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Design and Estimation of Low Cost Floating House

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ABSTRACT: An attempt was made to design a low cost floating house suitable for people in low lying areas such as Bangladesh. The prototype house considered for the present study has the carrying capacity of 1850 kg loads with sufficient freeboard of 30% excluding the self weights of the supporting ten airtight empty steel drums in water and having a floor area of 120 ft^2. These steel drums that are locally available and provide an atmosphere to live in without the fear of losing possession during flood. The value of metacentric height (10.22 ft) of the designed house was found to be positive indicating its stability at floating condition. The angular displacement of the house due to wind action was also calculated and this floating structure would be stable up to the wind speed of about 160 km/hr. To provide sanitation a floating toilet can be hinged with the structure. It would definitely give an eco-friendly out look to the structure. For variable fencing, flooring, roofing and floating elements costs were estimated to determine the most economic feasibility. The most economic house was supposed to be made of locally available materials such as chhon and golpata. But from the engineering point of view the most stable and durable house was found to be CI- sheet and angle bar. Above all, the house made of Bamboo could be used on the basis of availability and durability. This house could be used all the round year as a permanent address for landless people and gypsies.

KEYWORDS: Floating House, Metacentric Height, Moment of Inertia, Low cost House.

INTRODUCTION

Floating house is a unique mechanism of living on a buoyant platform without the fear of sinking and get afloat with the rising ups and downs according to the water level. It is not a house boat, but an actual house that's designed to float. The concept of these types of house developed to get rid of the debilitating and expensive damage due to floodwater incursion in low lying areas around the world. Different types of modern constructional materials are used in modernize floating structure and providing all the amenities required in this house. Two types of floating house are basically designed. One sits permanently on water as boat and another is an amphibious house that stand on dry land but in the event of flood able to rise with water**.** The Dutch technology consists of a floating concrete container that can be used as a lower level or cellar. The Canadian technology consists of a square container turned upside down and filled with polystyrene, an unsinkable structure. Switzerland architects design floating house on a catamaran pontoon which consists of 98% plywood from locally sourced birch. Ali (1995) and Suman (2007) had developed floating poultry house for flood-hit areas which may also used as flood shelter. They used local available material for the construction of this house. Abul Hasanat Mohammed Rezwan (URL) introduced solar-powered floating or boat school in 2002 for children with library, heath and extension work facilities. Bangladesh is located in the deltaic region of three enormous rivers. As the sea level is rising, the water from the floods is no longer being quickly pulled down towards the ocean. Tidal flow are most common scenario in the southern region of the basin area of Bangladesh and every year it appeared as havoc and made millions of people victims by losing their possessions and lives. So a vast area remains under water all round the year. However, floating people may sort out their dwelling problems using country boats of different types. But the costs of large boats are high which cannot be afforded by rural people. There are lacks of sanitation facilities in boats. Inadequate supply of well finished timber in the market is also a reason of choosing floating device other than boats. About half of the total population in the country is landless and lead a miserable floating life. Considering the reasons above an attempt was taken to make a low cost floating house that would be stable and durable.

Hence the present study was conducted with a view to address the following objectives:

- To design a floating house suitable for all the year round in flood affected area and used as a flood shelter.
- To analyze the stability of the designed house against the wind action at floating condition.
- To estimate the cost of floating houses made of different constructional materials for economic viability.

METHODOLOGY

An amphibious floating structure was designed to use it as a flood shelter with all the amenities so that one can meet their natural need during flood. To float the structure an assumption was made that drums should be provided in such a way that it will remain in complete balance. However, local materials were selected to design the floating house. In the present study a 'Middle class' family was considered as the family in the rural areas who has enough earnings to run the family easily for the whole year. Mostly its source of income is from agricultural products. The family was considered of five member's family. It consists of father, mother and three children. For design consideration their approximate body weights were considered as 60 kg, 55 kg, 40Kg, 15 kg and 10kg i.e. the total is 180 kg. To provide sanitation facilities a floating toilet must be hinged in such a way that stability of the floating structure does not hindered.

