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Preliminary Design of Traditional Fishing Boat (2 GT) With Additional Floating Compartment for Safety Reasons Using BKI Rules

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***Abstract* — traditional fishing boats are used by fishermen for finding fish to support their daily lives. Because there are many shortcomings in their boats (design problems) and natural conditions that often change, accidents can occur which cause their boats to easily overturn and sink to the bottom of the sea. Other problems were also encountered, such as the boat's obstacles, and the boat's floating compartment was not well designed. For this reason, the author conducted research on the design of a fishing boat with a floating compartment using the BKI rules. Using one of the existing boats was made as a design reference with boat sizes. The principal dimension of the fishing boat is LOA: 10.15 m, Lwl: 8,996 m, B: 1 m, H: 0.87 m, H: 0.3 m, and 2 GT. The results of the calculations find that the engine specification that suits the fishing boat is 3.5 kW with a speed of 7 knots. The author's research varies the Floodable Length of the original boat's floating compartment with a compartment size of 1.365 m AP, 1.325 m FP, and model 2 floating compartment using BKI rules with AP size 2.225 m and FP 2.425 m. The analysis result based on the design of the fishing boat shows that model 2 is the best design. Construction in accordance with BKI regulations, a mixed type of construction was chosen. The frame distance is 500 mm with the stiffener type model h = 25 mm, bb = 30 mm, and bc = 36 mm. Meanwhile, the total stringer is 6 stiffeners.**

Keywords— BKI, Boat 2 GT, Construction, Floating Compartment, Flodabel Length, Traditional Fisherman.

I. INTRODUCTION

Traditional fishermen are fishermen who catch fish in a short time, which is between 4-5 hours starting at 03.00 am in the morning. The fishermen use fishing boats measuring 6-7 meters with fiber material and powered by a 6.5 HP gasoline engine. Equipment for catching fish can be said to be very traditional nets and fishing rods. The catch is just for the day's needs and the next morning they will go to the sea again.

According to KIARA (People's Coalition for Fisheries Justice) in 2010 - 2014 there were 207 fishermen in marine accidents [1]. The causes of traditional fishermen accidents are the low mastery of maritime safety competence in fishing, boats not equipped with proper safety equipment and unpredictable bad weather resulting in large waves [2]. As a result of these several things, it is the biggest factor that often causes fishing boats to have accidents, causing the boat to overturn and sink to the bottom of the sea because the boat does not have a floating compartment that is sufficient to hold the boat on the surface of the sea. Beside of these problems, fishermen complained that the speed of their boat felt very slow, and they wanted to be updated with a more modern hull shape.

The modern boat design is adapted to the needs of small/individual traditional fishermen to go to the sea. By providing a boat hull shape design that has little resistance, making it easier for fishermen when they are sailing to where the fish are. Adding a floating compartment is necessary, so in case the boat is overturned, it stays at sea level so that it can be easily evacuated. The author also provides the construction of the boat according to the fiber material. The design of this boat was made in accordance with the rules of BKI Volume V Rules for Fiberglass Reinforced Plastics Ships, Sec 13 Watertight Bulkheads 2021 [3] and BKI Volume V Guidance for Certification of FRP Fishing Vessel less than 12 m 2020 [4].

A. *Gross Tonnage (GT)*

Gross Tonnage is a term used to calculate the size of a boat in addition to the main size of the boat. The determination of the gross tonnage of the boat is carried out based on various rules, both legally and technically construction [5].

Gross tonnage (GT) is a unit of the total volume of the ship which is measured based on the main dimensions of the ship both above deck/deck and below deck. According to the International Maritime Organization (IMO), GT is a quantity that describes the volume of buildings above deck and buildings below deck and is the size of the ship as a whole by taking into account the total contents of all enclosed spaces. Can be seen in Figure 1.

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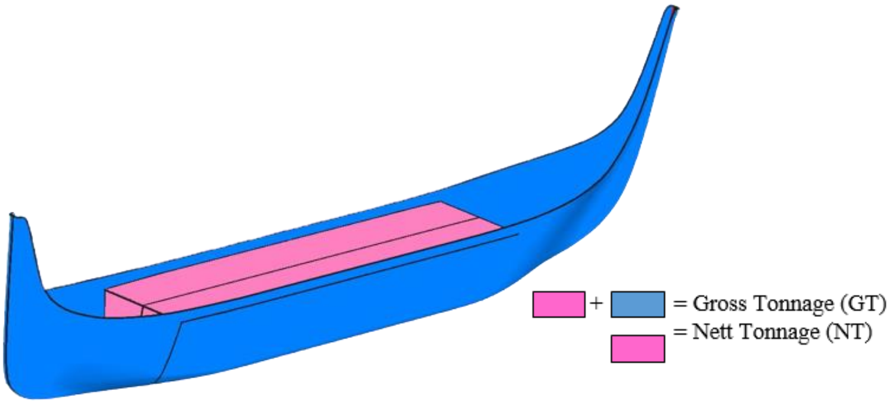

Figure. 1. Gross Tonnage dan Nett Tonnage

GT is calculated using a formula that takes into account the volume of the boat below the main deck and the enclosed space above the main deck. The volume is then multiplied by a constant which gives a dimensionless number. This means that the ton or m^3 unit does not exist after the calculated number. GT calculation according to the International Convention on Tonnage Measurement of Ship 1969, Intergovernmental Maritime Consultation Organization (IMCO) boats with a length of < 24 meters can be carried out using the Indonesian domestic method [6].

$$GT = (a + b)/2{,}83280 = 0{,}353\ (a + b) \qquad (1)$$

Where:
A = volume of enclosed space below the main deck (m^3)
B = volume of enclosed space above the main deck (m^3)

B. Resistance

The understanding of the components of a boat's resistance and behavior is important because these components are used in scaling the resistance of one boat to another or in other words can carry out an analysis from testing on the size of the model to the size of the pride [7].

To get the value and validation of the total resistance (RT) of the boat, we can get it through software analysis (in this design using resistance software) and using the empirical data calculation method (empirical method).

$$RT = CT\ (½\ \rho\ V2\ S) \qquad (2)$$

The margin of error allowed is 5% by comparing the results of the two methods to find the difference, while the calculation formula is as follows.

$$Difference = \frac{RT\ Maxsurf - RT\ Empiris}{RT\ Maxsurf}\ (\%) \qquad (3)$$

C. Construction Boat

Boat structures are very different types of structures, primarily in the arrangement of components, but also in the many unique constraints and regulatory contexts that influence the design of boat structures. Variations in dimensions and scantling are to be found in boat structures. The requirements of the classification society may differ from one another in this final project using the BKI Vol V 2020 Guidance for Certification of FRP Fishing Vessel less than 12 m [4], but basically the overall structure will have the same characteristics.

$$CuNo = LOA \times B \times H \qquad (4)$$

D. Floating Compartment

Each boat size has its own rules to determine the floating compartment according to the rules. These requirements are regulated in BKI Volume V Fiberglass Reinforced Plastics Ships, Sec 13 Watertight Bulkheads 2021 [3].

$$Collision\ Bulkhead = 0.05L\ (m) – 0.13L\ (m) \qquad (5)$$

E. Floodable Length

To design/plan a boat, it is necessary to pay attention to the safety or security factor of the boat. There are many things that affect the safety of a boat, one of which is a leak in the hull below the waterline. Floodable Length or Leakage Diagram is a curve or line from the location of the maximum length of the room which is limited by a transverse bulkhead, if the room is inundated with water (leaks) and the water laden from the boat touches the sinking boundary line (Margin Line), where the boat can still float or when the boat is about to sink. So in this situation, the boat still has a buoyancy reserve which is believed to be able to prevent the boat from sinking until the boat docks at the nearest port [8].

