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Amphibious Structure Design for Kuttanad

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Abstract - *Over these years, the World has endured large number of natural disasters. Among them the most disastrous one is flood. Flood can cause a potential threat to both life and property. The influence of global warming is one of the major causes that appear to worry the World, especially the effects of flooding happening at the riverside that causes potential loses.*

It is difficult to live against water, but it is possible to live with water level rising. The mean sea level increases all over the world due to Global Warming. The rising water level occupies the land surface. The land surface will be taken away by the rising water. The only way to live with rising water is by constructing houses on the water. So this paper focuses on amphibious structures that can be used as storage units and car porch. Kuttanad is a region in Kerala which always undergoes the problem of flooding. Every year the people in Kuttanad are facing floods and suffering the after effects. Amphibious structures are much preferable in regions like Kuttanad. From the survey conducted in Kuttanad region, it was found out that amphibious structures are mostly needed in this region. Design of an amphibious structure and its load analysis for proposed amphibious structure is being discussed here. Load analysis of the amphibious structure can be done using STAAD pro V8i. Software's such as AUTO CADD, Sketch up was used for 3D Modelling.

***Key Words*: Amphibious, Floating Structure, Flood, Climate Change, Buoyancy etc.**

1. INTRODUCTION

Global warming is a natural threat to all living being which effect different zones of the World. Due to global warming, the water level in sea rises and the water covers many low landislands. This is a great problem for many of the plants, animals and human beings occupying on such low lying areas. This paper mainly focuses on the construction technology of integrated amphibious structures for fluctuating water levels. The development of integrated amphibious structure system is a new idea and approach at present. Earth has a high density of 5.52g/cm^3. The amphibious technology itself is a big challenge because most of the material of our Earth is having higher density compared to water which is 1 g/cm^3. The selection of the materials with concern of density and strength will determine the possibility of this construction technology. Here we are applying the same idea to build amphibious structure of that of a ship. Buoyancy is the main principle behind floatation of structures.

Due to the new idea of construction technology of integrated amphibious structures, most of the knowledge and ideas will be a hurdle to gain the reliable resources and ideas match to our country's resources and local requirements. The purpose of this paper is that an amphibious structure should be able to give an answer to both climate change and meet the psychosocial needs of a growing number of people who live in high risk low lying and coastal areas.

Amphibious structures are becoming more popular among the people in Kerala, especially those who are familiar in living in parts such as the Kuttanad region and is receiving a lot of attention to this new style of houses. Amphibious structures are buildings that sit on dry land like ordinary buildings, except when there is a flood. During floods, they are capable of rising and floating on the surface until the floodwater recedes. A buoyant foundation beneath the structure displaces water and provide the required flotation when needed, and a vertical guidance post prevents the drifting and falling of structure from moving anywhere except vertically up and down, returning it to exactly its original position upon descent. Floating houses, amphibious houses, and floatable houses are the three kinds of houses with buoyant systems that are available according to the site condition. Amphibious structure construction is an adaptive flood risk reduction strategy that works in simultaneously with a flood prone region's natural cycles of flooding, rather than striving to obstruct them.

Fig- 1: Floating Houses in Iburg, Amsterdam, Netherlands

(Source:http://www.inspirationgreen.com/floating- homes.html.)

2. STUDY AREA

The contents under study area are taken from ground water information booklet of Alappuzha district, Kerala State. The study area selected is Alappuzha, one of the southern districts in Kerala, India having its North Latitudes – $9^0$05' and 9^0 54' and East Longitudes – $76^0$17'30" and 76^0 40'. Alappuzha district has an area of 1414 km^2. The district is bounded on the north by Ernakulum District, east by Kottayam and Pathanamthitta District, south by Kollam district and west by Arabian Sea. The District lies in the midland and coastal areas.The major rivers flowing though the district are Manimala River, Pampa River and Achankovil River.

All these rivers branch off in the low land and their branches intermingle and they ultimately drain into the Vembanad Lake at different places. Alappuzha has been traditionally vulnerable to natural disasters on account of its unique geoclimatic conditions and vast coastline. The frequent flood in Alappuzha encouraged selecting this as the study area. Based on the agro-ecological and climatic characteristics like the height from the mean sea level, influence of rivers, flood risk, risk of saline water intrusion, soil type and fertility and the cropping pattern, Kuttanad is divided in to six agro- ecological zones. They are- Upper Kuttanad, Purakkadu Kari, Lower Kuttanad, Kayal lands, North Kuttanad and Vaikom Kari.

