Design of A Sustainable Flood Resistant Structure for Rebuilding Resilient Kerala Post Floods

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ABSTRACT

As natural disasters are growing in frequency and severity, strategies to mitigate and minimize the impact of natural hazards must be implemented, particularly in the housing sector, as it is a key aspect of human life. This paper focuses on floods since they are proven to be the most prevalent of all natural disasters and this particular issue should be discussed. Owing to the importance of sheltering affected communities, resilient accommodation is not usually discussed. Houses, however, become fragile and are likely to be damaged or demolished in potential natural hazard events by neglecting the risks of exposure in building. That said, when it comes to housing, it becomes important to have resilience requirements, which in turn would allow new homes to better withstand the passage of time and natural disasters, in the safest way possible. In order to define guiding principles that flood-resilient housing should address, an in-depth analysis of permanent housing has been carried out by researching the different ways flood events impact housing. In addition, it is important to distinguish between flood zones because, according to expected flood characteristics, housing can respond to and resist flooding. This paper includes the review of different flood-resistant housing schemes and identifies the most effective design factors and proposes a new plan for resilient housing. Through this analysis, the housing plan is well within the limits of sustainability and addresses the problems of flood-related housing concerns in the most appropriate manner. The results of this study would be very beneficial for individuals living in areas impacted by the floods

Keywords: Resilient Housing, Flood, Sustainability, Pre-fabricated material, Amphibious House.

1 INTRODUCTION

Many states in India have large amount of water in form of river, lakes. Melting of ice and increase in population will increase the frequency of flood and sea level rise also increase the danger of coastal and riverside buildings. As flood events are increasing in frequency and intensity, it is imperative that strategies should be implemented to mitigate and reduce the effect of floods, particularly in the housing sector since it is a central aspect of human life. When talk about the condition in Kerala, the real problem lies in the conventional housing structures in Kerala i.e. its inefficiency to withstand the heavy rainfall and flood. The basic features of conventional housing consider only about the style and convenience of the people. Most of the housing structures don't have any aspect to protect from the climatic conditions. Even the rules and regulation doesn't take into account the importance of disaster management in the construction of houses seriously. When flood occurred in 2018, these types of housing structures easily collapsed. The numbers of damaged houses were so high that it became necessary for the government rebuild the houses for affected one. This means that "flood-resistant design and raw materials" should be mandatory in the conventional housing structures. It will therefore result in a sustainable and flood resistant housing structure.

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2 FLOOD RESISTANT HOUSING CONCEPT

The occurrence of major flooding will become more frequent across the world as global climate change causes sea levels to rise and weather events to become more serious. With main factors such as the affected population, the private sector, local authorities, national governments and NGOs resolving immediate problems, the flood scenario is typically chaotic. According to Ahmad et al.(2016) Permanent housing can take several forms, but it remains the essential and final step in the process of restoring housing. While housing repair is the cheapest and fastest way to provide sufficient housing, it depends on the degree of damage to houses and may not be feasible. The most fundamental factors for the planning of new housing were also listed by the author; these are location, site selection and settlement planning, construction methods and materials, design.

Bowker (2007) studied how floods influence buildings and how their associated effects and processes are described. Via brickwork and block work, joints between slabs and walls or in places where various building materials meet, suspended wood floors, airbricks and vents, seals between windows, doors and frames, cracks and openings in walls due to poor construction, insufficient damp proof course, service entries such as utility pipes and ventilation ducts, flood event water may reach the building. The damage caused by the various water depths is also mentioned. According to (Hawkesbury-Nepean Floodplain Management Steering Committee, 2006) damage to buildings caused by a flood event, classified according to the form of damage into three major categories. These are: movement of foundations as a result of geotechnical failure, water-generated forces, water flows and debris on house components, building materials in contact with water. Small-scale structural methods such as flood proofing etc. are also included in the non-structural approach. It is found that non-structural approaches are in line with sustainable growth. (Kundzewics, 2002). Flood-resistant domestic buildings are addressed in some parts of the world with various methods used for the purpose. The living area height is elevated above the elevation of the base flood (B F E). On some supports, the house is raised that should be sufficiently strong enough to bear the load of the framework and forces acting by the flood water and have ample space in case of flood for the flow passage. The space below the living area can be used to park the car, laundry or bathroom in an area with a low flood probability. etc(Saqib et al. 2014).

