                  |                      | 936,000,000.00                   |
| Total Labour Cost/year |        |                  |                      | 8,886,000,000.00                 |
Table 6. Estimation of productivity and the labour cost/unit meter on each diameter

| Diameter (mm) | Manual Productivity (Mhrs/meter) | Upgraded Productivity (Mhrs/meter) | Average productivity (Meter/mhrs) | Produced rope (m/year) | Total Cost/meter (IDR/meter) |
|---------------|----------------------------------|-----------------------------------|----------------------------------|------------------------|-----------------------------|
| 12            | 0.142                             | 0.018                             | 56.34                            | 2,163,380.28           | 4,107.46                    |
| 16            | 0.200                             | 0.025                             | 40.00                            | 1,536,000.00           | 5,785.16                    |
| 20            | 0.330                             | 0.041                             | 24.24                            | 930,909.09             | 9,545.51                    |

*) based on experimental data.

3.3.3 Total unit cost of production and price estimation

Based on cost per unit length (cost/meter) from material cost and labour cost calculation, it can be added up and tabulated as in Table 7. The overhead cost is estimated at 20% of total material and labour costs. While the tax is determined as 10% as well as the profit or margin is assumed at 15%.

Table 7. Total cost and price estimation of fibre ropes

| Price component Estimation | Rami fibre rope cost (Diameters (mm)) | Waru fibre rope cost (Diameters (mm)) |
|----------------------------|--------------------------------------|--------------------------------------|
| Material Cost (IDR/meter)  | 15,767.48                            | 43,798.55                            |
| Labour Cost                | 4,107.46                             | 9,545.51                             |
| Overhead Cost (20%)        | 3,974.99                             | 967.30                               |
| Total Cost                 | 23,849.93                            | 13,884.72                            |
| Tax (10%)                  | 2,384.99                             | 1,388.47                             |
| Profit (15%)               | 3,577.49                             | 2,082.71                             |
| Price (IDR)                | 29,812.41                            | 17,355.90                            |

Table 8. Price Comparison of natural fibre ropes with several synthetic fibre ropes (IDR/meter)

| Diameter size (mm) | Ramie Fibre rope | Waru Fibre rope | Synthetic fibre rope ***) | Braided Polyester Dockline Mooring Rope *) | Multifilament polypropylene *) | 3 Strand Polyester Rope *) | Multiply/Octoplait/Ancorbraid Mooring rope *) | Multiply rope (nylon/octoplaid) *) |
|-------------------|------------------|-----------------|---------------------------|-------------------------------------------|-------------------------------|-------------------------------|---------------------------------------------|-----------------------------------|
| 12                | 29,812.41        | 7,254.74        | 9,000.00                  | 64,800.00                                 | 25,200.00                     | 28,260.00                     | 74,880.00                                  | 74,880.00                         |
| 16                | 50,724.34        | 10,621.83       | 12,000.00                 | 106,020.00                                | 45,000.00                     | 47,700.00                     | 111,780.00                                | 111,780.00                        |
| 20                | 80,016.08        | 17,355.90       | 24,700.00                 | 155,520.00                                | NA                           | 73,800.00                     | 172,980.00                                | NA                                |

*) https://www.ropelocker.co.uk/  ***) https://www.indotrading.com/

Concerning the inherent strength, availability and cost of natural fibre, especially for Waru fibre for the mooring rope. The advantages of these organic fibres, in the long term after degrading, they will be easily decomposed, and it will not induce pollution to the environment. Further study to investigate the
longevity and the durability of these fibres and the possible application for bigger capacity can be conducted. The impact on the environment and the green technology in the marine industry should be continuously explored, enhanced and applied for a brighter future.

4. Conclusions

After researching by way of the experimental approach to derive mechanical properties followed by the production and cost analyses on the utilisation of Hibiscus Tiliaceus (Waru) and Boehmeria Nivea (Rami) fibres as fishing vessel mooring rope, some findings are summarised as follows:

1. The average tensile strength values obtained from the test on 12 mm, 16 mm and 20 mm diameters of mooring rope made from Waru fibres without immersion treatment are 31.87 MPa, 26.58 MPa, and 23.67 MPa, respectively. For the case of mooring ropes made of Rami, strands reveal the average tensile strengths of 37.25 MPa, 29.03 MPa, and 23.76 MPa. The immersion treatment slightly increases the value of the tensile strength of the rope.

2. The thicker the diameter of the rope, the more significant the elongation at peak load for all specimens. The immersion treatment also slightly adds the value of the elongation.

3. The average tensile strength of mooring fishing boat made from Waru and Rami fibres for ropes with a diameter of 12 mm, 16 mm and 20 mm meet the technical requirements of BKI, where the values should be higher than 26, 51 MPa, 24.85 MPa, and 22.59 MPa, respectively.

4. Fishing boat ropes made from Waru and Rami, which are organic fibres have the advantage of inherently environmentally friendly. In the long term after degrading, they will be easily decomposed and do not induce pollution to the environment. Moreover, Waru trees and Rami plants are easy to grow and have a fast harvesting period; thus, they are primarily renewable material. Those natural materials are more desirable than synthetic fibre ropes, which are not environmental friendly because these are hard to decompose in nature and lead to pollution in the long term.

5. If the mooring ropes made from Waru fibres and compared to synthetic ropes, for the 12 mm, 16 mm and 20 mm diameter can save 19.4%, 11.5%, and 29.7%, respectively. Mooring ropes made from Rami bark fibres have higher prices than synthetic fibre ropes which is almost double or threefold. Therefore, it suggests the more favourable natural thread used in producing fishing vessel mooring ropes is from Waru fibre, which has more economic value than mooring lines made from synthetic fibres.

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