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Flood Mitigation Measures – Design of an Amphibious House

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Abstract - *Natural disasters have caused a lot of damage and destruction throughout the world. A major natural catastrophe among all the disasters is flooding. Flooding is very common in India as India is one of the most flood-prone countries in the world with almost 30 million Indians getting affected on an average annually. India's average economic losses due to natural calamities are estimated at INR 746.83 billion, of which over INR 532.94 billion are attributed to floods. Along with financial and real-estate losses, it also causes emotional damage to people. To minimize these losses, we thought of different Flood mitigation measures and chose to further work on Amphibious housing. Amphibious houses are the structures that majorly work on two principles i.e. Archimedes Principle and Pontoon principle. So, these houses act like normal houses but when a flood occurs, it rises to the height of flood level and floats with the help of pontoons or hollow basements. It is supported by the vertical mooring poles to avoid displacement due to external forces. Once the floodwater is drained off, the house comes back at rest to the ground level. For making the houses float, the foundation or the sub-structure is made up of Expanded Polystyrene Foam (EPS) blocks. While the superstructure can be made using different materials like timber, EPS blocks, light-weight concrete, Ferro cement, etc.*

Key Words: **Natural disasters, Floods, Flood mitigation measures, Amphibious houses, Archimedes Principle, Pontoon Principle, EPS blocks, Vertical mooring poles, Timber.**

1. INTRODUCTION

1.1 Floods in India

We all know that due to sudden climate changes and global warming, heavy rain, severe hurricanes tsunami, flooding, and other natural disasters lead to the rise in the water table. Therefore, there is an immediate need to adopt several effective countermeasures against these catastrophes, especially flooding. Flooding in India has affected nearly 30 million people and caused deaths of 1500 people on average annually. Flooding causes immense destruction where there is loss of lives, loss of livestock, loss of property, loss of capital, also it causes mental trauma during and after floods. There have been significant losses due to natural calamities of almost INR 746.83 billion of which over INR 532.94 billion are attributed due to floods.

Fig -1: 2021 Floods in Chiplun, Maharashtra

The most affected regions are the sections of Raigad, Ratnagiri, Sindhudurg, Satara, Sangli, and Kolhapur. Due to heavy rains, further, than townlets are affected in these sections. Over people have been vacated, of whom around are from Sangli quarter and around from Kolhapur quarter. There have been more than livestock deaths and around 350 other poultry deaths in Kolhapur, Sangli, Satara, and Sindhudurg sections. Original estimates state that over 2.2 lakh hectares of crops have been damaged in the seasonal flood. Different infrastructural installations were impacted and damaged. Around 850 bridges have been submerged, preventing physical dispatches with multiple villages. The drinking water supply of around 600 villages was affected and the precipitation also caused damage to about electric transformers, affecting the power supply to nearly 9 lakh consumers. As of 28 July 2021, the power supply to about 6 lakh consumers was restored through repairs of nearly 9000 transformers. Around 35 troops from National Disaster Response Force (NDRF) were deployed for rescue operations in all the regions. The Central Government on 27 July 2021 declared fiscal aid of ▯ 730 crores.

1.2 Amphibious Housing

In concern to this, from various flood mitigation measures and water dwellings, we have adopted the concept of Amphibious House here, which refers to architectural structures that will function both inland and water in response to floods in low-lying coastal or other areas. Amphibious houses are the structures that are at rest in normal conditions, but during flooding, they rise up to the height of the floodwater and then come back to normal position once the floodwater is drained out. These houses are supported by vertical poles in the corners to avoid lateral displacement due to external factors. However, this concept is not new to the world but has still not been introduced majorly in our country "India". The idea of Amphibious Housing gives the experience of living in both water and land which indeed saves lives of people and livestock and also saves from the capital losses that may occur. Various materials can be used for the construction of this structure like lightweight materials such as expanded polystyrene (EPS), precast blocks made with ferrocement, movable rollers, prefabricated materials, timber, etc. The main advantage of this concept is that it is an economical solution for flood mitigation which also prevents the migration of people and also gives the experience of normal living during floods.

2. OBJECTIVES

The goal of this study is to give a suitable design for the Amphibious house. To explore designing using EPS and lightweight concrete for sub-structure and Timber for the superstructure. To minimize the capital losses. To avoid damage caused to mental health. To avoid the need to migrate after floods. To give exposure to new sustainable housing systems and materials. To provide an economical solution for flood mitigation.

3. CONSTRUCTION METHODOLOGY

Constructing an Amphibious House requires consideration of the factors related to normal houses as well as the factors related to flooding conditions of an area where the project is being implemented along with annual rainfall data, the average height of floodwater, buoyancy factors, density, and strength of materials being used, loading conditions, etc. to withstand the extreme flooding conditions and to provide a safe and working solution.

