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The Impact of Span Width and Outrigger Shape on Fishing Boats at Palabuhanratu Fishing Port, Indonesia

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***Abstract* - Outrigger boats are prevalent in Indonesian waters. In Indonesia, the majority of Outrigger boats have a gross tonnage of less than 7 GT, resulting in their classification as "boats." After being hit by waves, the outrigger serves as a balancing mechanism on the boat, ensuring that it does not capsize and that it continues to keep its stability. In spite of the fact that they have a number of benefits, outrigger boats also have a number of drawbacks. One of these drawbacks is that they need a mooring space that is sufficiently large to anchor the boat at the beach or pier. This research was carried out through the use of experimental methodologies. The stability value is a reference to the design parameters established by IMO A.749 (18), which are applicable to all boats. Type 2 boats have a maximum GZ value that is greater than that of type 1 boats. According to the findings of the study, the utilization of the Palabuhanratu pool was increased by 33% on model B boats and by 52% on boat C when the outrigger boom was pulled while the boat was in the port pool. This was in comparison to the original value when the boat was anchored without pulling the outrigger boom.**

Keywords - outrigger boat., outrigger span., outrigger forms., boat stability.

I. INTRODUCTION

A fishing vessel's stability refers to its capacity to straighten out after experiencing tilting or slipping due to external forces like wind and waves, or internal forces like cargo movement [1]. Boats can operate well when they have a high boat stability value. This condition can minimize the rate of accidents caused by the boat's inability to return to its original upright position after experiencing a heel due to external and internal factors. One of fishermen's efforts to increase boat stability is using outriggers [2].

Boats with slender rafters, like "jukung" boats, commonly use the outrigger. The outrigger is a crucial part of boat construction [3]. The outrigger helps fishermen by balancing the boat, which enhances stability. This is attributed to the installation of bamboo or round wood across the left and right sides of the boat. Abramovitch [4] explains that the outrigger stabilizes the boat's tilt during rolling movements. A structural component, positioned parallel to the boat's body, can cause this phenomenon. According to Siadadi et al. [4], the part of a boat's construction that spans across the left and right sides is called the outrigger boom. Installed parallel to the boat's body, the outrigger float aids in preventing rolling. Furthermore, Siadadi et al. [5] also term outrigger arm (OA) for the connecting construction between the outrigger boom (OB) and the outrigger float (OF).

The advantage of the existence of the outrigger construction is that it can also reduce lifting and pitching movements [6]. If you install the float outrigger with the front position higher than the back, it can also function as a wavebreaker [7]. Adding an outrigger construction to the boat provides excellent reserve buoyancy. We conducted this research on boats with the following dimensions: a length overall (LoA) of 8 meters, a width of 1 meter, and a height of 0.8 meters. The boat's righting arm (GZ) reaches its maximum height at an angle of 40 degrees, and its steering arm measures 0.429 m-radians. According to

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International Maritime Organization (IMO) standards, the maximum GZ should occur at a 30-degree angle, with a minimum steering arm of 0.2 m-radians.

Apart from the benefits, the presence of an outrigger can also have a negative impact or cause problems. Among them is the need for a mooring area for a berth that is larger than the size of the boat's hull itself. Ilham et al. [8] state that we can calculate the space requirements for mooring a boat using the formula (LoA max + 1.5) x B. LoA is the total length of the boat (length over all), and B is the width of the boat (breadth). The width of a hulled boat and the span of the outrigger boom on both the left and right sides determine dimension B. This is why outrigger boats require a mooring area that is wider than it should be. Inefficient use of the mooring area at the pier results from this condition. Moreover, the existence of outrigger construction can occasionally lead to friction and collisions when the beams of adjacent boats come into contact due to wave action.

Solutions to the aforementioned issues are undoubtedly necessary for boats. For example, we need to redesign cruise boats by shortening the outrigger boom's length. It is also important to pay attention to whether the stability of the boat will be better if there is a modification to shorten the length of the outrigger boom. Khalid et al. [9] demonstrate that the adjustable outrigger enhances boat stability, conforming to the necessary IMO standards. Santoso et al. [10] conducted a study on the efforts to shorten the outrigger boom, its relationship to boats, and the resulting resistance to boat motion. In this research, the author connects the existence of boatmen not only to their resistance to motion but also to the stability of the boat. This research aims to analyze how modifications to shorten the outrigger boom on the boat affect the boat's stability performance.