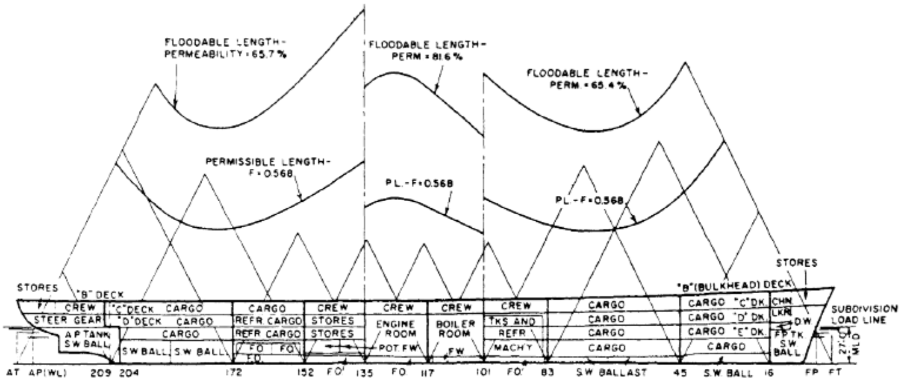

Figure. 2. Curve Floodable Length [9]

II. METHOD

The methodology y used in this study to determine ship resistance using 2 methods, namely simulation and calculation. As for the floating compartment using a simulation method with boat loading. More details are described as follows.

A. Hull Model

Modeling this boat using a boat on Blimbingsari Beach, Banyuwangi, is used as a reference for designing the shape of the hull.

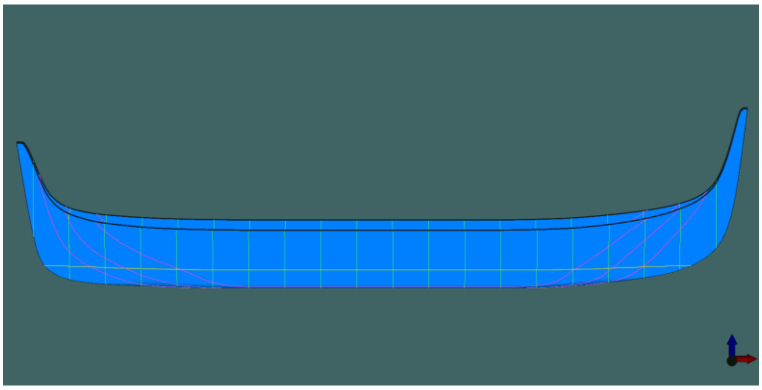

Figure. 3. Design Boat Based on Blimbingsari Beach

TABLE 1.
PRINCIPAL DIMENSION BOAT

Parameters	Dimension
Length overall	10,15 m
Length between Perpendicular	8,65 m
Length Waterline	8,996 m
Breadth	1 m
Breadth Draft	0,882 m
Draught	0,87 m
Draft	0,3 m
Vs	7 knot
Cb	0,63
Cp	0,704
Cm	0,895
Volume Displacement	1,5371 t
Gross Tonnage	2,072 GT

B. Resistance Calculation

In the calculation of resistance using 2 methods, using ship design software and empirical calculations.

1. Resistance (Ship Design Software)

To perform a resistance analysis, the author uses the ship design that able to perform resistance analysis, with using the Holtrop method to displace it at a speed of 7 knots. The resistance vs speed ratio is obtained as follows.

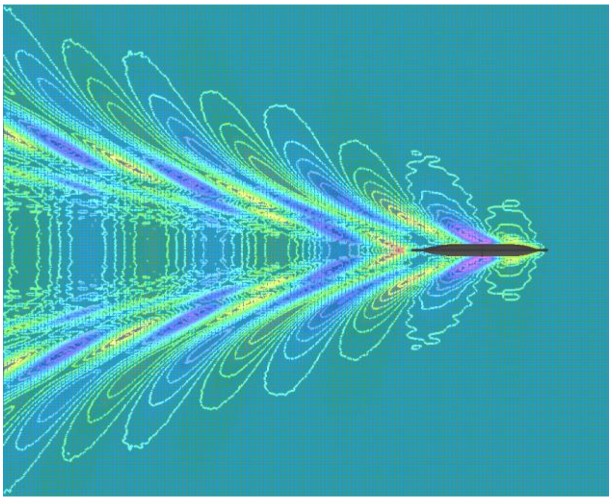

Figure. 4. Boat Wave Pattern

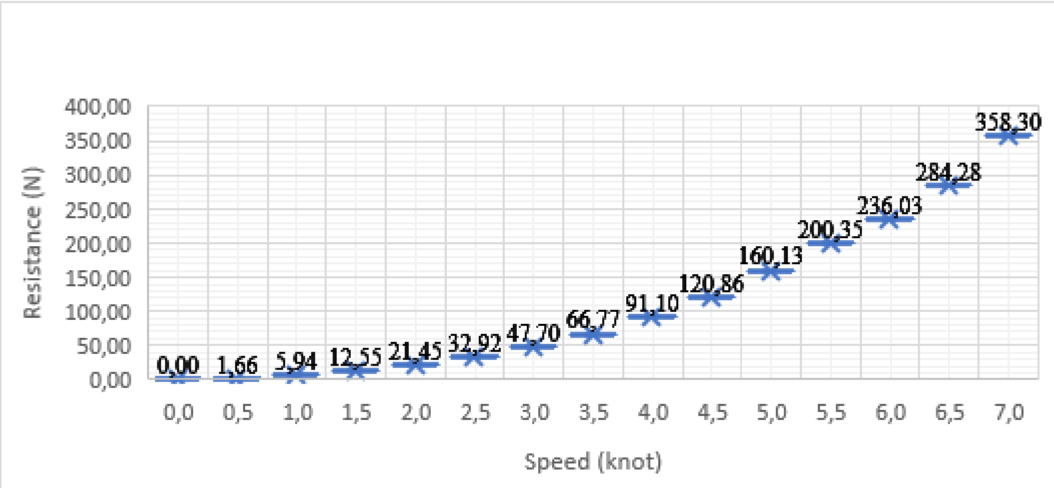

Figure. 5. Graph Resistance Boat

TABEL 2.
RESISTANCE BOAT MODEL 2

Speed (Knot)	Froude number (Fn)	Resistance Maxsurf (N)
7	0,383	358,3

2. Resistance Empirical

To get the resistance of empirical calculations, the author refers to the book [10]. The formula used is as follows.

