Civil Engineering

CONSTRUCTION OF LOW-RISE BUILDINGS IN THE COASTLAND AND WATER AREAS

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Abstract
Introduction: Artificial islands for new construction and works in a dry environment are created in water areas by installing enclosures, which allow buildings to remain rigid and stable and withstand the influence of climatic factors. **Purpose of the study:** We aim to develop a method for the construction of low-rise buildings in the coastland and water areas with the least labor effort required to erect buildings and ensure their safe operation. **Methods:** In the course of the research, we have performed theoretical studies in the field of experimental construction and analyzed the results of Russian and foreign scientific research related to the construction of buildings in water areas. **Results:** We have examined methods for the construction of waterproof enclosures in water areas that make it possible to erect buildings in a dry environment in open water areas with unstable wave conditions. Such methods reduce labor efforts, decrease the term of construction, and improve performance indicators.

Keywords
Water area, waterproof enclosures, cofferdam, pontoon platforms, pier foundations, coastland, telescopic piles.

Introduction

By the start of the 21st century, there were many projects for the construction of buildings of various purposes on artificial islands. Such architects as N. Foster, R. Piano, E. van Egeraat, and A. Asadov dealt with the matters of design and construction in water areas. Their projects were not implemented. However, they boosted the development of similar projects.

Additional territories for new construction are created by means of artificial islands in water areas (Zadvoryanskaya, 2008). This issue is usually addressed when dealing with design concepts of buildings and structures in cities and countries with high exposure to flood risk (Karmazin, 1973). For instance, in the Netherlands, three artificial islands were created by means of hydraulic filling (Mikhailova, 2016; Zhogoleva and Bedulin, 2018). In the Black Sea water area, at a distance of 13 km from the Adler airport, an artificial island was built that connects to the mainland via two tunnels and a footbridge. In Venice, entire neighborhoods are built in water areas. The structures are supported by piles sunk into the sea bed (Ilicheva, 2016).

Starting with 1933, territories for passenger port construction on the coast of the Gulf of Finland in Leningrad were hydraulically filled. A three-story administration building, a water tower, and other structures were built in the area in 1935–1937. The General Plan of Leningrad provided for the construction of 700 ha using water areas (Tilinin and Vorona-Slivinskaya, 2018).

In Saint Petersburg, in the western part of Vasilyevsky Island, 400 ha of new territories were hydraulically filled along the coastline of the Gulf of Finland, Marine Facade and a passenger sea port were built (Tilinin and Vorona-Slivinskaya, 2018; Verstov and Gaido, 2013).

Environmental disasters and infill development around the world force people to search for new accommodation.

Methods and Materials

At the first stage, when designing a building in a water area, it is necessary to solve tasks related to pre-construction activities under normal conditions.

When preparing for the construction of low-rise buildings in hydraulically filled territories, the following works shall be performed:

- construction of enclosing dams along the perimeter of the future development area;
- dredging of the water area, excavation of clay deposits and sandy soil required for hydraulic filling.

Results

Currently, when artificial islands are built in water areas, steel sheet piles forming a cellular

DOI: 10.23968/2500-0055-2021-6-1-58-63

structure are used to support excavations. To drive guide elements in cells or to drive several pre-assembled elements in stacks joined on top with rigid caps, special floating equipment is used. Within a structural cell being formed, the stacks are driven down to the design elevation using a vibratory driver fixed to each of the stacks.

The use of large-diameter (up to 16 m) shells made of coiled steel is the most efficient method for the erection of waterproof enclosures (Yudina et al., 2020).

With the help of a crane, coiled steel is firmly fixed in a stand, located on the coastline, to be uncoiled. The sheets are laid in an overlapping manner (with an overlap of 50–100 mm) and welded. These shells are transported to the installation site with the use of flotation equipment, where they are installed into position on a crushed rock base with a crane and filled with sand using vibration (Fig. 1).

To ensure that the joints between the shells are waterproof, sheet piles are installed between them (Fig. 2).

To accelerate sand dewatering within the territory made by the shells, well points lowering the water level (down to 20 m) are installed.

After the final stabilization of sand settlement within the sheet piling area, the erection of buildings is started (Fig. 3).

Due to pre-assembly on the shore, enclosures made of coiled steel reduce labor effort almost by half and metal consumption — by 2.5 times (as compared with steel sheet piling).

The works carried out using flotation equipment are technically challenging and labor-intensive. Besides, they represent one of the most important activities performed when erecting buildings in water areas. Many operations have to be conducted directly in situ, in the water or underwater. The cofferdam was invented especially for such cases. It is rather widely used to make enclosures when building artificial islands in water areas. It consists of temporary waterproof cases used for construction and repair underwater (Figs. 3, 4) (Jin, 2012; Kramola.info, 2019).

The cofferdam is built directly in the water. Then water is pumped out of it, and the cofferdam is used for construction in a dry environment. It can also be built on the shore and then floated out and sunk into place.

