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Floating Architecture: A Design on Hydrophilic Floating House for Fluctuating Water Level

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Abstract

Even it is difficult to live against the water, it is possible to live with the rising water level. Global warming increases the mean sea level all over the world. The rising water level occupies the land surface. Netherland is the place where most of the land surface is not available for the construction of houses, the land surface were all taken away by the rising water. It is the only way for them to live with the rising water, and they started constructing houses on the water itself. A floating house of dimension 6.15m x 4.33m x 3m is designed for a water depth of 6m. Staad.pro v8i software is used for the analysis of structural members in the floating compartment. Manual design for the entire floating house is done. Stability analysis of the structure is also carried out for the safety of the structure.

Keywords: Floating House, Global Warming, Netherland, Rising Water Level, Staad.pro v8i

1. Introduction

Global warming is affecting many parts of the world. Global warming makes the sea rise, and when the sea rises, the water covers many low land islands. This is a big problem for many of the plants, animals, and people on islands. The water covers the plants and causes some of them to die.

This project focuses on the construction technology of integrated floating house for fluctuating water level. The development of integrated floating house system is a new idea and approach at present. The idea behind this project is a conceptual model designed by Dura-Veermer.

Our earth has a high density of 5.52 g/cm^3. The floating technology itself is a great challenge because most of the material of our earth having higher density compare to water which is 1 g/cm^3. The selection of the materials with consideration of density and strength will determine the practicality of this construction technology.

Due to the new concept of construction technology of integrated floating house, most of the knowledge and ideas have to be obtaining from the overseas researches and experts. It will be an obstacle to gain the reliable resources and ideas from overseas experts and match to our country's situation and local requirements.

2. Aim and Objectives

The aim of this project is to develop an integrated floating house conceptual model for fluctuating water level. To achieve the aim, there are three main objectives as below.

- To investigate the basic fundamentals of floating system.
- To investigate the current system in floating house.
- To develop the floating house technology by taking into the consideration of ability to endure the lateral current effect, floating stability and foundation system.

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3. Scope and Limitaiton

3.1 Scope

The scopes of the project are:

- The study focus on the floating house which is integrated with a house structure.
- Comparison with the existing concept and suit to our requirements.
- The floating part has to be simple float that has the characteristics of stable and can withstand lateral forces from the water current[3].

3.2 Limitation

The project is based on the limitation of -

- The study focus on Construction Technology of floating house with regard floating system, support system, construction technology and not includes the detailed analysis of the structure.

4. Degree of Floating Stability

The term stability refers to the tendency of a body to return to its original state after it has suffered a small disturbance[4]. The degree of stability refers to how quick will the body return to the upright or its original position (Rawson and Tupper, 2001). For floating structure, the structural stability is very important to prevent structural failure caused by bending moment and displacement. Moreover, failure in maintaining the floating stability will cause the object to overturn[5]. Thus, the stability is one of the security requirements for all the floating structural design.

For the study of floating stability, its purpose is to determine the positions that various solids will assume when floating in a fluid, according to their form and the variation in their specific gravities[6]. For rigid body in a state of equilibrium, the resultant of all forces and resultant moment of the forces is equal to zero. If the rigid body subjected to a small disturbance from a positive equilibrium, tends to return to that state, it is said to possess positive stability[1,2]. If the disturbance causes the rigid body excursion from the equilibrium positive position tends to increase, then the body is said to be in a state of negative stability. For stability the meta-centric height GM must be positive[7]. Stability (restoring force) increases with increasing GM (White, 1994).

According to Roberson and Crowe (1993), the floating stability of an object is determined by the center of the buoyancy (C, the centroid of the displaced volume of fluid) of a floating body which depends on the shape of the body and on the position in which it is floating. If the body is disturbed by a small angle of heel, the center of buoyancy changes because the shape of the submerged volume is changed. The point of intersection of the lines of action of the buoyancy force before and after heel is called the Meta-centre (M) and the distance between the center of Gravity (G) and M, is called the meta-centric height (GM)[8].

The expression for the meta-centric height GM is,

$GM = I_{oo}/V - CG$

For a cubical object to float in a liquid of density, ρ, with a depth of immersion, h, the centre of buoyancy is C, and Gc and Gb are the centers of gravity of the object as shown in Figure 1. The centre of gravity of the object is G and its meta-centre is M.

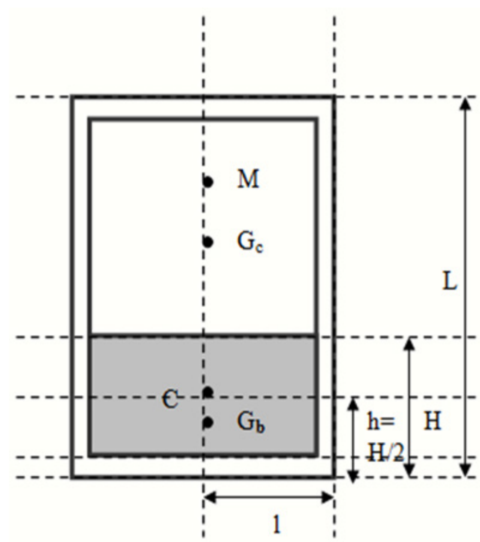

Figure 1. Meta-centric height for cubical floating body.

