Form and functional features of modular floating structures

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Abstract. The article describes the main aspects of form and functional organization of modular architecture on the water. The leading approach to the study is based on the system analysis of the types of modular floating foundations, above-water structures of various configurations and their functions. As a result of the analysis of realized and conceptual projects, two types of modular bases were identified: simple, consisting of repeating geometric forms (square, rectangle, circle, hexagon), and complex. The main typologies of above-water structures are also highlighted: a pavilion, a low-rise and a high-rise building. The study examined the main programs that floating structures provide: residential, public and industrial. Characteristic features of the modular floating structures are drawn on the basis of the identified classifications. The article can be used for practical and conceptual research in the field of modular architecture and structures in the water environment.

1 Introduction

Modular structures provide the possibility to create a primary experimental space for human habitation in the extreme environments. In the XXI century, adaptation of the water spaces of the planet for the existence of the society no longer seems a technically impossible task. The gradual development of the ocean began with the extensive construction of artificial areas of the Netherlands, the United Arab Emirates, Bahrain, Japan, China, the USA and Russian Federation. Another direction of the development of structures in the aquatic environment are the concepts of floating cities, identified in the works of R. B. Fuller, Y. Friedman, K. Kikutake, K. Kurokawa in the second half of the XX century. The ideas of floating structures were developed through the realized projects of Baca Architects, Waterstudio, Bjarke Ingels Group, Studiomobile. Conceptual research is conducted by the architects J. Rougerie, V. Callebaut, A. Gyorfi [1-6].

Floating structures have an indisputable advantage over stationary artificial islands, as they are able to withstand the potential rise of the level of the World Ocean. Since 1993, the sea level is increasing by 3.2–3.4 mm per year, to which the vast majority of modern buildings are not yet adapted [7-9]. Modular structures on floating foundations give

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architects the opportunity to conduct a primary experiment on the operation of structures in the water environment in a small scale [10-13].

2 Types of floating foundations

Forms of floating pontoons, based on the geometry of the basic figures, take a constructive start from the traditional wooden raft. Most of the individual residential houses on the water have bases of this type; however, there are also examples of some public buildings.

The project “Makoko Floating School” by Kunle Adeyemi and the developer NLE is a low-rise floating structure on a wooden raft. The module has a flexible internal spatial organization, which can be changed in accordance with the needs of the local population. During the school year, the floating installation accommodates classrooms, while in summer the module serves as a mobile station for fishermen [14].

A circle can serve as the base element of the floating module. The conceptual project “Sub-biosphere 2” is a spherical semi-underwater module, fastened together by a single spatial framework. Modular “biomes” move along framework rails, converting the difference in pressure at different depths to generate electricity.

The Shimizu Corporation’s “Green Float” project envisages the construction of round modular islands of various diameters (1000-3000 m). The modular islands are planned to be located in equatorial waters, where the risk of typhoons is minimal. High-rise multifunctional complexes have continuous vertical gardening of the facade. Through the “green” floating modules, it is planned to reduce the level of carbon dioxide in the atmosphere (fig. 1).

Fig. 1. The Shimizu Corporation’s “Green Float”, source:
<https://www.shimz.co.jp/en/topics/dream/content03>

Within the framework of the annual “H2O Competition” dedicated to the conceptual research in the context of architecture in the aquatic environment, the project of futuristic floating settlements “Human Second Origin” was developed. The pattern of the location of the modules was inspired by the molecular structure of water: horizontal bridges interconnect the circular molecules.

The project of a student dormitory “Urban Rigger” of BIG architectural group has a hexagonal foundation. Reused industrial containers are transformed into the living rooms placed on a pontoon of reinforced concrete. The shape of the hexagonal base allows freely interconnecting the modules of 680 m² each [15].

In 2014, the architects Studiomobile created the project of the floating hydroponic farm “Jellyfish Barge”, which consumes 70% less water than a traditional agricultural farm.

