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PECULIARITIES OF WORK CONCRETE AND FERROCONCRETE OF MARINE HYDROTECHNICAL CONSTRUCTIONS

ABSTRACT

At present most marine hydrotechnical structures are constructed of concrete and ferroconcrete. When designing and operating, special requirements are imposed on them the main ones are: strength characteristics; frost resistance; water resistance; permissible degree of water absorption; crack resistance; resistance to abrasion. It is known that in the course of operation, all hydrotechnical engineering structures are exposed to wind waves, drifting ice formations, such as level ice, single hummocks and hummock fields, as well as to seismic loads. Sea water is an aggressive environment with regard to concrete and ferroconcrete structures. In addition, hydrotechnical engineering facilities are in conditions when the water level is constantly changing under the influence of certain natural factors (overtaking, seiches, tides). At the same time, surface and underwater parts of hydrotechnical structures in winter periods are in different temperature zones. The difference in temperature along the height of the structure leads to the occurrence of temperature stresses in the structures, even with relatively small external loads. In the zone of the variable horizon at negative air temperatures, water penetrating into the microcracks leads to the destruction of the surface protective layer of concrete, and then the reinforcement. These factors should be taken into account when designing concrete and ferroconcrete hydrotechnical structures of various functional purposes. In this work, an analysis of the technical state of some types of marine hydrotechnical structures in the Odessa region built in the last century was made. Recommendations were formulated to take into account the local ice pressure, which is the determining factor for setting design strength of concrete and ferroconcrete structures. Recommendations for design were also given.

KEY WORDS: concrete, ferroconcrete, hydrotechnical constructions, wave and ice loads.

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ОСОБЛИВОСТІ РОБОТИ МОРСЬКИХ ГІДРОТЕХНІЧНИХ СПОРУД З БЕТОНУ ТА ЗАЛІЗОБЕТОНУ

АНОТАЦІЯ

Більшість морських гідротехнічних споруд в даний час побудовані з бетону та залізобетону. При проектуванні і експлуатації до них пред'являються особливі вимоги. У даній роботі виконано аналіз технічного стану деяких типів морських гідротехнічних споруд в Одеському регіоні, побудованих в минулому столітті. Сформульовані рекомендації з обліку локального тиску льоду, який є визначальним при призначенні проектної міцності бетонних і залізобетонних конструкцій, а також приведені рекомендації з проектування.

КЛЮЧОВІ СЛОВА: бетон, залізобетон, гідротехнічні споруди, хвильові і льодові навантаження.

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ОСОБЕННОСТИ РАБОТЫ МОРСКИХ ГИДРОТЕХНИЧЕСКИХ СООРУЖЕНИЙ ИЗ БЕТОНА И ЖЕЛЕЗОБЕТОНА

АННОТАЦИЯ

Большинство морских гидротехнических сооружений в настоящее время построены из бетона и железобетона. При проектировании к ним предъявляются особые требования, основные из них: прочностные характеристики; морозостойкость; водонепроницаемость; допустимая степень водопоглощения; трещиностойкость; устойчивость против истирания. Известно, что в процессе эксплуатации, все гидротехнические сооружения подвергаются силовому воздействию ветровых волн, дрейфующих ледовых образований, таких как ровные ледяные поля, одиночные торосы и поля торошения, а также сейсмическим нагрузкам. Морская вода является агрессивной средой в отношении бетонных и железобетонных конструкций. Кроме этого гидротехнические сооружения находятся в условиях, когда уровень воды постоянно меняется под воздействием тех или иных природных факторов (сгонно-нагонные явления, сейши, приливы и отливы). При этом надводные и подводные части гидротехнических сооружений в зимние периоды времени находятся в различных температурных зонах. Разница температур по высоте сооружения приводит к возникновению температурных напряжений в конструкциях даже при относительно небольших внешних нагрузках. В зоне переменного уровня при отрицательных температурах воздуха вода, проникшая в микротрещины, приводит к разрушению поверхностного защитного слоя бетона, а затем и арматуры. Эти факторы следует учитывать при проектировании гидротехнических сооружений различного функционального назначения из бетона и железобетона. В настоящей работе выполнен анализ технического состояния некоторых типов морских гидротехнических сооружений в Одесском регионе, построенных в прошлом веке. Сформулированы рекомендации по учету локального давления льда, которое является определяющим при назначении проектной прочности бетонных и железобетонных конструкций, а также приведены рекомендации по проектированию.

КЛЮЧЕВЫЕ СЛОВА: бетон, железобетон, гидротехнические сооружения, волновые и ледовые нагрузки.

INTRODUCTION

Economic recovery of Ukraine is impossible without the revival of industry. One of the most important spheres in this field is the construction industry and, in particular, marine hydrotechnical construction. It unites sea and river transport, shipbuilding and ship repair, protection of the banks of rivers, lakes, reservoirs and seas, as well as arrangement of offshore hydrocarbon deposits on the shelf of the Azov and Black Seas.