The formula for h in terms of the cubical object, the density of the liquid, ρ. The expression for the meta-centric height, GM, is,

$GM = I_{oo}/V - CG$

Where I_{oo} is the moment of inertia of the waterline area about the axis of disturbance, and V is volume of the displaced liquid. The moment inertia of a cubical body, $I_{00} = (bh^3)/12$.

4.1 The Existing Floating Structure Type

In general, there are two types of floating mechanism which are floating on the water and floating on the air[9].

For this project, the investigation will be done on the fundamentals of floating mechanism for the structure to float on water. In human technology, we tend to design various types of floating structure to fulfill our needs either for transportation or living. In order to design a floating structure, the knowledge of floating and the fundamentals of floating system is the root of thumb. The common application of floating system is being applied in the existing floating structure like Cruise, floating house, pontoon and so forth[10].

4.2 Commercial Floating Pontoon

Commercial pontoon as in Figure 2, are the manufacturing products from the factory. The design of floating pontoon normally by using the hollow fiber glass block for light load service and for high loads service at Jetty, the hollow concrete block will be using as floating structure. Recently, the application of floating pontoon by filling the hollow compartment with the expanded polystyrene which will be much helpful in case there is water leaking into the hollow concrete block.

Figure 2. Commercial floating pontoon.

4.3 Floating House

The floating house in Figure 3, designed in Netherland, New Zealand and other countries are using either the combination of steel structural and reinforced concrete design or reinforced concrete design alone. Latest technology of the floating mechanism of the floating house in Netherland uses the expanded polystyrene filled into the hollow concrete block and it is more safe and economical comparing the use of old design and steel structure design.

Figure 3. Floating house.

4.4 Development of the Model

By the selected information, the design of the floating house conceptual model was carried out with the selection of structural materials, type of design, floating mechanism, foundation system, connection and supports, floating stability and degree of withstanding lateral forces.

4.5 Structure of Floating House

The floating house is built as a load bearing structure with reinforced concrete and brick walls. The use of light weight concrete reduces the dead load of the floating house. Thus it is allowing higher live loads and flexible to use as a permanent house structure. Figure 4, shows the floor plan view of the floating house.

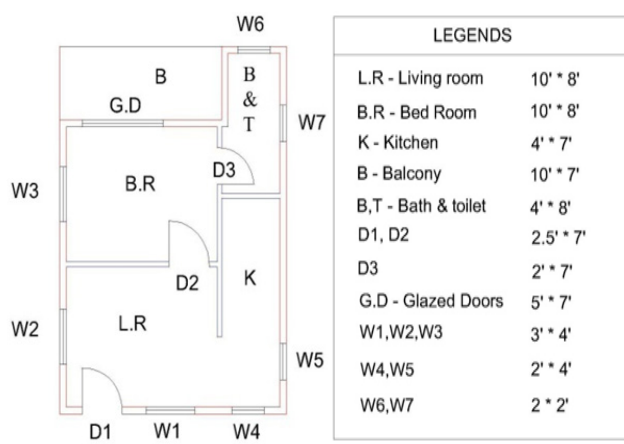

Figure 4. Floating house plan.

4.6 Floating Compartment

The floating compartment consists of six numbers of 150 x 150mm size columns, seven numbers 150 x 480 mm size beams (four columns of 3.07m length and three columns of 4.3m length). Top floor slab dimension is 4.33 x 6.15 x 0.120 m and the bottom slabs on which the column rests also the same dimension. The sides of the compartment are covered by shear walls of 3m height and 150mm thickness. The Figure 5 shows the isometric view of the floating compartment without shear wall. The inner clear space is covered with polystyrene blocks.

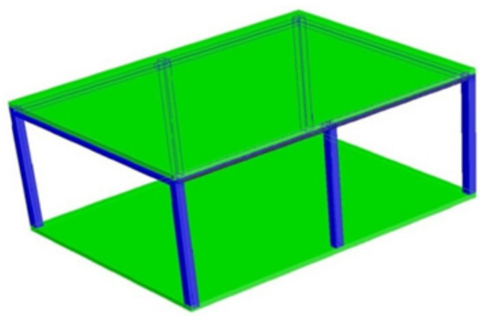

Figure 5. Floating compartment without shear walls.

4.7 Super Structure

The superstructure is 4m height. Loads on the slabs are transmitted through the brick wall to the bottom floating compartment slab. Figure 6 and 7 shows the floating house model. Analysis in Staad.pro v8i structural analysis software is carried out and the maximum bending moment for the floating compartment slabs and beams and maximum axial force for the columns are obtained as below.