Each floating farm provides a supply of products for up to two families and, when combined into modules, can contribute to the formation of a network of floating settlements. The farm is equipped with a collection and desalination system and photovoltaic panels on the roof.

A modular hexagonal floating park designed by WHIM architects was opened in 2018 in Rotterdam. Recycled Park floating foundations are constructed from plastic waste collected in the New Meuse River. The project aims to expand the park spaces in the city and improve the ecological state of the river: the underwater part of the modules serves as a support structure for river plants and creates shelters for fish and mollusks.

Modules of various shapes can be implemented to create a complex plan geometry. Within the project “Artisanopolis” by Roark3D, hexahedral and square modules were simultaneously applied to create an extensive network with internal spaces and ponds. The floating structure, which will be located off the coast of French Polynesia, is surrounded by the protective watershed (fig. 2) [16-17].

In the conceptual project “Floating City” by AT Design Office triangular and pentagonal modules up to 150 m long form the network of floating islands. Construction modules are planned to be prefabricated and shipped to the construction site.

Fig. 2. “Artisanopolis” by Roark3D, source: <https://www.meretdemeures.com/ru/news/design-artisanopolis-a-modular-city-on-water>.

3 Types of above-water structures

The surface part of the floating pavilion for Rotterdam, developed by DeltaSync and Public Domain Architects, consists of three combined hemispheres. The pavilion is currently used for exhibitions and events, but subsequently it is planned to redevelop the internal structure for residential functions. As a part of a strategic urban initiative, it is planned to construct 1 200 floating buildings capable of withstanding the sea-level rise.

Low-rise residential buildings are placed on the floating concrete foundations designed by K. Olthuis and D. Keuning (Waterstudio) on Lake IJssel in Amsterdam. The height of floating buildings does not exceed two floors, as hollow foundation tanks are able to withstand not too much weight of the surface structure.

The project of floating camps for fishermen in Chile by Sabbagh Arquitectos group, implemented in 2006, involved the creation of residential modules for a two-week stay. The modules of 14 by 9 m in size form a lightweight two-story construction of steel profiles.

Creating high-rise structures on the water requires a significant investment to ensure the sufficient mass. For the implementation of such facilities in the future it is possible to adapt the technology of oil and gas platforms (SPAR, EVA-4000, Troll-A).

Waterstudio architects are engaged in conceptual modelling of high-rise buildings on the water. The project of a 25-storey floating hotel on a mobile base was developed for a

resort in Dubai. The construction of glass and steel has an underwater foundation with a height of 11 m and is connected to the mainland with a floating bridge.

In 2015, Luca Curci Architects presented a project of a skyscraper on the water, moored to the seabed. The 180-storey tower is intended for the simultaneous residence of 25 000 inhabitants. The design provides a shell of photovoltaic glazing and vertical gardens, located in the modular openings of the facade.

4 Functional program

The main function of modular structures on the water is to create additional space for living. The realized project of an individual residential building on the water “Nautilus Hausboote” by the architect A. Hoffmann provides a two-story space for the life of one family. The project “2 BOATS” was created for the long-term living on water with the aim of conducting photographic observations [18].

Floating houses made of prefabricated structures can be transported anywhere in the world. The project “Floatwing” was designed for living on secluded lakes and rivers and has a maximum size of 6 by 18 m. According to the authors, all structural elements of the house, equipment and furniture can be assembled into two standard containers and shipped to the remote places.

In 2015, the architects of Atelier Bow-Wow & Architectuuratelier Dertien12 designed the floating public space “Canal Swimmer Club” to reduce the burden on the tourist centre by providing additional areas for recreation by the embankments. The creation of public bathing spaces in the city centre encourages citizens to be more careful about the state of ecology of the reservoir.