So, here we are constructing the amphibious house using expanded polystyrene foam (EPS) blocks and lightweight concrete cover on it for the substructure and timber frame for the superstructure including internal walls and ceiling and high strength steel pipes for vertical mooring poles. So firstly, we have to excavate the site and prepare the soil for laying the foundation and insert the vertical poles. Followed by which we have to lay the foundation made up of collective EPS blocks covered by lightweight concrete as per the design having drilled sections in the corners as per the design to insert the vertical poles. Later, we have to build the superstructure on it using the Pinewood for the external and internal walls where external walls are tied up to the vertical poles, and then the ceiling is constructed being of the same size as the foundation to provide support to the vertical poles throughout.

4. DESIGN OF AMPHIBIOUS HOUSE

STEP 1: DESIGN OF FOUNDATION:

For EPS Blocks, considering:
Length (L) = 2m,
Width (B) = 1m,
Height (H) = 0.62m
Density (ρ_{EPS}) = 30 Kg/m^3

Now, Buoyancy Analysis of an EPS Block:

1. Weight of EPS Block $= L \times B \times H \times \rho_{EPS}$
$= 2 \times 1 \times 0.62 \times 30$
$= 37.2$ Kg

2. Buoyancy Force of EPS Block $= L \times B \times H \times \rho_w \times g$
∴ ($F_{b\ EPS}$) $= 2 \times 1 \times 0.62 \times 1000 \times 9.81$
∴ $\mathbf{F_{b\ EPS}}$ **= 12164.4 N ... (i)**

3. Gravity of EPS Block (g_e) $= \rho_{EPS} \times$ Vol. of EPS $\times 9.81$
$= 30 \times 1.24 \times 9.81$
∴ $\mathbf{g_e}$ **= 364.93 N**

Check,
∵ $\mathbf{F_{b\ EPS} > g_e}$, i.e. 12164.4 N > 364.93 N ∴ OK.

∴ **The block will Float.**

STEP 2: LOAD ANALYSIS:

A. Lightweight Concrete cover on EPS Foundation:

Considering concrete cover for 2 EPS Blocks together, thus its dimensions will be L=B= 2m (making it a square block since it will be helpful while calculating the side volume).
Concrete cover thickness (t_c) = 6 cm = 0.06m,
Density of Lightweight Concrete (ρ_C) = 1600 Kg/m^3

1. Floor Plate Volume $= L \times B \times t_c$
$= 2 \times 2 \times 0.06$
$= 0.24$ m^3

2. Side Volume $= L \times H \times t_c \times$ No. of sides
$= 2 \times 0.62 \times 0.06 \times 4$
$= 0.2976$ m^3

∴ Total Volume of Concrete cover $= 0.24 + 0.2976$
$= 0.5376$ m^3

3. Weight of Concrete = Vol. of Concrete $\times \rho_C$
$= 0.5376 \times 1600$
$= 860.16$ Kg

∴ Weight of Concrete (for 2 EPS blocks) = 8436.16 N

∴ **Weight of Concrete (for 1 EPS block) = 4218.08 N ... (ii)**

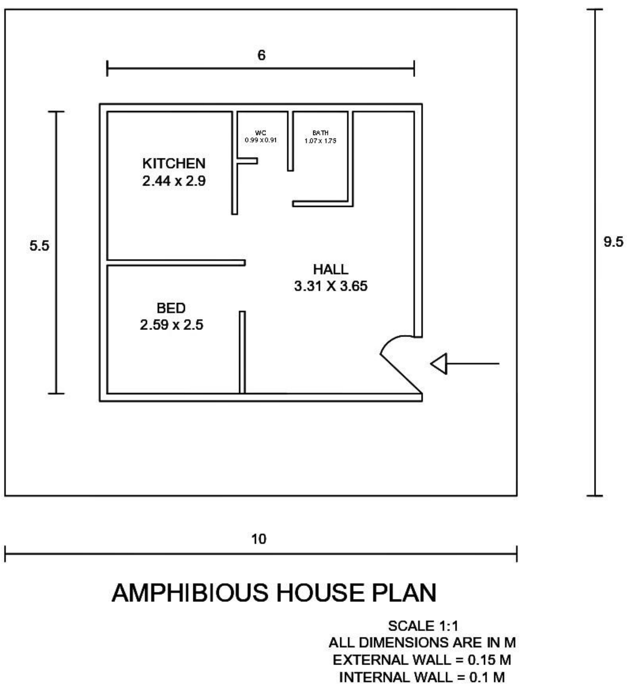

Fig -2: Proposed Amphibious House Plan Resting on the EPS and Lightweight Concrete Foundation

*** (NOTE: For safety and aesthetic reasons, we have designed the foundation having 1 block extra throughout the perimeter of the house, thus, the effective size of the foundation will be 10m × 9.5m) ***

B. <u>Load of Superstructure made up of Timber</u>:

The above plan in *Fig-2* shows the dimensions of each component of the proposed 1 BHK Amphibious house having the walls and ceiling made up of Timber, where ceiling dimensions are same as the foundation dimensions.

