FLOATING STRUCTURE

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Abstract: The rising population of India has led to the unmanageable use of land which ultimately leads to the destruction of our environment. Population is on the rise with each day passing and it is becoming a huge concern for the world. As per latest data (2017), population has already crossed 753.04 crores in the world. This paper presents the study concerning floating buildings to counter the ill effects of growing population in terms of energy efficiency performance and improving awareness to build them.

***Index Terms* – Concrete Pontoon, Floating Stability, Floating Structure, Global Warming, Urbanisation**

I. INTRODUCTION

Rapid population growth has already made the situation vulnerable to the negative consequences of climate change. Global warming has already affected many parts of the world and is still affecting the untouched parts of the world. Global warming makes the water level and when the sea rises, the water covers many low land islands. This project focuses on the design and construction of integrated habitable floating structure for fluctuating water level, an alternative to the land structure. The development of integrated floating structure system is a new idea and approach at present. The selection of the materials with consideration of density and strength will determine the practicality of this construction technology.

II. PREVIOUS AND NEW GENERATION TECHNOLOGY

During the Cholas period for their invasion across rivers, they made use of trained elephants that swim on the surface, over which they transported all elements of battle by laying planks over elephants. Figure 1 shows the invasion of Persian King Xerxes of Greece.

Fig.1: Old Floating Bridge

The techniques evolved over the last 30+ years are based on a reinforced concrete shell with a core of expanded polystyrene. Large floating pontoons or docks are built in one piece, unharmed or undamaged where launching and transportation is practical. In other cases a large floating pontoons or docks can be built in components and assembled as a single piece close to its desired location. Marinas which is a specially designed harbour with moorings and walkways are joined using a patented proprietary connector which allows movement between sections.

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

Concrete pontoons stand out in contradistinction to other pontoons for its firmness and imperishability. The concrete pontoons are filled with foam plastic which is then covered from all sides with concrete. The pontoons made up of concrete are designed to last for 40-50 years when compared with the pontoons which are lighter in weight and are made up of wood, for its functioning in harsh environmental conditions. The pontoons constructed from concrete and Styrofoam achieves a high degree of buoyancy along with high degree of stability thus making it practically unsinkable. The constructed pontoon structure has negligible effect on the built environment as well as on the aquatic life and has low to zero maintenance.

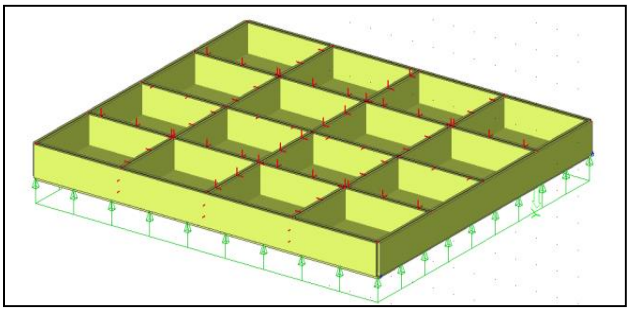

Fig.2: Pontoon Section

The most important thing for a floating structure is the weight of the construction. The buoyant force or lift capacity of the pontoon must be one-third higher than the weight of the structure above it for the stability of the entire structure. This weight must also include the self-weight of the pontoon. The structure constructed above the pontoon is almost half the weight of the pontoon. Floating structures are linked up to the shore line so that fresh water can be brought straight into the house and sewage can be pumped back into town lines.

Fig.3: Floating Pontoon

Floating structure design has slowly developed through the years, however it has only been recently that designs have become more environmentally aware and have begun to challenge the boundaries. This is mainly due to increasing concerns of the changing environmental conditions. With proper designs the floating structures can be situated far away from the shores so that it can rise and fall during high and low tides and is connected either to the shore or to the seabed so that it does not get carried away during the times of flood.

III. RESEARCH METHODOLOGY

A. Ambica and K. Venkatraman (2017) [1] in their paper "Floating Architecture: A Design on Hydrophilic Floating House for Fluctuating Water Level", expressed the concern of Global Warming all over the world. The rising water level occupies the land surface. Netherland is the place where there is scarcity of land for the construction of houses due to rising water level. Thus, they have started to live with the rising water level, by constructing houses which floats on water, thus providing safety against 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.