Considerable incoming loads in the house

For design purpose the weights are considered as given below:

The total weight of the family members	= 180 kg
Weight of food (one month)	= 250kg
Weight of seed of different crops	= 200kg
Self weight of the structure	= 900 kg
Weight of stored drinking water	= 80kg
Weight of the utensils, cloth and others	= 200 kg
Total weights	= 1810Kg

Design consideration

In designing the floating body 30% of drum diameter was maintained as free board above water surface (Garg, 2003).So, the total buoyant force was calculated as following:

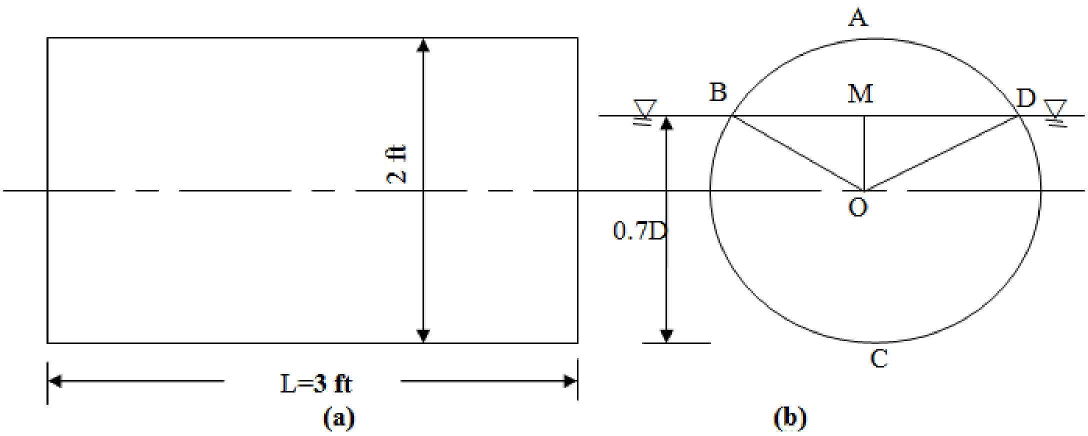


Fig.1 Front view and cross sectional view of a drum

The number of drums required to construct floating house are calculated from the ratio of total weight of structure and the net buoyant force developed by a drum (Suman *et al*, 2008).

Determination of center of gravity of the floating body (G)

Since, the whole floating body dealt in this experiment consists of different segment having different weight and shape, so center of gravity is to be determined following the law of composite body.

Now, the centroid distance of ABCDEF is Z_1 ft from the drum base (Meriam & Kraige, 1987), then Z_1 was calculated from the equation (1) and (2)

Z_1*ABCDEF=6*(8*12)+12*(4*12) (1)

Z_2 * 1900 = 1*50 + 8*900 + 5* 950) (2)

Determination of center of Buoyancy (B)

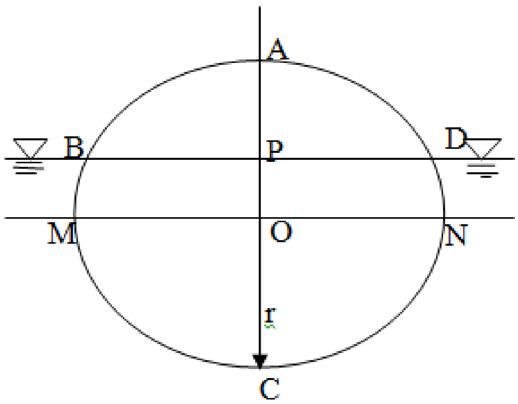


Fig.2 Determination of center of buoyancy

The distance of centroid of the BCD portion is Z_3 from base of the drum was (Ferdinand & Russell, 1978); **(**Fig.2).

Z_3 * area of BMCND = ($\frac{3\pi r - 4r}{3\pi}$) * area of semicircle + ($\frac{op}{2}$ +r)* BMND (3)

Determination of Moment of inertia (I)

In this experiment, only drums are in submerged condition, that's why the moment of inertia will be the combination of four water line sectional area of those drum. The plan view of water section area for four drum is given in Fig. 3.

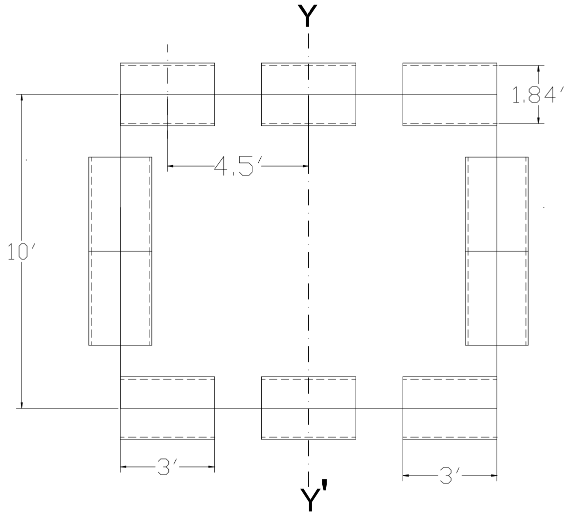


Fig.3 Determination of Moment of inertia

Moment of inertia for any drum along its center line (Meriam & Kraige, 1987), was calculated from equation(4)

