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Joint Types of Keel and Frame of Wooden Boats Built with Modular System

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Abastract --- The ocean's potential has not been fully exploited to date, with only 40 per cent of the ocean's potential being used. This is due to inadequate facilities and infrastructure. The lack of infrastructure and facilities is due to many factors. One of them is the lack of fishing boats compared to the existing potential. This is because it takes a long time to build a fishing boat. In addition, the existing fishing boats are not powerful enough to travel up to 200 nautical miles.

The way out of these problems is to build wooden boats using a modular system. This modular system is expected to produce fishing boats quickly but with a qualified construction. The problem in the production process with this modular system lies in the connection between the keel and the frame. The joint is a critical part in the construction of wooden boats where the joint must be able to withstand dynamic loads. The advantage of wooden boats built with this modular system is that the production process is relatively shorter, which can reduce production costs.

The results of tests carried out have shown that the tongue-and-groove type of joint on the keel has a better bending test than the oblique hook type of joint used by traditional boatbuilders. The frame connection type with internal reinforcement has the highest strength among the connection types commonly used by boatwrights and the type of frame connection reinforced on the left and right sides.

Keywords: Type of joint, main structure, fishing boat, modular system.

I. INTRODUCTION

The wealth of marine or fish resources (SDI) in East Java Province reaches 2 million tons annually. While the sustainable production of marine or fish resources is 12.5 million tons annually. To maintain the sustainability of fish in the sea, the amount of SDI production that can be caught is only about 80% or about 10 million tons per year. The wealth of fish resources is spread in the waters of the North Sea of East Java, which stretches from Tuban Regency to Sumenep Regency, then the Madura Strait, which is the sea between the islands of Java and Madura, the Bali Strait and the South Java Sea or the Indonesian Ocean. About 250 thousand fishermen go to sea every day to catch the fish that are allowed to be caught [1].

From the above description of the wealth of fishery resources, it can be seen that the wealth of fishery resources in East Java waters, which are exploited by 250,000 fishermen, is only half of it.

The figure above shows that in the northern region of Java, the relation boat between fishermen and their fishery resources can be said to be saturated (overfishing), so that fishermen in the coastal areas of East Java island need to search and fish in other areas that still have abundant fish resources. As in the Bali Strait area and the waters of the South Java Sea or Ocean Indonesia, the exploitation of fish resources is still suboptimal, with the average catch of fishermen being around 35% [2].

Figure 1. Potential of marine fisheries in East Java [2]

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According to the Marine and Fisheries Community Forum, the number of people working as fishermen in the East Java region is 495,000, and of these many fishermen, the majority are traditional fishermen. The number of fishermen will continue to shrink due to underdeveloped skills and the shackles of poverty that drive them into the informal sector. Only island fishing communities do not migrate because there are no alternatives to earning an income other than fishing at sea [2].

The fishermen in East Java province in particular, and fishermen in Indonesia in general, are at a low level of economic welfare, but they still have hope in the world of fishing and marine. In the third quarter of 2011, fishermen in East Java began to rise with the increase in aquaculture and capture fish. Looking at these circumstances and conditions, where the projection of cultured fish of 944 thousand tons by 2014 will be achieved. According to the head of the East Java Maritime and Fisheries Service (DKP), since the land revitalisation began, the yield of cultured fish this year has increased significantly compared to 2010, which reached 760 thousand tonnes. Until the third quarter of 2011, the yield of farmed fish was 621 thousand tons, consisting of snapper, vaname shrimp, tiger shrimp, catfish, milkfish and others. In 2014, it is targeted that the yield of cultured fish can reach 944 thousand tons from an area of 45 thousand hectares consisting of intensive, semi-intensive and traditional areas [2].

Fishing boats in East Java are dominated by traditional boats. This type of boat is usually made or built with wooden materials and the manufacturing process is very simple. The construction of this boat is built without the use of boat design and adequate specifications. The negative aspects of this traditional boat are: (1) waste of raw materials, (2) the resulting boat is not necessarily as expected, and (3) has a less (not) good performance [1].