$$R_T = C_T (½ \rho V^2 S) \quad (2)$$
$$= 0{,}00576 (½ \text{ x } 025 \text{ x } 3{,}6008^2 \text{ x } 9{,}4484)$$
$$= 361{,}4116 \text{ N}$$

3. Difference between RT Holtrop and RT Empirical

$$\text{Difference} = \frac{RT\ Maxsurf - RT\ Empiris}{RT\ Maxsurf} (\%) \quad (3)$$
$$= \frac{358{,}3 - 361{,}41}{358{,}3}$$
$$= -0{,}868 \% \text{ or } -0{,}0087 \text{ N}$$

TABEL 3.
DIFFERENCE BETWEEN SOFTWARE AND EMPIRICAL PRISONERS

Speed (Knot)	Resistance Maxsurf (N)	Resistance Empirical (N)	Allowable Difference 5%	Status
7	358,3	361,4116	-0,868 % / -0,0087 N	Accepted

C. Lines Plan

After the design on the modeling software is deemed sufficient, then the next step is to convert this 3D design form into a lines plan in CAD software, to get this lines plan design there need to be several stages to go through and are needed, while the stages are as follows:

1. CSA (Curve of Sectional Area) Design

To obtain a proportional CSA image, the vertical line drawing, which is a line that reflects the area of each station from station 0 to station 20, must be scaled. In this drawing, the scale used is 1 cm = 0.1 m2 (on the yaxis = area) and 1 m = 1 m (on the x-axis = distance of each station in the figure).

TABEL 4.
DATA CSA (CURVE OF SECTIONAL AREA)

Station	Area X (m)	Area Y (m^2)
AP	0,0000	0,0179
1	0,4325	0,0488
2	0,8650	0,1002
3	1,2975	0,1510
4	1,7300	0,1940
5	2,1625	0,2267
6	2,5950	0,2384
7	3,0275	0,2384
8	3,4600	0,2384
9	3,8925	0,2384
10	4,3250	0,2384
11	4,7575	0,2384
12	5,1900	0,2384
13	5,6225	0,2384
14	6,0550	0,2383
15	6,4875	0,2267
16	6,9200	0,1830
17	7,3525	0,1182
18	7,7850	0,0527
19	8,2175	0,0145
FP	8,6500	0,0000

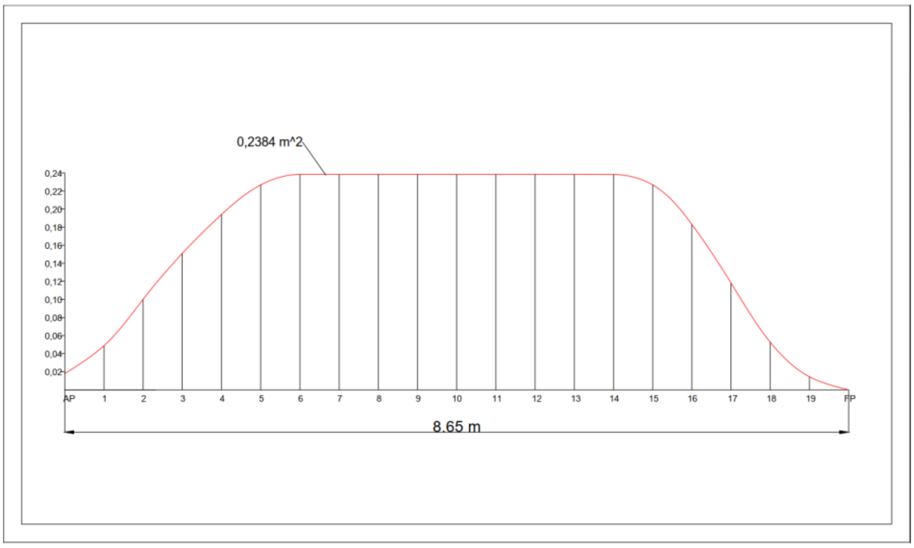

Figure. 6. Curve of Sectional Area

D. Main Drawing Line Plan

The lines plan design is obtained from the conversion of the buttock plan, half breath plan, and body plan images from the stability software that has been made and then trimmed according to Figure 7.

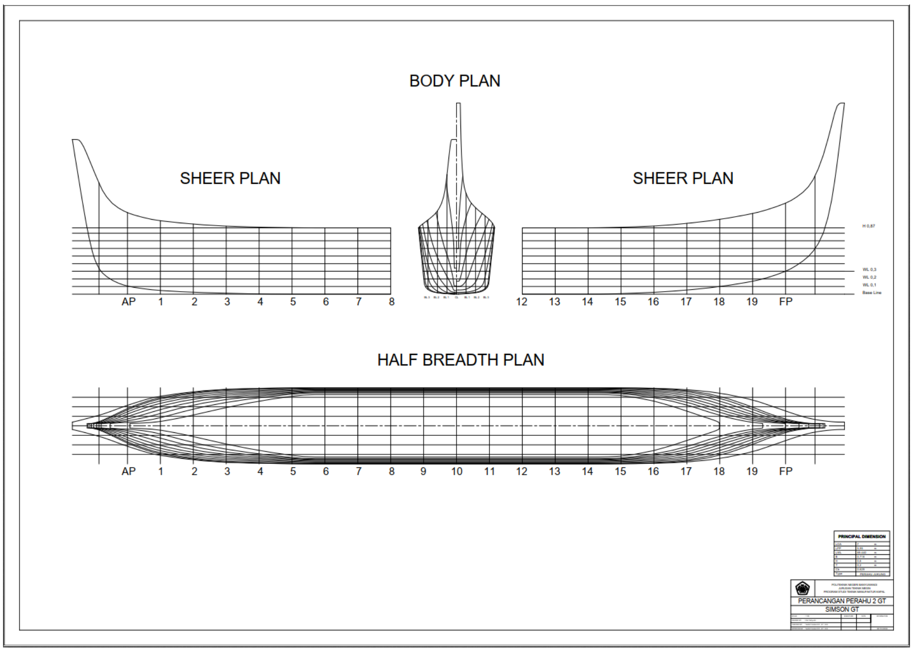

Figure. 7. Lines Plan

E. Hydrostatic and Bonjean

1. Hydrostatic Data and Curve

These hydrostatic data and curves were obtained with the help of stability software analysis, the data from the hydrostatics curve obtained are as shown in Table 5.

