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Analysis of Fiberglass Boat Construction Compliance with Indonesian Classification Bureau (BKI) Standards

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Abstract— Technological developments have encouraged the shift in the main material from wood to Fiber Reinforced Plastic (FRP) because of its light weight, noncorrosive, lower price, and simple production process. However, traditional FRP boat production in Indonesia generally has not implemented the construction standards set by the Indonesian Classification Bureau (BKI), including those of CV. Roni Marine boat production. This study aims to describe the construction of FRP boats produced by CV. Roni Marine and assess its compliance with BKI standards. The research was conducted through direct observation at CV. Roni Marine, measuring the dimensions of the 9.5 m FRP boat construction, and literature review of the BKI standard documents. The main components of boat construction analyzed include the boat's skin, keel, frames, longitudinal stiffeners, and deck beams. The results showed that boats produced by CV. Roni Marine use a combination of transverse and longitudinal construction systems with laminated materials, including CSM300 and WR600 fibers. The thickness of the hull laminate is 2.13 mm. The spacing between frames is 580 mm, the length of the longitudinal stiffeners is 8,700 mm, the width of the keel lamination is 60 mm, and the spacing between the deck beams is 2,900 mm. The results showed that all construction elements of the boats did not comply with BKI standards.

Keywords— BKI, boat construction, CV. Roni Marine, fiberglass, Indonesia.

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I. INTRODUCTION

The development of technology in the shipbuilding industry has changed the use of traditional boatbuilding materials from wood to Fiberglass Reinforced Plastic (FRP) [1]. FRP is widely used because it has several advantages compared to wood, such as lighter weight, resistance to corrosion, and ease of maintenance, since FRP material is not easily overgrown by marine organisms, thereby extending the service life of the boat [2]. The production process of boats made from FRP is also simpler and more economically efficient compared to wooden boats [3]. These advantages have encouraged many boat producers in various coastal regions of Indonesia to switch to using FRP as the main material in boat construction.

The use of FRP in boat construction needs to meet certain standards to ensure its quality and safety. In Indonesia, the provisions for FRP boat construction are established by Biro Klasifikasi Indonesia (BKI), which is a national classification body that carries out classification of Indonesian-flagged vessels as well as foreign vessels operating in the territory of the Republic of Indonesia [4]. BKI plays a role in formulating maritime regulations, conducting technical assessments, and establishing construction standards, including for boats made from FRP [5]. The implementation of these standards aims to ensure that boats produced domestically have structural and material quality that meet the standards, so that they can guarantee the safety of boat operations [6].

However, the implementation of regulations regarding boat standards has not been fully carried out by traditional shipyards in Indonesia, including FRP boatyards. Study [7] states that most domestic FRP boatyards do not implement clear and standardized engineering and quality standards. These shipyards generally only rely on traditional shipbuilding practices. This is also supported by study [8], which states that around 30% of FRP boat hulls built in seven domestic shipyards do not meet the construction requirements established by BKI. Boat construction that does not refer to BKI standards raises concerns about the potential rejection of the issuance of boat measurement certificates by the Directorate General of Sea Transportation (Ditjen Hubla) of the Ministry of Transportation [9]. This measurement certificate is used as one of the required documents for applying for a sailing permit, as stated in PM 39/2017 concerning Ship Registration and Nationality [10]. If a boat does not have a sailing permit, the authorities may at any time detain or prohibit the boat from operating. This condition can certainly hinder fishing activities.

One of the shipyards that constructs its boats without referring to the FRP boat construction standards established by BKI is CV. Roni Marine shipyard, located in Cilacap, Central Java. This was confirmed by the shipyard owner. The reason for not following BKI

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standards is that boats produced according to BKI standards become heavier. Study [11] provides an example case of FRP boat production in Cilacap where its design and construction refers to BKI standards, resulting in a heavier boat. This boat must be lifted by nearly 20 people, while a typical 3 GT FRP boat normally can be lifted by around 6 people. A heavier boat can reduce its capacity due to the excessive hull weight.