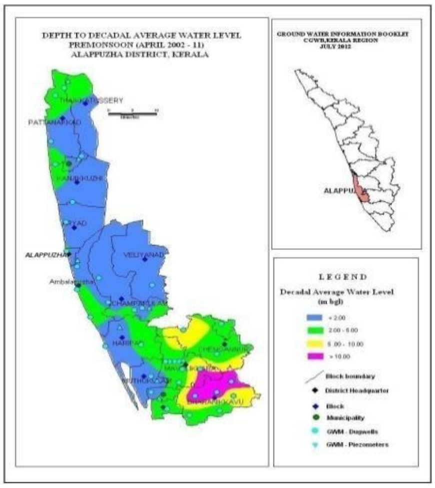

Fig-2: Pre monsoon Depth to water level of Alappuzha district(April 2002-11) (Source: Ground water information booklet of Alappuzha district, Kerala state)

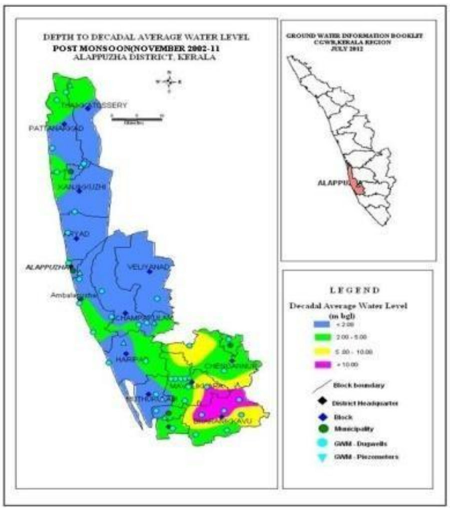

Fig -3: Post monsoon Depth to water level of Alappuzha district (Source: Ground water information booklet of Alappuzha district, Kerala state)

Table- 1: Block wise Decadal Average Depth to WaterLevel (2002-2011)

Sl. No	Block Name	Pre monsoon(mbgl)	Post monsoon(mbgl)
1	Ambalapuzha	2.20	1.10
2	Aryad	1.62	0.88
3	Bharanikkavu	7.91	6.27
4	Champakulam	1.50	0.44
5	Chengannur	4.36	2.78
6	Haripad	1.65	0.71
7	Kanjikuzhy	1.71	1.12
8	Mavelikkara	3.34	1.70
9	Muthukulam	2.89	1.57
10	Pattanakad	1.98	0.90
11	Thaikkatussery	2.23	1.06
12	Veliyanad	0.84	0.45

2.1 Data Collected: High Flood Level of Kuttanad Region

Flood hits most parts of Alappuzha, typically Kuttanad regionevery year with different frequencies. A 1989 study on water balance in Kuttanad stated, based on historic data that floods in Kuttanad have a return period or recurrence interval of two years, five years, ten years, twenty-five years and fifty years.

According to it flood with a return period of ten years and above are severe, while those with a return period of five years are less severe. The last time a severe flood hit Kuttanad was in 2005.

Table- 2: Data on high flood level in Kuttanad during 2018 flood

Sl. No	Block Name	HFL (m)
1	Ambalapuzha	1.4
2	Aryad	1.62
3	Bharanikkavu	0.6
4	Champakulam	2.06
5	Chengannur	0.5
6	Haripad	1.79
7	Kanjikuzhy	1.38
8	Mavelikkara	0.8
9	Muthukulam	0.93
10	Pattanakad	1.6
11	Thaikkatussery	1.44
12	Veliyanad	2.05

3. MATERIAL SELECTION AND DESIGNING

Material selection is a key step in the process of designing anyphysical object. The main idea of material selection is to reduce the cost while meeting product of desired performanceneeds. Systematic selection of the best material for a given application begins with properties and costs of selected materials. It is essential that a designer should have a proper knowledge of the properties of the materials and their behaviour under working conditions. Some of the important characteristics of materials are: strength, durability, flexibility, weight, resistance to heat and corrosion, ability to cast, welded or hardened, machinability, electrical conductivity, etc.