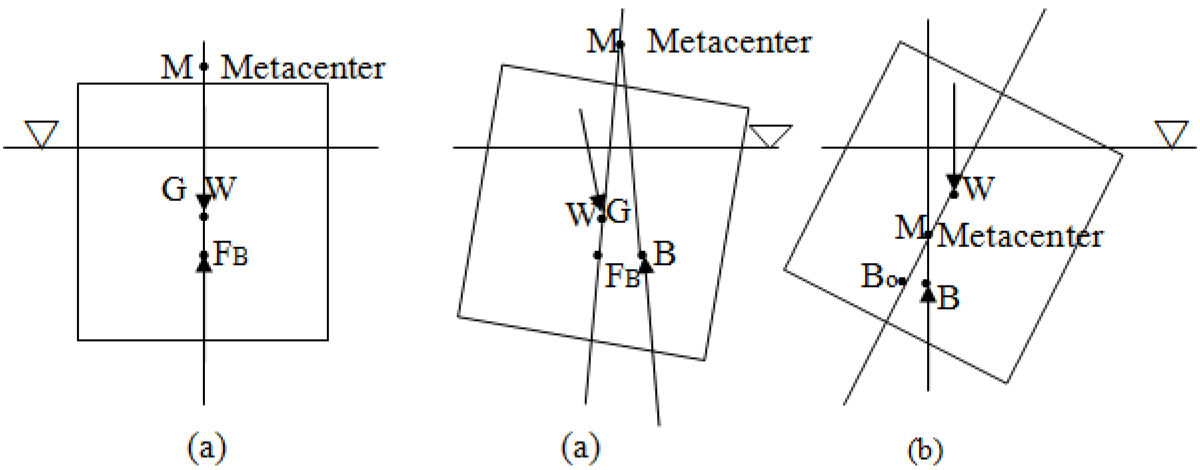
$$I_1 = \frac{1}{2} \text{*actual diameter of drum*(Lengh of drum)}^3 \qquad \textbf{(4)}$$

and moment of inertia for any drum With respect to Y-Y axis,

$$I = I_1 + 4.5^2 \text{ * (actual diameter of drum * Lengh of drum)} \qquad \textbf{(5)}$$

Stability analysis

A floating body is said to be stable if it comes back to its original position after slight disturbance (Bansal, 2005).Two alternate moments may act on the floating body depending on the relative position of center of gravity (G) and center of buoyancy (B) as shown in Fig. 4.



(a) Stable equilibrium, M is above G (b) Unstable equilibrium M is below G

Fig. 4 Stable equilibrium and unstable equilibrium of a floating body

The point M is known as the metacenter and its distance GM from the center of gravity is termed as metacentric height and was calculated by **,GM = MB_o - GB_o** **(6)**

For stable condition, GM must be positive (King *et al.,* 1963; Khurmi, 1998).

For small disturbance (Angle should be <5^0), **MBo =** $\frac{I}{V}$ **(7)**

where,

I = Moment of inertia of the water line section about the longitudinal axis through central point.

V = Volume of water displaced by submerged body.

Wind Force

Wind force was calculated by resolving θ from the Fig. 5. Also, a computer program was developed for calculating angular displacement of floating structure at different wind forces.