M. Hari Sathish Kumar, E. Saravanan, S. Manikandan, S. Akash Kumar (2017) [2] in their paper, uses floats (floating concrete) to support a continuous or separate deck for vehicle and pedestrian travel. It is used in the area where there is not feasible to suspend a bridge from anchored piers and also the area which has large deep sea bed. Pier-less bridge are not new to this world. During the Cholas period for their invasion across rivers, they made use of trained elephants that swim on the surface, over which they transported all elements of battle by laying planks over elephants. This paper also includes floating bridges which are pier less and whose design has been modified to bear heavy weight and possible to connect large distance and it is used in the area having heavy population. These bridges are made of suitable concrete sections and are continuous in length so that they could connect island and mainland even over sea which eliminates the cost of pier and makes the bridges more economic. It is evident that the pontoon bridges are not just a folkloristic curiosity or a military device, but they represent an effective and economical solution for crossing large stretches of even deep water (lakes, rivers,). The span of these bridges are not limited due to problems related to technical or structural concerns and some of them even span over 3000m (Hobart Bridge). Even though pontoon and other floating bridges are adopted where provision of traditional foundation will be difficult, they are also adopted where construction of other type of bridges proves to uneconomical due length of the bridges.

R.M. Manoj Kumar, J. Amit Binglesh (2015) [3] in their Paper, included floating bridges which are pierless and whose design has been modified to withstand more load and achieve more economy. These bridges are made of suitable concrete sections and are continuous in length so that they could connect island and mainland even over sea which eliminates the cost of pier and makes the bridges more economical. Thus an attempt has been made for design of economical section which could withstand more compressive stress compared to normal boat like structures of Chinese and U shaped coffer dams which float on lakes. This design reduces the stress acting on the structure by opposing the compressive stress and reducing the total stress acting on it, making it to be economical. Hence the capacity of sections to withstand load has improved considerably and it can be used to control the traffic these days. These bridges could be built across large lakes which would avoid a long ride around the river and reaching the other side of lake. Hence it again proves to be economical.

Shahryar Habibi (2015) [4] in his paper concerning floating buildings in terms of energy efficiency performance and improving awareness to build them. It included the capacity of floating architecture to deal with climate change by leading the use and application of innovative technologies in the built environment. Comparing floating buildings with land-based buildings reveals several benefits including the use of non-conventional energy sources and commence on developing new settlement planning. This paper presents an evaluation of the principle features of floating buildings that have a direct influence on global energy supplies and alternative non-conventional energy sources. Development of floating buildings needs the application of new technology, social and community understanding. The new knowledge and experience gained in floating architecture can lead to ideal future approaches. This paper presents recommendations for developing sustainable plans or decision-making frameworks for offshore renewable energy provisions. It will examine projects built on the seas in relation to offshore wind energy, wave energy and photovoltaic cells. The development and evaluation of sea energy sources should be considered as renewable energy source. It also provides new designs and procedures to reduce climate catastrophe regarding floating architecture and encouraging offshore energies as non-conventional energy resources. This paper reflected the significance of relevance to floating architecture as strategies for revamping to climate change and simplifies that offshore renewable energy resource should be concentrated in the study of future sustainable growth and energy efficiency targets. This paper not only discussed the construction of floating structures relevant to architecture design but also motivated the use of sea energy resources and assimilating them into the design. It scrutinized energy efficiency opportunities of sea energy as well.