Spanish architects J. Selgas and L. Cano developed a project for a pneumatic exhibition pavilion for Bruges Triennial, which serves as a mobile resting place and for tourist walks. The pavilion was assembled by hand directly on the site in the historical centre of the city. Floating pavilions are able to draw attention to the preservation of the architectural heritage in the city, opening previously inaccessible views of the historical buildings (fig. 3).

In 2018, architects T. Randall-Page and B. Rogers developed the “AirDraft” inflatable floating theatre project that allows navigating through the narrow canals of London. The design is able to unfold in 12 minutes and simultaneously accommodate up to 30 people. “AirDraft” is used as a temporary platform for holding festival performances and sightseeing tours.

Projects of modular structures should provide the autonomous functioning of life support systems, consequently they have facilities to grow crops and desalinate water supplies. Bart // Bratke and StudioDE architects' “Foram” project is a floating structure that uses solar energy to heat the water during the desalination process. The bionic structure of the facility is equipped with pumps for collecting seawater off the coast of Los Angeles in California. The piping system delivers the water to the heating tanks located on the roof of the structure, after which the desalinated water is distributed to irrigate the hanging gardens integrated into the building's walls. Due to the mobility of the floating platform, the object can be delivered to the remote areas anywhere in the world to solve the problem of lack of the fresh water.

In 2018 in Holland, the *Beladon* developers announced a project of a floating dairy farm to be accommodated in the city port near Amsterdam. The concept appeared under the influence of the idea of an independent farm capable of functioning during the shortage of products after the devastating effects of hurricanes.

Fig. 3. Pneumatic pavilion of the Bruges Triennial, source:
<https://www.dezeen.com/2018/05/19/selgascano-architecture-pavilion-triennial-bruges/>.

Machines for processing and packaging dairy products are located on the first floor of the floating structure; the second floor is a cattle-breeding farm, while clover and crops for animals are grown on the top floor. The project's developers are also planning to use grains left over from local breweries and mill by-products as food for cows. The floating farm will generate its own energy, derived from solar panels and the production of hydrogen during electrolysis.

5 Results and Discussion

As a result of the analysis of modern floating architectural structures, the main types of foundation forms were established:

- Simple, borrowing the shape of basic geometric forms (square, rectangle, circle, hexagon);
- Complex, formed by the composition of non-standard or variable elements.

Among the characteristic forms of surface structures identified:

- Pavilion;
- Low-rise building;
- High-rise complex.

The main functions that floating modular structures provide are:

- Residential function;
- Public;
- Industrial (hydroponic farms, desalination plants, energy-saving structures).

Based on the considered forms and functions, the following features of modular floating structures were highlighted:

- Functional flexibility: due to the repeatability of the elements, the modules can be adapted to the current needs of the population by changing the internal structure;
- "Branching" growth pattern: modules aggregate on the water surface according to the principle of a growing branch;
- Energy autonomy: isolated from the mainland, the modules are equipped with photovoltaic panels, aquatic farms to produce their own energy resources;
- Continuous greenery: while creating additional areas of the habitable surface, the modules should provide proportional green landscapes. In some cases, the facade structure becomes an extension of the artificial landscape.
- Minimization of the environmental impact: floating structures do not change the relief of the bottom of the reservoir and do not affect the life of the ecosystem;
- Shortening the time of construction: the modules are prefabricated and assembled directly on the construction site.

6 Conclusion

As a result of a system analysis of the forms of modular floating structures, the characteristic features of their shapes and functions were identified. The specific properties of the modular architecture offer promising opportunities for the construction of living habitat on the water. Due to the compactness and repeatability of modular structures, it becomes possible to create a masterplan of an unlimited scale from solid elements, prefabricated or 3D-printed, which significantly reduces construction time and costs. The use of "green" technologies in the implementation and operation of modular structures makes the construction on water an environmentally friendly process. Through the technological capabilities of modular floating foundations, it becomes possible to construct architectural objects of various sizes and height. Therefore, the modular design can bring the spread of life on the water closer.

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