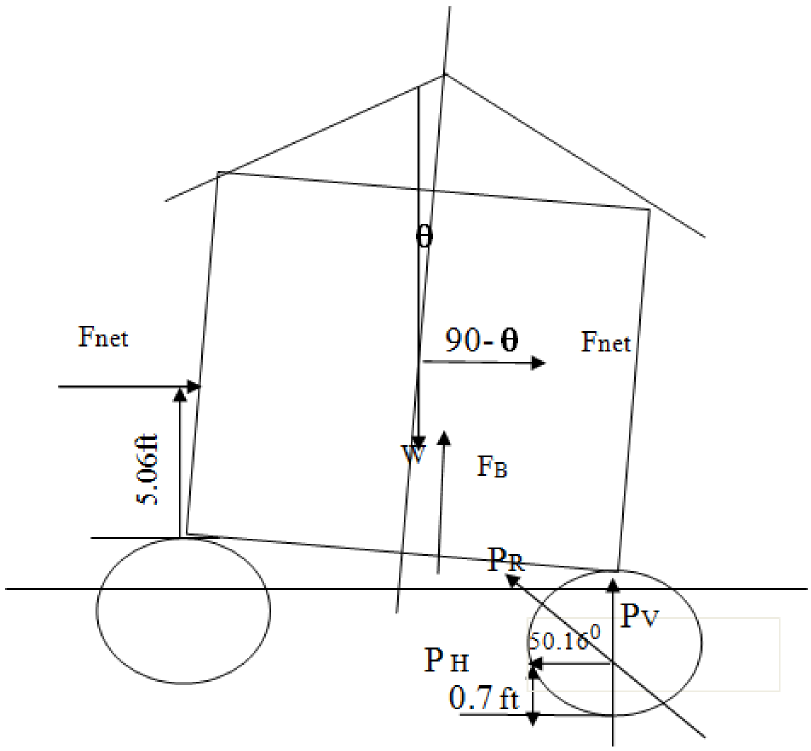


Fig. 5 Determination of resistance force of water

Considerations for sanitation

To provide sanitation a floating toilet was hinged with the main structure without disruption of the stability of the structure. A single drum will provide as septic tank with the capacity of holding sewage for three days. It also worked as a floating body for the toilet structure. After three days the drum will conveyed to the bank of the river and for exodus of sewage, a pit would dig at the bank of the river. For increasing capacity of holding sewage the drums can be used which are attached with the side wall of the main structure.

Estimation of Cost

With the consideration of locally available material, durability of the constructional materials and stability the structure, different types of materials are chosen for the estimation of the cost of design floating house. Different types of floating body such as drums, tires and boat are considered for estimating the cost and to find out the most economic and durable structure.

RESULTS AND DISCUSSION

The floating was designed by taking a dimension of 10′×12′ where a family with five members reside on it. The height of the house was considered 8 ft. The house will float on water during flood or any time as it is used. It required 10 steel drums of size 2 ft diameter and 3 ft long. The house then able to carry 1850 kg loads sufficiently with 30% free board excluding self weight of the drum.

Stability Analysis

Since, during flood or rising in water level there is possibility of tilting the house, so a details stability analysis was made with light of fluid mechanics. It was found that the combined center of gravity of whole floating body with loads in at 7 ft above the base of floating drum and the center of buoyancy was 0.78 ft above the base of the drum. The combined moment of inertia was found as 1159.2 ft^4**.** The metacentric height (GM), the principle criterion of the stability of the floating body was found as **10.22ft.** The positive value of GM indicates that the floating house able to gain its stable condition, if small angular displacement (<5°) is given in that structure. The net force is responsible for tilting of the house which was 8 kg at a wind speed of 85 mph. The tilting angel was calculated from the balance equation of righting moment of buoyancy and overturning moment for the net force which was found as 0.15^0. This value ensured the condition of small angular displacement, which was considered in calculating the metacentric height. It was found that from the computer program the floating structure would be stable up to the wind speed about 160km/hr.

Estimate of cost

Considering the economic condition of floating people an investigation was carried out to find a suitable building material which has economic viability and durability. So that, variable fencing, roofing and floating materials were considered to validate the cost. Estimated cost for a Bamboo Fenced floating house is shown in Table.1.

Table.1.Estimated Cost for Bamboo Fenced Floating House

Sl. No.	Materials	Quantity	Rate	Price (Taka)
1.	Fencing			
	a) Bamboo pillar	3 pieces	Tk.167.67/Pieces	503.00
	b) Bamboo wire	6 pieces	Tk. 50/Pieces	300.00
	c) Bamboo Mat	6 Nos.(5'×8')	Tk. 50/chatai	300.00
	d)Timber for door(2) and window(2)	1.5 cft	Tk.1200/cft	1800.00
	e) Nails	1.5 kg	Tk.60/kg	90.00
	f) G.I. wire	1.5 kg	Tk.60/kg	90.00
2.	Roofing			
	a) Wood frame and rafter	2.3 cft	Tk.1400/cft	3220.00
	b) Bamboo purlin	3 pieces	Tk. 50/Pieces	150.00
	c) Screw	1 kg	Tk.100/kg	100.00
	d) CI-sheet	1.2 ban	Tk.4000/ban	4800.00