According to English (2009) amphibious houses are built in such a way that as the flow recedes, they are free to float on the flood water and rise with the water level and return to their initial position. In Maasbommel, the Netherlands, and in Raccourci Old River, Louisiana, New Orleans and Bangladesh, these houses are built. In this case, the base is found to be economical; the house is dependable and comfortable. Floating house may also be called amphibious house and the author is categorised into two types: type of boat and type of lift. A primer on the assessment of residential buildings exposed to flood events is given by Jordan and Rogers (2012). An summary of flooding effects on structures is given, including hydrostatic force considerations, flowing water dynamic forces, buoyancy, soil saturation and associated movement of foundations, and environmental/contamination issues. Aglan and Wendt (2005) describe flood damage resistant material as "any construction product capable of withstanding direct and prolonged contact with floodwaters without suffering significant damage." The author referred to the acceptance and non-acceptance criteria for flood-resistant building materials. A comparative study on both current and proposed amphibious buildings, with discussion of their systems and components, was conducted by English (2009). The author also discusses amphibious construction limitations, some of the regulatory barriers that have prevented its development, and potential paths forward.

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2.1 Flood Resistant Buildings and Materials

Kerala faced a major threat i.e. flood which affected life and property of people. The complete destruction of houses leads to the need for the government to reconstruct houses. In this scenario, we have to consider sustainability (both flood resistant and eco-friendly housing models). The major objectives of our study are to examine the flood resistant, sustainable and feasible housing models.

2.1.1 Flood Resistant and Sustainable Materials

I. Recycled plastics are flood resistant and sustainable material and very cost-effective raw material which is available in free

II. Ferrock is a raw material which is already being used in Thrissur and Alappuzha is considered to be flood resistant, sustainable and cost effective

III. Hempcrete is a bio composite made of the inner woody core of the hemp plant mixed with a lime-based binder. Hempcrete buildings ten stories high have been built in Europe. It is also a flood resistant, eco-friendly and feasible raw material that can be used for the construction of houses.

2.1.2 Building Designs that are Flood Resistant

I. The amphibious houses will help residents overcome the constant threat of flooding in the islands. Amphibious houses are popular in countries like Indonesia and Philippines where the land is permanently flooded. They are also popular in countries including Japan, Vietnam, and Bangladesh where there is a constant threat of flooding. In Munroe Thuruthu, the government is planning to construct this type of house structure. But these houses are sensitive to land sinking.

II. Floating houses are those houses which are used as living spaces on water that are minimally mobile other than moving vertically with the tide. Houses which get uplifted during floods and move down during conditions when no water is there are guided vertically. These houses are meant for coastal areas.

III. Both these methods are cost effective and can be used as a method to reconstruct the houses in Kerala of places like coastal areas and river surrounded areas.

3 PLANNING OF HOUSING

Planning is a broad term which considers the efficient distribution of occupant spaces incorporating mobility concerns considering the functional and aesthetical approach by maximum exploitation of the given plot from within the stipulation of the KBR (Kerala Building Rules).Planning is the most important part of a construction process where safety, economy, and aesthetic approaches are duly considered while execution. The plan of the building is shown in figure.1 .The buildings are planned according to KBR rules which specify the building group height, access, and specification, lighting, and ventilation. The built up area of the building is 421.25 sq. ft. The sectional details (figure.2) are also provided. Height of the P.C.C column depends on the requirement of site. The details of the material used in each part of the building is shown in tabular form (Table.1)

