NEW TECHNOLOGIES OF CONSTRUCTION ON SERBIAN WATERS

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ABSTRACT

As the general concept of living on water in Serbia has not moved far from raft-type floating structures, the idea about urban development and activation of river courses, changing spatial-physical, economic, technological and modern sociological needs of living has to be changed and incorporated in the tendencies of modern architectural designing. Floating buildings, as architectural structures, are based on the principle of floatability, with flexible installations i.e. the system cannot sink as it can move with the fluctuation of water levels. Development and use of floating structures in large European cities as a new tendency in architecture could be the basis for defining the principle and technologies for construction of floating buildings in architectural designing and mapping of attractive locations for the referent model in Serbia. This research deals with the possibilities of developing the practice of designing floating structures in Serbia in terms of construction technology and energy performances.

The objective of this paper is to explain the principles and technologies in construction of floating buildings as the key parameters in architectural designing of such structures on water areas in Serbia. This paper offers a concept of floating buildings on river courses and other water areas that could be applied in Serbia and which would be based on systematisation of data about already constructed floating buildings in Europe.

KEYWORDS _ *floating buildings, urban regeneration, mobility, multi-case study approach activate rivers*

INTRODUCTION

Floating buildings, as a new dwelling concept in architecture of large cities, are becoming more necessary as a part in shaping of modern urban landscape. The term “floating” in architectural designing implies the following structural system: floating foundation and pontoon structure, where mobility, energy efficiency and sustainability are the priorities and the tendencies. (Koekoek, 2010; Olthuis and Keuning, 2010). Floating buildings compete with traditional houses on building land in terms of comfort, quality and price. The image of urban development should be altered by activating river courses in accordance with modern social demands of living on water and it should be integrated in the tendencies of the modern architectural design.
Floating buildings as architectural structures are based on the principle of navigability with unsink-

able floating structure which can move as the water level fluctuates. The objective of this paper is to explain the new concept of technologies of construction for floating buildings. The paper is based on the analysis of theoretical aspects of applicable technologies of construction of floating buildings and their integrity in a complex urban context of Serbia.
Floating buildings as architectural structures are based on navigability principles with flexible installations. Floating building involves a floating foundation which can be reinforced concrete shell or steel pontoon, or combination of wood and foam and wooden or steel superstructure build on the pontoon. Floating structures can be applied on all water surfaces, if they fulfil the following two conditions: they must not endanger the river fairway and the depth of the concrete/steel part of the floating structure has to fulfil the conditions stipulated in the rulebook on the relevant river or water area. A large advantage of floating structures is that they can be transported or moved to other location if necessary. (Koekoek, 2010; Olthuis and Keuning, 2010).

METHODOLOGY

This paper is based on multi-case study approach. The case study method refers to the research of the selected case studies of floating buildings in Europe, which includes the analysis of design concepts and technology of construction on water. The basic analytical method is comparative analysis and is conducted on two levels: by comparing architectural concepts and comparing them with reference theoretical concepts. In addition to the analytical method, this procedure includes the classification and systematization of formed knowledge.
The research includes insight into the properties and characteristics of river flows and lakes in Serbia and consideration of the conditions for the application of the concept of a floating building based on the systematization of formed knowledge. In this phase, research techniques are used: data collection, observation, analysis of photo documentation and mapping in order to select the location.
Research results would be presented as a commonly applicable typology in accordance with the concept, energy efficiency and construction technology of floating buildings, as a basis for construction of floating buildings on water areas in Serbia and as a basis for further research in the field of urban regeneration in Serbian cities and worldwide.
The paper refers to the theoretical concept of floating buildings and defines framework for their application in Serbia. It is a part of research that would add to development of a critical attitude towards floating buildings in Serbia as a new technological idea.

SELECTION OF REPRESENTATIVE PARAMETERS FOR FLOATING HOUSES IN THE NETHERLANDS, UNITED KINGDOM AND PORTUGAL

The objective of this paper is to research the design concepts and technologies of already constructed floating buildings in Europe by analysing selected case studies. A comparative analysis of representative cases was made and analogies were derived for the purpose of enabling generalisation and definition of floating building principles in further research. Complex requirements of their users, spatial-physical, social, technical and technological, economic and environmental impacts are causatively related to designs of floating buildings. This chapter analyses the extent of these impacts on the development of floating buildings in selected case studies, which will be used for definition of designing principles for floating buildings.