The next problem arises is why material selection and design is important. Failures arising from selection of bad material are not uncommon in many industries. In an application that demands a high tensile strength, a material with higher tensilestrength must be selected. If a proper material selection is not done, the product life tends to be highly unpredictable. Therefore, the material selection process is quite important for the long term success of engineering applications. The selection of material is a monotonous task because there are number of factors that have to carefully taken up before making the final decision. The main requirement may be the strength of a particular application, but depending on theworking environment and behaviour, other factors must also have to be considered.

3.1 Plan for Proposed Structure

We are proposing a 4 x 5 car porch, which consist of vertical guide posts attached to its side for the easy uplift and downward movement of the buoyant foundation during flood. As per the IS specification, height of normal structures is standardized to 3 meters. But in the case of our proposed structure we are providing a height of 5meters for safe lifting of valuables like cars, furniture and human life.

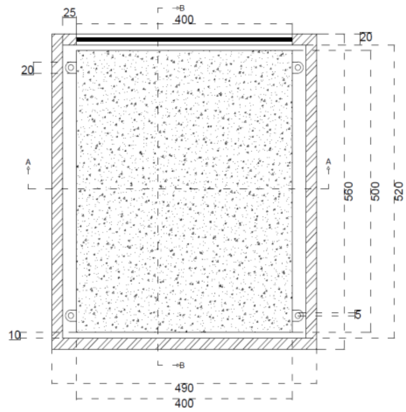

Fig-4: Plan for the proposed structure

3.2 Design Using Concrete

Concrete is a widely used construction material. Air tight bulkheads are provided in the foundation for the purpose of providing floatation. Since concrete is denser than water, concrete tends to sink in water. To overcome this, bulk heads are provided. Here Archimedes principle of buoyancy is being used. The structure is designed in such a way that force exerted by the water to the buoyant foundation is greater than the forceacting downward due to dead load and live load. Design of thestructure is in such a way that it can with stand load in both wet and dry conditions. Almost all the floating structures that exists today uses concrete as the foundation. Light weight concrete is being used for reducing the weight of foundation. The concrete hollow cube that helps for floatation can be converted as a room for living if it is been planned carefully.

Design using concrete structure is suitable both for flooding and non-flooding conditions. The designed is in such a way that during non-flooding conditions, the structure sits on ground as a normal structure and during flood it rises up due to the buoyancy of the foundation. The structure is guided through a vertical guide post to prevent drifting. Since the structure enclosed with brick and rubble masonry foundation, the structure wont effected directly by wave action. Concrete is more durable that other two materials as

RCC concrete can take both tension and compression very effectively. Compressive force is the major force acting in the structure. Unlike other two materials, there is only one phase of construction as there is no need of any pre-casting to be done.In design using concrete, both the structure as well as the buoyant foundation is been cast in site along with the work. A slab thickness of 10 cm is provided in structure and the total structure is divided into four bulk heads using partition slabs of 10 cm thickness to increase the rigidity. TMT steel bar of 8 mm diameter to 10 mm diameter is used for reinforcement of the buoyant foundation as well as for the roof slab.

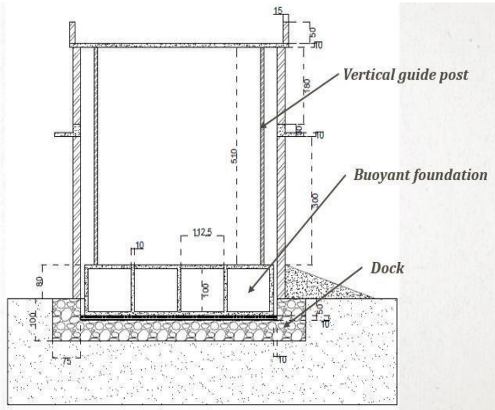

Fig-5: Section B-B, Side view of the structure using concrete.

