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Water Architecture: A Study to Make Structure Feasible

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***Abstract*: The study aims to learn architecture on water and analyze general characteristics and parameters to make a building feasible. The research begins with the comprehensive study of building projects in or on water that are explored on the basic of their significant role in water architecture. For a structure to be functional and serving its purpose, it is very important that the design and construction should be done by following some guidelines that are crucial to make a structure practicable, preferably accepted by government body. The main aim of this investigation is to analyze the fundamental features and general criteria that makes a building functional. The study has been justified with the help of different building codes and analysis of different case studies.**

***Keywords*: Water architecture, Idiosyncrasy of building, Feasibility, Architectural characteristics, Architectural challenges.**

1. Introduction

Water – an element in nature that life is constantly surrounded by; an element that has given birth to life on Earth and behaves as a basic an etiological potion of life is of great significance. Earth covering 70% with water and the man himself consists of 75% water, and that his well-being requires regeneration of his basic substance "WATER" makes this significant. However, water being continuous supporter of life, we have made our shift to land but the bond still remains significant as ever.

The architecture for water transcends time and space in its proliferation across geographies and cultures. From early settlements along rivers like Nile or Indus, to lakes like Dal lake or Polcat lake; from building decks to flyover or bridges moreover, from houseboats in Kerla to villas in Goa. These unique and diverse structures articulated the anthropogenic relationship to water. In that sense, they have a deep connect to the people and the physical environment in which they are located.

The study is to review the architectural characteristics and general parameters of building through built structures in or on water and to suggest the reference ideas for new projects so as to make a building feasible and functional. Every design in its starting has general guidelines and restrictions that are to be followed, so as to make it practicably possible. The research is also continued by the study of general guidelines that are useful at the time of designing a building. The guidelines are either present in building codes (accepted by the government) or are crucial parameters to make a structure functional. Development of floating buildings needs the implementation of new technology, social and community knowledge. The new knowledge and experience gained in buildings can lead to optimum future approaches. This paper presents guidelines for developing design strategies or decision-making frameworks to overcome challenges for building in or on water.

A. Need of architecture on water

The life on Earth is today plagued by adverse climate changes, global warming, the increasing toxic emissions, rising population, and scarcity of land and sky rocketing land cost. With various countries, such as Holland, Netherlands, etc. fighting rising water levels for decades, it is now time to brace ourselves against the unseen future and design solutions to cope with the ever-changing community on Planet Earth.

Water in city has been attracting increasing attention from an urban planning point of view. Cities are clearly turning their faces back towards their rivers and lakes, waterside and overwater living and work environment, city beaches, port regeneration and new riverside promenades are being developed to improve quality of urban life. Responding to this appositeness architecture both on water course itself and its banks have emerged and been implemented.

Over the years, man has been trying to explore new frontiers for living. After utilizing the earth's empire to its utmost extent, factors such as increasing population, scarcity of land, sky rocketing land cost, global warming have forced man to look out for new avenues for human settlements. After exploring all possibilities of architecture structures on land, for catering the need of habitable space, architects and designers have now attempted to explore the possibility of construction on water.

According to the increase of economic income level people want to live and enjoy leisure activities near or on the water. Therefore, water friendly building has emerged as a strong alternative architecture and needed more and more in the future to improve the living standard of people.

B. Water architecture – A new exemplar

According to different needs of architecture on water, water architecture is emerging as a strong and attractive alternative idea in field of architecture. Architecture on water entices major investments, structures and has spatial ability to provide for ecological restoration and social and economic recuperation. "The popularity of living, playing and working by the water is evident through a creative interface between water redevelopment and architectural place making" (Grau et al., 2010).

New exemplar features can be summarized as new buildings concepts, applications, and modular construction on water. Water Architecture- A new exemplar of architecture can be described as a new model or system of architecture with new concept and Zeitgeist like sustainability and green building (The Free Dictionary, 2012). A historically prevailed and having new prospective in future architecture on water can be exemplar in field of architecture.

C. *Relevance of the research work*

The history of water ranges from historian era to new future possibilities, in India and all over the world. Therefore, as a student of architecture it is of importance for us to extend the limits of our knowledge to every kind of architecture which has ever been prevailed or been put up in use for architecture purpose, for which architecture on water is of significant importance. Emerging as new architects and designers it is important to have vast knowledge in each and every kind of architecture that has present need and future scope. Being the stakeholders of architecture "ARCHITECTS" it is once responsibility to know all the designing, technical, and functional aspects of making a structure feasible. Therefore, finding it of great importance and as a researcher, the study has been inculcated.