The people's boatbuilding industry in Indonesia is generally traditional in both technology and choice of raw materials. The main raw material used is generally wood, which has been passed down from generation to generation, although there are several types of wood or other materials that have better properties than the wood used to date. These traditional boats are generally built without drawings, relying entirely on the cognitive abilities of the master craftsman. The size of the boat is not known until it is completed, and it is not uncommon for the final result to be different from what was expected [1,3].

From the above problems, it is necessary to take a measure that can speed up the production of wooden boats with a limited supply of raw materials. One of the obstacles is how to make joints on the keel and frame of the boat that meet BKI requirements.

The joint used in the main structure of the boat must be able to withstand moving loads, as the forces acting on the boat's structure are generally dynamic loads. One of the weaknesses of any material is that it loses strength when subjected to dynamic loading over a long period of time, and wood is no exception [4]. Since the strength of the joints that make up the boat must receive more attention, it is necessary to know the character of the joint against dynamic loads. Knowing the fatigue character of the joint also makes it possible to design or develop a suitable type of joint to be used in the main parts of the boat's structure, both in terms of the dimensions and the shape of the joint, suitable for the production of wooden boats built by the modular method. From the point of view of the weight design of the boat, the ratio between the load and the weight of the hull is as large as possible, with good stability and optimum design. We know that wood has a good strength-to-weight ratio compared to other materials [5,6].

The expected type of joint is one that is simple, easy to work with and meets the strength requirements of the Indonesian Classification Bureau (BKI) standard for wooden boatbuilding. The type of joint in the main structure of the boat in question is the joint that exists in the construction of keels and tusks made of wood.

The joint in wood is the construction of joining two pieces of wood so that it meets the desired length [7,8]. The joint is the weakest point in a timber construction. Since the joint has to be present in a long construction, determining the shape of the joint must be a major concern [6,9]. In the keel construction of wooden boats, the type of joint and the position of the joint are important factors in the design of a boat. For joints using adhesives as the joining material, the surface area of the joint and the flatness of the surface being joined are the main factors [10,11].

Marine structures, including boats, are repeatedly subjected to forces in excess of their service life and experience a reduction in strength compared to materials subjected to static loading. Therefore, the connection at the keel and tusk must be considered [4,12].

In order to overcome the above problems, it is necessary to study the type of connection at the keel and tusk built with a modular system, which is expected to make the boat building process faster with a limited supply of raw materials [13].

II. METHODS

A. *Materials and Instruments*

The materials used in this study are

1. Bangkirai wood (Dendrocalamus asper) [6].
2. Phenol formaldehyde based adhesive [14].
3. Pegs of the same wood material.

B. *Method and Procedure*

1. Tests.
   In this study the following tests were carried out Static bending strength for keel and frame joints.
2. Test standards.
   The test standards used are ASTM D 143-98 (Reapproved 2000) Standard Test Methods for Small Clear Specimens of Timber [15].
3. Data analysis.
   a. Stress and Strain Equation.

According to [16], the relationboat between stress and strain can be expressed by the following general formula

$$\sigma_i = C_{ij}\varepsilon_j \; ; \; i.j = 1 \ldots\ldots 6$$

where: σ_i = stress component
Cij = modulus of rigidity
ε_j = strain component

b. Real Difference Analysis.

The Complete Randomised Design test was used to determine the real difference between the joint types. With the results of this analysis, it is known that the treatment or factors in it have a real effect or no effect [17].

Further analysis/testing is then carried out using the Least Significant Difference (LSD) test to determine which factors have the greatest influence on the fatigue properties/characteristics. From these results it will be known which type of joints has the best properties, which will then determine the strength standard and size standard based on the results of this analysis [17].

III. RESULTS AND DISCUSSION

a. Keel Connection.

Wooden boats with a keel length of more than 8 metres will certainly have joints in the keel. This is because it is difficult to find wood of more than 10 metres in length with straight grain and no defects. This is possible because it is allowed in the Indonesian Classification Bureau's regulations for wooden boats [18,19]. One solution is to use two keel timbers joined together to achieve the desired length. In this research, the tongue and groove timber joint type is used as shown in Figure 2. This joint type has several advantages over other joint types, including: wider surface contact and ease of fabrication [9,20]. In addition to the reinforcement in the form of pegs, a phenol-formaldehyde-based adhesive is also used [14].