_ Table 1: Case Studies

Case	Name of floating building	Method of investigation	Location	Date
1	**"Floating House Ijburg"**	Site visit	Waterbuurt-West, Ijburg, Amsterdam	2017

2	**“Exbury Egg” Floating Home**	Internet research	Hampshire, UK	2019
3	**“FLOATWING” Floating House - Boat**	Internet research	Alqueva, Portugal	2019

Case Study: “Floating House Ijburg”

Project: “Floating House Ijburg”
Architects: Marlies Rohmer Architects & Urbanists
Location: Waterbuurt-West, Ijburg, Amsterdam, the Netherlands
Completed: 2011
Gross area: 10625 m2

_ Figure 1. Prefabricated Floating House in Netherlands, Source: photo by the Author

Construction technology: floating system of concrete tanks (concrete box-type platform) The floating building concept has been recently accepted in the Netherlands as an important solution for modern housing requirements. In the past years the number of residential buildings on the water increased as they have several advantages over living on the ground. Floating buildings are a part of Dutch urban design in the process of planning and shaping of cities lying close to water. Water areas reserved for floating buildings have been classified as immovable resources competitive to land in the central city zones, both in terms of finances and comfort level. Living and working on the water enables multiple uses of undeveloped areas, by adapting obsolete harbour ends or submerged quarries and their natural surroundings.
CONCEPT – The team of architects tried to achieve the appearance of apparently separated, informal arrangement of water apartments, by a designing a triangular geometrical structure in the water area. Different spacing between floating buildings and their orientation create a simple play of continuously variable sights. The objectives included pleasant water ambience, fluidity, movement, feeling of individuality and a vessel moored next to the house. Such a concept gives the feeling of scatter and individuality, which is opposite to the block approach in construction. Communication and access to the floating buildings in this quarter were provided by means of the so-called floating footways, which also enable access to vessels and contact with water. Floating buildings in Ijburg are a functional solution consisting of three storeys. The lowest storey is partly submerged and it can accommodate several bedrooms, the second storey is an elevated ground floor that offers privacy from the harbour and waterway and provides access to the terrace and upper storey. The upper storey leads to the terrace used for sunbathing and socialising.
CONSTRUCTION TECHNOLOGY – Technologically, the floating buildings consist of concrete “tubs” floating under waterline to the depth of one half of the storey and steel load-bearing structures filled with a combination of glass and panels. This model of a floating building allows transformation of its shell i.e. outer structure of the building. This transformation is achieved by altering the layout of façade panels, which enables the user to change the view or ensure privacy. Apart from that, this model offers a possibility of transforming the interior base plan by physical alteration of the building inside structure and layout. This transformation is achieved by altering the layout or structure of indoor partitions, adjusting multipurpose elements or altering the shell. It also allows extensions by adding previously designed extension modules for floating buildings. Floating terraces and canopies can be easily fixed to this skeleton frame. Floating buildings in Ijburg can be also considered a

modular architecture because they allow interconnection into a large number of units in accordance with the users' requirements. The system used in Ijburg offers a possibility of water treatment before its discharge, which involves surface water infiltration in the ground through special drains that treat water before it channelled out of the water area. All public utilities (gas, electricity, drinking water, sewerage, telephone, cables) are supplied to a central platform specially designed for that purpose. For the purpose of ensure smooth operation of all public utility connections, pipelines are heated in winter order to prevent freezing of drinking water pipes and they are cooled in summer in order to prevent development of bacteria in drinking water. This platform rests on piles, which gives it a fixed level and connections between the platform and floating buildings are flexible since the buildings move with the fluctuation of water levels. The owners of these floating buildings are responsible for flexible connections between their house and meters installed on the platform and responsibility of public utility companies ends at the meters. Floating buildings in Ijburg were designed to consume 15% less energy than housing units on the ground. They are heated with natural gas supplied through the pipes that run below the footway of the units.