Figure. 1. The construction of an outrigger is used by fishermen in Palabuhanratu Fishing Port, Sukabumi, West Java.

TABEL 1.
RESEARCH TREATMENT

Outrigger Type	Control (existing *outrigger)*	***Outrigger boom* length treatment**	
		$\frac{1}{2}$ **initial length**	$\frac{1}{4}$ **initial length**
Type 1	P_1	$P_{1.1}$	$P_{1.2}$
Type 2	P_2	$P_{2.1}$	$P_{2.2}$

II. METHOD

We conducted this research by simulating the length of the outrigger boom as a treatment. We will shorten the outrigger boom to 1/2 (Treatment 1, P1) and 1/4 (Treatment 2, P2) of its original length. The outrigger construction that will be used as a simulation reference in this research is the outrigger construction commonly used by fishermen in Palabuhanratu Fishing Port, Sukabumi, West Java (Fig. 1).

The boat that will undergo modification has an overall length (LoA) of 11.7 m, width of 1.5 m, height of 1.3 m, and draft of 0.7 m. The boat under study has an outrigger boom measuring 7 m in length. We made direct measurements of the outrigger construction at Palabuhanratu Fishing Port during the field observation stage. We measured the construction of 35 boats in the Palabuhanratu Harbor pool. We will measure the length of the outrigger boom, outrigger float, and outrigger arm. In addition, we will measure the cross-sectional area of each component of the outrigger construction. Fishermen in Palabuhanratu Fishing Port use two types of outrigger construction: type 1, which uses outrigger arms both at the front and behind, and type 2, which only uses outrigger arms behind the outrigger. We obtained the boat dimensions from 10 sample units of type 1 and 10 sample units of type 2 boats during the observation process. So, the total sample of boats was 20 units. In addition, we measured the primary dimensions and hull curvature of the research sample boat by employing a fisherman.

The data obtained on the dimensions of the outrigger were then processed and analyzed descriptively to obtain the construction performance of the outrigger used by fishermen. Then the data on the main dimensions of the boat and the curvature of the boat's hull are processed using Maxsurf software (education version) to obtain a lines plan image. Because there are 2 types of outriggers, the outrigger boom treatment is carried out for each type of outrigger. Table 1 shows the treatments used in the research.

The boat stability calculations carried out in this research analyzed the condition of each model that had been made, using the IMO A.749 (18) Design Criteria Applicable to All Boat parameters. The modeling conditions are: The boat is 100% full and is in the harbor pool.

III. Results And Discussion

1. Design and construction of the outrigger boats.

The observations of the outrigger boats at Palabuhanratu Fishing Port reveal that their main dimensions range from 7.00 to 12.5 m for the length (LoA), 0.77 to 1.8 m for the width (B), 0.4 to 0.9 m for the draft (d), and 0.80 to 1.3 m for the height (D). The dimensions of the outrigger are between 5.00 and 8.10 m for the length of the outrigger float (LoF), 4.9 and 10.50 m for the length of the outrigger boom (LoB), and 0.2 and 0.7 m for the length of the outrigger arm (LoR).

The initial study on the length of a boat with a berth (LoA) determined that the boat with a berth of 11.7 m will serve as a treatment object. This is because a boat with a LoA of 11.7 m is typically found on boats with a capacity of 57% in Palabuhanratu Fishing Port. Next, we measured the main dimensions of the Outrigger boat, as shown in Table 2.

TABEL 2.
THE PRIMARY DIMENSIONS OF A BOAT SERVE AS A SAMPLE FOR MEASUREMENT.

