Technical and Economic Analysis Repair of the Wooden Boat using Fiberglass Laminates on Fishing Boats in Lamongan District

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Abstract: In 2016 there are 3,263 vessels fishing boats in Lamongan, and 90 percent uses wood as the primary material for fishing vessels. The wooden boat repair activities in the Lamongan Regency are very high, considering the wooden vessels repaired regularly so that the vessels' condition remains suitable for fishing activities in fishing. At present, repairing wooden vessels still uses conventional methods, such as attaching the skin of the boat with fiber or cloth axis and replacing damaged wood with new ones. Conventional methods are inefficient and ineffective because it has checked periodically and it is expensive to buy new wood, considering the price of wood is increasingly expensive because of the difficulty of finding wood material. One new method in repairing damage to new boats by using FRP (Fiberglass Reinforced Plastic) lamination. In this research, tensile testing carried out on several fibreglass layers on wood to obtain the most significant strength. Furthermore, we have an economic analysis to get the cheapest variations of fibreglass lamination.

1 INTRODUCTION

Lamongan Regency located on 6º51 '- 7º23' South Latitude and 112º33 '- 112º34 East Longitude. Lamongan Regency has approximately 1,812.8 km2 or ± 3.78% of the total area of East Java Province. With a length of 47 km, the sea area of Lamongan Regency is 902.4 km2, if calculated 12 miles from sea level (Norromadani, 2016).

According to data from the Central Statistics Agency of Lamongan Regency in 2008, fish production in Lamongan District amounted to 61,436 tons, Lamongan with the most significant amount of fish production in East Java, it also had an impact on the lives of the community, where most of the Lamongan community utilize resources fisheries as their livelihood or work as fishermen, both permanent fishermen. With the most significant amount of fish production in East Java, resulting in the number of fishers in Lamongan because of the many fishermen, Lamongan Regency become the highest number of fishers (Utami, 2016).

Maintenance of wooden boats used to catch fish is needed to keep the boat in good condition, and repairs are needed if damage occurs. In general, a wooden boat maintenance and repair must be done on regular basis, and if not done properly and adequately, it will result in high costs for the boat repair process. (Arif, 2018) The process carried out in repairing the damage uses several conventional methods, including using natural fibres and fabric wicks to patch the boundaries between the wood. From a technical perspective. this is obviously lacking and needs to be done both technically and economically. As a result, one method of repairing a wooden boat using fibreglass lamination exist.

This study aims to conduct a technical and economic analysis of wooden boat repairs using fibreglass laminates application methods on existing boat objects in the coastal fishing community of Lamongan. The technical analysis carried out is to obtain the number of fibreglass layers that will be applied to the repair of wooden boats that meet the classification requirements, and economic analysis to get the cost of repairing wooden boats using fibreglass laminates.

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2 LITERATURE REVIEW

2.1 Damage to Wooden Boat

There are several types of damage to wooden hulls as follows:

2.1.1 Marine Growth

Marine growth is a various species of marine animals/plants that grow and colonize the surface of buildings/structures in the sea, where temperature, food/nutrition, pH (acidity) factors, and other environmental conditions are suitable for their growth. The growth of marine growth on the surface of this building may cause various problems. Marine growth that grows on wooden boats will cause the boat's weight to increase, causing additional resistance to the boat. In addition, marine growth on fishing boats will increase the boat's resistance when moving because the surface of the boat's skin becomes rough.

Figure 1: Marine growth.

2.1.2 Wood Weathering

Wood Weathering occurs in the natural process of the wood itself, also caused by destructive marine animals such as moulds and barnacles attached to the body of the boat and microbes in the form of mould mildew. During this time, the process of drying/preservation of material carried out at the Boatyard naturally and takes up to one month, which will affect the strength of fishing vessels.

Weathering on wooden boats will cause damage to the boat hull in the form of leakage or reduced strength of the boat when receiving loads, both internal and external.

Figure 2: Wood weathering.

2.1.3 Leaks (holes)

Leakage on the hull is one of the results of several previous events, such as the condition of weathered wood and the presence of sea animals that enter the construction of the wooden hull (Greene, 2016).

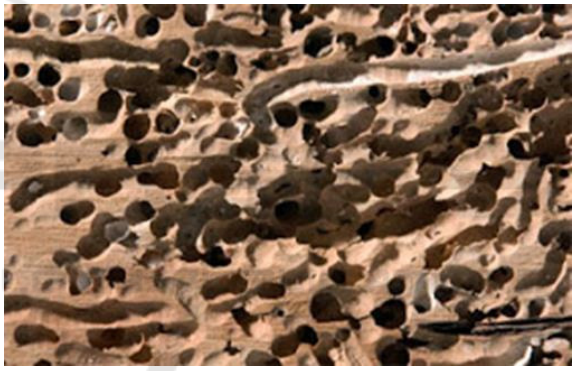

Figure 3: Leakage because of sea animals.