Case Study: "EXBURY EGG" Floating House

Project: "Exbury Egg" Floating House
Author: Stephen Turner, "PAD" architect studio
Location: the Beaulieu River, Hampshire, UK
Completed: 2013
Gross area: 22 m2
Construction technology: floating system with recycled tanks filled with water

_ Figure 2. "Exbury Egg" Floating House, Source: http://exburyeggtour.com/about.html

Stephen Turner was commissioned by the Space Placemaking and Urban Design to design together with "PAD" architect studio an original artful space on the Beaulieu River in the UK. The "Exbury Egg" is a floating wooden dwelling and working space constructed for the purpose of studying the riparian area, life on the river and fluctuation of water levels.

CONCEPT – Inspired by the nests of birds that lay eggs along the river, in high grass, and manually constructed by applying technics used in shipbuilding, the Egg was intended for Stephen Turner to dwell all 12 months in its. The floating house concept, egg, symbolises life. The egg, as aesthetically perfect structure, contains embryo that represents new life. From primates to planktons, it embodies the idea of rebirth and renewal, protection and fragility. In accordance with the artist's needs, the space was designed to have all life necessities: bathroom, kitchenette, small desk and sleeping area. The structure is 6 m long with the diameter of 3.6 m, its construction lasted six months and cost 46,690.00 EUR.

CONSTRUCTION TECHNOLOGY – The inside of the egg was made of recycled wood and egg outside was lined with red cedar boards intentionally left untreated with chemical – the objective was to enable the wood to weather under external impacts. All measures were taken from the central line and temporary frame made of chipboard as a skeleton for the "egg shell". There are actually two "shells" with a layer in between, which ensures water-tightness of the egg. Narrow wood moulding adds to its elasticity, enabling the wood to wind smoothly around the frame. Fir wood was used for shall bracing and inside shaping of the floating house, which continued the old tradition of using wood material for water structures that could be traced back many centuries on the Beaulieu

River. The floating house – egg is moored like a ship that moves with fluctuation of water levels. Light touch and basic nature of Exbury Egg were intended to enable reassessment of the life we are living and proper consideration of sustainable and future use of nature resources. Stephen Turner is interested in researching the empathic connection with the nature that reveals the precious and transcendent in everyday life. Changes of the "Exbury Egg" resulted from Stephen's occupation of the house, which reflected on the interior and art pieces created through direct experience of local nature cycles and processes and relation between the nature and narratives of human activities. The "Exbury Egg" floating house was made of natural, local materials and as such it is an energy efficient and self-sustainable space. It is heated with solar energy and cooled exclusively by ventilation and it is equipped with water recycling system. The project objective was to research effects on life and work in a floating structure, by using materials with low energy consumption and available in the radius of 32 km for its construction. Photovoltaic panels generate electric power by using solar energy to start up small LED lights and charge a laptop, maintaining communication with the outside world.

Case Study: "FLOATWING" Floating House – Boat

Project: "FLOATWING" Floating House - Boat
Author: "Friday SA" architect studio
Location: Alqueva, Portugal
Completed: 2015
Gross area: from 28 m2 to 52 m2
Construction technology: "Panoramah" system