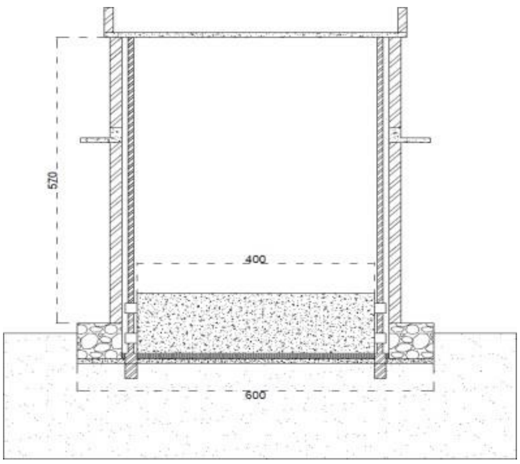

Fig 6: Section A-A, Front view of design using concrete.

3.3 Components of Proposed Design

The proposed design consists of: Dock, Vertical Guide Post, Flexible pipes and buoyant foundation.

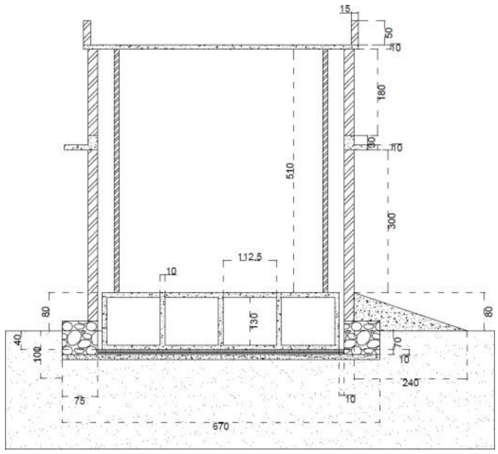

Fig -7: Components of proposed foundation.

DOCK: Dock is structure that is built under the ground surface using rubble masonry for the purpose of accommodating the buoyant foundation. The soil to be excavated for the construction of dock depends upon the strength and other soil parameters of different areas. A layer of rubber mesh of 10cmthickness is being provided on top of the dock for the safe placement of the buoyant foundation. The rubber mesh also helps in reducing vibrations acting upon the foundation. One of the major role of the dock is to transfer the load acting on the whole structure to the ground. The brick wall enclosing the buoyant foundation is being built up on the dock. The rampfor vehicle movement is also being built up on the dock. the whole structure to the ground. The brick wall enclosing the buoyant foundation is been built up on the dock. The rampfor vehicle movement is also being built up on the dock.

Vertical guide post: The vertical guide posts are steel structures integrated to the dock and roof slab. The main purpose of the vertical guide post is the vertical movement of buoyant foundation without drifting, as the buoyant foundation moves up and down through vertical guide post using ball bearings, the horizontal motion is being restricted. The vertical guide post of required length diameter and IS grade is provided according to the drag force acting on the structure. In our project stainless steel round bars of 10mm is provided

Flexible pipes: Flexible pipes are components that are used to provide electricity and water supply to the structure and it'salso used for the safe removal of sewage waste from the structure. Commonly PVC heavy duty hose pipes are used for the purpose of water supply and sewage transfer. Electricity istransferred through high quality copper wires with high insulation.

Buoyant foundation: Buoyant foundation is the main component of the proposed design. It is the part of the structure which helps for the floatation of the foundation. Reinforced concrete is being used for the construction of buoyant foundation. The principle behind the flotation is buoyancy.

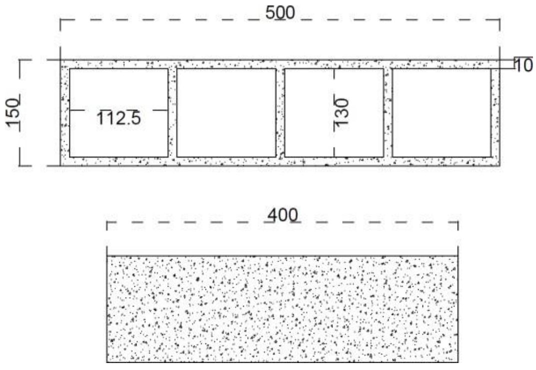

Fig-8: Sectional & front view of foundation.