Max Bending moment for slab = 48.74 kNm.
Max Bending moment for beam = 114 kNm.
Max axial force = 18 kN.

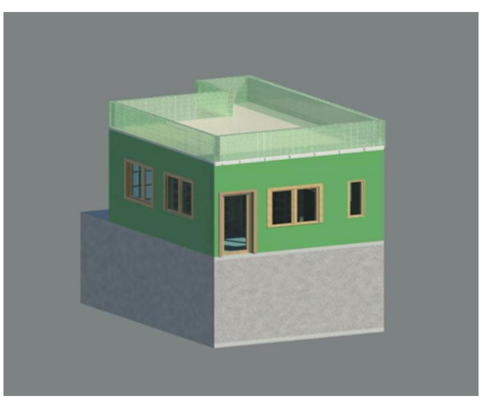

Figure 6. Superstructure and floating compartment.

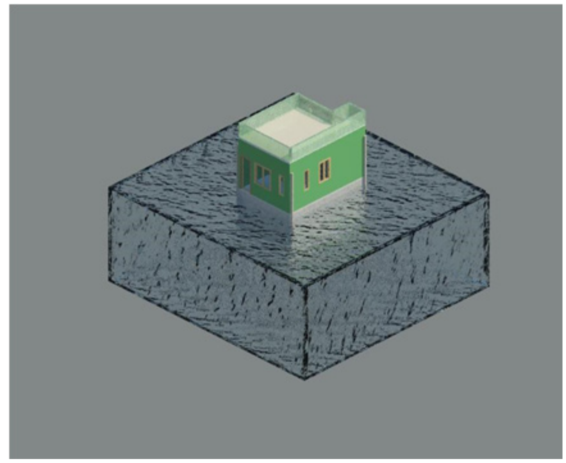

Figure 7. Floating house with water.

4.8 Buoyancy Force

Archimedes Principle states that the buoyant force on a submersed object is equal to the weight of the fluid that is displaced by the object (Rorres C., 2004).As referred to the imposed load and dead load which had been computed in previous section a, the total unfactored imposed and dead loads on model are as below:

The total load on the structure = 578.27kN

Depth of the water is assumed as 6m. Thus, the weight of water replaced by the submersed part of the model is equal to the compartment weight submersed in water. As referred to Figure, the compartment is consisted of six numbers of RC columns and seven numbers of RC beams. The overall depth of this compartment is 3m.

Thus, total weight of air, which is trapped inside this compartment area, is as follow:

Total weight of water being replaced by air,
= [(4 x 5.85 x 2.73)-(4 x 0.48 x 0.15 x 3)] x 1000 kg/m^3
= 63664 kg x 9.81/1000
= 624.54 kN

From the analysis above, it is noted that the total weight of structure, N of 583.1 kN is lesser than the weight of water replaced by air in compartment, which is 686.89 kN. Hence, the buoyant force is:

Bouyant Force = (624.54 – 578.27) kN = 46.27 kN

4.9 Buffer Height

Basically, the floating house model is to be able to have at least 150mm above the water surface when it is fully loaded. The buffer height of 150mm above water surface is to cater for any miscellaneous loading added which might cause the structure to be just above the water surface. The idea of buffer height of 150mm above water surface is to prevent the water from spreading onto the slab. As referred to the target of having at least 150mm buffer height above the water surface as discussed, this buffer height is evaluated as below:

Buffer height above water = {[(46.27 x1 000/9.81)]/1000}m^3/(4 x 5.85) = 0.201 m = 201 mm > 150 mm

4.10 Stability Analysis

Stability analysis is carried out to determine the stability of the structure. Figure 8, shows the stability analysis drawing. The meta-centric height is at 1.18m from the bottom slab of the floating compartment. The centre of gravity of the floating compartment is acting at a distance of 1.53m. As the position of meta-centre is greater than the centre of gravity of the structure, the floating house has a stable arrangement.

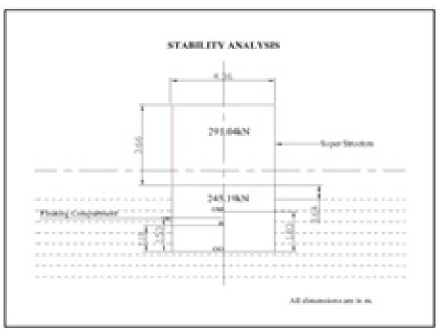

Figure 8. Stability analysis.

5. Conclusion

The rise of water level due to global warming increases the sea level over the land surface. Floating architecture provides the way to live safely with the rising water level. Floating houses reduce the damage due to property and human life significantly. The design is carried out using light weight construction materials and the entire structure has a stable arrangement. This upcoming technology will be in practice in many part of the world, when the existing land surface is taken away by the rising water level.

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