

Model Comparison of The Floating Foundations for The Development of Floating Houses at Coastal Areas

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ABSTRACT

Floating house is a building, which stands or floats on water by relying itself on the weight and the area sunk as the load parameter compatible to the structure. This house can float or be placed on the seashore on the water. This research was conducted by comparing the magnitude of the floating force (Fa) of the three foundation materials of the houses, namely plastic drum, Styrofoam and bamboo. The materials were calculated based on the total load of the house (G), with the safety number of 1.5. .

The research result is the total load of the floating house structure (G) is 364.585,5 Newton (down), the floating force (Fa) magnitude of plastic drum as the foundation material is 549,814 Newton (upward), Styrofoam as the foundation material is 552,720 Newton (upward), and Bamboo as the foundation material is 540,883 Newton (upward). The amounts of the foundation materials for plastic drum are 232 pieces, for Styrofoam are 56 sheets, and for bamboo are 3900 sticks.

Keywords: *Floating house, floating foundation, floating force, plastic drum, Styrofoam, bamboo*

1. Introduction

At present, the development of residence in the coastal areas becomes the most important part in sustaining a continuous development, which leads to national welfare improvement, particularly to the people living in the area. Coastal area has a promising potential and becomes substantial factors, which improve the national economy. In both developed and developing countries, economic activities in the area are dominant following the population growth. This situation has direct impacts on the housings and settlements. But unfortunately, these housings and settlements in the area are not well organized and appear to be seedy, densely populated and uninhabitable.

In the frame of the research, the researcher would do analysis and comparison towards the floating house structure using plastic drum, Styrofoam, bamboo as the bottom structure or floating foundation. Other than analyzing the use of different foundation materials, the researcher would design a simple and economic floating house, which could be applied as a residential house for people living in the coastal areas. For the sloof, column and back ring structure, wooden materials were used. For truss, lightweight steel was applied, while for the top cover, Sakura roof was used.

2. Definition of Floating House

Based on the Law No. 4, year 1982 on housing, house is "a building that functions as a domicile and means of building a family". It is a place of commodity if interpreted as a noun and will be a state or process of human in building its occupant if interpreted as a verb, (Turner 1972 in Masri, 2010).

Floating house is a building structure built to float on water using a foundation system that has a high floating force, so it is able to hold the structure of the building above it which experiences from up and down movements according to the height (level) of the water (Asrasal, 2018).

2.1 Plastic Drum as Foundation Material

Foundation of the floating house design is a structure under the house that serves to withstand the total load of the house in order to float. The foundation materials of the house are the materials made of plastic drum, which has good, floating force, is light and is easy to find, as it is available around us.

2.2 Styrofoam as Foundation Material

Styrofoam is a material derived from a substance **b** polystyrene (PS). In the process of its production, it is mixed with air bubbles, so it can expand. It is light, as light as foam. In the construction of the foundation, the *Styrofoam* used was a beam Styrofoam with the length of two meters, width of one meter, and thickness of half meter. For the amount, it is tailored to the need. The bigger and heavier the design of building is, the more Styrofoam is needed.

2.3 Bamboo as Foundation Material

Bamboo is a light, hollow material. Most people think that the cavity in the middle of the bamboo is a weakness, and that is not true. The bamboo inside is hollow, but the central cavity on the bamboo is actually a strength and serves as a *bracer*. *Bracers* can reinforce bamboo and make the elements commonly used as structures lighter and less rigid. Bamboo is also elastic and does not break easily, so making bamboo structures stronger and more reliable. Because of its natures, which are light, hollow and strong, this

material is often used in the construction of floating houses or rafts in Indonesia. Bamboo serves as a foundation for lifting the building's loads so that it can float.

