International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Design Parameters and Fluid Interaction of Amphibious Structures: A Review

Jainandan I, Govind, Chethan R, Jagannath Gopal Rathod

UG student, Department of Civil Engineering, Dayananda Sagar College of Engineering, Bengaluru (560078), Karnataka, India

A B S T R A C T

The rise in sea level has been one of the primary effects of global warming due to which water is invading coastal regions, influencing glacier melt, affecting high river discharge, and causing the disappearance of vast low-lying areas. The subsequent downpours, winds, and floods have become a noticeable component of the destruction of houses and loss of life. Many flood-resistant techniques such as the construction of floodwall, structure elevation, and high discharge sewers prove to be costly. There is a need for low-cost flood-resilient structures and flood-resistant urbanization. Amphibious architecture is found to be a solution for such problems. The amphibious structure floats during the occurrence of flood and rests on the ground during the dry season. This paper reviews current research and development related to the Amphibious system.

Keywords: Amphibious; Flood-resilient; Low-cost; Float; Global warming

1. Introduction

Global warming has caused an increased frequency of floods. Thousands of people die. Loss of property and infrastructure has made civilization difficult especially in areas residing near the coast and as well as low-lying areas. (Climate.gov) The mean level has risen about 21-24cm since 1884. The rate of rising is accelerating at an industrial pace. Through Agreements and conferences such as COP26 (UN Climate Change Conference) attempts are made to lower the emission of greenhouse gases. The increase in global temperature and wave height has caused bloodshed and destruction. To reduce the impact of global warming a low-cost flood mitigation technique called amphibious architecture has risen over the last few decades and it is getting popular in recent days. Amphibious structures are lightweight systems that rest on the ground during non-flood seasons and float during floods. This structure consists of a guidance post to restrict them from moving away while floating. The structure is designed for the following forces 1. Hydrostatic force (floodwater depth) 2. Hydrodynamic forces (Floodwater velocity) 3. Forces of debris 4. Self-weight and Live load 5. Wind pressure and earthquake if necessary. The forces should be uniformly distributed across the structure in order to avoid tiling. The structure should be designed to resist 1in the 100-year occurrence of flood.

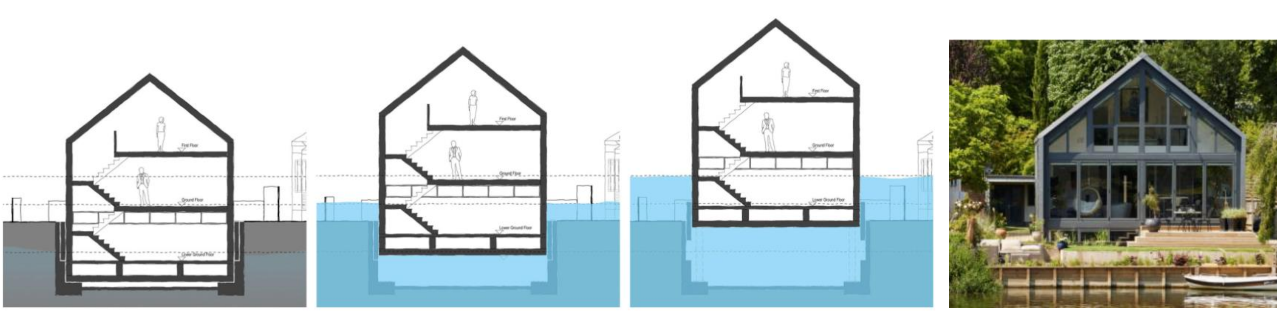

Fig. 1- Floatation of Amphibious House during flooding (Baca Architects, Buckingham UK)

* *Corresponding author.* Tel.: ; +91 6362183137
E-mail address: jainandan.dsce@gmail.com