2.1.4 Crack

Crack damage on wooden boats occurs due to several possibilities such as collisions with objects, collisions on the hull of the boat and in the form of collisions with fellow boats or collisions between boats with objects in the water such as rocks, buoys, beams, logs, chunks of ice or collisions with other boats with objects in the water such as rocks, buoys, beams, logs, chunks of ice and others.

Collision with objects on the edge of the land, such as jetty and breakwater, occurs when they jutting into the water. Another possible cause of cracking is the damage associated with wave propagation to the hull of the boat due to the vibration of the propulsion engine and the other engines as well as the impact of the waves on the hull of both waves from the outside and waves that arise due to the spinning of the propeller engine and the other engines as the impact

of the waves on the hull of both waves from the outside and waves that arise due to the spinning of the propeller engine and the other engines as with the waters when the boat is operated in the construction of the boat and damaged due to excessive vibration caused by faults in the design of construction where the vibration is not channelled correctly so that the construction experiences a cracking and release of welding from certain parts of the construction caused by defects in the design of construction where the vibration is not appropriately channelled so that the construction experiences a cracking and release of welding from certain parts of the construction due to other defects in the design of construction where the vibration is not appropriately channelled. Propeller leaf damage.

Figure 4: Crack on the wooden boat.

2.2 The Material Used for Wooden Boat Repair using Fiberglass

Materials used in boat repair using fiberglass lamination are (Baskoro, 2018):

2.2.1 Resin

Resin is a binder used to support fiberglass so that the fiberglass stays in place. The resin consists of three main components, glycol, organic acids, and active thinners (usually styrene). Resins that used are polyester resins, vinyl ester resins, and epoxy resins (Bader, 2002).

2.2.2 CSM (Chopped Strand Mat)

Chopped Strand Mat (CSM) is a type of fiberglass made of glass fiber placed and arranged randomly between one another. CSM Fiberglass is distinguished by weight per square meter. For example, CSM 300 means that each square meter of fiberglass weighs 300 grams.

2.2.3 WR (Woven Roving)

Woven Roving (WR) is fiberglass made of glass fiber woven in two directions continuously at an angle of 90°. Fiberglass WR is the reinforcement material most often used for the construction of marine structures.

2.2.4 Catalyst

The catalyst has the function of accelerating the curing and polymerization between resin and fiberglass.

2.2.5 Talc

Talc serves as a mixture of fiberglass dough to make it rigid and somewhat flexible; as the name suggests, this material is white powder-like sago.

2.2.6 Gelcoat

Gelcoat is a layer made of resin, aerosol, and cobalt (accelerator). In making Gelcoat, the three materials mixed evenly. When the gel coat has cured, the gel-coat will have a shiny and smooth surface. Therefore the gel coat is generally applied as the outermost layer of the laminate after the release agent layer.

The method used in this boat repair process is by direct application (Boat Structure Committee, 1990). Fiberglass is applied to damaged wooden fishing boats using the multi-layered (3-layer) method and then analyse economic feasibility calculations with the repair method compared to traditional wooden-boat repair.

3 METHODOLOGY

3.1 Technical Method

The material, tensile, and compressive testing are carried out to find out the strength of the tensile and compressive. There are five variations of material to be used as shown in Table 1.

Table 1: Variations and lamination schedule.

Name	Lamination Schedule
1st Variation	Wood (reference material)
2nd Variation	Wood + CSM300 +WR600 + CSM300
3rd Variation	Wood + CSM450 +WR600+ CSM300
4th Variation	Wood + WR600 + CSM450 +CSM300
5th Variation	Wood + WR600+ CSM300 + CSM300

After determining the Variation of material to be tested, the next step is making the material, while the stages in making the material are as follows:

- Prepare five pieces of teak wood material with dimensions of 30 cm x 30 cm x 2 cm.
- Preparing the resin that will be used for the material and mixed with a catalyst that functions to dry the resin, the ratio of catalysts and resins is 1: 100.

Figure 5: Wood as a primary material.

- Coating wood with resin and fiberglass fibers by the lamination schedule using a roll and brush to avoid air bubbles that enter during the lamination because it will reduce the laminate's strength.