CV. Roni Marine is a pioneer of FRP boatyards in Cilacap. Boat production at CV. Roni Marine is based on traditional shipbuilding practices commonly applied in the shipyard. Even though BKI construction standards are not implemented, the boats produced can operate for up to 20 years without structural failure. Boats produced by this shipyard have also been widely ordered for operation outside Cilacap, including in Sumatra, Bali, and Lombok. This indicates that the boats are capable of operating in Indonesian coastal waters. In 2019, CV. Roni Marine was entrusted by the Ministry of Marine Affairs and Fisheries (KKP) to build 119 units of FRP boats.

Several studies regarding the construction suitability of FRP fishing boats based on BKI standards have been conducted in several shipyards in Indonesia. However, similar evaluations have not yet been conducted on FRP fishing boats produced by CV. Roni Marine. Therefore, this study provides initial information on the construction characteristics and conformity of FRP fishing boats produced by CV. Roni Marine with BKI standards.

Based on the explanation above, this study aims to describe the construction of FRP boats produced by CV. Roni Marine and assess its compliance with BKI standards. The results are expected to inform and, if applicable, establish a more appropriate reference standard for FRP boats operating in coastal waters.

II. METHOD

This research was conducted at the CV. Roni Marine shipyard located in Cilacap, Central Java, in April 2026. The equipment used in this study included measuring tools and a camera. The boat used as a sample in this study was a 9.5 m boat. The selection of this boat size was based on the consideration that the 9.5 m boat is the type of boat most frequently ordered by fishers.

A. *Research Procedures*

The research began with interviews with 30 fishers to obtain an overview of the utilization of boats produced by CV. Roni Marine. The next stage was observation of the FRP boat construction at the shipyard and in-depth interviews with shipyard workers. The data obtained from the observations were then processed to describe the boat construction. The final stage was conducting a literature review on FRP boat construction standards based on the BKI document (Guidance for Certification of FRP Fishing Vessel Less than 12 m) and comparing the measurement results obtained in the field with these standards to assess the level of compliance.

B. *Data Analysis*

The data collected in this study included the main dimensions of the vessel, material specifications, production methods, construction details, laminate arrangements, and literature data on FRP vessel construction standards established by BKI.

Data analysis was conducted using descriptive and comparative methods. Descriptive analysis was used to describe the boat construction based on the observation results. Comparative analysis was used to assess the compliance of the boat construction with BKI standards based on the document Guidance for Certification of FRP Fishing Vessel Less than 12 m. These two analyses were used sequentially to provide an overview of the construction of FRP boats produced by CV. Roni Marine. The construction standards required by BKI are presented in Table 1.

TABLE 1.
CONSTRUCTION STANDARDS REQUIRED BY BKI

Construction	BKI Standards (mm)
Hull laminate thickness	4.8
Frame spacing	500
Minimum keel laminate width	70
Longitudinal stiffener length	9,500
Deck beam spacing	580

III. RESULTS AND DISCUSSION

The CV. Roni Marine shipyard is a family company that is currently managed by the second generation. This shipyard is capable of producing boats with principal dimensions of Length Over All (LOA) ranging from 9.5–12.5 m, maximum beam (Bmax) ranging from 1.1–1.4 m, and depth (D) ranging from 0.7–0.9 m.

The shipyard has relatively high production capacity, as it can produce 15–18 units of boats per month. The 9.5 m boat is the type most preferred by fishers because it is considered the most suitable for the needs of traditional fishers in Cilacap.

A. Characteristics of the Utilization of FRP Boats Produced by CV. Roni Marine

Boats produced by CV. Roni Marine are widely used by fishers in various regions, especially in Rawa Jarit Beach, Cilacap. Based on interviews with 30 respondents, these boats are used with several types of fishing gear such as gillnet, handline, and arad net for one-day fishing operations.

Out of the total respondents, 22 people (73.33%) stated that they had previously used wooden boats before switching to FRP boats. According to [10], wood is prone to decay and susceptible to attacks by marine organisms, so wooden boats tend to deteriorate more quickly.