Testing using the ASTM D 143 standard method [15] for flexure testing. In this study there were 2 (two) dummies and this test was carried out in two ways, with one plinth and two plinths. This is done to draw the keel of a wooden boat that will experience hogging and sagging during SAT sailing and is described as Figure 3.

In this study, in addition to the single load and double load tests, the position of the joint was also tested, i.e. the load in the direction of the joint and the load perpendicular to the joint, in order to determine the strength of the joint in this position. The loading in the test was as shown in Figure 4.

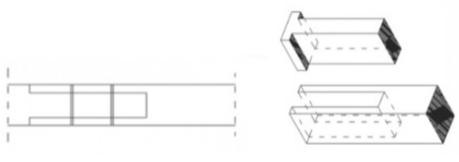


Figure 2: Tongue and groove joint

From the above data, it can be seen that a single joint with a protruding tongue type and loading in the direction of the joint has the highest strength (Modulus of Elasticity [MoE] value, 86412.45297 kg/cm2), but is even stronger than wood without joints.

This indicates that the joints in combination with dowels and adhesives used in the keel construction of wooden boats have high strength values.

From the analysis of covariance with a confidence level of 95%, the difference in load-bearing strength at the keel joint has a significant difference, which is shown by the value obtained being smaller than the value in the table. From the results of data testing, it can be concluded that the tongue and groove joint with pin reinforcement and marine adhesive meets the requirements for use in the construction of wooden boat keels [18].

b. Frame Connection.

In this research there are 3 (three) types of joints on the frame of wooden boats, namely joints with pegs, this joint is the standard type, the type of joint commonly used by traditional boat craftsmen. The second type of joint is a middle reinforced joint and the third type of joint is a left and right reinforced joint. All types of joints are reinforced with pegs and coated with a marine grade adhesive. Joint types as shown in Figure 6.

In this study, tests were carried out in 2 (two) ways, namely tests that represent the pressure or load from outside the boat's hull, such as waves, and tests that represent the load or force from inside the boat, such as the load inside the boat. Further details of the test implementation can be seen in Figure 7.

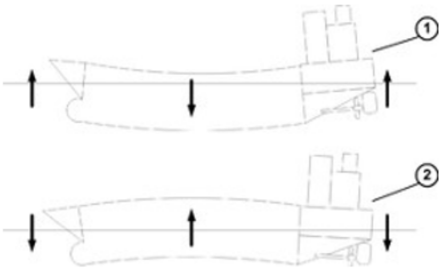
From the test results in the upright position, where this shows the force or pressure of the boat's tusks or hull from outside such as waves, that the joint with the type of trap in the middle has the highest compression value, which is 720.67 kg / cm2.

From the results of the external load tests carried out, the type of joint reinforced in the middle has the greatest strength compared to the standard type of joint and the left and right reinforced joints. From the results of the co-variance analysis at 95% confidence level, it can be seen that the centre reinforced type of joint is very significantly different from the standard type and the left and right reinforced types. This is due to the resistance to external forces compared to the other types of joint [21].

Figure 9 shows the pressure exerted on the hull by the load and the speed of the boat as it sails.

During the test with a flat position, which shows the presence of force or pressure from the inside, which describes the weight of the cargo in the boat, the type of joint with a latch in the middle shows the greatest resistance to the load of the boat's cargo, which is an average of 3.22 N/mm2.

Similarly, the test with loading from the inside shows that the type of joint with reinforcement has the same result, which has the best strength. The test results are shown in Figure 10.



Description: (1) Sagging (one load test).
(2) Hogging (test with two loads).

Figure 3. Force received by the keel

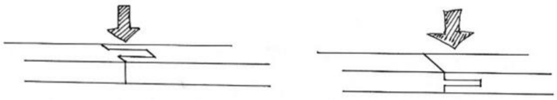
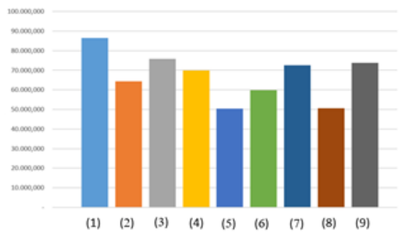
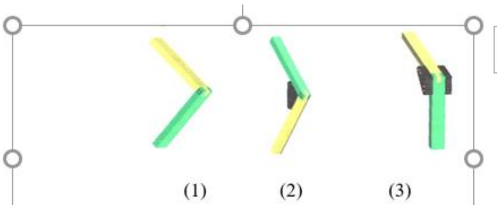