2. Illustrations of building projects

A. *IBA Dock*

Location: Hamburg, Germany
Year of completion: 2009
Area: 1640 square meter

This building was the headquarters of the IBA (international building exhibition) Hamburg Germany as well as an information and event centre for the IBA. Now the building is being used for Urban and Architecture information centre in Hamburg

Idiosyncrasies of building:

- The IBA Dock (Fig 1- left) has 3 stories, situated on an approximately 43m long and 26m wide concrete pontoon and the building is made of steel in prefabricated modular construction.
- The IBA Dock not only houses the exhibition IBA, but is also itself an exhibition of innovative building components and integrates numerous renewable energy technologies (IBA DOCK. (2017)).
- The building is based on "zero balance concept", which focuses on solar energy management and systems that provide buildings with sustainable heating and cooling all year round (Fig. 1 - right) (Archdaily. (2012)).
- Installation of ready-made heating and cooling ceiling elements in the entire building.
- The building was planned that air conditioning might be possible without conventional energy sources such as oil and gas.

Application of various renewable energy systems:

Solar energy captured from roof top photovoltaic panels feeds into an electric heat pump that draws its environmental heat directly from the Elbe using a heat exchanger built into the base of the concrete pontoon. This provides both the heating and cooling requirements for the water and air conditioning of the building. The building features heating and cooling ceiling system, along with a ventilating machine that provides air exchange for the entire building. Almost no further cooling or heating energy is needed. (Darren Quick, 2012).

Fig. 1. IBA DOCK view (right), Sectional view (left)

B. *Floating mosque*

Location: Palm Jebel Ali, Dubai, UAE
Year of completion: 2007

Idiosyncrasies of building:

- A single storey floating mosque (Fig 2- left) has traditional Islamic arches and two rows of transparent plastic columns that support the roof and give daylight through the prayer hall.
- The mosque could be floating by the large pontoons made of concrete & Styrofoam.
- The design of building is self-supporting in terms of energy
- The interior is characterized by giant funnel-shaped transparent columns that do not only support the roof, but also allow filtered light to illuminate the inner space (Waterstudio, 2014).
- Roof and columns are made transparent by composite material. (fig. 2- right)
- Sea water is purified and pumped from outside through the building components like floor, wall & roof, and it flows out again over the roof via the columns.
- A transport controller ensures that the transparent columns always keep the water in full, to give continuously visual attraction (Olthuis, K. and Keuning D., 2010).
- The flat-roofed floating mosque is environmentally friendly by using the hydrothermal temperature,

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pumping sea water from the Arabian Gulf through a vein-like system of wall and floor cools the building structure down by 15 degree Celsius (from 45 degree to 30 degree), reducing the cost of cooling by around 40 percentage.

- Air conditioning by the electricity from solar photovoltaic cells brings the temperature down even further to 21 degrees Celsius. Electricity from solar energy is also required for the pumping machine (James Reinl, 2007).
- The roof and walls could absorb little heat because of porous exterior material, consisting of a sponge like ceramic substance with highly low density.
- The fat external walls have a high accumulative volume due to their extraordinary density and great size (Reinl, J., 2007)
- New concept of mosque with light on water, adoption of renewable energy system (hydrothermal energy usage and solar panel system in cooling), and application of maximum daylight influx & special exterior wall material makes it feasible.

Fig. 2. Floating mosque view (right), Transparent roof view (left)

C. *The Ark Hotel*

Location: Nyeri, Kenya
Year of completion: 2010
Area: 14,000 square meters

The ARK: floating hotel (Fig. 3 - left) designed by Russian architectural firm Remistudio is a massive dome-shaped building, proposed to address climate change effects like rising sea levels and massive floods.

Idiosyncrasies of building:

- The arch shaped building has a structure that enables it to float safely and stay autonomously on the surface of the water.
- The Ark was also designed to be a bioclimatic building with independent life-supporting systems, including elements ensuring a closed-functioning cycle (fig 3- right) (Alison Furuto, 2011).
- The Ark concept, designed with the UI Architects Work Program “Architecture for Disaster Relief,” could be realized in various climates and especially in seismically dangerous regions because its basement is a shell structure without any ledges or angles.
- A load-bearing system of arches and cables allows weight redistribution along the entire corpus in case of an earthquake. And also its prefabricated frame can allow for fast construction (Anastasia Vdovenko, 2014).
- The building has an optimal relationship between its volume and its outer surface, significantly saving materials and providing energy efficiency.
- Its shape is convenient for installing solar photovoltaic cells at an optimal angle toward the sun and wind turbine on the roof.
- The cupola, in the upper part, collects warm air which is gathered in seasonal heat accumulator to provide an uninterrupted energy supply for the whole building complex independently from outer climate conditions in winter.
- The heat energy from the surrounding environment - the outer air, water or ground - is also used.
- The structural solidity is provided by compression of timber arches and tension of steel cables.
- The framework is covered by a special foil made of Ethyl Tetra Fluoro Ethylene (ETFE). It is a strong, highly transparent foil that is self-cleaning, recyclable, and more durable, cost-efficient and lighter than glass.
- The foil itself is affixed to the framework by special metal profiles, which serve as solar energy collectors for heating water and as gutters for collecting rainwater from the roof (ARK, 2014).
- Enough daylight penetrates through the transparent roof to illuminate the inner room as well.
- The tired balconies serve as social and recreational areas
- An open layout that can easily be adapted to different functions over time.
- The project uses solar panels and rain water collection system.
- All the plants are chosen based on the principal of compatibility, illumination and efficiency of oxygen producing.
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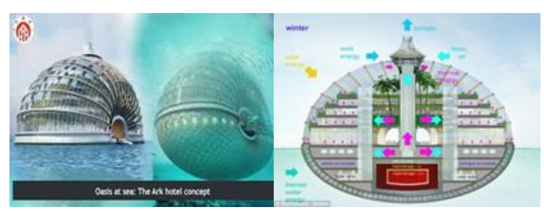

Fig. 3. The ARK Hotel view (right), Sectional view (left)

D. *The Makoko Floating School*

Location: Lagos, Nigeria
Year of completion: 2013

A movable floating prototype structure, (fig4- left; fig 5-right) conceived by NLE Architects, that addresses physical and social needs of the aquatic community of Makoko, in view of the growing challenges of climate change in an urbanizing African context. Though primarily serving as a school, it can be customized and adaptable for other uses, such as a community hub, health clinic, market, entertainment centre or housing.

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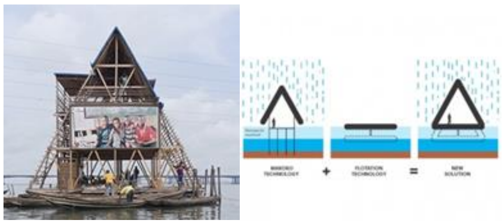

Fig. 4. The Makoko Floating School view (right), Floating techniques (left)

Idiosyncrasies of building:

- The special construction, able to safely support a hundred adults, even in extreme weather conditions, is also designed to use renewable energy, to recycle organic waste. (fig. 4 - right)
- Strategies to make the floating architecture sustainable by applying PV cells to the roof and incorporating a rainwater catchment system.
- The building is the true example of sustainable floating building not an example of a completely energy efficient floating building. (fig. 5 - left).

Fig. 5. The Makoko Floating School section (right), conceptual view (left)

3. Architectural characteristics of buildings on water

- Building on water utilizes the various renewable energies because solar, hydrothermal, wave and wind energies can be obtained easily on the water comparing with the building on land.
- Users of building can enjoy the peaceful, comfortable, and social atmosphere around the water within the natural environment. Connection to the nature is likely to generate the positive states of well-being and health for the residents and visitors.
- Fast and low-cost construction due to prefabrication & modular design.
- Water architecture can play different basic roles in the quest to resource conservation. Water can be exploited in passive cooling strategies both for indoor and outdoor climate.
- Self-sufficiency with regard to supply and disposal one of the undeniable advantages of a structure is their location direct on water – a huge energy source under the floor. The investigations of the IfSB are aimed at optimizing the heat- and mass transfer processes of underwater heat exchangers to improve the energy efficiency of the whole heat- supplying system.
- Floating building construction concepts can provide unprecedented opportunities for carrying out energy efficiency innovation and improving building energy efficiency beyond minimum requirements.
- Design strategies for floating buildings based on sustainable architecture and sea energy resource can not only improve sustainability goals in the areas of renewable energy sources, energy efficiency, and water but can also increase the attractiveness of floating building designs to avoid climate change and global warming. Also, floating buildings can be generally regarded as positive in ecosystem because the buildings have a closed premises services system, sometimes stimulates diversity in water milieus and provides a protected habitat for small fish and other aquatic animals.