One of the advantages perceived by fishers is the lighter weight of FRP boats produced by CV. Roni Marine. A total of 82% of the 22 respondents stated that the boats are easier to move, both from sea to land and vice versa, requiring approximately 5–7 people depending on the boat size. Despite being lightweight, the boats are still considered strong because the damage that occurs is generally minor, such as scratches, abrasions, or small cracks that can be repaired independently.

All respondents stated that they are satisfied with the boats produced by CV. Roni Marine. The boats are considered lightweight, strong, have good speed, and have a neat and symmetrical finish. In addition, the boat paint is not easily peeled and appears glossier compared to boats from other shipyards, thereby increasing their attractiveness to fishers

B. Design and Construction of Boats Produced by CV. Roni Marine

a. Design of FRP boats produced by CV. Roni Marine

The CV. Roni Marine shipyard is capable of producing boats with sizes adjusted to the demands of fishers. Study [12] states that the suitability of boats with the needs of local fishers is strongly influenced by the shipyard's understanding of the habits and operational characteristics of users in the local area. Generally, these boats have a size of > 3 GT and are used for small-scale fishing activities in the waters of Cilacap and its surroundings. Boats produced by CV. Roni Marine are presented in Figure 1. The boat design uses an open deck type, which provides a wider working space for fishers during fishing activities.

The type of hull used is a monohull, or a boat with a single hull [14]. The hull form used is a U-bottom. This form is chosen because it provides good stability when the boat operates during operation. The U-bottom hull form generally has a high block coefficient (Cb), which means it has a larger carrying capacity [15], but results in relatively higher resistance, so it tends to move more slowly during operation [16].

The bow of the boat is designed to be pointed to reduce wave resistance from the front and to reduce friction between the water and the hull, thereby improving motion efficiency [17]. Meanwhile, the stern is designed in a transom form, which functions to improve stability during maneuvering and to facilitate the installation of an outboard engine as the main propulsion system.

b. Construction of FRP boats produced by CV. Roni Marine

The construction analysis is focused on FRP boats with a length of 9.5 m (LOA) because this type is more frequently produced based on consumer demand. The construction process of FRP boats is carried out in stages and systematically, starting from the preparation of tools and materials, mould cleaning, application of miracle gloss, application of gelcoat, lamination process, installation of frames, installation of longitudinal stiffeners, installation of deck beams, removal from the mould, to the stage of surface smoothing and finishing.

The main components of the construction of FRP boats produced by CV. Roni Marine include the hull, frames, longitudinal stiffeners, deck beams, and keel. This boat uses a false keel, which is commonly applied to fiberglass boats because the forming process uses a moulding system [18]. Each component has a different structural function according to the load distribution in each zone of the boat.

The hull acts as the main component that determines buoyancy, which is the force that supports the weight of the load and the entire boat structure [19]. The hull is reinforced by several structural elements, including longitudinal stiffeners, frames, deck beams, and the keel to maintain the stability and rigidity of the boat structure. Based on the direction of reinforcement, the boat construction system is divided into longitudinal and transverse systems. The longitudinal system functions to strengthen the structure along the length of the boat, while the transverse system functions to strengthen the structure across the width of the boat

Longitudinal stiffeners act as the main reinforcing elements in the longitudinal direction [20]. Frames and deck beams function as transverse structural reinforcements that maintain hull rigidity when the boat is subjected to wave loads [21]. Meanwhile, the keel is an important element that provides the main strength along the length of the boat. The components included in the longitudinal construction system of boats produced by CV. Roni Marine consist of the keel, hull, and longitudinal stiffeners, while the transverse construction system consists of frames, deck beams, and hull. The hull functions as the main binding element that works in both systems. This is in accordance with statement [22] that some parts of boat construction play a role in strengthening the structure both longitudinally and transversely. In addition, the size of the boat also affects the construction system applied. According to [23], the larger the length of the boat, the greater the dimensions and number of structural sections required.

Figure 1. The boat design uses an open deck type

(1) Hull

The strength and thickness of the laminate layers are important factors in the construction of fiberglass boats [12]. A hull that does not have sufficient strength will increase the risk of damage or boat accidents. Therefore, the strength of the hull construction must be considered in the construction process.