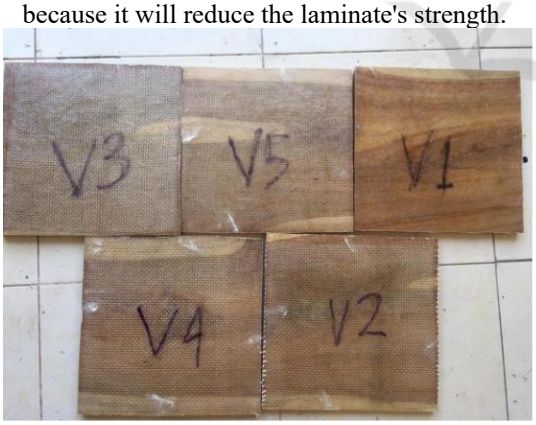

Figure 6: laminated wood with fiberglass.

Before testing and pulling, the first thing to do is to prepare the test material. Test materials are numbered in accordance with variations so that it is accessible when recording test results. In tensile testing, the engine used is Universal Testing Machine MFL/UFD 2.0.

Figure 7: Universal testing machine MFL / UFD 2.0.

The width size for tensile and bending specimens is determined by the laminated material thickness, while the length of the specimen is free as long as it exceeds 20 times the thickness of the material. The size of tensile and compressed specimens is determined by the size of fiberglass material specimens determined in the 2016 Indonesian Classification Bureau annex, Rules for Fiberglass Reinforced Plastic Boats.

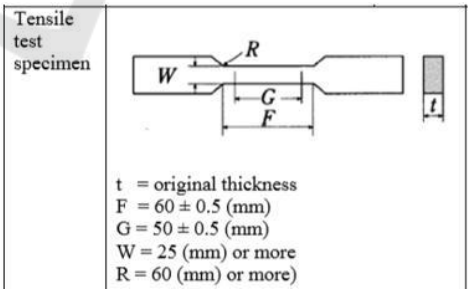

Figure 8: BKI Tensile Specimen Standard.

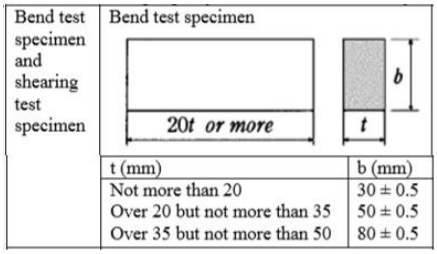

Figure 9: BKI Bending Specimen Standard.

Figure 10: Specimen of tensile and bending test.

Then the test specimen is made following the provisions of predetermined standards.

3.2 Economic Method

Economic analysis is carried out after technical analysis. Repair of wooden boats using the fiberglass lamination method adjusts to technical aspects, including the number of layers of fiberglass laminate according to the Variation of specimens that have been made. The cost components calculated are as follows:

3.2.1 Material Cost

To calculate the cost of repairing wooden boats using the fiberglass lamination method, it is necessary to know the price of the material used in the boat repair process, including the price of resin, the price of mat/CSM, catalyst, nails used per m^2.

Table 2: Tensile strength result and stress calculation.

Code	Fu (kN)	Stress (Mpa)	Average Stress (Mpa)
V1.1	14	29.41	
V1.2	13	27.18	27.11
V1.3	17	24.75	
V2.1	18	34.71	
V2.2	15.5	33.73	32.99
V2.3	13.5	30.52	
V3.1	21	47.23	
V3.2	23	52.66	47.87
V3.3	18	43.71	
V4.1	15.5	38.88	
V4.2	15	41.63	39.82
V4.3	15	38.94	
V5.1	19.5	45.27	
V5.2	17.5	42.14	44.59
V5.3	20	46.34	

3.2.2 Labor Cost

Labour costs are calculated to determine how much these costs are used to repair wooden boats using the fiberglass lamination method per m^2.

3.2.3 Total Cost

The total cost is calculated by adding the material cost and labour costs together.

4 ANALYSIS OF RESULTS

The results of the tensile test are tabulated in Table 2. It can be seen that the third variation has the highest average tensile test results, which are equal to 47.87 MPa. Whereas the results of the compressive test can be seen in Table 3.

From the bend test results table above, we can see the most significant buckling test results is the third Variation that is equal to 4.20 MPa.

For economic analysis, we do the following calculations. In Table 4 we can see that the material costs in variations 2 and 5 are the same, Rp 284,537 while variations 3 and 4 have the same material cost, Rp. 317,056. This difference is due to the different thickness of the woven roving, and the CSM used. Meanwhile, the labour cost for each m2 is Rp 208,907, so that we can see economically that variations 2 and 5 have the advantage of being cheaper than variations 3 and 4.

Table 3: Bend test result.