Gowthama prasanth.U, Jeyaraj.C, Sivaperumal.B, Thirumurugan.S and Preethiwini.B (2016) [5]. This experiment deals with the construction of floating concrete precast slab with addition of pumice stone, a light weight aggregate and vermiculite, a replacement for sand. Buoyancy plays major role on floating objects. In order to design a floating concrete slab Light Weight Concrete (LWC) plays a prominent role in reducing the density and to increase the thermal insulation. Light weight concrete (LWC) is formed by Natural aggregate, synthetic light weight aggregate. Vermiculite is a light weight and cheap product because of its thermal resistance has become a valuable insulating material. The density of these concrete lies between 750 Kg/m³ to 2050 Kg/m³. Pumice is a natural graded light weight coarse aggregate which has a dry density of 1200 Kg/m³ to 1450 Kg/m. The light Weight Concrete (LWC) M20 using the light weight coarse aggregate as Pumice stone as a full replacement to 100%, light weight fine aggregate as Vermiculite as a replacement of fine aggregate to 75 %. The Ordinary Portland cement is partially replaced by Fly Ash by up to 50 % and some other mineral admixture are added which are Steel Fibre and Super plasticizer (SP 430). An experimental work concluded that the mix design of conventional concrete has higher compressive strength and weight. For the floating condition, the specimen must have a low density so, specific proportion has low density while comparing to other mix. The slab is designed to float above water surface and with a load carrying capacity of 1.5 kN. The mix also yields on compressive and split tensile strength of 5.07 N/mm2 and 2.17 N/mm^2.

The experimental investigations of precast floating slab have been concluded from the experimental tests:

- In our investigation, pumice and vermiculite are used as light weight aggregate due to its low bulk density.
- Pumice stone and vermiculite is a better replacement of coarse aggregate and fine aggregate.
- Aluminium powder as an air entraining agent, steel fibre is used to increase its strength and Super plasticizers 430 is used to increase it workability.
- The chicken mesh or the bamboo stick can be used for better stability.
- The precast floating slab is a good replacement of over bridges at efficient cost.

IV. DESIGN OF SUPERSTRUCTURE

The superstructure is 4m in height. Loads on the slabs are transmitted through the steel columns to the bottom floating compartment slab. Figure 4 shows the floating structure model. Analysis in Staad.pro v8i structural analysis software has been carried out and the maximum bending moment for the superstructure slab and beams and maximum axial force for the columns.

Figure 4 shows floating structure which has been designed using the combination of steel sections and reinforced concrete alone. The grade of concrete chosen is M25 and reinforcing steel is Fe415, for slab and ISMB sections for beams and columns. 10mm Φ bars with an effective cover of 25mm has been chosen for the reinforcement detailing in slab. The thickness of the slab of superstructure is 125mm. The bending moment and shear force is calculated by the following equation:

$$\text{Ultimate Bending Moment} = 0.138 x f_{ck} x b d^2 \quad (1)$$

$$\text{Ultimate Shear Force} = w_u l/2 \quad (2)$$

- Maximum Bending Moment for slab = 12.65 kN-m from Eq.1
- Maximum Shear Force for Slab = 23.35 kN from Eq.2

The floating structure transmits a load of 4676 kN to the floating base or pontoon below.