2.4 Determining Material Weigh (G)

Material weight (G) is the multiplication between the weights from the floating house component, which is multiplied with the weight of the floating house material.

$$G = V \times \dots\dots\dots(2.1)$$

Where :

G : Specific gravity (kg)

V : Material Volume (m³)

: Specific gravity (kg/m³)

2.5 Determining the Magnitude of the upward force (Fa) at the Floating Foundation

$$Fa = \frac{\mu \cdot d^2}{4 \cdot g \cdot l} \dots\dots\dots(2.2)$$

Where :

Fa : Floating force of completely submerged material (Newton)

: Fluid Density (kg/m³)

d : Diameter of floating foundation

: 3.14

g : Acceleration of gravity (m/s²)

l : Length of foundation material (m)

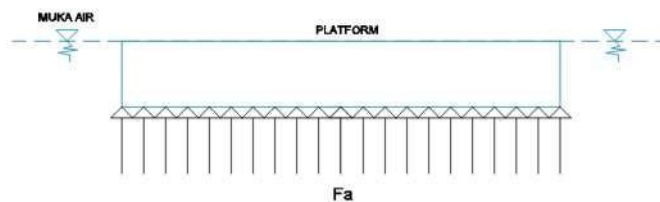


Figure 1. Upward pressure on the floating foundation completely submerged
(Source: Asrasal.2018)

2.6 Stability Control of Structure

Structure stability control is very important to know whether the floating foundation can float after being loaded by the upper structure of the building. In this research the

stability control value of the structure has been determined that it is equal to 1.5. To calculate structure stability, the following equation is used:

$$\frac{F_a}{G} > 1.5 \dots\dots\dots(2.3)$$

Where:

F_a : Floating force from the floating foundation (Newton)

G : Total weight of the floating house structure (kg/ton/N)

1.5 : *Sefty Factor* (predetermined safety number)

3. Research method

Before the analysis, data, which have been collected (primary and secondary data), are first processed to produce relevant information for the analysis, these data include:

1. Data of the floating house design, which function as a place to live with an area of the building (11m x 9,) = 99 m² and the area of the floating foundation (12 m x 15 m) = 180 m² as shown in the following figure.

2. Technical data from the floating foundation materials

In this research data analysis is needed to:

1. To calculate the structure and total weight of the floating house using SAP 2000 and Microsoft excel software.
2. To calculate the Budget Plan (RAB) of a floating house design using foundation materials made of plastic, styrofoam and bamboo drums. This calculation was conducted using Microsoft Excel software.

4. Result and Discussion

4.1 Loading at the Upper Structure

To calculate the weight of the upper structure in this research, the SAP 2000 software application was used. This application served to help calculate the amount of load in the design of the floating house, which consisted of the loads of roof, truss, column, ring beam, sloof, wall, door and window, as well as wind. While to calculate the load of fences and house floor plates, Microsoft Excel software was used.

Table 1. The Load Calculation Result of the Floating House using SAP 2000

TABLE: Joint Reactions									
Joint	OutputCase	CaseType	F1	F2	F3	M1	M2	M3	
Text	Text	Text	Tonf	Tonf	Tonf	Tonf-m	Tonf-m	Tonf-m	
16	COMB1	Combination	-0.0315	0.001	0.4644	-0.00055	-0.05035	-0.00089	
17	COMB1	Combination	-0.0301	0.0024	1.0865	-0.00372	-0.05071	-0.00079	
18	COMB1	Combination	-0.0144	-0.009	1.1694	0.01441	-0.02798	-0.00093	
24	COMB1	Combination	-0.0171	0.0008257	0.8384	-0.00526	-0.03361	-0.00283	
38	COMB1	Combination	-0.0155	0.0004657	0.7029	0.00003552	-0.03602	-0.00061	
39	COMB1	Combination	-0.0236	0.0035	1.5703	0.00129	-0.04115	-0.0009	
42	COMB1	Combination	-0.0187	0.0023	1.0126	-0.00065	-0.03485	-0.00068	
43	COMB1	Combination	-0.0215	0.0062	0.695	-0.00903	-0.04146	-0.00144	
44	COMB1	Combination	-0.0282	-0.0088	1.5144	0.00011	-0.05039	-0.00276	
45	COMB1	Combination	-0.0139	-0.0442	0.7587	0.0354	-0.02794	-0.00454	
46	COMB1	Combination	-0.0158	0.0037	0.2648	-0.00754	-0.02902	-0.00301	
47	COMB1	Combination	-0.0047	0.0054	0.3534	-0.00906	-0.02421	-0.00046	
48	COMB1	Combination	-0.0079	-0.0094	1.1889	0.01177	-0.01867	0.00007509	
49	COMB1	Combination	0	0	0.005	0.00042	0	0	
50	COMB1	Combination	-0.0158	0.0329	1.3861	-0.03596	-0.03097	-0.00082	
51	COMB1	Combination	-0.0257	-0.0137	0.8336	0.01352	-0.04467	-0.00006671	
52	COMB1	Combination	-0.022	0.0002573	0.9981	0.00319	-0.03942	-0.00072	
53	COMB1	Combination	-0.0158	-0.0085	1.4116	0.00517	-0.03447	-0.00151	
54	COMB1	Combination	-0.0369	0.0057	0.9241	-0.00937	-0.05496	0.00077	
56	COMB1	Combination	-0.0283	-0.0016	0.4386	0.00066	-0.04599	-0.00087	
57	COMB1	Combination	-0.023	-0.00061	0.8738	-0.0004	-0.04383	-0.00096	
58	COMB1	Combination	-0.0063	0.0067	0.6247	-0.01347	-0.01832	0.00073	
59	COMB1	Combination	-0.0213	0.0052	0.3887	-0.01133	-0.03674	0.0008	
60	COMB1	Combination	-0.0171	0.0125	0.7657	-0.01681	-0.03289	0.00137	
61	COMB1	Combination	-0.0189	0.0068	0.335	-0.0112	-0.03195	-0.00246	
Jumlah Berat Total					20.6047	Ton			