The strength of FRP boat hulls is influenced by the structure and thickness of the laminate, which are determined by the type of fiber, lamination technique, fiber density, fiber specific gravity, resin specific gravity, and fiber mass content. The types of fiber commonly used in FRP boat construction are Chopped Strand Mat (CSM), Woven Roving (WR), and Multiaxial (DB) [6]. Based on the observation results, the CV. Roni Marine uses CSM and WR fibers in the lamination process.

CSM fiber is a type of fiberglass with a random arrangement that is easy to apply and has a relatively affordable price [24]. CSM fiber is differentiated based on its weight per square meter [2]. The CV. Roni Marine uses CSM300 with a density of 300 g/m², which functions to produce a smoother laminate surface [25]. Boat lamination using CSM fiber is often combined with fibers that have higher strength, namely WR. This combination aims to improve the structural strength of the laminate in FRP boats.

WR fiber is arranged regularly in two directions, namely horizontal and vertical [26], so it has higher tensile strength compared to CSM because its fiber structure is stiffer [25]. The type of WR used by the CV. Roni Marine shipyard is WR600.

The boat lamination process at CV. Roni Marine is carried out using the hand lay-up method. The initial stage begins with the application of miracle gloss on the mould to facilitate the release of the moulded product [18], followed by the application of gelcoat as the outermost layer of the hull which has been mixed with color pigments. The subsequent lamination process is carried out by arranging layers of CSM300 and WR600 bonded using Yukalac 157 resin mixed with a catalyst to accelerate curing [26]. The base layer of the boat hull consists of 3 layers with a composition of CSM300, WR600, and then covered again with CSM300. An illustration of the base laminate arrangement on the boat hull is presented in Figure 2.

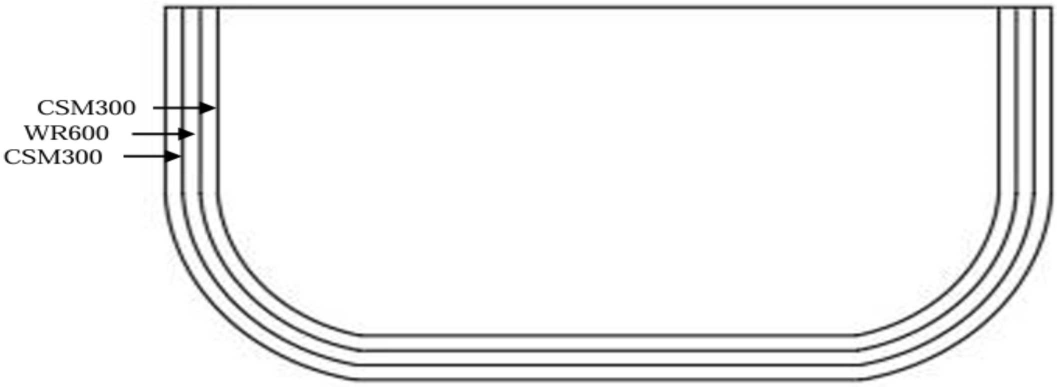

Figure 2. Illustration of the base laminate arrangement on the boat hull

After the base layer, the lamination process is continued with the provision that there are differences in the number of layers and the use of combinations of WR and CSM in the bottom hull (chine plate), bow (stem plate), and keel (keel plate) sections in accordance with the structural load in each zone. This adjustment of thickness based on stress zones is in accordance with the provisions in Guidance for Certification of FRP Fishing Vessel Less than 12 m [27]. Information regarding the laminate arrangement of FRP boats produced by CV. Roni Marine is presented in Table 2.