At present most of the marine hydrotechnical structures, including the structures of the continental shelf, are constructed of concrete and ferroconcrete. The operation of such facilities has its own characteristics, which must be taken into account at the design stage in order to ensure their trouble-free operation during the estimated service life. These features include: a constant fluctuation of the water level, causing temperature stresses in structures; force impact of storm waves, accompanied by a negative air temperature splash icing; global ice loads; local ice pressure; abrading effect of ice; abrasion by weighted and bottom sediments, moving currents and waves.

Regardless of the class of responsibility of hydrotechnical structures of concrete and ferroconcrete, special requirements are imposed on the composition and quality of hydrotechnical concrete such as: strength characteristics; frost resistance; water resistance; permissible degree of water absorption and linear changes when moistened and dried; resistance to aggressive water; crack resistance; absence of harmful interaction of cement alkalis with aggregates; permissible degree of heat release during hardening; resistance to abrasion by water streams, bottom and suspended sediments, as well as drifting ice formations in the zone of variable water level. In the process of implementing projects of hydrotechnical structures, it is necessary to comply with the requirements for the composition of concrete mixes, the quality of their manufacture and the production of concrete works. Violation of the requirements provided by the drafts and recommendations of normative documents leads to a reduction in the service life of the facilities commissioned.

ANALYSIS OF THE LATEST SOURCES OF RESEARCH AND PUBLICATIONS

Specialists in various countries around the world where hydrotechnical structures are designed and built study the composition of concrete. These hydrotechnical structures undergo the above listed factors during the exploitation. The local pressure of ice is the most important one. It is realized at the initial moment of contact of drifting ice formations with hydrotechnical structures. Calculated values of local ice pressures at the design stage are decisive when assigning a concrete grade of a particular object, depending on the natural and climatic conditions of the construction area. For this reason a great attention was given to research of local ice in many countries [1-5]. In the former USSR departmental norms were developed [6]. Recommendations for calculating the local ice pressure under the influence of level ice were first presented in these departmental norms. An analysis of these recommendations has shown that they relate to the semi-local ice pressure, which can be realized with the area of contact of an even ice field at its entire thickness. The local ice pressure, which is realized in smaller areas, is much higher than the maximum values of the semi-local pressure recommended by these norms.

Based on the results of experimental studies conducted on a freshwater lake during several winter seasons, and also taking into account the generalization of the data of other authors, recommendations were developed for calculating the local pressures of ice [7, 8]. They were included in the departmental document [9]. Their use in engineering practice will allow more justified designation of the brand of concrete designed hydrotechnical structures.

THE PURPOSE OF THIS WORK IS: review and analysis of the technical state of hydrotechnical structures built in the last century; identification of the main causes of premature destruction of their structural elements; providing a method for calculating the local pressure when exposed to level ice on the vertical profile; development of recommendations for the creation of concrete that can successfully resist the effects of natural factors throughout the life of water bodies.

MAIN MATERIAL

Within the framework of this work, bank protection structures were surveyed in the city of Odessa. Despite the fact that the structural elements were manufactured in the factory, many of them are in an emergency condition nowdays (Fig. 1).

An analysis of the technical state of shore protective structures shows that the main reasons for their destruction are low quality of concrete and construction works. This fact led to intensive destruction of both structural elements and structures as a whole under the influence of the natural factors listed above.

The photograph (Fig. 2) presents the technical state of the active protection bank with concrete structural elements.

In the zone of variable water level, the structure was subjected to the power of waves and level ice, as well as the temperature difference between water and air.

When the drifting ice fields are affected by the structure, local ice pressures arise at the initial moment of contact of the ice with the structure, which significantly exceed the ice strength parameter for uniaxial compression. They are the cause of local destruction of the concrete surface (Fig. 3, 4).

The poor quality of the concrete mix during its laying lead to further destruction of structural elements of hydrotechnical structures and in surface parts during operation (Fig. 5).

The presented fragments of the technical state of bank protection structures made of concrete and ferroconcrete are in principle unacceptable for marine hydrotechnical structures of a higher class

Fig. 1. The current technical condition of the coastal protection structures of the passive type on the Odessa coast (B. Fontansky cape)

Fig. 2. The state of the root part of the buna in the zone of the variable water horizon

Fig. 3. The hummocking of an even ice field on the shore protective structure of the sloping type (PJSC Odeskabel)

of responsibility [10]. A high class of responsibility include breakwaters, dry docks, as well as offshore structure that are operated in the open sea.