TABEL 5.
HYDROSTATIC DATA

Waterline (m)	Displacement (Ton)	MSA (m^2)	WSA (m^2)	WPA (m^2)	LCB (m)	LCF (m)	KB (m)	TKM (m)	LKM (m)	TPC (m)	Cp (m)	Cb (m)	Cm (m)	Cwp (m)
0,000	0,000	0,000	0,000	0,000	3,000	3,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
0,050	0,143	0,026	4,173	4,095	4,075	4,129	0,030	1,138	85,567	0,042	0,774	0,561	0,725	0,825
0,100	0,380	0,065	5,363	4,981	4,136	4,192	0,059	0,707	45,084	0,051	0,735	0,583	0,793	0,783
0,150	0,649	0,107	6,321	5,418	4,166	4,204	0,087	0,524	31,975	0,056	0,718	0,603	0,839	0,774
0,200	0,934	0,150	7,215	5,657	4,177	4,195	0,114	0,439	24,626	0,058	0,709	0,616	0,869	0,765
0,250	1,231	0,193	8,127	5,877	4,185	4,202	0,141	0,403	20,576	0,060	0,706	0,625	0,886	0,765
0,300	1,537	0,237	9,043	6,062	4,187	4,191	0,168	0,389	17,670	0,062	0,704	0,630	0,895	0,764

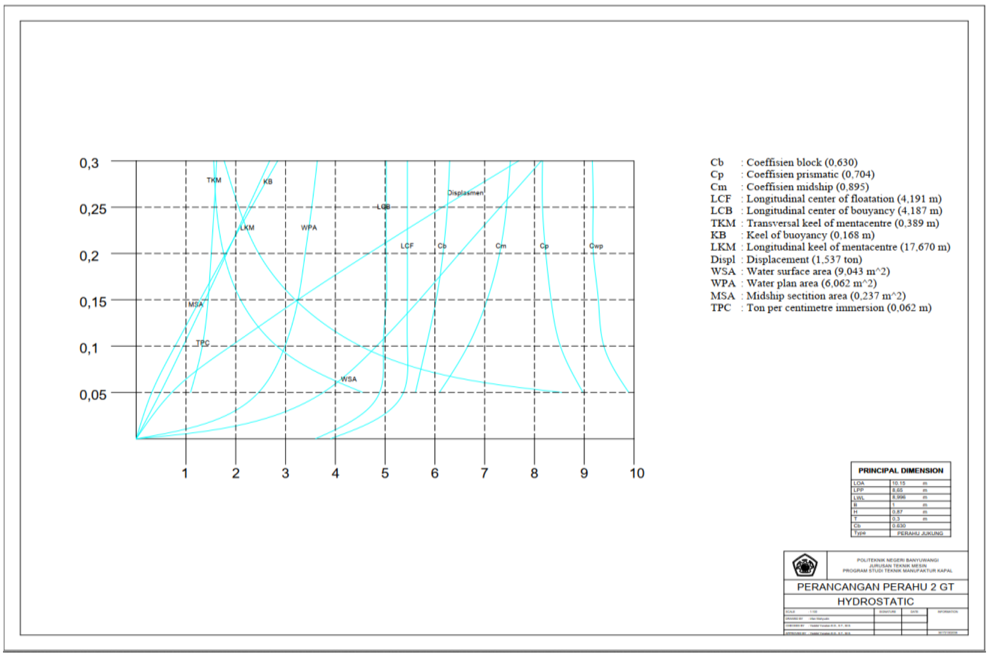

Figure. 8. Hydrostatic Curve of Fishing Boat

2. Bonjean Data and Curves

The data from the Bonjean curve obtained through the help of ship design stability software analysis can be seen in Table 6.

After getting the value of the area scale at each station, the value of these areas is depicted vertically on the side of the scaled boat hull. Then the results of the Bonjean design are obtained as shown in Figure 9.

TABEL 6.
BONJEAN DATA

Water line (m)	fr 0 x (m^2)	fr 1 x (m^2)	fr 2 x (m^2)	fr 3 x (m^2)	fr 4 x (m^2)	fr 5 x (m^2)	fr 7 x (m^2)	fr 8 x (m^2)	fr 9 x (m^2)	fr 10 x (m^2)
0	0	0	0	0	0	0	0	0	0	0
0,1	0,1783	0,1501	0,5048	1,0046	1,4352	1,6251	1,6251	1,6251	1,6251	1,6251
0,2	0,4485	0,6240	1,5742	2,5720	3,3699	3,7416	3,7416	3,7416	3,7416	3,7416
0,3	0,8338	1,3875	2,9536	4,3440	5,4053	5,9209	5,9209	5,9209	5,9209	5,9209
0,4	1,3544	2,4164	4,5507	6,2556	7,5116	8,1522	8,1522	8,1522	8,1522	8,1522
0,5	2,0433	3,6820	6,3250	8,2832	9,6881	10,4358	10,4358	10,4358	10,4358	10,4358
0,6	2,8911	5,1475	8,2434	10,4100	11,9404	12,7731	12,7731	12,7731	12,7731	12,7731
0,7	3,8760	6,7782	10,2863	12,6298	14,2635	15,1637	15,1637	15,1637	15,1637	15,1637
0,8	4,6415	8,5482	12,4383	14,9415	16,6543	17,6052	17,6052	17,6052	17,6052	17,6052
0,87	7,1230	9,8570	14,0017	16,6142	18,3693	19,3434	19,3434	19,3434	19,3434	19,3434

Water line (m)	fr 11 x (m^2)	fr 12 x (m^2)	fr 13 x (m^2)	fr 14 x (m^2)	fr 15 x (m^2)	fr 16 x (m^2)	fr 17 x (m^2)	fr 18 x (m^2)	fr 19 x (m^2)	fr 20 x (m^2)
0	0	0	0	0	0	0	0	0	0	0
0,1	1,6251	1,6251	1,6251	1,4534	0,8517	0,1807	0,2246	0,0971	0,0735	0,1179
0,2	3,7416	3,7416	3,7416	3,5161	2,5342	1,1444	0,7382	0,3256	0,2130	0,2183
0,3	5,9209	5,9209	5,9209	5,6476	4,3751	2,3835	1,4082	0,6106	0,3556	2,7411
0,4	8,1522	8,1522	8,1522	7,8330	6,3308	3,8069	2,2335	0,9508	0,4593	--
0,5	10,4358	10,4358	10,4358	10,0741	8,3905	5,4025	3,2263	1,3641	2,1376	--
0,6	12,7731	12,7731	12,7731	12,3788	10,5514	7,1637	4,4031	1,8777	--	--
0,7	15,1637	15,1637	15,1637	14,7454	12,8063	9,0833	5,7754	2,3183	--	--
0,8	17,6052	17,6052	17,6052	17,1680	15,1445	11,1424	6,8511	4,8274	--	--
0,87	19,3434	19,3434	19,3433	18,8953	16,8278	12,6618	9,4504	--	--	--