Information	Mark
L_{OA}	11.8 m
B (Breadth)	1.5 m
D	1.3 m
d (Draft)	0.7 m

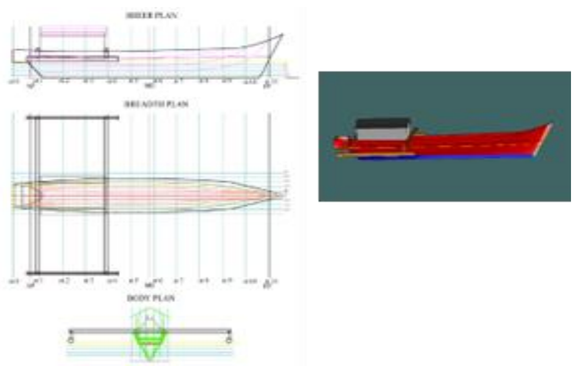


Figure. 2. Lines plan and design of a boat with a type 1 (P1) boat shape.

The next stage, data processing of boat curvature measurements, was carried out using Maxsurf software to produce lines plan images and the shape of Outrigger boats presented in Figures 2 and 3. Figure 2 shows an Outrigger boat with type 1 (P1) and Figure 3 shows an Outrigger boat with Outrigger type 2 (P2).

Referring to the lines plan drawings as presented in Figures 2 and 3, the shape of the boat's hull is transversally shaped like a V-bottom in the middle of the boat. The longitudinal shape of the boat's hull is double pointed. In Figures 2 and 3, you can also see the

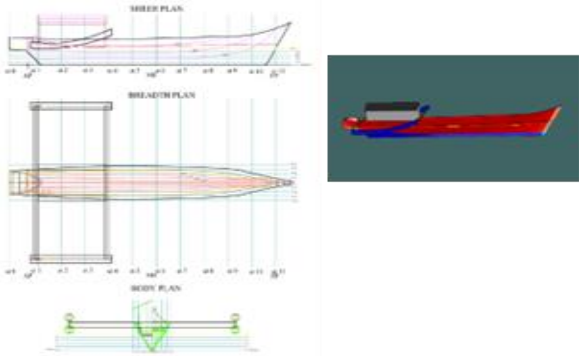


Figure. 3. Lines plan and design of a boat with a type 2 (P2) boat shape.

TABEL 3.
BOAT HYDROSTATIC DATA

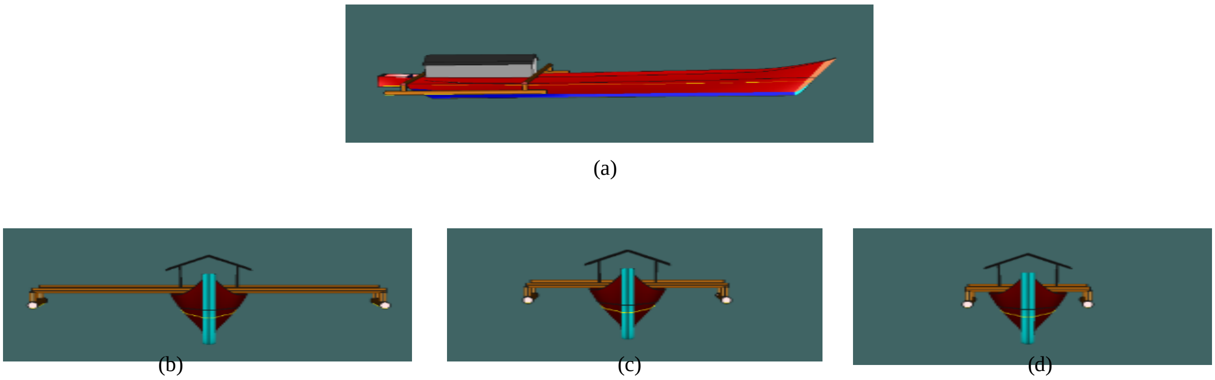
Measurement	**Drafts**			
	0.0	0.2	0.4	0.7
Displacement kg	0.0000	519.1	1510	3194
Heel deg	0.0	0.0	0.0	0.0
Draft at FP m	0,000	0.233	0.467	0.700
Draft at AP m	0.000	0.233	0.467	0.700
Wetted Area m^2	0.000	6,290	11,910	17,997
Waterpl. Area m^2	0.000	2,774	5,573	8,748
Prismatic coefficient. (Cp)	0.000	0.805	0.792	0.799
Block coefficient. (Cb)	0.000	0.559	0.467	0.415
Waterpl. coeff area. (Cwp)	0.000	0.714	0.824	0.815
Immersion (TPc) tonne/cm	0.000	0.028	0.057	0.090
MTc tonne.m	0.000	0.022	0.038	0.065