From the load calculation result using software SAP 2000, it is reported that the total load of the upper structure is 20.6047 tons or 20604.7 kg

a. Load of the Upper Structure calculated using Microsoft Excel

Load on the floor plate

Size of the floor plate : 200 x 20 x 0.2 cm
 Volume of the floor plate : 3.6 m³
 Specific gravity of wood : 1.25 kg/cm² (1250 kg/m³)
 Weight of wood : Volume x BJ
 : 3.6 x 1250
 : 4,500 kg

Load on the fence

Size of wood beam : 10 x 10 cm
 Volume of the fence : 1.787 m³

Specific gravity of wood	: $1.25 \text{ kg/cm}^2 = 1250 \text{ kg/m}^3$
Weight of wood	: Volume x BJ
	: 1.787×1250
	: 2,233.75 kg

b. Live load

Occupant Load	: 6 People
Weight per person	: 80 kg (assumption)
Total life load	: $6 \times 80 \text{ kg}$
	: 480 kg

The total load acting on the Upper structure is:
 $= 20,604.7 \text{ kg} + 4500 \text{ kg} + 2,233.75 \text{ kg} + 480 \text{ kg}$
 $= 27818,45 \text{ kg}$ (Downward direction)
 Conversion kg - Newton
 $= 27,818.45 \times 10$
 $= 278,184.5 \text{ Newton}$ (Downward direction)

4.2 Loading on the under structure

The load on the lower structure for the floating house came from the load of the foundation framework, which was located under the sloof, composed of wooden frames, bound and integrated with the structure of the floating house.

a. Framework Load of the foundation

Vertical Wood Beam Load

Size	: 8 x 12 cm
Volume	: 3,456 m ³
Specific gravity of wood	: 1.25 kg/cm^2 (1250 kg/m ³)
Weight of wood	: Volume x BJ
	: $3,456 \times 1250$
	: 4,320 kg

Horizontal wood beam load

Size	: 8 x 12 cm
Volume	: 3,456 m ³
Specific gravity of wood	: 1.25 kg/cm^2 (1250 kg/m ³)

$$\begin{aligned} \text{Weight of wood} & : \text{Volume} \times \text{BJ} \\ & : 3,456 \times 1250 = 4,320 \text{ kg} \end{aligned}$$

The total load acting on the lower structure: the total load of foundation framework
 $= 4,320 \text{ kg} + 4,320 \text{ kg} = 8,640 \text{ kg}$ (Downward direction)

$$\begin{aligned} \text{Conversion kg} - \text{Newton} \\ = 8,640 \times 10 = 86,400 \text{ Newton} \text{ (Downward direction)} \end{aligned}$$

4.3 Total weight of structure (G)

Based on the results in the load calculation of the upper and lower structures for the floating house design, the total weight of the house is:

Total structure weight due to working load:

$$\begin{aligned} \text{Total Load of the upper structure} + \text{Total Load of the lower structure} \\ = 27818,45 + 8640 \text{ kg} \\ = 36458,45 \text{ kg (downward)} \end{aligned}$$

$$\begin{aligned} \text{Conversion of Kg to Newton} \\ = 36458,45 \text{ kg} \times 10 \text{ (downward)} \\ = 364.585,5 \text{ Newton (downward)} \end{aligned}$$

4.4 Floating Force Analysis (Fa)

Floating force analysis (Fa) refers to the analysis of the magnitude of the floating force in a floating foundation material, which will be compared to the downward force due to the weight of the floating structure. A floating foundation is considered strong or stable when the upward force (Fa) is more than the total weight of the structure (G). In this research, the comparison value between the magnitude of the floating force and the weight of the house structure is 1.5. The followings are a comparison of the force among the three materials (plastic, Styrofoam and bamboo drum).

4.5 The analysis of floating foundation made of plastic drum

Based on the calculation results in the analysis, it is revealed that the magnitude of the floating force (Fa) is 549814 Newton (upward), using 232 plastic drum as the foundation materials. Therefore, the foundation system was made in one layer with the arrangement as shown in Figure 2. below.

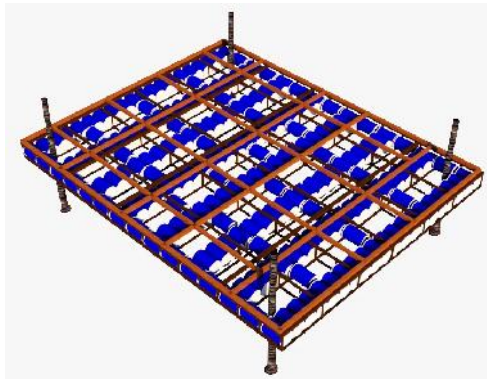


Figure 2. Placement detail of plastic drum as the floating foundation material (as many as 232 pieces)

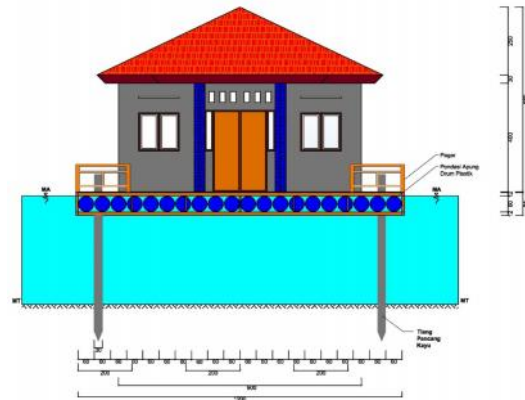


Figure 3. Front view of the floating house with the plastic drum as the foundation material

The calculation analysis of the Styrofoam as the floating foundation material. Based on the calculation results above, the floating force (F_a) is 552.720 Newton (upward), using 56 pieces of Styrofoam as the foundation material. Therefore, the foundation system is made in one layer with the arrangement as shown in Figure 4 below.



Figure 4. Placement detail of Styrofoam as the floating foundation material (as many as 56 sheets)

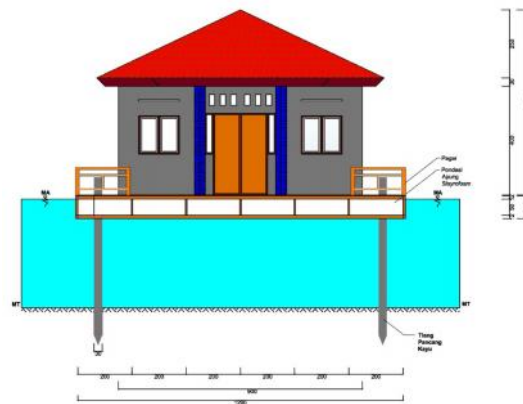


Figure 5. The front view of the floating house with Styrofoam as the foundation material

4.6 The calculation analysis of bamboo as the floating foundation material

Based on the result in the analytical calculation above, it can be inferred that the floating force (F_a) magnitude is 540.833 Newton (Upward), using 3,900 sticks of bamboo as the foundation material. This bamboo had the length of 5 meter and the diameter of 0.1 m.