TABLE 2.
LAMINATE ARRANGEMENT OF FRP BOATS PRODUCED BY CV. RONI MARINE

Boat Part	Material	Laminate Arrangement
Stem plate	5CSM300+WR600	CSM300+WR600+CSM300 (base laminate) CSM300+CSM300+CSM300 (additional laminate)
Chine plate	5CSM300+WR600	CSM300+WR600+CSM300 (base laminate) CSM300+CSM300+CSM300 (additional laminate)
Keel plate	4CSM300+2WR600	CSM300+WR600+CSM300 (base laminate) CSM300+WR600+CSM300 (additional laminate)

Based on the laminate arrangement used, the stem plate and chine plate sections are composed of a combination of 5CSM300 and WR600, while the keel plate section uses a combination of 4CSM300 and 2WR600. The differences in the number and arrangement of these layers indicate adjustments to the structural strength requirements in each part of the boat.

Each type of fiber has a different density and thickness. CSM300 fiber has a density of 300 g/m² with a fiber mass content of 0.30, while WR has a density of 600–800 g/m² with a fiber mass content of 0.50. The specific gravity of glass fiber is 2.6 g/cm³, while polyester resin is 1.2 g/cm³. Based on the calculations, the thickness of CSM300 fiber is 0.70 mm, WR600 is 0.73 mm, and WR800 is 0.97 mm. The base laminate arrangement of the hull produces a thickness of 2.13 mm, the stem and chine sections produce a thickness of 4.23 mm, and the keel section produces a thickness of 4.26 mm. This increase in laminate thickness indicates structural reinforcement in parts of the boat that receive greater loads.

(2) Frames

Based on field observations, the frames of the FRP boats produced by CV. Roni Marine use albiso wood, commonly known as albasia or sengon (Albizia chinensis). The installation of the frames is carried out after the base laminate of the hull has been completed and fully cured. This is important to prevent damage to the laminate layers, as installing the frame while the laminate is not yet cured can risk damaging the boat structure [29].

The frames are installed transversely along the hull, totaling 12 units on each side (port and starboard), with a wood thickness of 40 mm. The thickness of the frames plays an important role in the structural strength of the boat, where thicker frames result in a stronger structure, especially in resisting wave loads [5]. In addition to thickness, the spacing between frames also affects the structural strength. The spacing between frames on boats produced by CV. Roni Marine is recorded at 580 mm.

Each frame is coated with CSM300 fiberglass to improve the bonding strength with the hull. On the side parts of the hull, two layers of CSM300 are applied with a total thickness of 1.4 mm, while on the bottom part, three layers of CSM300 are applied with a total thickness of 2.1 mm. Each joint between frames is also reinforced with an additional two layers of CSM300 to enhance the structural strength of the connections.

(3) Longitudinal Stiffeners

Longitudinal stiffeners in FRP boats produced by CV. Roni Marine are installed longitudinally from the stern to the bow, functioning to secure the position of the frames as well as to strengthen the longitudinal structure. The combination of longitudinal stiffeners and frames plays a role in increasing the hull strength against transverse and longitudinal loads. The longitudinal installation of stiffeners has been shown to improve the structural capacity of the boat in supporting large loads under both calm and rough water conditions [30].

The longitudinal stiffeners are made of albasia wood coated with two layers of CSM300 fiberglass with a total thickness of 1.4 mm using the hand lay-up method and Yukalac 157 resin mixed with a catalyst. The length of the longitudinal stiffeners is 8,700 mm, with a total of two units on the starboard side and two units on the port side, and a transverse spacing between stiffeners of 400 mm.

(4) Keel

The keel is the main structural component that functions as a longitudinal reinforcement as well as securing the position of the frames at the bottom of the boat. The presence of the keel directly affects the stability of the boat because most of the loads are concentrated in this part [31]. Based on field observations, the width of the keel laminate in boats produced by CV. Roni Marine is 60 mm.

(5) Deck Beams

Deck beams are transverse structural components located at the upper part of the boat that connect the frames on the port and starboard sides and function to strengthen the transverse structural strength of the boat [32]. The deck beams on boats produced by CV. Roni Marine are installed transversely above the frames and are directly connected to the upper hull, and are equipped with vertical supports that function to resist deflection.