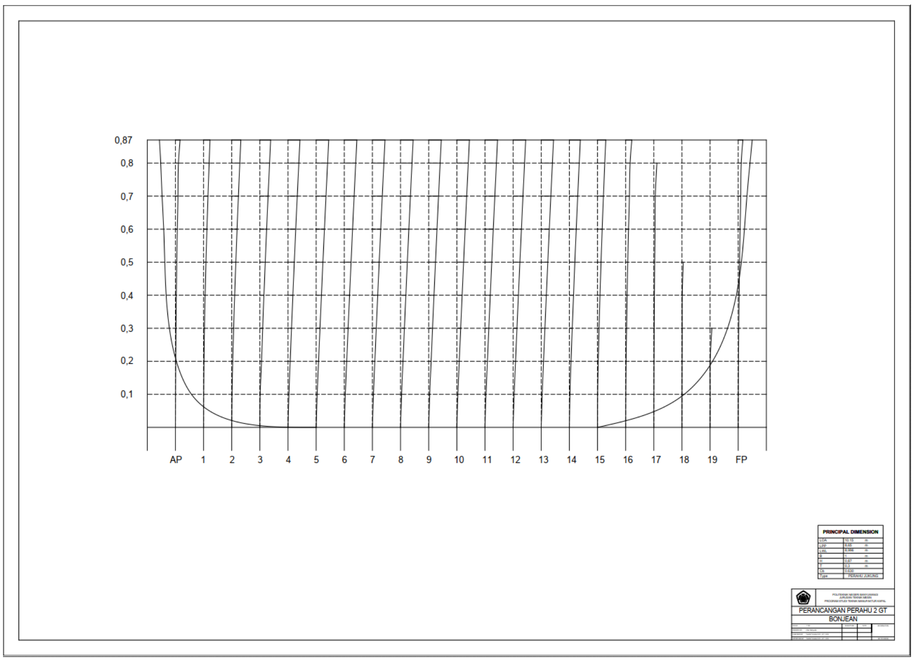

Figure. 9. Bonjean Curve

F. General Arrangement

1. Main Engine

From the calculation on the main motor power obtained BHPmcr of 3.4609 kW, to adjust the motor on the market, the main motor of 3.5 kW was chosen.

2. Deadweight (DWT)

The need for fuel and freshwater can be calculated using the Deadweight (DWT) formula below [11].

DWT = Wfo + Wfw + Wcp + Wr + Wpc (ton) (6)
= 0,0024 + 0,0029 + 0,15 + 0,175 + 0,6305
= 0,9607 ton

LWT = Displacement – DWT (7)
= 1,5370 ton - 0,9607 ton
= 0,5763 ton

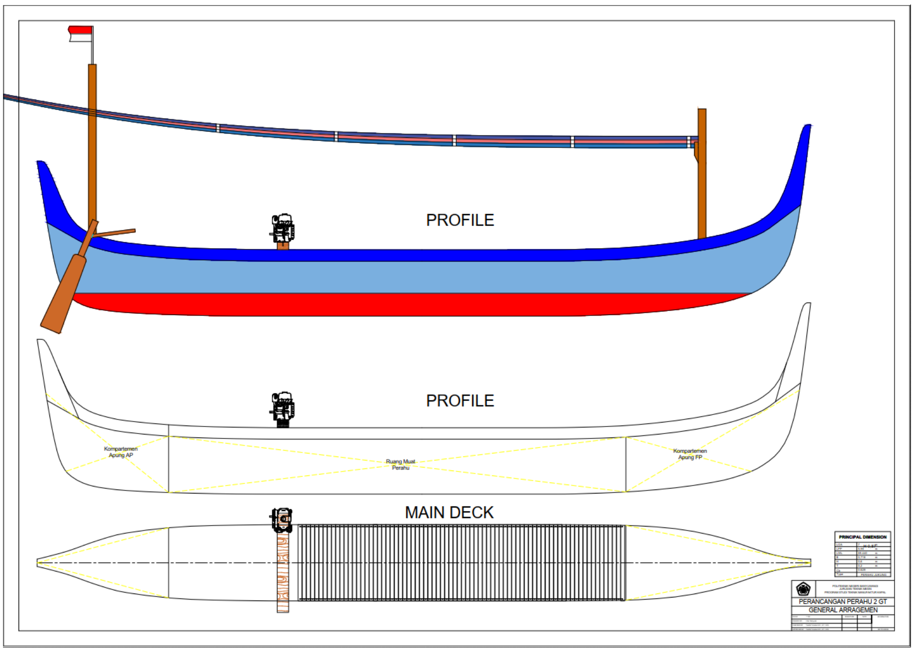

Figure. 10. General Arrangement

G. Construction

This boat construction plan refers to BKI Vol B 2020 Guidance for Certification of FRP Fishing Vessel less than 12 m, section 7 FRP Structural Design [3].

1. Cubic Numeral (CuNo) factor calculation

This calculation is to find the value that is made as a reference in choosing the appropriate type of construction at BKI.

CuNo = LOA x B x H (4)
= 10.15 m x 1 m x 0,87 m
= 8,8305 m^3

Because the designed boat does not have a deck, it is obtained with the following values.

CuNo = 10 m^3
Displacement= 1500 kg

TABEL 7.
VALIDATION CONSTRUCTION

Item Name	Dimension/ Modulus	Dimension/ Modulus min BKI	Size (mm)	Status
Thickness Hull	5,4	5,4	5,4	*Pass*
Stiffener Spacing S	500	500	500	*Pass*
Hull Additional Reinforcement Weight and Width	90	90	90	*Pass*
Keel	2,2	2,2	2,2	*Pass*
Chine	1,7	1,7	1,7	*Pass*
Web Frame	1,8	1,8	(h 25) x (bb 36) x (bc 30) x (t 5)	*Pass*
Longitudinal Stiffener	1,8	1,8	(h 25) x (bb 36) x (bc 30) x (t 5)	*Pass*