We have used Pinewood for the construction of the superstructure because of its promising properties.

Density of Pinewood (ρ_{PW}) = 500 Kg/m^3
Considering,
Thickness of External wall (t_{ext}) = 150 mm = 0.15m
Thickness of Internal wall (t_{int}) = 100 mm = 0.1m
Floor Height (H_f) = 3m

1. Quantity of Wood Required:

a. External Walls $= L_{Ext.\ Walls} \times H_f \times t_{ext}$
$= (6+6+5.5+5.5) \times 3 \times 0.15$
$= \underline{10.35\ m^3}$

b. Internal Walls $= L_{Int.\ Walls} \times H_f \times t_{int}$
$= (2.9+1.07+1.75+1.75+0.99+3.5+2.5) \times 3 \times 0.1$
$= \underline{4.338\ m^3}$

c. Ceiling (0.15m thick) $= (10 \times 9.5) \times 0.15$
$= \underline{14.25\ m^3}$

∴ **Total Wood Quantity** $= 10.35 + 4.338 + 14.25$
$= \mathbf{28.938\ m^3}$

2. Weight of Superstructure $=$ Qty. of Wood $\times\ \rho_{PW}$
$= 28.938 \times 500$
$= 14469$ Kg

∴ **Weight of Superstructure** **= <u>141940.89 N</u> ... (iii)**

C. <u>Load of Furniture, Accessories, and Daily Needs</u>:

Here, considering the weight of furniture, different accessories that we use, and the items that we need and use on daily basis:

Table -1: Calculation of load of Furniture, Accessories, and Daily Needs

<u>Type</u>	<u>Weight (in Kg)</u>	<u>Weight (in N)</u>
Bed + mattress	90	883
Sofa	40	393
Double Wardrobe	45	442
Chairs (2 nos.)	12	118
Cooktop, Gas, Refrigerator, Washing machine, Fans (4 Nos.)	250	2453
Sanitary fittings & W.C.	80	785
Kitchen Storage Cupboard	15	147
Clothes, Utensils	200	1962
Food, Drinking water	350	3434
∴ TOTAL	1082	10615
∴ TOTAL	**≈ <u>1100</u>**	**≈ <u>10800</u>**

∴ **Total weight of Furniture, Accessories, and Daily Needs** **= <u>10800 N</u> ... (iv)**

D. <u>Live Load Calculation</u>:

Considering that a family of '5 members' live in this house, having an average weight of '80 Kg' each.

∴ Total Live load $= 5 \times 80 \times 9.81$
∴ **Total Live load** = **<u>3924 N</u> ... (v)**

Thus, adding (i), (ii), (iii), (iv) & (v), we get:

∴ **TOTAL LOAD ON THE FOUNDATION** = <u>160882.97 N</u>
= <u>160.88 KN</u>

∴ **TOTAL LOAD ON THE FOUNDATION / m²** (Downward Force) = 160.88 / 10 × 9.5
= **<u>1.693 KN/m²</u> ... (vi)**

STEP 2: <u>TOTAL BUOYANCY OF THE FOUNDATION</u>:

1. Total number of EPS Blocks required
 = Size of Foundation / Size of 1 EPS Block
 = 10 × 9.5 / 2 × 1
 = 47.5 ≈ **48 nos.**

∴ Total Buoyancy = Buoyancy of 1 EPS block × Total No. of blocks
∴ [From (i)] = 12164.4 × 48
 = 583891.2 N
 = <u>583.89 KN</u>

∴ **TOTAL BUOYANCY / m²** (Upward Force)	**=** 583.89 / 10 × 9.5
	= **<u>6.146 KN/m²</u> ... (vii)**

∴ **Comparing (vi) & (vii), we get that:**
∴ (vii) > (vi)

i.e.	<u>6.146 KN/m² > 1.693 KN/m²</u>	∴ <u>OK</u>
i.e.	**Upward Force > Downward Force**	

∴ **<u>Our Total Structure will float on the water whenever a flood occurs</u>.**

Hence, we have successfully designed an Amphibious House.

5. CONCLUSION & FUTURE SCOPE

We have successfully designed an Amphibious house and concluded that the Total Buoyant Force of the Foundation (Upward Force) is significantly greater than the Total Load on the Foundation (Downward Force) by considering all the possible loads that can be imposed. Also, Amphibious housing has proved to be very innovative and beneficial as a flood mitigation measure over the past years and we aim to use this emerging technology to improve the living of people in the flood-prone areas. EPS blocks have proved to be very useful in structures requiring low-density foundation and providing good buoyancy. Timber, especially Pinewood has proved to be a suitable material for constructing a lightweight amphibious house. While, the future scope of the Amphibious house involves increasing the number of floors, making necessary arrangements for parking, constructing stables for livestock using this technology, elongate this concept into Green Homes.

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