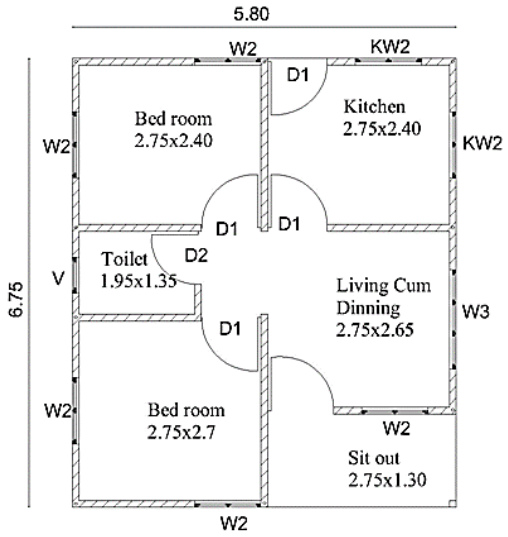

Figure 1. Building plan

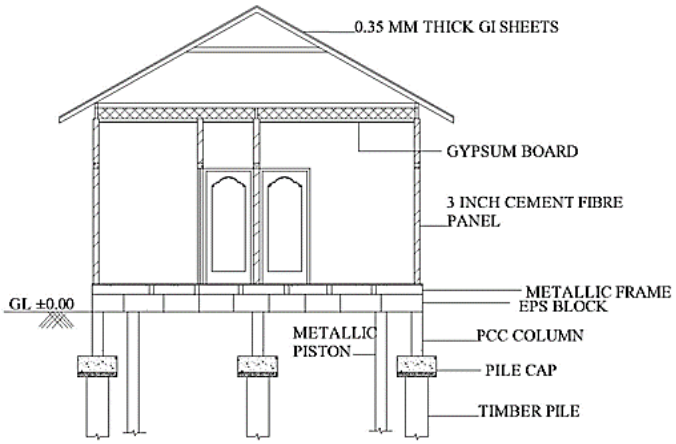

Figure 2. Building section

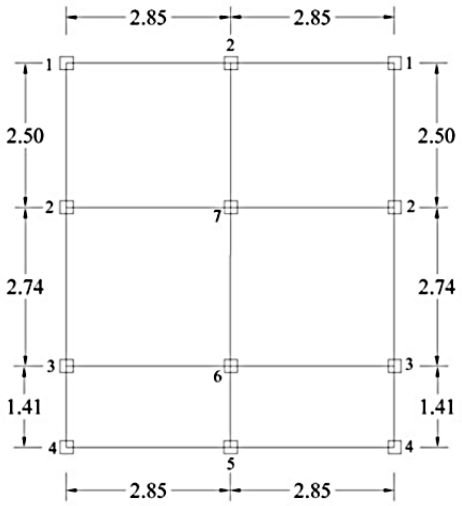

Figure3. Location of pile under column

Table 1. Material details of the building

Sub-Structure materials		Platform Pad	Galvanized Steel
Floor Construction	Galvanized Steel	**Super-Structure materials**	
Anchor	Galvanized Steel Ring Pipe	Roof Truss	Light steel Construction
Floating Platform	Metallic frame with EPS Blocks	Ceiling	Gypsum Board
Reservoir	PVC	Wall	3 Inch Cement Fibre Panel
Foundation	Timber pile with R.C.C pile cap	Floor	GRC Panel

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4 DESIGNING OF HOUSING

Design of the housing consists of design of roof truss and foundation. The design sections for the truss elements are shown in table2. The foundation for the building is designed based on the soil data of Munroe Island obtained from the PWD Road Division. The water level is assumed at 20 cm from ground level and soil is loose sand of SPT value 4. The shallow foundation cannot be provided as bearing capacity is obtained as 50kN/m^2. Hence, timber pile foundation is provided here. In the high lands comprising of medium to dense sand and where the ground water table is at lower level, the shallow foundation can be provided based on bearing capacity. Piles are designed based on the load coming on each column. Here, the timber piles are taken which carries load by end bearing and skin friction. Also the timber pile shows maximum strength in wet condition.

The circular timber pile of length 6 m and 40 cm diameter are provided. The piles are designed for end bearing and skin friction. The reinforcement details for the pile cap shown in figure.4.

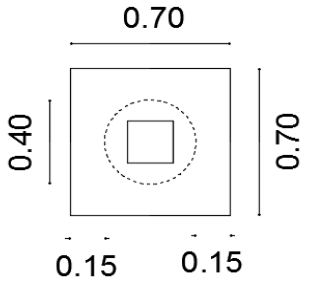

Figure.4 Details of reinforcement in pile cap

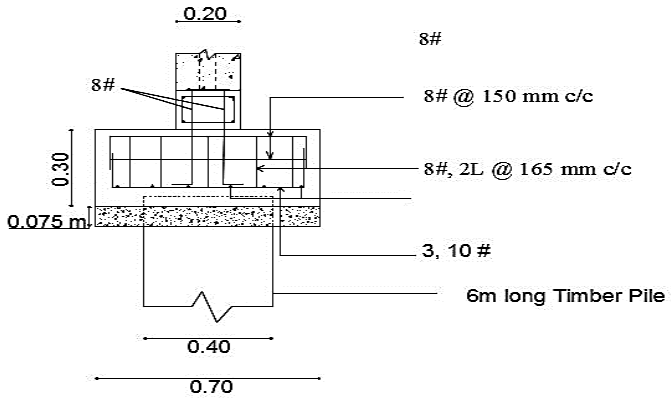

Figure.5 Plan of pile with pile cap

Table.2 Details of truss elements

Trafford shaped GI roofing sheet	0.35mm thickness
Purlin	RHS80x48x3.2mm
Rafters	RHS80x48x3.2mm
Wall Plate	RHS 80x40x3.2mm
GI Column	48.3mm@3.56Kg/m