Four bulk heads are provided along the longer side of the foundation to achieve enough buoyancy for floatation. RCC slabs of 10cm thickness is been constructed. The height of the buoyant foundation is calculated to be 150 cm which makes the height of bulk heads to be of 130 cm. the width of bulk heads provided are 112.5 cm each and the bulk heads span along the entire width of the foundation that is of 4 m. TMT steel bars of 8 mm is been used for the reinforcement of the entire buoyant foundation.

3.4 Load Calculation of Proposed Structure

Volume calculation:

Volume of top and bottom slab $=0.1\times 5\times 4\times 2 = 4m^3$

Volume of front and back slab $=0.1\times 1.3\times 5\times 2 = 1.3m^3$

Volume of side and pillar slabs $=0.1\times 1.3\times 3.8\times 5 = 2.47\ m^3$

Total volume = $4+1.3+2.47 = 7.77\ m^3$

Note: density of RCC = 2500 kg/m³

Mass of foundation = volume * density

$= 7.77\times 2500 = 19425kg$, say $19500kg$

Live load $= 2000kg$

Total weight = $2000+19500=21500kg$ Force of foundationacting downwards

$= 21500\times 9.8 = 210700\ N$

Note: density of water 1000 kg/m³

Buoyant force acting on the foundation = ρgv

$=1000\times 9.8\times 5\times 4\times 1.5$

$=294000\ N$

Since buoyant force is greater than downward force acting,the structure will float.

3.5 Freeboard Calculation for the Proposed Design

Total downward force $= 210700\ N$

Buoyant force for equilibrium, $\rho vg =$

$210700\ N$

ie) $1000\times 4\times 5\times x\times 9.8 = 210700$

$x = 1.075m$

ie) freeboard available is $1.5 - 1.075 = .425m$

$= 42.5cm$

Freeboard of $42.5cm$ is provided.

3.6 LOAD ANALYSIS

The building loads are taken up by the frames. A residential building frame needs to resist the loads and must be designed to withstand eight of these loads which include wind, earthquake and snow without catastrophic stress on the structure.

Structural analysis is important because it can evaluate whether a design will be able to withstand external stresses and forces expected for the design. A primary reason that structural analysis is beneficial is to determine the cause and reason for structural failure. Once the dimensional requirement for a structure have been defined, it becomes necessary to determine the loads the structure must support. Structural design therefore begins with specifying loads that acts on the structure. The design loading for a structure is often specified in building codes. There are two types of codes: general building codes and design codes.

In this paper different software are used for load analysis, first of all the basic design was made using Auto CADD, software such as Staad.Pro, Ansys are used for load analysis, the software we used in load analysis is Staad.Pro. Staad.Pro software is widely used in analysing and designing structures- buildings, bridges, towns etc. It's the world's number one structural analysis and design software that supports Indian andInternational codes. Staad.Pro allows the Structural Engineersto analyse and design virtually any type of structure. The structures are analysed assuming static conditions like a point of time during flood at extreme situations.

3.7 LOAD ANALYSIS FOR NON-FLOODING CONDITION

Load analysis was done using STAAD pro. During non-flooding condition, the buoyant foundation simply sits in the ground. Therefore the foundation is assumed to be fixed in the ground during non-flooding condition. An area load of 5 kN/m is been applied to the top slab as live load and dead load of 195 kN is provided to the whole structure and maximum absolute bending moment is found out as load analysis.

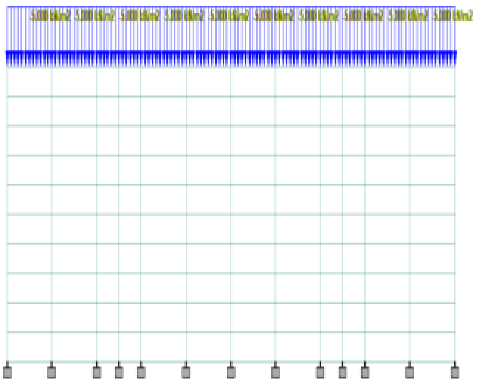

Fig-9: Side view of live load on structure at non-flooding condition.