Based on field observations, FRP boats produced by CV. Roni Marine have two deck beams installed at the front and rear with a spacing between beams of 2,900 mm. The length of the deck beams follows the beam of the boat, which is 1,100 mm. The deck beams are formed in a profile using albasia wood as core material and are coated with three layers of CSM300 and one layer of WR600, resulting in a thickness of 2.83 mm. The connection between the deck beams and the hull edge is reinforced with six layers of CSM300, reaching a thickness of 4.2 mm to provide strong bonding strength.

C. Compliance of FRP Boat Construction Produced by CV. Roni Marine with BKI Standards

The assessment of the compliance of FRP boat construction produced by CV. Roni Marine was conducted based on the Guidance for Certification of FRP Fishing Vessel Less than 12 m issued by Biro Klasifikasi Indonesia (BKI). This standard serves as a reference for the design of FRP fishing boats with a length of Less than 12 m. The results of the comparison between the construction of boats produced by CV. Roni Marine and BKI standards show that all analyzed parameters are still below the recommended requirements.

The base laminate thickness of the hull produced by CV. Roni Marine is 2.13 mm, while the BKI standard recommends a thickness of 4.8 mm, resulting in a difference of 55.63% thinner than the standard. The spacing between frames is 580 mm, which is larger than the maximum BKI standard of 500 mm representing a difference of 16%. Excessive frame spacing can reduce the structural strength of the boat because the frames function as structural reinforcements [34]. However, the smaller the frame spacing, the greater the number of frames required, which results in an increase in the weight of the boat.

The length of the longitudinal stiffeners is recorded at 8,700 mm, while the BKI standard recommends that the length should correspond to the boat length, which is 9,500 mm. This difference shows a deviation of 8.42%. The length of longitudinal stiffeners affects the strength, stiffness, and stability of the boat [34]. The spacing between deck beams on boats produced by CV. Roni Marine is 2,900 mm because they are only installed at the front and rear, whereas the BKI standard recommends that the spacing follows the frame spacing of 580 mm, resulting in a difference of approximately 400%.

The width of the keel laminate is 60 mm, which is smaller than the BKI recommendation of 70 mm, with a difference of 14.29%. This width represents additional laminate on the right and left sides of the keel, each measuring 30 mm. This difference indicates that the keel reinforcement is still below the recommended standard.

The determination of construction dimensions by the CV. Roni Marine shipyard is based on technical experience and the operational needs of fishers, without directly referring to BKI standard formulas. Construction dimensions that exceed the standard can indeed improve boat durability; however, they result in increased weight, higher production costs, reduced load efficiency, and increased engine load [33]. Heavier boats also have the potential to experience reduced carrying capacity and poorer heaving motion response [11]. On the other hand, construction dimensions that are below the standard can lead to lower structural strength and increase the risk of damage as well as higher maintenance costs [33].

Differences in construction dimensions that do not comply with BKI standards need to be further tested through mechanical strength tests, such as tensile, compressive, and bending tests, to ensure the structural feasibility of the boat. This testing is important so that the assessment of the construction of boats produced by CV. Roni Marine is not only based on dimensional compliance with standards, but also on structural performance in accordance with Indonesian water conditions.

IV. Conclusion

The construction of FRP boats produced by CV. Roni Marine consists of laminates forming the hull, keel, frames, longitudinal stiffeners, and deck beams. These boats use CSM300 and WR600 fibers with a base laminate arrangement of CSM300 + WR600 + CSM300, resulting in a thickness of 2.13 mm in the hull. The spacing between frames is 580 mm, the length of the longitudinal stiffeners reaches 8,700 mm, the minimum width of the keel laminate is 60 mm, and the spacing between deck beams is 2,900 mm. The construction process uses the hand lay-up method, in which the frames and longitudinal stiffeners are first formed using albasia wood and then coated with fiberglass. The comparison results with BKI standards indicate that all analyzed construction elements of the fishing boats produced by CV. Roni Marine did not meet the construction requirements recommended by BKI. Therefore, further studies are needed to evaluate the suitability between boat construction and operational water conditions to determine whether construction dimensions below BKI standards remain safe and feasible for fishing operations in Indonesian coastal waters.

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