2. Literature Review

2.1 Building Resilience through Flood Risk Reduction: The Benefits of Amphibious Foundation Retrofits to Heritage Structures
Elizabeth C. English, Meiyi Chen, Rebecca Zarins, Poorna Patange, and Jeana C. Wiser (2019)
In this paper overview of amphibious retrofits and application to the preservation of historic sites have been provided. Case studies of retrofits:
a. Princeville, North Carolina, United States was founded by freed slaves incorporated by African Americans. This town has been devastated by the 100-year hurricane and put 80% of the town underwater. In order to preserve the Baptist church, which was built 100 years ago, and the museum, the amphibious retrofit design was proposed to the church in such a way as to preserve its historical appearance. The loss avoidance ratio for the house was 4.68 and for the museum was 2.2. b) Charleston, South Carolina is threatened by flooding and is predicted to experience 180 days of tidal flooding by 2045 (Riley 2015) and flooding is estimated to occur more than 26 times a year. Permanent static elevation was the only practical approach yet it was expensive and upsets the presence of historical neighborhood. C) Farnsworth House, Plano, Illinois is designed by architect Ludwig Miles van der Rohe, was retrofitted with vertical guidance posts which are extensions of columns reaching 4.0-4.6m allowing it to rise and fall during the flood. Buoyant foundation retrofit serves as a remedy for the preservation of historically important structures from flood damage.

Fig. 2-(a, b) Farnsworth house, Plano, Illinois; (c) Mt. Zion Primitive Baptist Church in Princeville after flooding (3D render) (d) Mt. Zion Primitive Baptist Church in Princeville before flooding

2.2 Drag coefficient for amphibious house
Mohammad Ali Nekooie, Mohamad Ibrahim Mohamad & Zulhilmi Ismail (2017)
This review plans to identify forces that occur from flood onto amphibious structures and develop an equation for the drag coefficient. An Experimental method was used to calculate drag force on 1/25 scaled amphibious structure in a down plain model. The experimental setup consisted of 12m long fume with 1m wide and .0.5m deep cross-section, the slope of the channel was considered zero. Imitation of the scaled-down model of the amphibious structure consists of 1cmx1cm the lateral columns used were made of aluminum, Similarly, the pontoons and the slab were connected to the column using the SKF bearing system. Linear variable differential transformer (LVDT) a sensor was used to measure the displacement of the structure. The platform and pit area was installed 8m from the opening. With the equation developed the test shows a maximum of 10% error. The equation can be used with flood plain which doesn't exceed 2m/s and the equation can be used for Froude number values between 0.1 and 0.6.

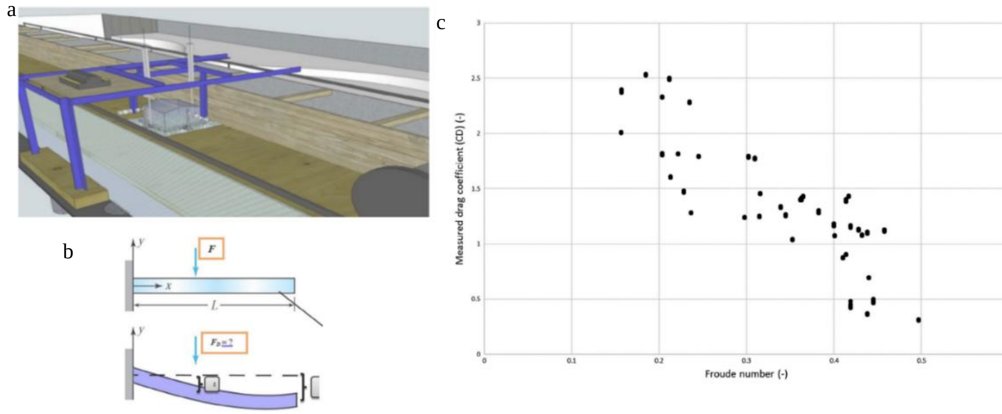

Fig. 3 - (a) Frame installation of test setting; (b) LVDT ;(c) Correlation between drag coefficient and Froude number

2.3 Thriving with water: Developments in amphibious architecture in North America

Elizabeth English, Natasha Klink, and Scott Turner (2016)

Elizabeth English, et al have reviewed existing and well-proposed amphibious buildings and also their limitations and regulatory obstacles during the development. Amphibious strategies have accepted the flood water rather than creating barriers but preventing it from causing significant damage to the system. The amphibious system is not a new concept, it has been over forty years. Residents of Louisiana, have been retrofitting their fishing camps with expanded polystyrene as buoyancy blocks as a flood mitigation strategy caused by the Mississippi River. The Netherlands has a long history of severe flooding. In the last 2 decades, they have built amphibious houses along the mass river(fig) Morphosis Architects designed an amphibious house and completed it in October 2009 under the "Make It Right" foundation launched by Brad Pitt in New Orleans (fig). Several other prototypes have been built in the UK, Thailand, United States, Bangladesh.