difference in the design of the outrigger between types 1 and 2. Type 1 features an outrigger float that aligns with the boat's bow direction. This differs from a type 2 outrigger, which features an outrigger float positioned either upwards or at an angle towards the boat's bow. The results of interviews with several fishermen who use type 1 or type 2 outriggers were solely influenced by their individual habits. Bangun et al. [11] and Haq et al. [12] are currently conducting research on this topic, where they found that traditional boatyards typically construct boats based on hereditary customs or local characteristics.

Based on the measurement results of the dimensions of types 1 and 2, it is known that both types of the outrigger have the same dimensions. The length of the outrigger boom is 7 m, the outrigger float is 3.45 m, and the length of the outrigger arm is 0.3 m. The difference is that in a type 2 outrigger, the front does not have an outrigger arm. This condition causes the position of the installed outrigger float to dive upward at the front. Abramovitc [4] explains how the outrigger works, namely, to hold the tilt of the boat during a rolling movement, so it is suspected that type 2 outrigger booms have a lower ability to resist the boat's rolling rate compared to type 1 outrigger booms. This is caused by the outrigger float's installation position, which is not parallel to the water surface when it touches the water surface. The GM value of the boat was found to be different [13].

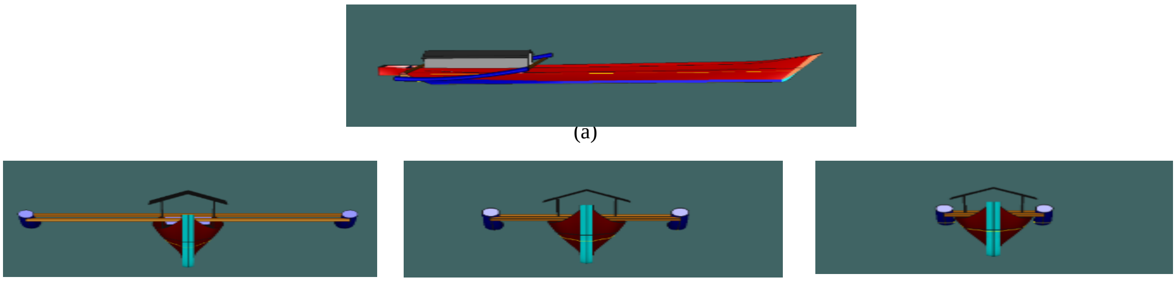
Table 3 shows the results of calculating the hydrostatic parameters of the boat that was used as a measurement sample. When the boat has a maximum draft (d) of 0.7 m or is carrying a maximum load, the hydrostatic parameter values presented indicate the boat's condition statically.

Table 3 illustrates that a higher design draft of the boat will result in a larger displacement and volume. The characteristic shape of the boat below the waterline greatly influences the overall volume of the boat, which is directly related to the speed, resistance, and power of the boat. Table 3 shows an increase in the boat's displacement value from a draft of 0.0 to the highest draft of 0.7 m. This is also influenced by the increasingly larger wetted area on the boat, starting from 0.0 to 17.99 m2. Because the larger the volume of the boat, the greater the resulting boat resistance; conversely, the smaller the boat volume, the smaller the resulting boat resistance [14].