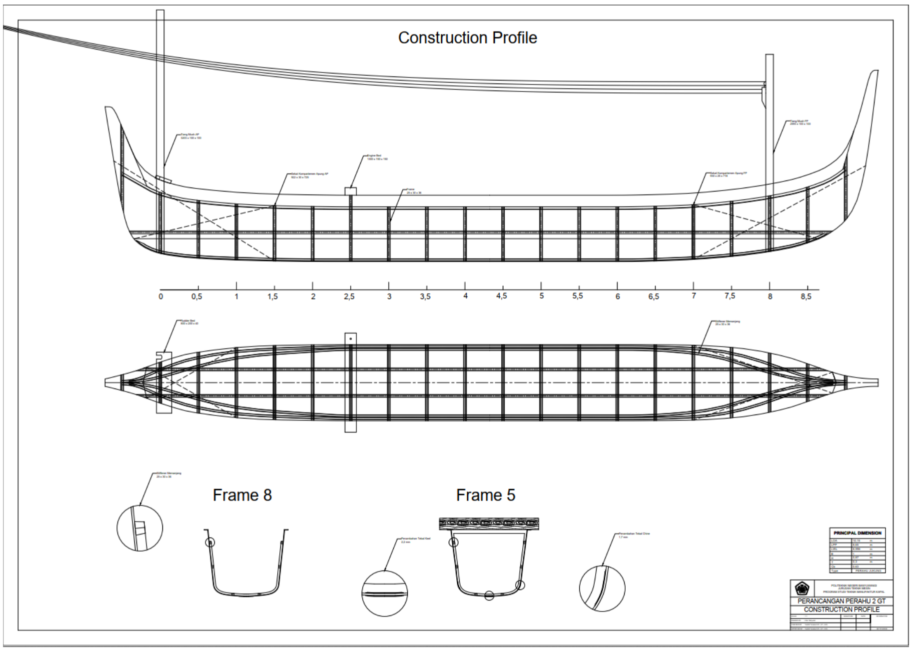

Figure. 11. Construction Profile

TABEL 8.
CALCULATION WEIGHT CONSTRUCTION

Item	Value	Unit
Weight Hull Boat		
Hull Area	23,021	m^2
Stomach Thickness	5,4	mm
	0,0054	m
Stomach Volume	124,3134	m^3
r Fiberglass	2,6	gr/cm^3
	2600	kg/m^3
Total Weight	323,21484	Kg
Weight Construction Cross		
Total volume of frames	0,0231	m^3
r Fiberglass	2,6	gr/cm^3
	2600	kg/m^3
Total Weight	59,9671	Kg
Weight Construction		
Total Volume of Stringer	0,0239	m^3
r Fiberglass	2,6	gr/cm^3
	2600	kg/m^3
Total Weight	62,05342	Kg
Weight Mush Mast & Engine Bed		
Total Volume	0,08425	m^3
Meranti Wood Density	630	kg/m^3
Total Weight	53,0775	Kg
Main Engine, shaft & propeller	30	Kg
Rudder	20	Kg
Anchor	10	Kg
Total	60	Kg
Weight Total LWT	**558,3**	**Kg**

2. Validation Construction

In Table 4.9, it is found that the LWT correction value is met, and the difference between LWT GA and construction LWT is 0.0180 tons which does not exceed the tolerance value (0.5% or 0.0288 tons), it can be said that the LWT used is qualified.

TABEL 9.
VALIDATION CONSTRUCTION

LWT	Calculation Formula	Nilai	Unit
GA Calculation	Displacement - DWT	0,5763	ton
Ship Construction	Weight of the Construction	0,5583	ton
Tolerance	5% x DWT	0,0288	ton
Tonnage Difference Between 2 Methods	LWT (GA) - LWT (Construction)	0,0180	ton

H. Load case

The load case aims to provide a load on the boat while sailing. The load case in question includes the weight of the boat's construction, the weight of the boat's cargo, the weight of the boat's equipment and all items on the boat.

In this analysis and testing, the author uses 3 load case criteria. Criteria 1 is when the boat leaves for sea, criteria 2 is when the boat is fishing and criterion 3 is when the boat is traveling home. Load case conditions are distinguished by the number of fish caught by fishermen.

The catch of fish by fishermen is uncertain depending on the conditions of the month. The results obtained by fishermen are at most 50 kg, but in the analysis that will be careful, the authors take 100 kg.

TABEL 10.
CRITERIA LOAD CASE

Load case 1	Load case 2	Load case 2
0,810 ton	0,710 ton	0,910 ton

I. Floating Compartment

1. Floating Compartment Original

In accordance with the field study, the author made measurements on the floating compartment on the fishing boat Pacemengan, Banyuwangi. The data obtained are as follows.

In the floating compartment used by fishermen, namely, the AP compartment length is 1.365 m and the FP is 1.325 m, it can be seen in Figure 12.

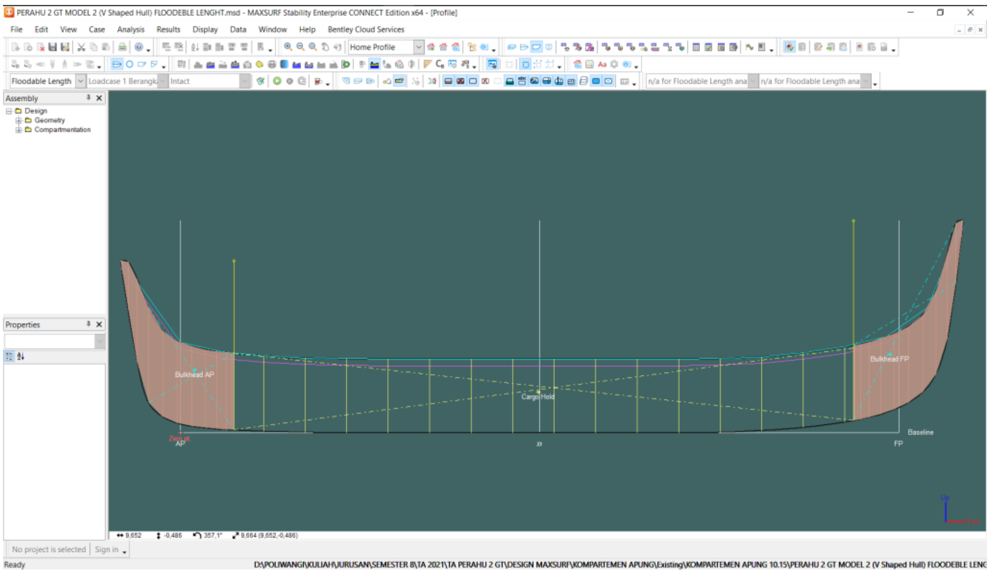

Figure. 12. Floating Compartment Original

2. Floating Compartment Planning

The design of this floating compartment refers to the BKI Watertight bulkhead Vol V 2021 Rules for Fiberglass Reinforced Plastics Ships, Sec 13 Watertight Bulkheads [3].

Collision Bulkhead = 0.05L (m) – 0.13L (m) from the front side of the bar

Collision Bulkhead = 0.13 x 8.65 m
= 1.1245 m from the front or rear end of the boat (min)

Because the floating compartment must be strong enough to float the boat, the impact and stern bulkheads are taken on frame 2 (2,225 m) and frame 14 (2,425 m). The inner floating compartment is left empty of air and there is no access to open or close it and this compartment is left permanently for safety in the event of a boat accident in accordance with (BKI, 2021). Can be seen in Figure 13.