Currently, in the world practice in the construction of offshore oil and gas facilities on the shelf of freezing seas, various additives are used in concrete mixes that exclude the destruction of ferroconcrete in the zone of an alternating horizon under the influence of temperature differences (for example, in air -25°C ÷ -30°C, and in water + 2°C). In this case, tidal waves in the seas reach several meters and occur daily (Fig. 6).

Fig. 4. Local fracture of concrete caused by local ice pressure

Fig. 5. Wave-breaking wall of the shore protection structure (PJSC Odeskabel)

Such advanced technologies of the composition of concrete and the manufacture of structural elements in dry docks are, unfortunately, not available for our country now days.

In Russia, with the construction of offshore fields on the Sakhalin shelf of the Sea of Okhotsk on an ice resistant ferroconcrete platform in the zone of variable water level, metal bands of alloyed stainless steel were used (Fig. 7).

An analysis of the technical state of marine hydrotechnical structures showed that a number of factors affecting the longevity of the structures were not taken into account when designing them. The main ones are the lack of recommendations in the regulatory documents for assessing the magnitude of the local ice pressure and temperature stresses occurring in structures with significant temperature differences.

The method for estimating the local pressures of ice, depending on the initial area of contact between ice and strength on uniaxial compression, was developed on the basis of experimental studies in full-scale conditions when hard stamps of various sizes were introduced into natural ice fields [7, 8]. As a result, recommendations were formulated and were included in the departmental document of Russia [9].

In accordance with the recommendations of norms [9], the magnitude of the local pressure from flat ice fields and from the average consolidated part of hummocks is determined by means of an empirical relationship:

$$p_i = k \cdot k_v \cdot k_{b,loc} \cdot R_c \qquad (1)$$

where k - is the coefficient: for freshwater ice $k = 1$; for sea ice $k = 1.164$; k_v - coefficient, taking into account the rate of deformation of ice formation, is taken in accordance with [8] (item 5.5, table 31); $k_{b,\,loc}$ - coefficient that takes into account the stress-

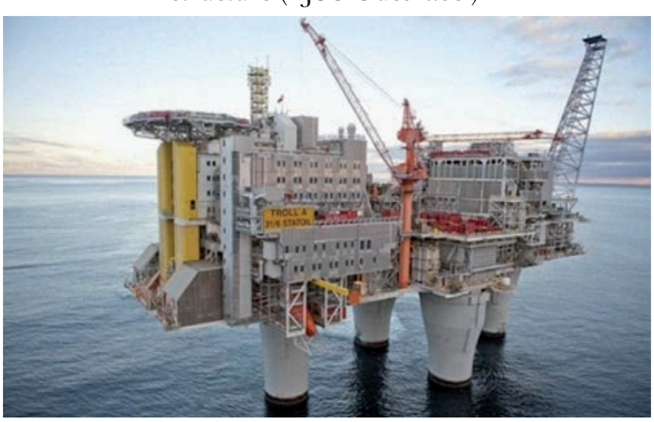

Fig. 6. Ice-resistant stationary gas production platform Troll-A in the North Sea, installed at 300 meters depth of water (Norway)

Fig. 7. Ferro-concrete ice-resistant stationary platform in the Sea of Okhotsk

strain state of ice in the zone of its contact with the surface of the structure is determined by the formula:

$$k_{b,loc}=\left(\frac{1,12}{\sqrt[4]{\frac{S}{h_d^2}}}+0,56\right)^2+0,93, \qquad (2)$$

R_c - ice strength for uniaxial compression, MPa.

In the same way, the local pressure from the average consolidated part of the calculated hummock formation can be determined. In this case, instead of the design strength of an even ice field on a uniaxial compression R_c, the integral strength of the middle part of the field of hummocking or a single hummock R_m should be used.

CONCLUSIONS

1. At present Ukraine is energetically dependent country. To reduce this dependence, there is an urgent need to develop promising hydrocarbon deposits on the Black Sea shelf, which are located at various depths of the water. As the world experience shows, when developing offshore deposits at moderate depths of water, sea ice resistant platforms made of reinforced concrete are used.
2. The design of any types of hydrotechnical structures in accordance with the requirements of the norms [10] should be carried out with scientific accompaniment.
3. In the process of scientific support, due to the relatively short time of the design stages, it is impossible to solve the scientific problems on the basis of which the recommendations of normative documents are developed.
4. In the process of designing hydrotechnical structures of various functional purposes in freezing water bodies, it is necessary to estimate the value of the local ice pressure in order to justify the design strength of concrete and ferroconcrete structures that will be located in ice impact zones.
5. Researchers in the field of reinforced concrete structures should develop new compositions of concrete that would best correspond to the working conditions of marine hydrotechnical structures.
6. Scientific research aimed at creating modern regulatory documents for the design and construction of concrete and ferroconcrete hydrotechnical structures can not be carried out without the financial support of the state of Ukraine.

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