Therefore, the foundation system was made by tying the bamboo on the beam of 6 cm x 12 cm, with the length of 5 meter, with the width of 1 meter, and with the thickness of 1.5 meter, filled up with 150 sticks for one bunch of bamboo. There are as many as 26 bunch of bamboo and all were installed one layer with the arrangement as shown in figure 6 below.

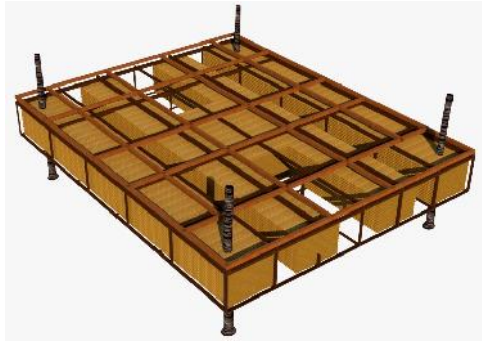


Figure 6. Placement detail of bamboo as the floating foundation material (as many as 3900 sticks)

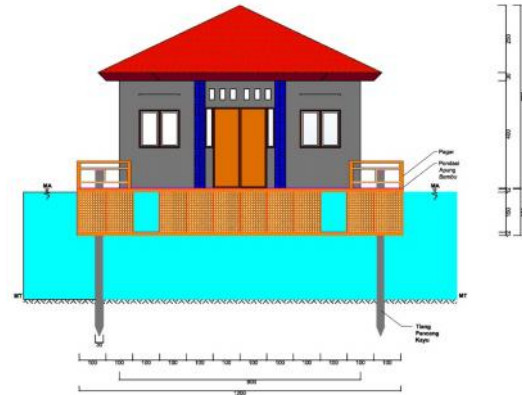


Figure 7. The front view of the floating house with bamboo foundation

4.7 Comparison Summary of the Three Material Foundations

This recapitulation aims to find out in detail the results in this research pertaining to the use of the three types of foundation materials, and to find out the comparison, starting from the floating force (F_a), the amount of foundation material, the stability control of the structure and the total amount of the Budget Plan. For more information, details can be seen in the following table:

Table 2. The recapitulation result in the three material comparison

No.	Floating Foundation Materials	Floating force (F_a)	The amount of materials	Stability control	Value of budgeting plan
1	Plastic drum	549,814 Newton	232 Pieces	1.5	IDR. 358,270,000.00
2	<i>Styrofoam</i>	552,720 Newton	56 Sheets	1.5	IDR.360,140,000.00
3	Bamboo	540,883 Newton	3900 Sticks	1.5	IDR. 369,066,000.00

5. Conclusion

Based on the analysis result in the discussion of the previous chapters, it can be concluded as follows:

1. From the analysis result in the discussion, it is revealed that the total weight of the floating house structure (G) is 36,585.5 Newton (downward), the safety number allowed

in the research is 1.5, so the floating force magnitude (F_a) is obtained among the three foundation materials:

- a. Plastic drum as the foundation material : 549.814 Newton (Upward)
 - b. *Styrofoam* as the foundation material : 552,720 Newton (Upward)
 - c. Bamboo as the foundation material : 540.883 Newton (Upward)
2. From the analysis result, it can be reported that the amount of foundation materials of each type of the floating foundation is as follow:
- a. Plastic drum as the foundation material : 232 pieces
 - b. *Styrofoam* as the foundation material : 56 slices
 - c. Bamboo as the foundation material : 3900 pieces
3. From the result in the calculation analysis of the budget plan, it is revealed that the total expenses from each foundation are as follow:
- a. The budget plan value of plastic drum as the foundation material Rp. 358,270,000.00
 - b. The budget plan value of *styrofoam* as the foundation material Rp. 360,140,000.00
 - c. The budget plan value of bamboo as the foundation material Rp. 369,066,000.00

From the results of the above analysis, it can be concluded that design of the floating house using plastic drum as the floating foundation material is cheaper or economical compared to the floating foundation made of either *Styrofoam* or bamboo.

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