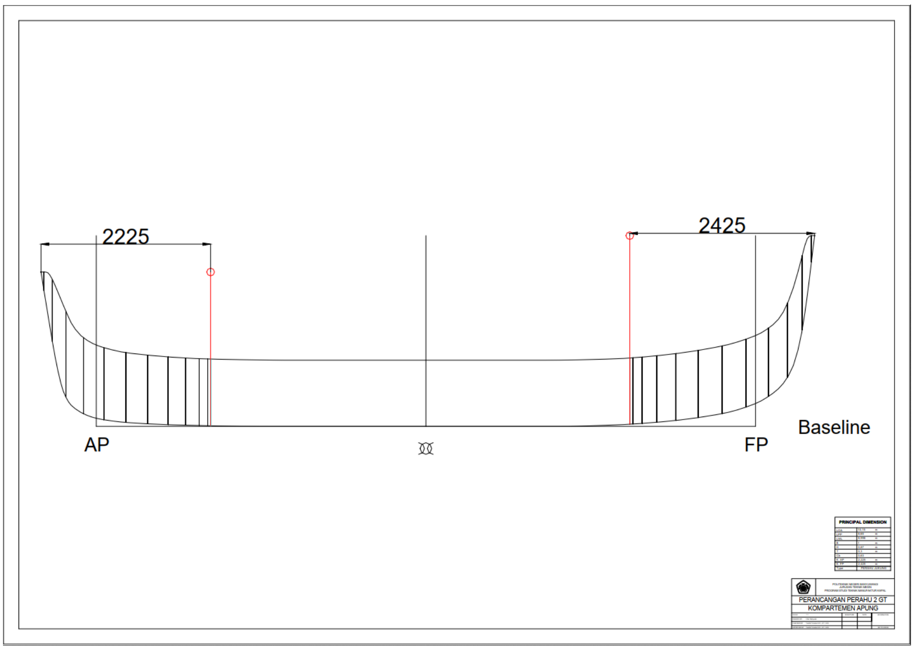

Figure. 13. Floating Compartment of Boat

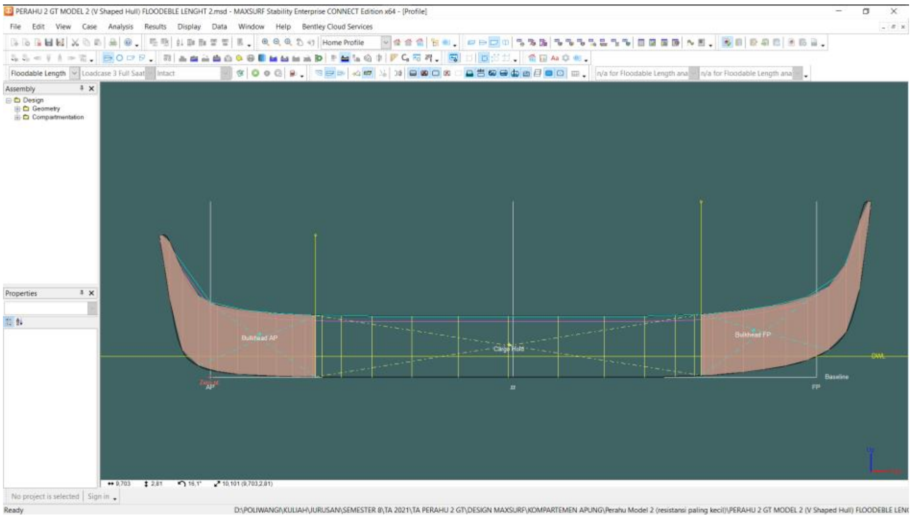

Figure. 14. Floating Compartment of Boat (Simulation Software)

TABEL 11.
VARIATIONS COMPARTMENT FLOATING

Model	Load case 1	Load case 2	Load case 2
Compartment Floating Original	0,810 ton	0,710 ton	0,910 ton
Compartment Floating Rules BKI	0,810 ton	0,710 ton	0,910 ton

III. RESULTS AND DISCUSSION

A. Analysis and Testing Floodable Length Floating Compartment

Floodable length analysis and testing aim to determine whether the original boat floating compartment and the boat floating compartment according to BKI can float the boat when the cargo space is flooded. This analysis and test use 3 load case criteria.

1. Floating Compartment Original

Analysis of the original boat floating compartment using 3 load case criteria. For the results of the original boat floodable length analysis as follows.

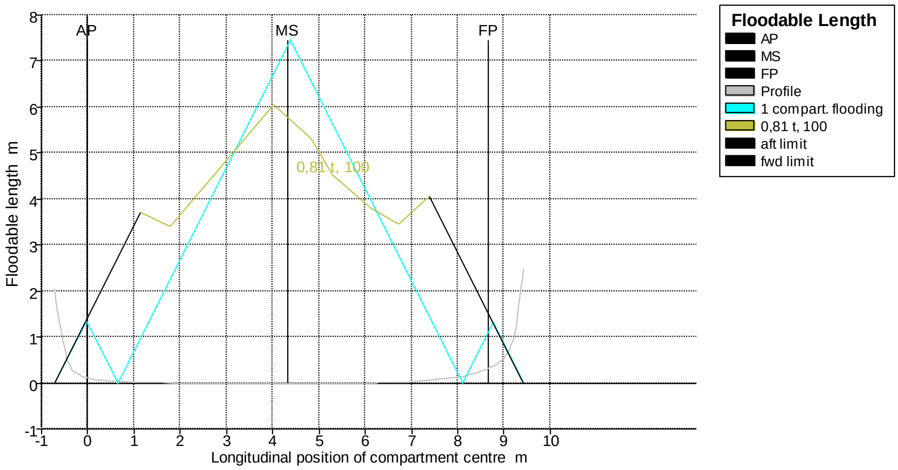

Figure. 14. Analysis Result Floodable Length Load case 1 Original Boat Floating Compartment

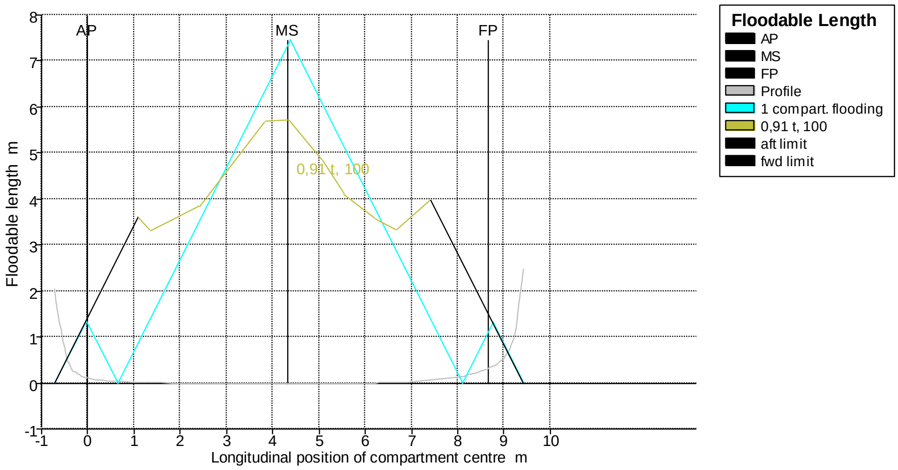

Figure. 15. Analysis Result Floodable Length Load case 2 Original Boat Floating Compartment

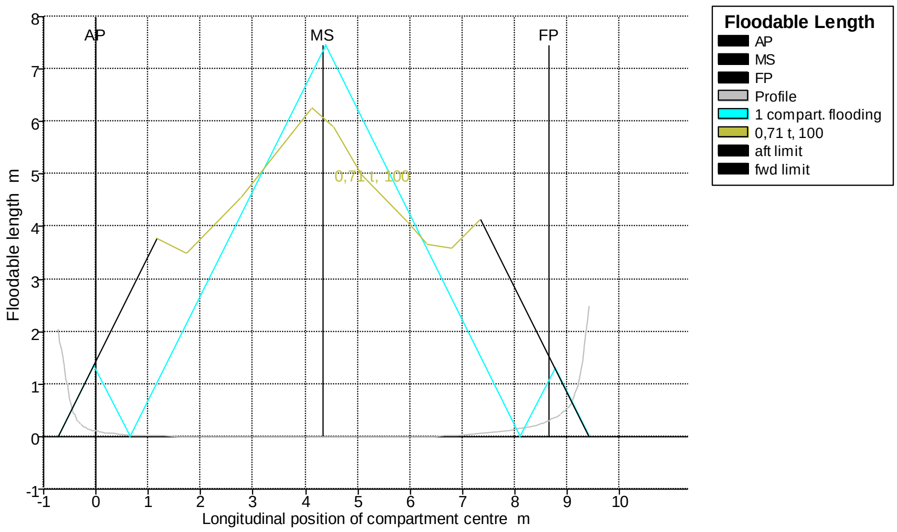

Figure. 16. Analysis Result Floodable Length Load case 3 Original Boat Floating Compartment

It can be seen in Figure 14,15,16, the results of the floodable length analysis show that the results of the graph of 3 load case criteria with a total weight of 810, 710, 910 kg boats, the original boat compartment is not strong enough to float the boat. The long line from the blue boat compartment exceeds the floodable length curve and it means that the boat is in a flooded condition, so the boat sinks.