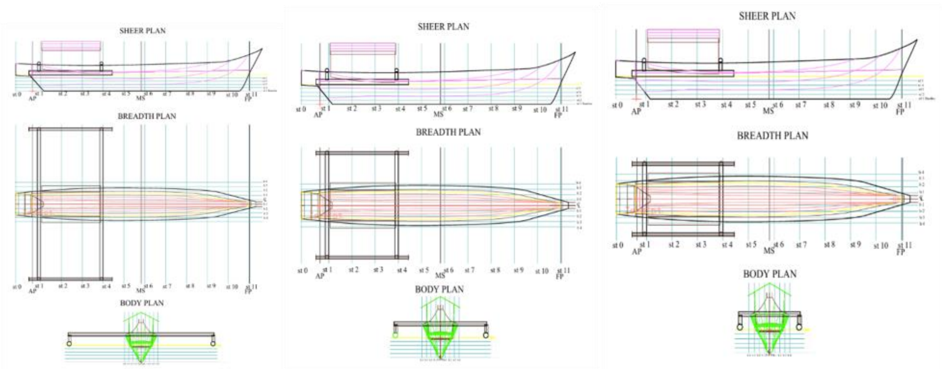
(a) (b) (c) (d)

Figure. 4. Illustration of the difference in outrigger boom length for outrigger type 1 (P1). (a) Tipe 1 outrigger side View, (b) L existing OB (7 m), (c) ½ L existing OB (3.5 m), (d) ¼ L existing OB (1.8 m).



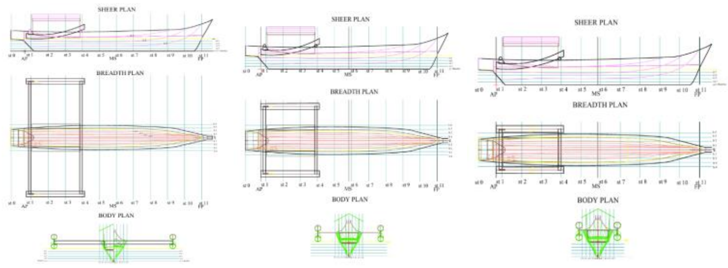
(a) (b) (c) (d)

Figure. 5. Illustration of the difference in outrigger boom length for outrigger type 2 (P2). (a) Tipe 2 outrigger side View, (b) L existing OB (7 m), (c) ½ L existing OB (3.5 m), (d) ¼ L existing OB (1.8 m).



(a) (b) (c)

Figure. 6. Illustration of the difference in outrigger boom length (a) Type 1 (Control: P 1), (b) Type 1 (Treatment 1: P 1.1) and (c) Type 1 (Treatment 2: P 1.2)



(a) (b) (c)

Figure 7. Illustration of the difference in outrigger boom length (a) Type 2 (Control: P 2), (b) Type 2 (Treatment 1: P 2.1) and (c) Type 2 (Treatment 2: P 2.2)

2. The influence of the length of the outrigger boom and the shape of the outrigger on the stability of the outrigger boat.

As explained in the method, the outrigger boom is treated by shortening it to ½ and ¼ of the existing length used by fishermen, namely 7 m. We applied this treatment to both types of boats, specifically types 1 and 2. Figures 4 and 5 illustrate the variation in the length of the outrigger boom (LoB) on vessels equipped with outriggers of types 1 (P1) and 2 (P2). Figures 4 and 5 present images of the boat's fishermen, aligned with the boat's plan image.

Typically, we create boat line plan drawings as an initial step to facilitate the visualization of the boat's hull or space. Figures 6 and 7 present the line plan of the boat in this study. We conducted the stability analysis of the boat's berth under both full load and final hauling conditions. The calculated load includes the weight of the boat itself, the weight of the fishing equipment (gillnet and fishing line), the fish caught (100 kg), the crew (2 people), fresh water, ice cubes, the anchor, the driving engine (multi-purpose outboard engine 15 PK), and fuel (FUEL). Table 4 presents the weight and position of the cargo on the boat, which are crucial factors in stability calculations. The units of mass, long arm, trans arm, and vert arm in Table 4 have the following meanings: Unit mass is the weight of the cargo; long arm is the distance.We calculate the cargo's center of gravity longitudinally from the boat's stern towards the bow; we calculate the cargo's center of gravity transversally from the center line, and we calculate the cargo's vertical center of gravity from the bottom of the boat's hull. In this calculation, all cargo is assumed to be positioned exactly in the middle of the boat in transverse terms, so that trans.arm=0 m.