Code	Fu (kN)	Deflection (mm)	Stress (MPa)	Average Stress (MPa)
V1.1	2.6	11	2.74	2.71
V1.2	2.55	12	2.68	
V2.1	2.7	13	3.00	2.97
V2.2	2.8	13	2.95	
V3.1	4.15	11	4.15	4.20
V3.2	4.25	10	4.25	
V4.1	3.6	13	3.79	3.53
V4.2	3.1	13	3.26	
V5.1	3	12	3.33	3.28
V5.2	2.9	12	3.22	

Table 4: Cost calculation.

Code	Material Cost (Rp)	Labour Cost (Rp)	Total Cost (Rp)
2nd Variation	284,537	208,907	493,444
3rd Variation	317,056	208,907	525,963
4th Variation	317,056	208,907	525,963
5th Variation	284,537	208,907	493,444

5 APPLICATION

Fiberglass lamination on a wooden boat is the process of repairing a wooden boat using fiberglass coating to a wooden boat by attaching fiberglass fibres to the damaged or in need of repair part of the boat or the entire body of the boat. Repair purposes replace the damaged part of the boat and protect the hull from leaks and strengthen the hull's construction. Fiberglass lamination can increase the thickness of the hull between 0.5-1 centimetre.

The steps in the process of repairing wooden vessels using fiberglass lamination are explained as follows:

5.1 Drying the Boat

Wooden vessels to be laminated must be dried before starting to make repairs. The purpose of this drying is to avoid water content into the wood, which would damage the fiberglass layer, which will would otherwise adhere tightly to the hull of the boat. Resin, fiberglass, and wood cannot bond effectively if exposed to water, even in minimal amounts (Sunardi, 2018).

Figure 11: Boat drying process.

5.2 Cleaning the Hull

After the wooden boat underwent a process of drying, the boat first cleaned all parts using a grinder and sandpaper. It aims to remove the rest of the paint, putty or dirt that still attached to the boat's hull and the remnants of marine plants connected to the boat.

5.3 Installation of Fiberglass

After the boat undergoes a drying and cleaning process, the next step of the boat is ready to be repaired by the fiberglass lamination method. Fiberglass laminates are used in 3 layers (Wood + CSM450 +WR600+ CSM300). This laminate will add a thickness of 5-10 mm.

Figure 12: Installation of fiberglass fiber.

The installation of fiberglass lamination will make the hull of the boat impermeable and not leak so that the boat will avoid the entry of seawater. Boat construction will also be stronger, and weathering in wood, which usually occurs due to seawater, will be avoided.

5.4 Fiberglass Lamination Nailing

Strengthening of the laminate with anti-rust nails measuring 3 cm at 20-30 cm. The purpose of nailing is to strengthen the fiberglass layer attached to the hull, so there is no possibility of the fiberglass separated layer from the hull.

Figure 13: Nailing on the fiberglass layer.

5.5 Retardation and Refinement

After the layers have been installed, the heating process is carried out. The putty used is made up of talc and resin with a catalyst added. After stirring, putty is applied to the hull of the boat. Once it has dry, mashed the putty using sandpaper.

6 PAINTING AND FINISHING

After all the processes are done, the last step is to apply unique paint with colour pigments. This colour pigment is mixed with resin and addictive to make the surface of the boat more glossy and not easy to get dirty. This paint can also avoid the sticking of sea animals or dirt that usually attached to the hull of the boat.

Figure 14: Painting on the hull of a boat.

The economic benefits of fiberglass lamination for wooden boat repair compared to traditional boat repair explained as follows:

1. Repair and maintenance with fiberglass lamination can reduce maintenance in cleaning marine growth because, in fiberglass, marine growth cannot eat the fiberglass material differently.
2. Repair and maintenance in a conventional way need more time than the fiberglass method, fiberglass method faster 50% than the conventional way.

Fiberglass lamination on wooden boat repair will offer the following benefits:

1. Damages that occur on a wooden boat can be overcome by doing fiberglass lamination, which prevent wooden boats leaks.
2. Fiberglass laminated material, which marine animals and plants do not eat, allows the boat's life to be longer.
3. Facilitate the cleaning of the hull so that maintenance costs are lower compared to wooden boats.

a. Before

b. After

Figure 15: Boat Repair Before and After Results.

4. With fiberglass lamination, the boat repair process will become more comfortable and lighter in terms of price.

7 CONCLUSIONS

Fiberglass lamination on wooden boat repair can increase the strength of the hull construction and prevent leakage in the boat. Repairs using fiberglass lamination benefit fishers because it can save maintenance costs and repair boats. The boat's lifespan is also longer because maintenance can be more routine.

From the tensile and bending tests that have been carried out on five variations, with the highest value is obtained in the 3rd Variation of the tensile strength of 47.87 MPa and the bending strength of 4.20 MPa. The cheapest boat repair cost is obtained for variations 2 and 5, which is Rp.493,444 / m2

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