Fig. 4 (a)Netherland's settlement (b) Float house, New Orleans (c) Amphibious housing in Leeville (d) Lift house Dhaka Bangladesh

2.4 Amphibious Architecture and Design: A Catalyst of Opportunistic Adaptation? - Case Study Bangkok

Polpat Nilubonab, William Veerbeekab, and ChrisZevenbergen (2016)

Polpat Nilubonab, et al have studied the potential role of amphibious structures in the transformation of Bangkok as a long-term flood-resilient city. Amphibious technology can be applied to an existing building or replace the existing building if flood-occurring areas have floodwater depth of 0.6m to 4m. For flood depth between 0.3m to 0.6m wet proofing technology is preferable. In the area where floodwater depth is below 0.3m, dry floodproofing techniques are more appropriate.

2.5 A Loss Avoidance Study of Amphibious Housing

Snehanjali, Sumantha, Elizabeth English (2015)

Research has been conducted on the "Loss Avoidance study" for houses that have buoyant foundations in Leeville located in Louisiana's coastline, USA. Leeville has lost approximately 70% of its land area. Loss avoidance study (LAS) is an evaluation of losses that would have occurred if it has not been retrofitted with a buoyant foundation. LAS is assessed based on building repair costs, contents losses, displacement costs. Loss avoided ratio for following depth of water 1.5 feet = 1.28, 3 feet = 2.06, 4.5 feet = 2.58. As found by the estimation, higher flood depths have a higher loss avoidance ratio. So even though flood increases the house remains intact at the same cost of retrofit showing system is extremely beneficial and cost-effective

2.6 Amphibious Urbanization as a Sustainable Flood Mitigation Strategy in South-East Asia

Mohamad Ibrahim Mohamad, Mohammad Ali Nekooie, Zulhilmi Bin Ismail, Roohollah Taherkhani (2013)

This review is conducted point load test and drag force estimation. Studies have been conducted on the control of tilting, horizontal stability. Amphibious structures were analyzed on 2 parameters, 1. Width varying from 7m to 14m and 2. Point loads vary from 1Kn to 20 Kn. The drag coefficient is assumed 1.25. The figure shows a house with a 12m width having a load of 20kn has a maximum rotation of fewer than 5 degrees. The results show tilting and rotation of structure during the flood are under control. Lateral supports systems should be designed with safety factor 2.

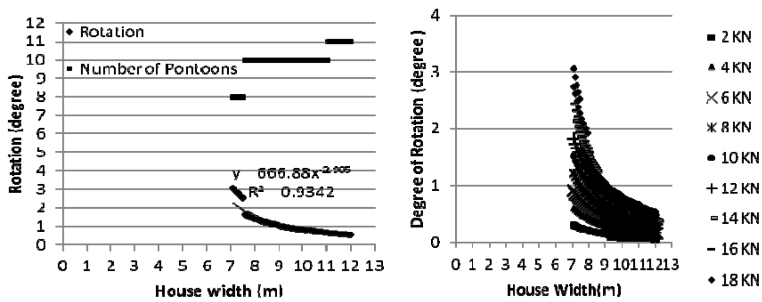

Fig. 5 (a) Pontoon design with rotation due to 20KN Point load (b) Results of tilting

2.7 Building Damage due to Riverine and Coastal Floods

Norberto C. Nadal; Raúl E. Zapata; Ismael Pagán; Ricardo López ; and Jairo Agudelo (2010)