TABLE 4.
WEIGHT AND POSITION OF CARGO ON A OUTRIGGER BOAT

Item Name	**Quantity**	**Mass Units (kg)**	**Total Mass (kg)**	**Long. Arm (m)**	**Trans. Arm (m)**	**Vert. Arm (m)**
Lightboats	1	700	700	5.75	0	0.4
Gillnett Net	1	15	15	4	0	0.6
Fishing rod	1	8	8	4	0	0.6
Catch	1	100	200	3,4	0	0.6
crew	2	75	150	3	0	0.6
Ice Cube	1	80	80	5	0	0.6
Generator	1	20	20	2.7	0	0.6
15 PK Outboard Engine	1	25	25	0.5	0	0.6
Ballast (Anchor)	1	15	15	8.8	0	0.4
Fuel	30%	30	9	1.5	0	0.5
Freshwater	30%	30	9	1.6	0	0.5
Total Loadcase			1131.4	3,655	0	0.473
VCG						0.477

Table 4 shows that the boat's total cargo in the load condition (load case) is 1,1381 kg, while the boat itself weighs 700 kg. The position of the cargo on the hull sets the vertical center of gravity (VCG) at a height of 0.477 meters from the boat's keel point, which is the bottom of the boat's hull. The position of the center of gravity of a load above the keel, which is known as the vertical center of gravity (VCG), must have a value smaller than the KM (Keel Metacentric) value. A metacentric pseudopoint establishes the boundary beyond which point G cannot cross, ensuring the boat maintains a positive or stable position. The Palabuhanratu Fishing Port berth boat, which was used as a research sample, showed a VCG <KM value with each KM value of 0.394 m at a draft of 0.4 m and 0.630 m at a draft of 0.7 m, according to Table 3. This suggests that the study's berth boat maintains a stable value. positive. Positive stability occurs when M is above G or the M value is greater than the G value [15], [16].

negative stability. Figures 7 and 8 present the GZ curve that results from the stability analysis of the research vessel. The results of calculations using Maxsurf software for each of the three types of vessel conditions (Type 1: 1.1 and 1.2; Type 2: 2.1 and 2.2), show that for Type 1 vessels, the GZ value is 0.82 m and the value is formed at an angle of 70.9 deg, and for Type 1.1 boats, the GZ value is 0.71 m and the value formed is 95 deg, and for Type 1.2 boats, the GZ value is 0.73 m and the value formed is 99 deg. Looking at the three conditions, the GZ value and the value of the area under the GZ curve will change if there is a change in charge distribution; the GZ value and the distance value between points G and M (GM) decrease when there is additional charge; the GM value can be seen in Figures 7 and 8. In some outrigger models, Angle of Loll occurs. Angle of Loll is the tilt of the boat when it oscillates. This is because the GM core value is negative before increasing to a positive value. This condition causes the

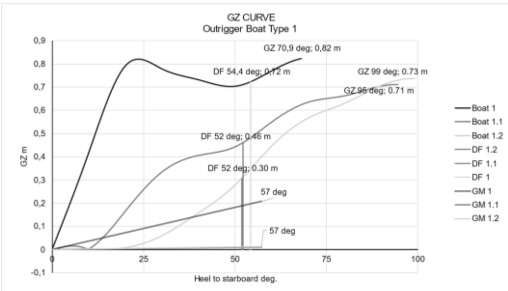


Figure 8. GZ curve of a Type 1 boat

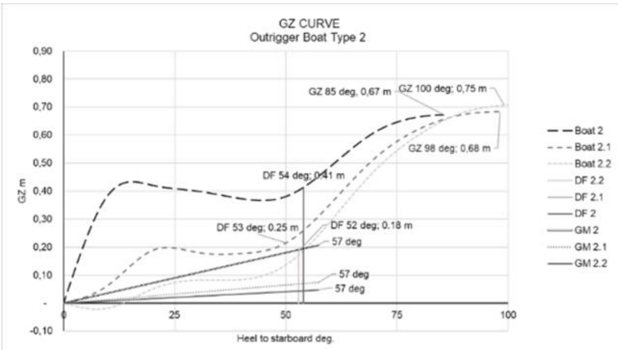


Figure 9. GZ curve of a Type 2 boat

The first stage of analysis is to examine the influence of LoB differences on the stability of a boat with a berth. In Figure 8 and Figure 9, the stability curve (GZ) is presented for each treatment, the differences in LoB in each type of outrigger.