4. Architectural Challenges of building on water

Budget: Building beneath water is a very costly way because of using heavy machinery, devices and professional employees. Building below water also includes some of welfare and it desires to large price range.

Building should be,

- Self-sufficiency with regard to supply and disposal
- Safety of users and construction, pontoons should be investigated with regard to fire protection, water waves, water chemistry and ice formation
- Adaptation of architecture and design to the regional and national conditions.
- Eco friendly (environment protecting)
- *Erosion:* Erosion is the method of weathering and delivery of solids (sediment, soil, rock and different rock particles) in the natural surroundings or their source and deposits them someplace else. It normally takes place because of transport with the resource of wind, water, or ice so engineers ought to pick out appropriate materials for beneath water building.
- *Location of fuel:* Any coincidence may also be possible when the driller machines and other machinery are trying to find out oil or to any ship also can damage the outlook and structure of the building it's far out of manage.
- *The hassle of warmth of the water:* The temperature varies reasonably over the surface of water, it is heated from the ground from the below by the usage of daylight hours, but at depth maximum of the water may be very cold.
- *The problem of pressure:* Humans can only stay under water for a limited amount of time. The limiting factors here are the supply of oxygen, but more importantly, the high pressure under water. Water is much denser than air and is incompressible. This means that while air, when put under pressure, will increase its weight and decrease its volume, water will

retain its volume and weight.

- *Problem due to aeration:* No doubt that the primary problem that is to be had in our mind at the equal time as talking approximately the development of underwater systems is the problem of aeration. There need to be a supply of renewable air that helps in respiratory, and removing unwanted gases.

5. Design strategies to make a building feasible

- Develop a relationship between human-environment and the link between human's space perception and physical architectural elements.
- Designing an architecture sample which contain within itself human rather than product scope.
- Making spaces that are spacious, socially active, and thermal comfortable so as to satisfy human comfort level.
- The perception in human psychology should be taken into consideration and the comfort on sea will be made by minimizing wrong decisions about the space during the pre-design stage (stadler, 1941).
- Physical comfort such as lightening, ventilation, noise, inner aesthetics, field size, material etc. should be taken into consideration.
- Service areas, wet spaces, circulation areas, under-storage space should be designed with special attention.
- A lot of social spaces, sun spaces, food & beverage, activity and party spaces in open spaces of a structure appear as factors which increase satisfaction level of users.
- Use of re-usable & up-cycled building material due to environmental and economical considerations.
- The underside of floating building foundation can even be rough to encourage the attachment and growth of water plants, algae and shellfish. The water plants have a purifying effect on the water (Koen Olthuis & David Keuning, 2010).
- Introduction of modular construction and ready-made equipment elements, use of local raw material, dual purpose usage, long term usable and relocable facility, use of special wall material (green building); to minimize the negative environmental impact
- Hybrid system of solar energy with wind power will be useful and complementary because the sun usually shines when there is no wind in day time and the wind usually rises when there is no sun. So solar - wind hybrid renewable energy system will be popular when the design of the hybrid system can be integrated with that of floating architecture
- The supply and disposal can be carried out by means of the infrastructure of landside.
- Due to temperature difference between the water and the outdoor air, hydrothermal use of the water can play a significant role in providing energy source which can be used both for cooling and heating. Therefore, the main infrastructures to maximize the use of water should be provided before establishing a new project.
- Encouraging the use of sea energy resources (renewable energy) and integrating them into the design; so as to make it self–supporting, self-sufficient and self-sustaining.

ASEM design strategy to design,

Adaptation, Sustainability, Efficiency, and Management (ASEM) is one floating building design strategy that can help to provide an efficient alternative related to energy and environmental issues ASEM can be used as a common approach and methodology for creating self-sufficient floating buildings in terms of water and energy supply. It needs to address design objectives and local site conditions and should be based on a regularly updated evaluation of materials, water pollution, energy performance and environmental problems. Although, there are disadvantages of floating buildings such as water pollution, harms to marine life and animals but ASEM design strategy has ability to deal with part of sustainable and climate change issues.