Figure 4: Test model of the joint on the keel



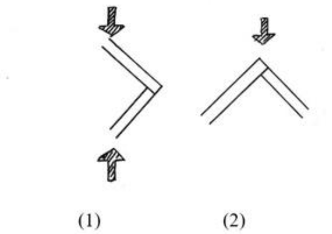
Description : (1) - one pedestal one join, loading in the same direction as the joint.
(2) - one support one joint, loading perpendicular to the joint.
(3) - one pedestal two joints, loading perpendicular to the joint.
(4) - one pedestal two joints, loading in the same direction as the jint.
(5) - two supports one joint, loading perpendicular to the joint.
(6) - two supports one connection, loading in the same direction as the connection.
(7) - two pedestals two joints, loading in the same direction as the connection.
(8) - two supports two joints, loading perpendicular to the joints.
(9) - control.

Figure 5. Chats of the results of the keel joint tests



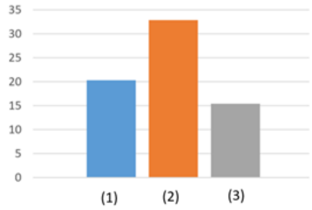
Description : (1) Frame joint without reinforcement
(2) Frame link with centre reinforcement
(3) Frame joint with external reinforcement

Figure 6. Frame joint model



Description : (1) External loading.
(2) Internal loading.

Figure 7. Test model of joints on Frames



Description : (1) - external loading on joints without reinforcement.
(2) - external loading on joints with reinforcement in the centre.
(3) - external loading on joints with reinforcement on the side.

Figure 8: Results of Connection Tests on Ivories with External Loads

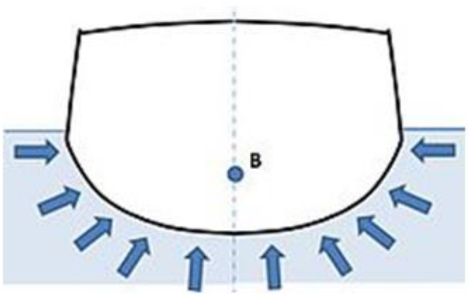
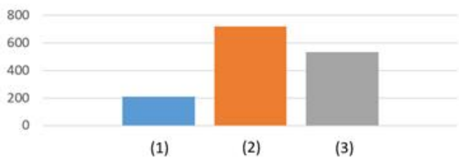


Figure 9. Boat's hull receive force from the outside



Description : (1) - internal loading on joints without reinforcement.
(2) - internal loading in joints with reinforcement in the centre.
(3) - loading from inside on joints with reinforcement on the side.

Figure 10. Test Results of Joints on Frame with load from inside

IV. CONCLUSIONS.

The following conclusions can be drawn from the results of testing the type of joint in the main structure of wooden boats built using modular systems:

Keel:

- The static bending strength with two loads has the highest strength (77599.374
  16 kg/cm2) and the fatigue or fracture limit (833.416 kg/cm2), so this type of joint meets the requirements for use in the construction of the keel joint of wooden boats.

Frame:

- The type of lap joint in the centre of the frame joint of a wooden boat has a high resistance to the load acting on the outside of the boat (720.67 kg/cm2).
- Similarly, the type of joint that has a trap in the middle has a high resistance to loads or forces on the inside of the boat (3.22 N/mm2).
- The strength of the tongue and groove joints meets the requirements for use in wooden boatbuilding.
  By using tongue and groove joints on the keel and trap on the frame, it will speed up the production process of wooden boats, but still have the strength required by the Indonesian Classification Bureau on Wooden Boat Construction.

REFERENCES

[1]. Jenis dan Type Perahu Perikanan Tradisional di Jawa Timur. Dinas Perikanan dan Kelautan Propinsi Jawa Timur, 2010.

[2]. Laporan Tahuan Dinas Perikanan dan Kelautan, Propinsi Jawa Timur. Tahun 2015.