Flood events can be classified into riverine and coastal. Riverine can be caused due to overflow of stream channels. Coastal floods can be caused by tsunamis or unusual high tides [Meteorological Organization(WMO)2005]. Norberto C. Nadal, et al have analyzed the building damage due to riverine floods and coastal floods using Monte Carlo simulation. Monte Carlo simulation is used to perform load resistance analysis and also account for uncertainly of input parameters. Expected flood damage is expressed as vulnerability matrices or 3-dimensional surface plots relaying on hydrostatic (floodwater depth) and Hydrodynamic forces (floodwater velocity). This study shows the significance of considering hydrodynamic forces for vulnerability assessment located in flood-prone areas, while only hydrostatic forces were used. Each of these matrices represents the mean damage suffered by 10000 hypothetical buildings due to unique flooding. Every one of the structures was assessed at eight different 45°-rotational intervals, where the rising water might conceivably move toward the structure. Riverine floods shows maximum EFD (expected flood damage) for the case depth= 3.0m and Velocity=3.0m/s is 54% by considering flood velocity, whereas without considering floodwater velocity results show (d=3.0m, v=0m/s) 36% EFD, represents 18% of underestimation. EFD calculated for coastal storm surge for d=3.0m, v=6.1m/s was found to be 140%. Significant damage was observed for depth and velocity greater than 1.8m and v=5.5m/s. Flood Damage by tsunami for depth and velocity of 3.0m, 1.2m/s was found to be 190% compared to flood damage by still flood water. Total damage by the tsunami was depth and velocity beyond 1.5m and 7.3m/s.

Conclusion

The amphibious structure is a simple flood mitigation strategy but requires precise structural calculation for the functioning of elements. There is a need for more scientific research in large-scale development, where the building could sustain a higher load-to-weight ratio and its application could be in form of public buildings, hospitals, Signal towers, etc. Amphibious structures could be planned as a whole network and can be made to work like an amphibious village with amphibious infrastructure. Dynamics of flood forces, preparedness of tsunami, flood routing, workable MEP elements, are some of the areas of research required for the operation of the amphibious village. Usage of IoT, hydraulic systems, green energy generators, could make the system more technologically advanced for the years of flooding to come. The application of recycled materials would reduce the risk of global warming.

References

Elizabeth C. English, Meiyi Chen, Rebecca Zarins, Poorna Patange & Jeana C. Wiser (2021) Building Resilience through Flood Risk Reduction: The Benefits of Amphibious Foundation Retrofits to Heritage Structures, International Journal of Architectural Heritage, 15:7, 976-984, DOI: 10.1080/15583058.2019.1695154

Mohammad Ali Nekooie, Mohamad Ibrahim Mohamad & Zulhilmi Ismail (2017) Drag coefficient for amphibious house, Urban Water Journal, 14:10, 1045-1057, DOI: 10.1080/1573062X.2017.1325914

Thriving with water: Developments in amphibious architecture in North America Elizabeth English, Natasha Klink , and Scott Turner E3S Web Conf., 7 (2016) 13009;DOI: https://doi.org/10.1051/e3sconf/20160713009

Nilubon, Polpat & Veerbeek, William & Zevenbergen, Chris. (2016). Amphibious Architecture and Design: A Catalyst of Opportunistic Adaptation? – Case Study Bangkok. Procedia - Social and Behavioral Sciences. 216. 10.1016/j.sbspro.2015.12.063.

Sumanth, Snehanjali & English, Elizabeth. (2015). A Loss Avoidance Study of Amphibious Housing.

Mohamad, Mohamad & Nekooie, Mohammad Ali & Ismail, Zulhilmi & Taherkhani, Roohollah. (2012). Amphibious Urbanization as a Sustainable Flood Mitigation Strategy in South-East Asia. Advanced Materials Research. 622-623. 1696-1700. 10.4028/www.scientific.net/AMR.622-623.1696.

Norberto C. Nadal and Raúl E. Zapata and Ismael Pagán and Ricardo López and Jairo Agudelo (2010) Building Damage due to Riverine and Coastal Floods; Journal of Water Resources Planning and Management 136-3.327-336; DOI: 10.1061/(ASCE)WR.1943-5452.0000036

https://www.newindianexpress.com/cities/kochi/2020/feb/20/flood-resistant-structures-2105888.html
https://www.thebetterindia.com/204381/kerala-floods-innovation-floating-house-monsoon-sustainable-architecture-india/
https://www.architecturalrecord.com/ext/resources/Issues/2017/April/continuing-education/Amphibious-House-What-is.pdf
https://architectureprize.com/winners/winner.php?id=3736
https://www.buoyantfoundation.org/vietnam-amphibiation-in-the-mekong-river-delta
http://www.baca.uk.com/amphibioushouse.html
http://icaade.org/
https://www.construction21.org/case-studies/h/the-thames-amphibious-house.html
Fema P-55 (2011) Costal Construction manual Volume I,II