The boat generates a force known as the straightening arm (GZ) to return to an upright position. This GZ determines whether the boat has positive stability or

boat to oscillate. At P 1.1 and P 1.2, an angle of loll occurs due to shortening of the Outrigger boom by ½ and ¼ of the initial length, so that the GM initial is small and even approaches zero at P 1.2. This phenomenon caused a decrease in the initial GM value to 0.010 m (P 1.1) and 0.013 m (P 1.2) from the original 0.207 m (P1). At P2, the angle of loll phenomenon also occurs at P 2.1 and P 2.2, but at P 2.2 a negative initial GM occurs.

From this treatment, the outrigger modification at P 1.2 and P 2.2 has a greater probability of drowning than P 1.1 and P 1.2. The angle of inclination of the boat in certain different conditions is also caused by differences in the outrigger boom on the two types of boat [17], [18], [19].

Tables 5 and 6 present the stability analysis results for type 1 outrigger boats, including the boat's dowfloading and the angle of inclination that leads to the entry of sea water. This analysis displays the results for three different types of outrigger boom lengths on type 1 boats. Type 1 boats have a GZ value of 0.82 m, formed at an angle of 1.23 rad. Type 1.1 boats have a GZ value of 0.71 m, formed at 95 deg, and type 1.2 boats have a GZ value of 0.73 m, formed at 1.72 rad. Reducing the length of the outrigger boom (LoB) of a outrigger boat also affects the downflooding (DF) of the boat. On type 1 boats, the down flooding value of the boat is 0.948 rad; on a type 1.1 boat, the DF value is 0.911 rad; and on a type 1.2 boat, it has a DF value of 0.905 rad. The GZ value changes along with changes in the mode of the outrigger arm type, as in tables 5 and 6. This change will impact the stability of the boat. This is in accordance with research by Sun et al. [19], where there is an influence of the angle of roll or stability of the boat on the use of outriggers; the stability value decreases with decreasing length of the outrigger.

Figure 9 displays the stability analysis results for a type 2 outrigger boat, along with the boat's dowfloading data. This analysis displays the results for three types of outrigger boom lengths on type 2 boats. Type 2 boats have a GZ value of 0.67 m, which forms at an angle of 1.48 rad; type 2.1 boats have a GZ value of 0.68 m, which forms at 1.71 rad; and type 2.2 boats, with a GZ value of 0.75 m, form a value of 1.74 rad. Reducing the LoB of a outrigger boat also affects the downflooding of the boat. On type 2 boats, the downflooding value of the boat is 0.941 rad; on a type 2.1 boat, the DF value is 0.940 rad; and on a type 2.2 boat, it has a DF value of 0.922 rad. According to research by Sun et al. [18], the angle of roll or stability of the boat influences the use of

TABLE 5.
TYPE 1 BOAT CURVE VALUES

Boat Type	GZ (rad)	GZ (m)	DF (rad)	GM
2	1.483949	0.67	0.94199	0.9
2.1	1.710906	0.68	0.94051	0.9
2.2	1.745823	0.75	0.92221	0.9

TABLE 6.
TYPE 2 BOAT CURVE VALUES

Boat Type	GZ (rad)	GZ (m)	DF(rad)	GM (rad)
1	1.237438	0.82	0.94831	1
1.1	1.6580622	0.71	0.91192	0.9
1.2	1.7278753	0.73	0.90587	0.9

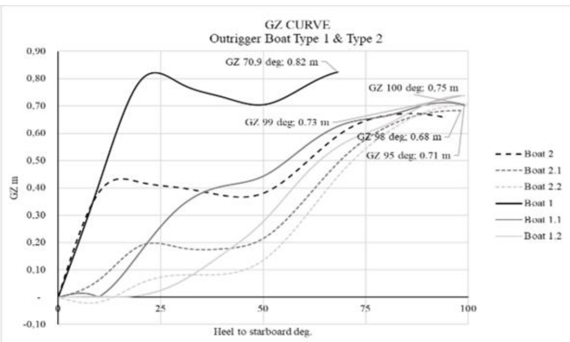


Figure 10. GZ curve of comparison of Outrigger types

outriggers, and the stability value decreases as the length of the outrigger increases.