2. Floating Compartment Model 2

The analysis of the floating compartment of the model 2 boat uses 3 load case criteria. The results of the analysis of the floodable length model 2 are as follows.

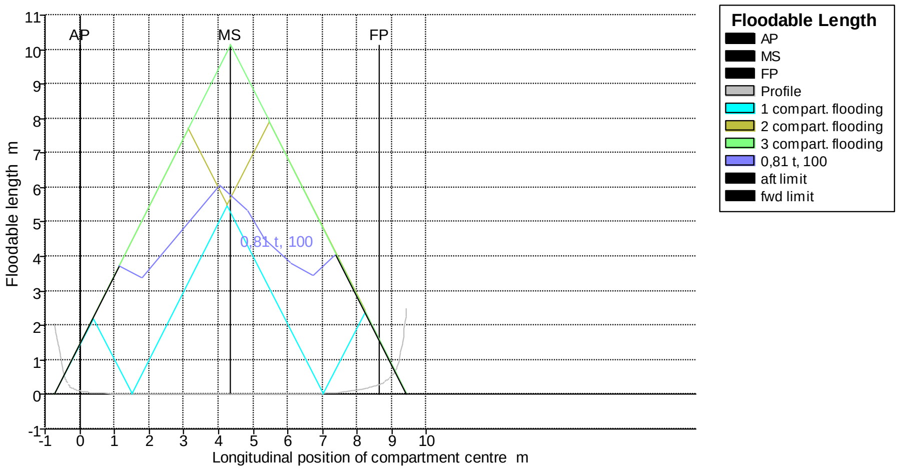

Figure. 17. Analysis Result Floodable Length Load case 1 Model Boat 2 Floating Compartment

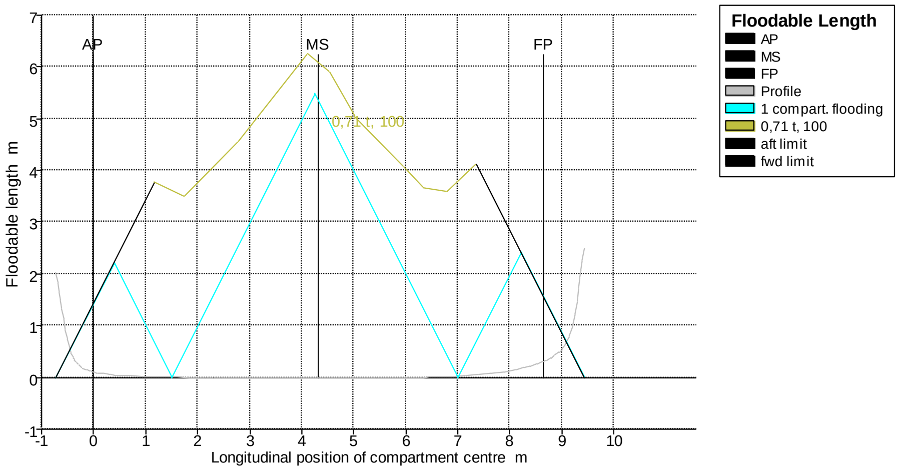

Figure. 18. Analysis Result Floodable Length Load case 2 Model Boat 2 Floating Compartment

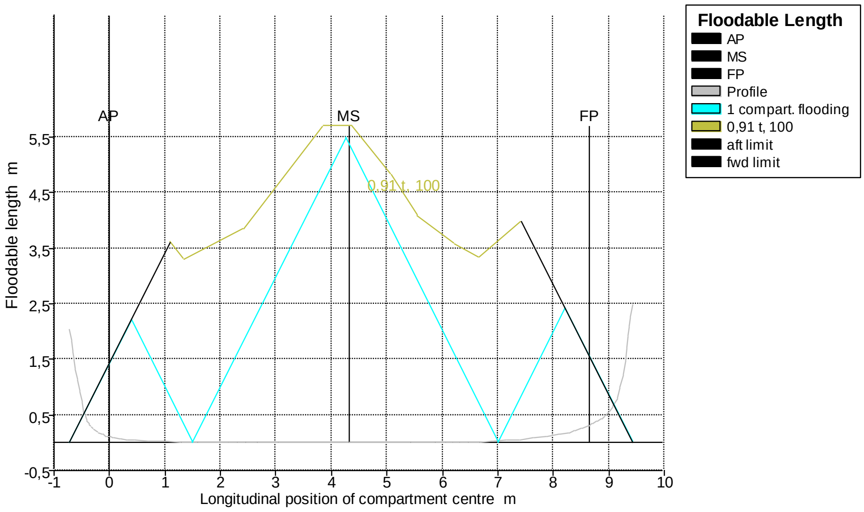

Figure. 19. Analysis Result Floodable Length Load case 3 Model Boat 2 Floating Compartment

It can be seen in Figures 17, 18, and 19 that the results of the floodable length analysis show the graphic results of 3 compartment load cases, designing a model 2 boat that is strong enough to float the boat. The long line of the blue boat compartment does not exceed the floodable length curve and it can be interpreted that the boat in the condition of the flooded cargo hold can still float.

IV. CONCLUSION

From the analysis and testing, it was found that the floating compartment used by fishermen at this time was still not big enough. Based on the BKI Vol V Rules for Fiberglass Reinforced Plastics Ships, Sec 13 Watertight Bulkheads 2021, the floating compartment design results in a Floodable length simulation that can float the boat when a leak occurs in the cargo hold with the size of the collision bulkhead and stern on frame 2 (2,225 m) and frame 14 (2,425 m), used on the Jukung model 2 boat. The boat sizes are LOA: 10.15 m, B: 1 m, B(wl): 0.882 m, H: 0.87 m, H: 0.3 m, Vs: 7 knots Cb: 0.63 and: 1,5371 tons.

Based on the design of the boat construction in accordance with BKI regulations, a mixed type of construction was chosen. The ivory distance is 500 mm with the stiffener type model h = 25 mm, bb = 30 mm, and bc = 36 mm. Meanwhile, the total stringer is 6 stiffeners.

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