[3]. Patria, AA dan Pribadi,TW. Analisis Teknis dan Ekonomis Pembangunan Kapal Ikan Tradisional ukuran <10 GT Berbahan Kayu Utuh Dengan Teknologi Laminasi Kayu Mahoni. Jurnal Teknik ITS Vol.6, No.1. 2017.

[4]. Fahety, KF and Williamson, TG. Wood Engineering and Construction Handbook. McGrawHill. NewYork. 1995.

[5]. Rosyd, DM dan Widodo, AB. Laporan Alkhir Riset Unggulan Kemitraan (RUK) VI tahun 2000. Pengembangan Material Konstruksi Laminasi untuk Aplikasi Kelautan. Kerjasama antara ITS dengan PT. PAL dan PT. Pamolite Adhesive Industry. Surabaya. 2000.

[6]. Martawidjaja, et al. Timber Used for the Boatbuilding Industry in Indonesia. Lembaga Penelitian kehutanan. Bogor. 1978.

[7]. Sadiyo, S., Nugroho,N., Surjokusumoi, S dan Wahyui, I., Nilai Desain Acuan Sambungan Kayu Geser Ganda Denan Paku Berpelat Sisi Baja Akibat Beban Uni Aksial Tekan Menurut Berbagai Analisis Pendekatan. Jurnal Presial 6 (1) : 1-10. 2009.

[8]. Fakhri, Gusstafri., H dan Yohanes. Peningkatan Kuat Geser Joint Struktur Kayu Mengguakan Tipe ambunan Kombinasi Perekat-Baut. Jurnal Inersia (Edisi khusus) Volime Viii No.2 September 2016.

[9]. Jenis Sambungan Kayu. Archizone.org (internet).2017. avaiable from : https://dekori.id /jenis-sambungan-kayu-gambar.

[10]. Bodiq, J and Benyamin AJ. Mechanics of Wood and Wood Composites. Nostrand Reinhold Company. 1982.

[11]. Pizzi A. Wood Adhesives, Chemistry and Technology. Marcel Dekker Inc. New York. 1983.

[12]. Collins, J.A. Failure of Materials in Mechanica Design. Analysis Prediction Prevention. A Wiley Interscience Publication. John Wiley and Soon. NewYork. 1981

[13]. Widodo, AB dkk. Rancang Bangun Kapal Ikan dengan Menggunakan Sistem Lengkap Lepas Terurai (Completed Knockdown) dan Sistem Berkembang (Modullar) Dalam Rangka Memenuhi Kebutuhan Kapal Nelayan Secara Nasional. Lapoan Akhir Riset Andalan Perguruan Perguruan Tinggi dan Industri (RAPID) tahun 2018. Direktorat Riset dan Pengabdian Masyarakat Direktorat Jenderal Penguatan Riset dan Pengembangan. Kementerian Riset, Teknologi dan Pendidikan Tinggi. Jakarta. 2018.

[14]. Spesifikasi Teknis Phenol Formaldehyde Adhesives Produksi PT. PAI Probolinggo (PA-302).

[15]. ASTM D 143-98 (Reapproved 2000) Standard Test Methds for Small Clear Specimens of Timber. In Annual Book of ASTM Standards, American Society for Testing and <aterials, Philadelphia.

[16]. Douglass C. Montgomery. 1997. Design and Analysis of Experimental. John Wiley and Sons.

[17]. Haeruman, Js. H. Prosedur Analisa. Rancangan Percobaan (bagian pertama). Departemen Manajemen Hutan, Institut Pertanian Bogor. Bogor. 1972.

[18]. Biro Klasifikasi Indonesia (BKI), Konstruksi Kapal Kayu. 1996.

[19]. Sea Fish Industry Authority. Construction Standards for New Fishing Boats less than 15 meters Length Overall. United Kingdom. 2004.

[20]. Handayani, S., Metoda Perekatan Dengan Lem Pada Sambungan Pelebarab Kayu. Jurnal Tekni Sipil & Perencanaan. Nomor 1 Volue 11, Januari 2019.

[21]. Aji, S dan Dermawan, L. Alternatif Sambungan Finger Joint Pada Balok Kayu Tehadap Pengujian Kuat Lentur. Majalah Ilmiah UKRIM Edisi 2 tahun XVIII-2013.