Differences in s/L on boats provide different Max GZ values, where the highest Max GZ value occurs at an s/L value of 0.3 with a GZ value of 16.4 deg. This is also influenced by the rolling that occurs on boats with different s/L [20], [21]. The GZ value for each condition of boat types 1 and 2 with each of the 3 different models of outrigger boom length does not show a significant change. The GZ value is positive; usually in the angle range 0° to 90°, the boat will return to its original position after the moment that causes the tilt is lost [22]. This shows that the upright moment, or the moment that will return the boat to its original direction after experiencing a tilt due to external forces, is greater than the predetermined conditions. The GM value for both types of boats exceeds the IMO A749 Ch 3 standard, so it can be concluded that it meets the specified conditions.

The next stage of analysis is to examine the influence of the shape of the outrigger on the stability of the boat. In Figure 9, the stability curve (GZ) is presented, which can show the stability quality of a boat with a different type of outrigger with the same LoB at each LoB length treatment.

Figure 10 shows the results of stability tests that have been carried out on boats with types 1 and 2. Based on the curve, it can be seen that the type of outrigger has no significant effect; this is indicated by the maximum GZ value for each type of outrigger, which is not much different. The maximum GZ value range on type 1 boats is around 70.9° to 99°. In type 2 outriggers, the maximum GZ value is between 85° and 100°. This shows the highest maximum GZ value, namely the type 2.2 outrigger with a GZ value of 100 deg; 0.75 m.

Figure 10 shows the results of a comparison of the stability of type 1 and type 2 Outrigger boats. In this analysis, the results are shown for each of the 3 types of outrigger boom lengths for type 1 and type 2 unrigged boats. On type 1 boats, the GZ value is 0.82 m and the GZ Max is at an angle of 70.9 deg, while on type 2 boats, the GZ value is 0.67 m and the GZ Max value is at an angle of 85 deg. On types 1 and 2, the highest GZmax value is on type 2 boats. Comparison of the values for type 1.1 boats and type 2.1, namely the GZ value of type 1.1 boats is 0.71 m and the GZ Max value is formed at an angle of 95 deg; for type 2.1 boats, the GZ value is 0.68 m and the value formed is 98 deg. This shows that the GZ value for type 2.1 is > that of type 1.1 boats. On a type 1.2 boat, it has a GZ value of 0.73 m; the value formed is 990. Type 2.2 boats have a GZ value of 0.75 m; the value formed is 100 deg. Based on the values that have been submitted, it shows that differences in the type of Outrigger boat can have a real effect on the GZ Max value. The existing outrigger span model is the optimum model that can be used when going to sea, but the function of shortening the outrigger boom for use in harbor pools can be carried out. The difference in stability values for the two types of boats is due to hull interference or the occurrence of water flow around the distance between their asymmetrical hull and outrigger boom. Differences in boat type have an influence on stability values [23], [24], [25].

IV. CONCLUSION

1. The influence of the length of the outrigger boom on types 1 and 2 shows a significant difference in boat stability. The comparison between type 1 and type 2 outrigger boats demonstrates the difference in the maximum GZ value, with type 2 outrigger boats exhibiting the highest maximum GZ value. Changes in shortening the outrigger will provide more boat loading space in the port pool. The use of type 1.1/2.1 berth vessels can reduce 25% of the pool, and type 1.2/2.2 reduces 60% of the port pool.
2. The width of the outrigger span or the length of the outrigger boom (LoB) of a berthed boat in Palabuhanratu influences the value of the boat's stability. The stability simulation results on boats type 1 (type 1; type 1.1; type 1.2) and type 2 (type 2; type 2.1; type 2.2) demonstrate this. We can use types 1.2 and 2.2 to increase the space in the pool harbor.
3. The design of the type of outrigger boat also influences the stability value of the boat; the results show that the design of the type 2 boat has a higher Gzmax value compared to the type 1 boat.

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