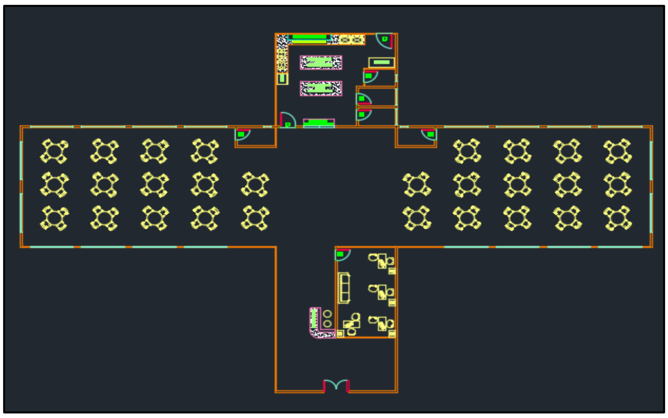

Fig. 4: Architectural Plan

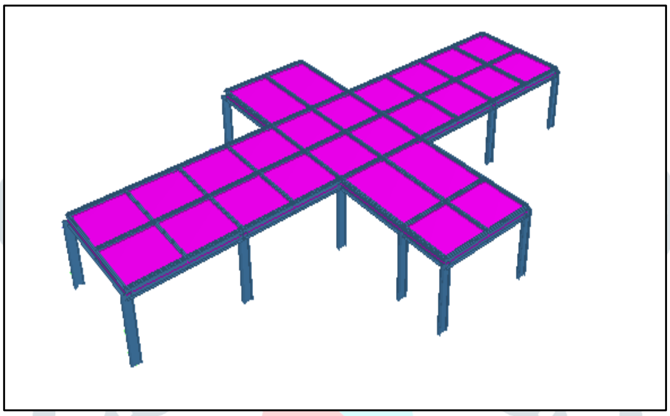

Fig. 5: Superstructure Model

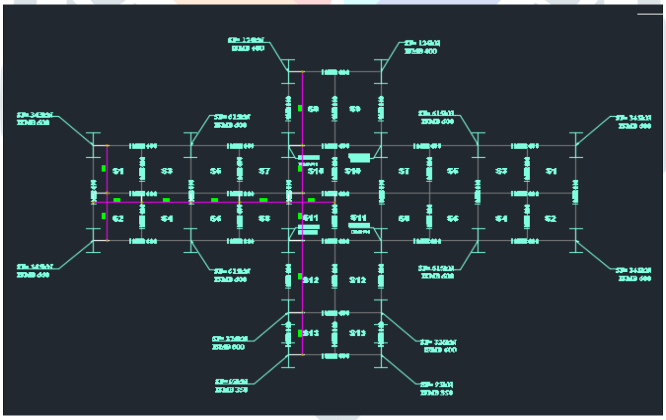

Fig. 6: Structural Plan

V. FLOATING COMPARTMENT

The floating compartment or pontoon consists of 34 nos. of slabs supported on all four sides. The entire size of the pontoon is 60m x 45m x 8.475m. The dimension of the pontoon's top slab is 60m x 45m x 0.775m while that of bottom slab is 60m x 45m x 0.70m. The thickness of shear wall is 300mm and is 7m high. The grade of concrete chosen is M40 and reinforcing steel is Fe415. The thickness of the top slab has been determined by the embedment of steel columns in the concrete of pontoon's top slab. The depth of embedment in the concrete has been determined by using the Pocket Base approach. The approach uses Working Stress Method or W.S.M. The depth of embedment is found to be 744.92mm. Thus, providing an overall depth of 775mm of pontoon's top slab. The safe axial load carrying capacity at this depth is 709.21 kN which is far greater than the axial load of 615 kN of the column section. The maximum shear force and bending moment values for pontoon's top slab is as follows:

- Maximum Bending Moment = 773.88 kN-m
- Maximum Shear Force = 454.51 kN

The concrete wall has been provided to carry the load of the structure above. The thickness of concrete wall is 300mm with an unsupported length of 7m. The total area of the concrete wall is 175.14 sq.m. The grade of concrete chosen is M40 and reinforcing steel is Fe415 for the design of concrete wall. The concrete wall has been designed as per IS 456:2000, Clause 32. The maximum load acting on long wall and short wall is 425 kN/m and 355 kN/m. The load carrying capacity of this wall section is 2502 kN/m length.

The dimension of the pontoon's bottom slab is 60m x 45m x 0.70m. The grade of concrete and that of reinforcing steel is M40 and Fe415 and 20mm Φ bars with an effective cover of 35mm to the steel from the bottom. The maximum shear force and bending moment values for pontoon's bottom slab is as follows:

- Maximum Bending Moment = 2255.53 kN-m from Eq.1
- Maximum Shear Force = 994.52 kN from Eq.2

VI. Force of Buoyancy

When a body is immersed in a fluid, an upward force is exerted by the fluid on the body. This upward force is equal to the weight of the fluid displaced by the body and is called force of buoyancy or simply buoyancy. It is based on Archimedes Principle which states that, "upward buoyant force that is exerted on a body immersed in a fluid, whether fully or partially submerged, is equal to the weight of the fluid that the body displaces and acts in the upward direction at the center of mass of the displaced fluid." As referred to imposed load and dead load which had been computed in the previous section, the total unfactored imposed and dead loads on the structure are as below:

The total load on the structure = 4676 + 145061.8 = 149737.8 kN

The structure is being planned on Vihar Lake having a maximum depth of 34m. Thus, the weight of water replaced by the submersed part of the structure is equal to the compartment weight submersed in water. The total area of the hollow space of the compartment has been calculated equal to 2524.861 sq.m. Thus, the total weight of air which is trapped inside this compartment is as follows:

Total weight of water being replaced by air = [(2524.861 x 7) x 1000] x 9.81/1000 = 173382.2 kN

From the analysis above, it is noted that total weight of structure is 149737.8 kN which is lesser than the weight of water replaced by the air in the compartment, which is 173382.2 kN. Hence the buoyant force, F_B is:

Buoyant force, F_B = 173382.2 – 149737.8 = 23644.38 kN

VII. Degree of Floating Stability

The buoyant force, which supports a floating body, is equal to the weight of fluid displaced by the body. As the force of buoyancy is a vertical force and is equal to the weight of the fluid displaced by the body, the centre of buoyancy will be the centre of gravity of the fluid displaced. The term stability refers to the tendency of a body to return to its original state after it has suffered a small disturbance. The degree of stability refers to how quick will the body return to the upright or its original position. 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. 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. 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. 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 must be positive.

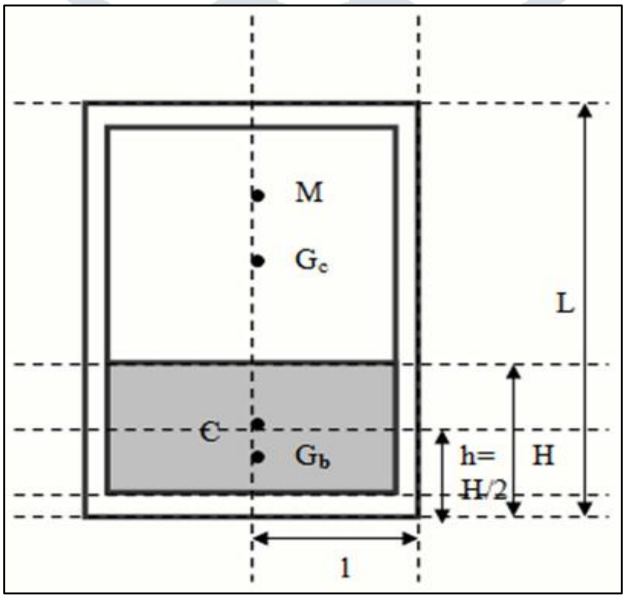

Fig. 7: Meta-Centric Height for a floating cubic body

The expression for the Meta-centric height, GM is,

Meta-centric height, GM = I/V - CG where,

I = Moment of Inertia; V = Volume; CG = Centre of Gravity

The meta-centric height for the floating structure is calculated as 28.265m.

Basically, floating house model is to be able to have at least 500mm above the water surface when it is fully loaded. The buffer height of 500mm 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 500mm above water surface is to prevent the water from spreading onto the slab. As referred to the target of having at least 500mm height above the water surface as discussed, this height is evaluated as below:

Height above water surface = [(23644.38 x 1000)/9.81] / (60 x 45 x 45) = 0.89m = 890mm

VIII. Merits and Demerits

Merits:

- Manufacturing and installation process is simple
- Suitable for all types of water including oceans
- Unlimited Size is possible
- Excellent Stability of the structure
- Low maintenance

Demerits:

- Mooring Connector technology is still exploratory
- The cost of construction is high as skilled labours and high end equipments are required

IX. Conclusion

This paper analysed a brief description of the general characteristics of floating structures and energy resources produced by tides. Construction of floating structures shows that they not only have environmental benefits but also conserve onshore energy resources resulting in economic benefits. The design is carried out using light weight construction materials and the entire structure has a stable arrangement. This paper presented that floating structures can be an interesting way to combine tidal energy resources and floating architecture. 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 and increasing growth of population.

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[6] The Structure Is Designed With The Reference From The Book “Design Of Reinforced Concrete Elements” By “Krishna Raju” And “Limit State Method” By “B.C Punmia”.

[7] The coefficient values are taken from the code book “IS: 456-2000”.

[8] The concrete has been designed as per “IS 10262:2009”.

[9] The design of beams and columns has been carried out from the code book “IS 800:2007”.

[10] The design of slab has been carried out from the code book “IS 456:2000”.

[11] The live load is taken from the code book “IS 875 PART 2” according to the building.