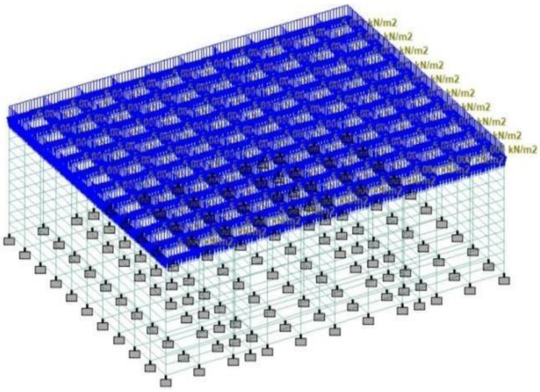

Fig -10: Isometric view of live load on structure at non-flooding condition.

The obtained maximum absolute stress on the structure during non-flooding condition is 1778 kN/m². The maximum permissible compressive stress of concrete is 0.446 fck, ie; for M30 grade cement the value is 13380 kN/m². Hence thestructure in noon flooding condition is safe.

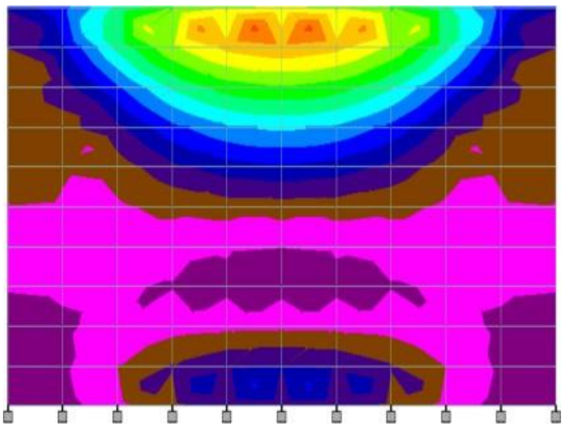

Fig 11: Side view of absolute maximum stress on structure at non-flooding condition.

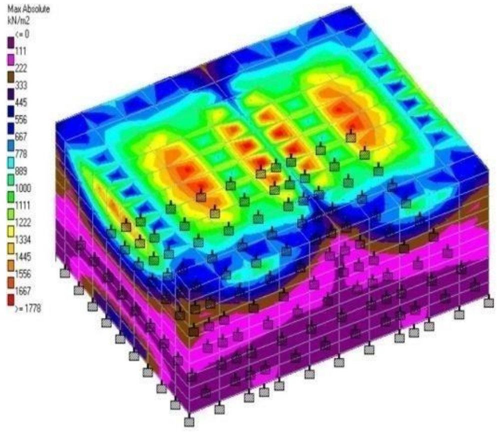

Fig 12: Isometric view of absolute maximum stress on structure at non-flooding condition.

3.7 LOAD ANALYSIS FOR FLOODING CONDITION

During flooding condition there will be variation in load takingsituations. As the foundation floats on water during flooding, the load acting on structure varies from top to bottom. Here the foundation moves up and down through the vertical guide post. Vertical guide post is attached to the foundation using ball bearing and fittings. This is a dynamic situation where the foundation moves vertically and the water pressure varies with height. For analysing this situation software which is apt to analysing dynamic structures like ANSYS Fluent or HyroD is required. To analysis this as a static structure, a point of time is chosen for analysing. For analysing the structure during flooding in STAAD Pro, supports for the structure is tobe determined. The vertical guide post is been chosen as the fixed support. Live load of 5kN/m² is provided to the top slab. Total buoyant force acting upon the structure is 294 kN. When converting to pressure it becomes as a hydraulic pressure of 14.7kN/m². The hydraulic pressure is acting form the point under the freeboard of 42.5 cm. the pressure value starts from zero and increases along the downward direction and reaches the maximum value of 14.7 at the very bottom end. A constantvalue of 14.7kN/m^2 will act along the entire area of bottom plate upwards. This situation is analysed in STAAD Pro.

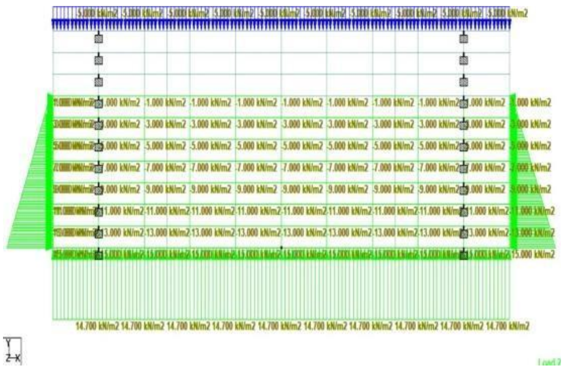

Fig -13: Side view of live load and buoyant force on structure at flooding condition.