The cofferdam is erected as follows:

- A special welded metal structure with piles of a certain length fixed in the water is installed on the bottom. The required length is determined by analyzing the depth, layers of the underwater soil, and seasonal temperature fluctuations. In case of inadequate pile length, the external water pressure can destroy the cofferdam;
- Water is pumped out from the cofferdam using high-duty pumps.

Generally, cofferdams are made of steel elements. Recently, inflatable cofferdams have been started to be used as well. Their advantage is repeated use. Such structures are currently considered to be state-of-the-art. However, they cannot be installed wherever it is required.

Building cofferdams is labor-intensive and expensive, but they make it possible to perform construction works in places where it is virtually impossible. Engineers must carefully design these in order to ensure safe construction. Cofferdams are used everywhere, both in civil and industrial engineering. In particular, they were used to build bridges over such wide rivers as Mississippi, Hudson, and Ohio, to eliminate the consequences of the accident at Fukushima, and to build locks on most dams. On the one hand, the use of a cofferdam

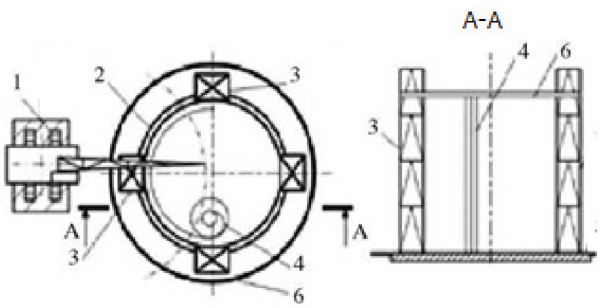

Figure 1. Diagram of a stand for shell manufacturing:
1 — crane; 2 — guide ring in the upper level of the shell;
3 — assembly towers; 4 — coiled steel being uncoiled;
5 — guide ring

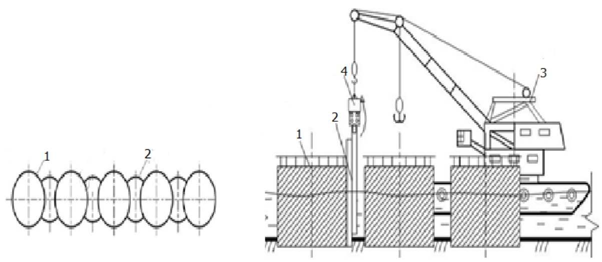

Figure 2. Diagram of the joints between the steel shells, made with the use of sheet piles:
1 — shells; 2 — sheet piles; 3 — crane; 4 — vibratory driver

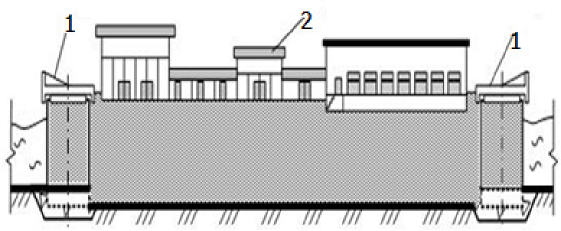

Figure 3. Diagram for the erection of buildings and structures on an artificial island:
1 — superstructure; 2 — buildings to be erected

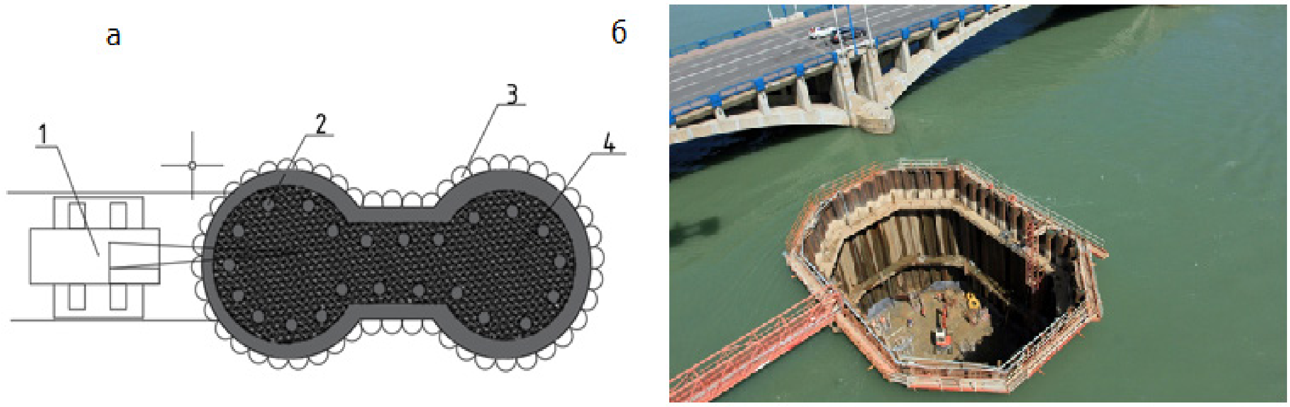

Figure 4. Cofferdam structure: a — cofferdam construction diagram; b — finished cofferdam; 1 — assembly crane; 2 — piles lowered into the water; 3 — welded metal structure; 4 — concrete base

in the water makes construction easier. But on the other hand, due to high labor-intensity, its application is limited (Kramola.info, 2019).