_ Figure 3. "FLOATWING" Floating House – Boat, Source: http://www.gofriday.eu/

"FLOATWING" floating house-boat is an energy autonomous, environmentally sustainable Mediterranean floating house-boat, an which was designed by Portuguese architect studio "Friday SA".
CONCEPT – "FLOATWING" floating house is of multipurpose nature because it can be used as a floating oasis for relaxation and living on water or as a vessel-boat for a large number of activities in open air (sailing, rowing, water skiing and fishing). The concept of this floating house appeals to environment sustainability and at the same time offers comfort of a home. Modular nature of the floating house manifests in the following: 1. selection of platform size, 2. interior typology, 3. number of bathrooms, 4. equipment level and 5. dimensions of the outer platform. All types of this floating house were functionally conceived to consist of two levels, with a lower spacious deck and upper unit with a terrace. The first level contains a living room enclosed in glass, fully equipped kitchen, sleeping area, wine cellar, thermal pump, outboard motor and AC generating unit. The second level contains a sunbathing area, countertop with grilling equipment and thermal and photovoltaic solar panels. The floating house has a fixed width of 6.0 me but its length is adjustable from 10.0 m to 18.0 m, with 0.80 m draught. It has two longitudinal metal pontoons, which ensure excellent stability on water and up to 1 m high waves.
CONSTRUCTION TECHNOLOGY – "FLOATWING" floating house can be constructed in only four months. Manufacture is followed by packing. Modular design of the house means that all its components, including equipment and furniture, can be easily packed in two standard containers and shipped to almost any location on the planet. It was designed with environment-friendly materials and technologies that reduce emission of carbon dioxide and energy requirements of the house. The floating house has a galvanised steel structure resistant to corrosion. The structure is lined with a combination of "Planitherm" double glazing and "Tricapa" sandwich panels, which consist of 19 mm

thick outer metal sheet and 10 mm thick infilling of black agglomerated expanded cork. The inside walls are made of 13 mm thick "Tricapa" hardwood or 10 mm thick sandwich panels. The floor is made of 20 mm thick "Riga" hardwood emplaced over agglomerated expanded cork insulation with the thickness of 10 cm. Terrace floors are made of hard Scottish pine with the thickness of 25 mm and with special "ThermoWood" finishing resistant to weather impacts. The ceiling is lined with 10 cm thick black agglomerated expanded cork insulation and 8 mm thick TRICAPA wood lining. FLOATWING floating house is a solar house focused on energy efficiency and environmental protection. From the ecological aspect, this floating house does not only exert minimal adverse impact on environment but it can generate 100% of its energy demands in only six hottest-month period. It is self-sustainable for at least seven days.

_ Table 2: Comparison of Technologies of Construction

Case	Floating system	Technology of Construction	Energy efficiency	Public utilities
1	**System of concrete tanks (concrete box-type platform)**	Prefabricated modular architecture with a large number of units	Consume 15% less energy than housing units on the ground	On central platform
2	**System with recycled tanks filled with water**	Made of recycled wood and egg outside, lined with wooden boards	Self-sustainable space, heated with solar energy and cooled exclusively by ventilation	Self-sustainable
3	**Panoramah system Floating House - Boat**	Modular design of the house including equipment and furniture, can be easily packed in two standard containers and shipped to almost any location	It can generate 100% of its energy demands in hottest six-month period. Self-sustainable for at least seven days	Self-sustainable

CONCLUSIONS

The scientific justification of this paper is based on insufficient research of the floating buildings phenomenon and possibilities of its application in Serbia.

Floating buildings advantages can be grouped into 4 categories: flood resistant, energy efficient, environmentally friendly, and socially acceptable. Different floating system can be applied for different construction technologies applicable in Serbia. Advantages of such building system is unsinkability and movability.

Advantages of prefabrication technology and use of diverse renewable energy sources and nearly self-sufficient energy efficiency in floating houses make them energy friendly. House movability, long term usage, water cycle system, prefabrication and modular construction make them environmentally friendly. Water houses are peaceful and comfortable due to direct connection to nature.

Based on the comparison between the explained case studies and
the general picture of the concept of water-dwelling in Serbia the referent model of a floating building with a concrete the box-type platform is selected as the most suitable for utilization on the water surfaces in Serbia. Defining of the suitable locations for construction of such floating settlements with a large number of modular units could be the next step in the development of the new technologies of construction on Serbian waters.

Considering the above conclusions floating houses can provide possibilities for larger population density in the urban core as well as flexibility. Flexibility of floating buildings manifests in their easy removal if they are not needed any longer but they can also have extended lifetime at some other location.

Financial feasibility of construction of floating buildings manifests in the savings of costs of earthworks, infrastructure, public utilities and building land. Social justification manifests in development of a concept that can be used by all social strata, from social dwelling to dwelling preferred by the wealthy.

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