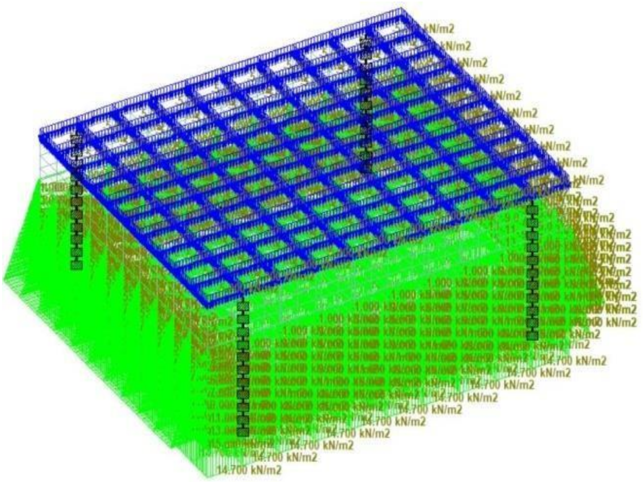

Fig- 14: Isometric view of live load and buoyant force on structure at flooding condition.

The obtained maximum absolute stress on the structure during non-flooding condition is 13000kN/m^2. The maximum permissible compressive stress of concrete is 0.446 fck, which is for M30 grade cement the value is 13380 kN/m^2. Hence the structure in flooding condition is also safe.

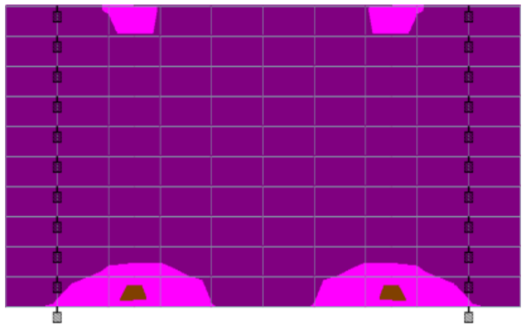

Fig- 15: Side view of maximum absolute stress on structure at flooding condition.

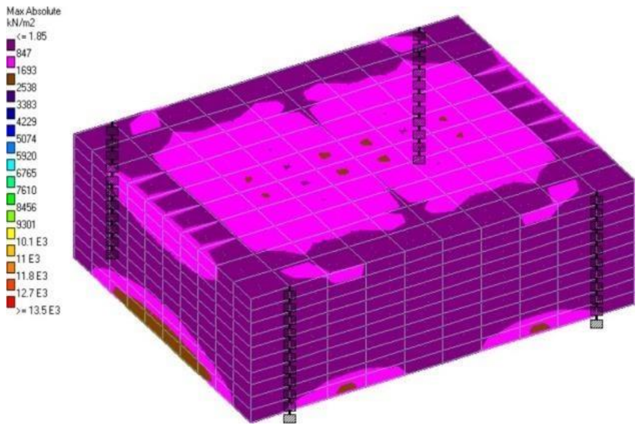

Fig -16: Isometric view of maximum absolute stress on structure at flooding condition.

4. CONCLUSIONS

From the survey conducted on KUTTANAD, it is found that amphibious structure is possible in KUTTANAD. This type of structures would help in reducing property loss as well as loss of life during unpredicted floods. Load analyses of the proposed structure during flooding and non-flooding conditions are done in Staad.Pro and are found to be safe.

Construction of such types of Amphibious structures are possible if we can afford a little more of Capital. When comparing the estimated cost for the proposed structure with the normal structure it was found that, around 13 % extra money of the normal structure is being used for the construction of the proposed amphibious structure. For the cost of 13% extra money, we can float a structure of a single room successfully.

For the people in Kuttanad availing a full flourished amphibious house very difficult since a complete amphibious house will cost crores to build. Since we know that amphibious structures are expensive than a normal structure, and for the normal people to own an amphibious structure for protecting themselves as well as their valuables from flood, then single room amphibious can be economically built without spending too much extra than an normal structure.

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