Construction in the water, with account for the architectural and planning designs of buildings and other specifics of construction, requires design documentation to be developed, including documents on choosing the foundation type and measures to ensure safe operation.

For a long time, structures were built on a pile foundation made of tree trunks. Nowadays, traditional pile foundations are almost replaced by new structural elements, such as pier foundations.

The process of pier foundation installation is nearly the same as the process of pile installation. Piers are made on the shore and then delivered to the installation site using flotation equipment. Before installation, on the top and bottom edges of foundation slabs and blocks, special indelible marks are made that are used to fix the position of the slabs' and blocks' axes. The bearing surfaces of such slabs and blocks shall be clean.

During the construction of a bridge in France, piers with a diameter of 90 m and a height of 65 m were used to transmit the load to the ground. Foundations with single-column and multi-column (frame) piers, as well as combinations of pile and pier foundations, are also used in construction.

It is also possible to use pontoon platforms during the construction of buildings in water areas. Pontoons can be made of various materials: steel, reinforced concrete, plastic, timber. Metal pontoons are lighter than concrete ones. Besides, they are high-strength and have reliable locks that do not self-open (Valtanen, 2016).

To choose the material for a pontoon platform, it is necessary to calculate its capacity based on the foundation load. The construction of a pontoon platform involves the manufacture and installation of special pontoons fixed to each other in a single floating platform that can withstand the load of the entire building.

The use of telescopic piles is another promising direction. They serve as an alternative when preventing water-related hazards and can be used when building a pontoon platform (Spagnoli and Weixler, 2013).

Sections of telescopic piles are able to extend. In case the water level becomes higher, the building comes up as a fishing float. In other words, it rises together with the pontoon platform. Telescopic piles are made of light and strong teflon material. The lighter the pile material, the less is the section thickness of the pontoon platform. This is due to the fact that the vertical movement of the pile section depends on the weight of the pontoon and the building erected upon it. A pile made of teflon material must have sufficient strength in order to withstand high water and floods.

To improve the quality of construction on the coastland and in water areas, it is necessary to study the characteristics of the territory, the construction product (building), the processes of its erection, and the conditions of the water environment. Using these factors, we can develop an accurate organizational and technological model, taking into account the special conditions of building construction (Sandan, 2012).

When preparing for the construction on the coastland and in water areas, we shall bear in mind the following: the method used to build waterproof enclosures; the climatic factors; the characteristics of the water body; the conditions of machinery disposition as well as the conditions of materials and structures' storage on the coastland, etc.

A building erected in a water area cannot properly operate without utilities. Most often, autonomous equipment is used for that purpose, since it is not always possible to connect to municipal networks. For instance, solar panels, diesel or wind generators can be installed. Solar collectors can be used to provide heat. Pumps and filters are installed for the purification of water collected from water bodies (Samogorov and Khodotova, 2014).

DOI: 10.23968/2500-0055-2021-6-1-58-63

Conclusion

After the analysis of construction projects in water areas, we arrived at the following conclusion: in the nearest future, the technologies considered can solve a number of issues related to the creation of additional territories for new construction and favorable conditions for accommodation. To ensure the prospective development of this direction in construction, we need to account for both the climatic environment and architectural and planning designs.

Waterproof enclosures used when building artificial islands, made of large-diameter shells sunk to the bottom of a water body and filled with sand, make it possible to perform construction and installation works, needed to erect a building, in a dry environment. This method reduces the duration and labor intensity of operations in open water areas with unstable wave conditions.

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СТРОИТЕЛЬСТВО МАЛОЭТАЖНЫХ ЗДАНИЙ В ПРИБРЕЖНОЙ ЗОНЕ И НА АКВАТОРИИ

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Аннотация
Создание на акватории искусственных островов для нового строительства и производства работ насухо решается путем устройства ограждений котлованов, позволяющих сохранять жесткое и устойчивое положение здания на воде и противостоять климатическим факторам. **Цель исследования:** Разработка технологии строительства малоэтажных зданий на акватории и в прибрежных зонах с наименьшими трудозатратами на их возведение и обеспечение безопасной эксплуатации объектов. **Методы:** Теоретические исследования в области экспериментального строительства, анализ научных разработок отечественных и зарубежных исследователей по развитию строительства объектов на воде. **Результаты:** Рассмотрены технологии устройства водонепроницаемых ограждений на акваториях, позволяющих выполнять работы по возведению зданий в сухом пространстве (насухо) на открытых акваториях с неустойчивым волновым режимом, что позволит сократить трудоемкость работ, сроки возведения объекта и повысить технико-экономические показатели.

Ключевые слова
Акватория, водонепроницаемые ограждения котлованов, коффердам, понтонные основания, пилонные фундаменты, прибрежная зона, телескопические сваи.