Table.1.Estimated Cost for Bamboo Fenced Floating House

Sl. No.	Materials	Quantity	Rate	Price (Taka)
3.	a) Ceiling	1 No. (12'×10')	Tk. 80/chatai	80.00
	b) G.I Wire	1 kg	Tk.60/kg	60.00
4.	Flooring			
	a)Wooden Frame	2.3 cft	Tk.1400/cft	3220.00
	b) Bottom frame of bamboo mat	3 pieces	Tk.167.67/Pieces	503.00
	c) bamboo mat	1 No.((12'×10')	Tk. 80/chatai	80.00
	d)Nails	1.5 kg	Tk.60/kg	90.00
	e)G.I. wire	0.5 kg	Tk.60/kg	30.00
5.	Float			
	a)Drum	10 Nos	Tk.1000/Drum	10000.00
	b)Weilding	20 bars	Tk. 30/bar	600.00
6.	Labour cost	a) 1 labour/day(4 days)	Tk. 200/day	800.00
		b) 1 carpenter/day(3 days	Tk. 250/day	750.00
7.	Transportation cost			500.00
8.	Miscellaneous cost			850.00
9.	Subtotal cost			**28916.00**
10.	Floating Toilet			2500.00
			Grand Total =	Tk.31416.00

The cost of a bamboo fenced house with CI-sheet roofing above on drum was estimated to Tk. 31416 where as the cost varied to Tk.**44880** for CI-sheet fenced house with angle bar. But the stability and durability of CI-sheet structure was more than the bamboo fenced structure. For a middle class farmer’s family this type of shelter reduced the misery and damage of food, seeds and livestock during flood. If the fencing, flooring and roofing(i.e. chhon, golpata, kanchi and hard board) materials are changed by the locally available cheap resources than the cost would reduced to Tk. 25820 to Tk. 29631. Variation in estimated cost for different floating house is shown in bar chart (Fig.6).

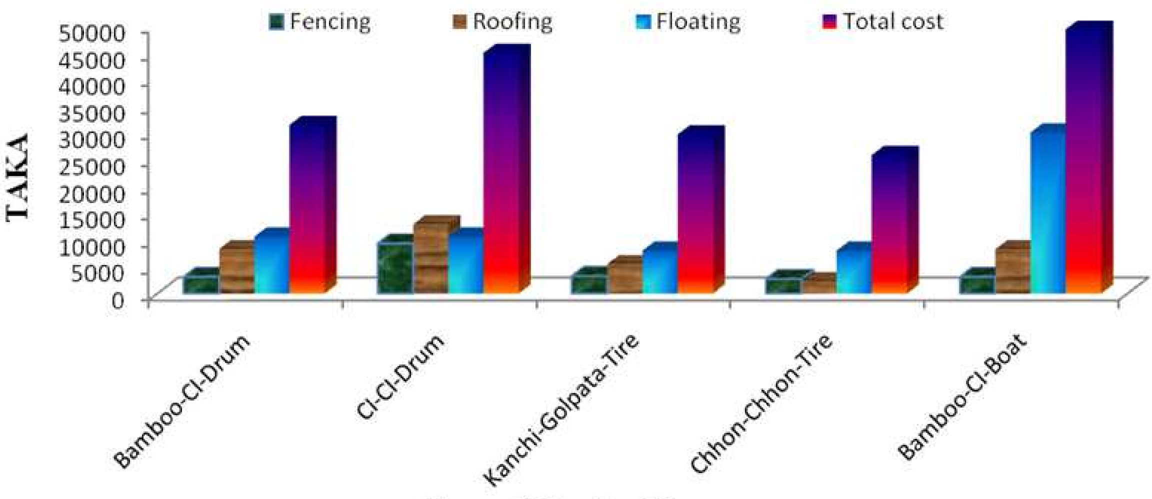


Fig. 6 Variation in Estimated Cost for Different Floating House

For landless poor community, gypsies and bede community people, this type of house may be a permanent shelter for themselves with low cost. People can use this type of house for transportation. One can easily choose their type of house for themselves with variation in fencing, flooring, roofing and floating elements which would results in fluctuation in cost. Hence the real cost of construction of such type of house would be reduced substantially.

CONCLUSIONS AND RECOMMENDATIONS

The designed floating house had been found stable from engineering point of view and it had been found economically viable if the house was constructed by locally available materials. This house has the capacity of accommodating the family members of the owner including all necessary commodities they need to live with sufficient safety and comfort during flood with internal space arrangements. If this house was constructed practically then the merits and demerits of this house may come out more basically. The designed floating house is suitable for the flood-hit areas and providing a permanent address for dwelling in a home like environment to the landless people and gypsies. Instead of drum, airtight plastic cylinder may be used to increase the durability. To rear the poultry and livestock another floating house would be made hinge with the main structure. The sanitation facility can be improved by the use of honey pot with pump and the hose pipe connects to the nearest sewage line or the nearest pit. For low costing the single drum may be used as septic with three days capacity. Then it will distinguish as an eco-friendly structure. With the provision of solar power the house may enjoy the electricity and it would definitely change their life style. The information and the design facts of such floating house should reach to the concerned communities through different media towards fostering them to use this functional live saving invention.

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