5 WORKING METHOD OF THE BUILDING

The super structure consists of the portion above P.C.C column and sub structure consist of the portion below the EPS block. The super structure simply rest on the sub structure, there is no connection in between. The super structure is rigidly connected to the 4 pistons at the corners of the building. When flood occurs, the water will exerts a pressure on the EPS block and it will start to move vertically up to a maximum of 3m height. The Piston will make sure the building will not move laterally. When the water recedes, the building will rest to the same position as before.

6 CONSTRUCTION DETAILS

As per the structural design, following are the construction details with specifications

i. The site chosen for the construction is investigated and information about subsurface condition like ground water level at the site is obtained. Here the soil exploration data obtained from PWD Road Division, Kollam is referred for designing the foundation. The soil investigation was done for the proposed Konnailkadavu, Bridge at Munroe Island. The bore hole data at Perungaalam, Munroe Island has been taken as reference for design.

ii. The design carried out here is based on the extreme conditions assuming the very loose sand is up to depth of 10m with SPT value 4 and ground water water is at depth of 20 cm from top.

iii. The construction is commenced with the driving of timber piles after proper treatment of pile in accordance with IS 401- 1967. In a pile group sequence of installing piles should be either from centre to periphery of group or from one side to other side. The piles are driven at proper location of columns with centroid of piles in a group coinciding with the axis of loading.

iv. Pile cap is cast over 75 mm thick levelling course of concrete. The clear overhang of the pile cap beyond the outermost pile in the group shall be 150 mm. The clear cover for main reinforcement is provided as 75 mm and the pile should project 40mm into the cap concrete.

v. Small PCC columns of size 20cm x 20cm are casted and the height of the column will depends on the site condition. The EPS blocks and the super structure will rest on the foundation. There is no connection between the foundation and the super structure.

vi. Metallic frames which can accommodate the total number of EPS block have to be made. Fill the metallic frame with the EPS block.

vii. A metallic piston of 25 feet depth is placed at four corners of the house and which will rigidly screw to the metallic frame with EPS block.

viii. Flooring is to be done using GRC panels.

ix. After flooring, erection of roof truss is done. Rectangular hollow section wall plates of size 80x40x3.2 mm are welded over the columns using the steel plates. Then RHS 80x48x3.2 mm are erected at a center to center spacing of 1.05 m with proper connection with wall plate. Similarly purlins are supported over rafters and over that trafford shaped 0.35 mm thick GI sheets are laid.

x. For wall construction, install 60cm x 60cm grid frame to connect the fibre cement board. Screw the fibre cement board to the frame.

7 DISCUSSIONS AND CONCLUSIONS

Kerala experienced a high rainfall and flood which caused damages to the property and life. The major impact was on the houses of all the people irrespective of their socio-economic status. The government have to rebuild Kerala in all sense. The fund allocation for the reconstruction of houses has also been planned. It is very important to consider the construction of houses that is sustainable in all aspects. This can be done in cost effective manner. The paper includes planning, designing and estimation of flood resistant floating house using light weight building material. The functional planning of building was done as per Kerala Building Rules and designed as per IS Code provisions. The analysis and design of all structure members are done economically. The planning and designing is based the soil condition of Munroe island. The materials used for the construction is light weight, sustainable and flood resistant. The floating house will rise up to 3 m from ground level at the time of flood and will rest to the initial position without any displacement. The cost of construction

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is very low as compared to the conventional buildings. The conventional houses built in Kerala are ignorant of withstanding any natural calamities especially flood. There are flood proofing techniques that can be adopted in the construction of houses such as wet proofing and dry proofing. Raw materials like recycled plastic wastes, ferrock, hempcrete plays a major role in flood resistance and also in eco-friendly approach. They are also cost saving materials. This design will be useful for the "Rebuild Kerala" project.

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