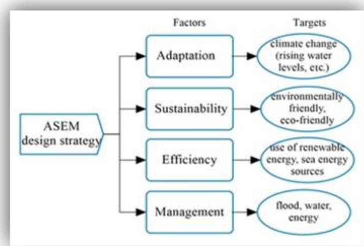

Fig. 6. Flow chart ASEM design strategy

- Most popular renewable energy sources for the floating architectures are use of solar energy (heat panel and PV cell) and hydrothermal energy.
- Illustration: Use of hydrothermal energy in renewable energy is applied to the projects such as Floating Mosque, IBA Dock, and floating hotel "Salt & Sill". And solar PV cells are mostly used in the projects like Floating Mosque, The Ark, IBA Dock, and Autark Home. Solar heat panels are used for The Ark, IBA Dock and Autark Home.
- Until now, it is very hard to find out wind power application in floating architecture. Usually there is more wind resource on water space of sea or river than on urban land because there is daily land and sea breeze circulation and no windbreak on water. If small wind turbine with little noise is developed, it will be applied more often for the architecture on water than for the building on urban land.

A. General parameters

Means of Transportation:

- At the time of constructing a building, one of the most critical issues that come in mind would be the approach of transportation. Therefore, it is very important to plan an approach that connects to the structure.
- Illustration- Hotel HYDROPOLIS of Dubai
- It is inclusive of three elements: the land station, where guests are welcomed, the connecting tunnel, where the guest are transported to the prime area of the hotel by the means of trains, and the 220 suites within the submarine leisure complex.
- Maintenance: Maintenance of a building in water is very expensive and tame taken, so a low maintenance involving building must be designed at pre–designing stage of a structure.
- This hassle may be solved, by way of dividing the constructing into components that can be separated from the complete building; those additives can be transferred to land in order that a less high-priced renovation can take area.
- Use of self-cleansing system can also be of great help.

6. General criteria's

To create a building, it needs to take key design points into consideration. But, there is not any prominent standard related to design it. For example, Queensland Development Code 2006 is only reference that provides recommendations and design criteria for permanently moored floating buildings. According to the mentioned guideline, the main principles and concepts of environmental design process in floating buildings are as follows:

Access: A floating building must have adequate means of access to and from the shore appropriate to the likely number of people accommodated in the floating building.

Flotation system: A floating building must have a floatation system which maintains an acceptable level of stability appropriate to the use or likely use of the building and which will not be affected by minor impact; and is capable of withstanding the most adverse combination of loads it is likely to be exposed to.

Mooring piles: Mooring piles must be designed to adequately and safely resist all lateral loads resulting from the most adverse combination of loads which are likely to act on the flotation system and superstructure of the floating building and any vessel attached to the floating building or mooring piles

Materials (generally): All materials used in a floating building or any structure associated with a floating building must be suitable for the conditions to which they are exposed.

Materials (fastenings): All fastenings used in a floating building or any structure associated with a floating building, must be appropriate for the conditions to which they are exposed taking into account.

Location: The location of a floating building must maintain an acceptable level of amenity between any other building and any proposed building.

Safety equipment: Floating building must have appropriate life safety devices suitable for marine use.

Firefighting equipment: Floating building must have access to appropriate levels firefighting equipment to safeguard against fire spread.

Minimum water depth: Water depth under a floating building must at all times be sufficient to prevent grounding of the building.

Non- slip surfaces: The external floor surfaces of a floating building and the floor surfaces of all surfaces of all gangways, pontoons, wharfs, stairways, ramps and the elements which give access to a floating building must be finished in approved manner to prevent slipping.

Balustrades and handrails: The perimeter of a floating building and all gangways pontoons, wharfs, stairways, ramps and the like which provide access to a floating building, must be provided with a barrier which must be –

- Continuous and extend for the full extent of the hazard of a height to protect people from accidentally falling from the floor or roof or through the opening
- Constructed to prevent people from falling through the barrier
- Capable of restricting the passage of children of strength and rigidity to withstand-
- The foreseeable impact of people
- Appropriate, the static pressure of people pressing against it.

7. Conclusion

The findings from the illustrations in terms of architectural characteristics can be summarized as followings; application of modular design and construction, re-usable & up-cycled building material, solar heat panel and solar photovoltaic cells, hydrothermal heating/cooling system, heat recovery system, and self-sufficient system, installation of water treatment system, providing the revitalization possibility of old urban declining area, offering the place to enjoy water-related leisure activities, natural view, and social support & activities. Therefore, building on water can have advantages from both environmental/economic and social/psychological aspects.

The construction of the buildings on water can be advantageous to the people and the environment if proper techniques are used and if people get success in achieving such structures. Main interest of the research was to find a building on water can be eco-friendly, sustainable, energy efficient and so on.

The general criteria's cannot be limited to the above mentioned criteria's, but as per research done till date few are available. The researcher has elaborated the same; the new findings can be further illustrated.

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