Natural Effects on Offshore Structures in the Arctic

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Abstract. The article deals with the effects of the environment on offshore structures in the Arctic region. On the basis of the analysis of the influence of natural impacts, the most important factors affecting the offshore constructions of structures in the region of the Arctic belt have been identified. The relationship between the depths and tipping moments is revealed depending on the maximum loads. The influence of the load on the hydraulic engineering structure is shown depending on its width.

1. Introduction
In the modern world, the Arctic is a priority for the development of oil and gas fields [1, 2]. Huge natural resources in this region are of economic interest for many states. Russia occupies 78% of the territory in the Arctic, so the construction of new offshore structures and the study of natural effects on them come to the fore [3, 4]. Most of the most reliable data on hydrocarbon resources available for drilling is concentrated on the shelf with a bottom depth of 20 to 50 m and sediments of different ages lying at depths to 4-5 km [5,6]. Despite the fact that the Arctic region is rich in a huge amount of hydrocarbon resources, the extraction of the latter is associated with a lot of problems. To the difficulties of extracting hydrocarbons can be attributed to the load on oil rigs. These loads include wind [7, 8], waves [9, 10], seismic activity [11, 12], corrosion [13, 14], ice abrasion [15,16].

The purpose of our scientific research is to determine the most dangerous natural impacts on marine engineering structures in the Arctic.

The main objectives of the study:
1. Determine which factors of natural impact have the strongest impact on offshore structures.
2. Determine the load from the most dangerous impacts.

2. Results and Discussion
When designing marine hydraulic structures it is necessary to take into account the influence of a complex of natural factors (Fig. 1). Some factors have a direct power effect on the structure, which is important when choosing the type of construction and justifying its size. Others create difficulties in construction and exploitation.

So, among them one can single out:
1. Seismic impacts (earthquakes, tsunami waves) [17].
2. Wind influences [18].
3. Wave impacts [19]
4. Corrosive destruction [19, 20].
5. Ice impacts (ice load, load from hummocks, and contact with iceberg) [20].
Due to earthquakes, precipitations and dislocations can occur, leading to inoperative condition the construction. Therefore, in the construction of hydraulic structures it is necessary to take into account seismic impacts and conduct measures to strengthen structures. In the Barents Sea for the period from October 2011 to May 2013, 19 earthquakes were recorded from the Franz-Victoria and Orla trough areas. The magnitudes of the recorded earthquakes vary from 1.1 to 3.6 [3]. In this area, earthquakes produce minimal impact on the construction; therefore, there is no need for calculations.

Tsunamis are huge ocean waves of destructive force, which are formed as a result of the powerful impact of natural disasters on the entire thickness of the water. They are caused by underwater earthquakes, volcanic eruptions or underwater landslides. In connection with a small magnitude of earthquakes, the phenomenon of tsunami in the Arctic region is a rarity.

Wind impacts on offshore structures are manifested in the form of a static wind load and small oscillations of structures. It is also possible the appearance of tilt of the structure by strong wind directed along the front of high and extended structural elements of the structure (the phenomenon of sailing). However, the platform superstructures on shelf, as a rule, do not have such a large width and extent that the design storm could significantly tilt the structure.

In conditions of the open water area of the Arctic seas, the impact of waves is a frequent occurrence. It is impossible to avoid waves in an open sea area of the restless, prone to frequent storms. Waves have a large mass and energy, hence, and the force of the impact, which varies depending on the parameters of the wave. Consequently, the wave load is significant, and should be taken into account at the design stage of the structure.

Sea water is characterized by the presence of salinity, which contributes to the corrosive effects on hydraulic structures. In this case, both corrosion of concrete and corrosion of reinforcement and metallic outer elements can be observed. There are using high-grade concrete and special chemical additives for resist these types of corrosion.

Ice should be considered in the form of ice fields, hummocks and icebergs. Ice fields have a large area in terms of, thickness of ice and, accordingly, mass. Large ice layers have a considerable ice load. As a protection against colossal ice loads, ice belts, special structural elements, and an increase in the total weight of the structure are used [9-10]. The accumulation of ice in the form of hummocks has a special effect on the structures in contact and is calculated by a special method. Contact of the
structure with an iceberg can lead to unpredictable consequences; therefore the impact of icebergs is unacceptable. It is necessary to provide for measures to prevent such situations.

Thus, the greatest influence on the choice of design and material of the structure, its overall dimensions and other parameters is provided by ice and wave influences.

To assess the impact of ice and wave effects, it is necessary to calculate their force effects on the conditional structure and compare the significance of each of them with different parameters. The initial data are given in Table 1.

Table 1. Basic design parameters

| Wave load | Ice cover | Hydraulic engineering structure |
|-----------|-----------|----------------------------------|
| Wind speed, m/s | Extension of the wave top from the structure, m | Wave height, m | Wavelength, m | Ice strength, MPa | Ice thickness, m | Ice field area, km² | Size, m | Depth, m |
| 25 | 13.88 | 10.79 | 138.8 | 1.5 | 1.5 | 100 | 20x20 | 20 |
| | | | | | | | 40x40 | 30 |
| | | | | | | | 50 |
| | | | | | | | 70 |
| | | | | | | | 120 |

According to the methods of normative documents [21, 22], the values of wave and ice loads at different depths were calculated. For each impact, the positions of the resultant force relative to the base of the structure were determined. Based on the results of calculations, the dependencies of a tipping moment force and a depth for platforms of 20 m and 40 m wide were simultaneously obtained for ice and wave loads and graphs were plotted (Fig. 2). Also plotted is the graph of the averaged value of the tipping moment force on the width of the structure at an average depth for ice and wave effects (Fig. 3).

![Figure 2. Dependence of a tipping moment force on a depth for the constructions of various sizes](image-url)
Conclusion

In the course of the study, the results of a theoretical generalization of natural impacts on marine structures were obtained.

1. It is revealed that ice and wave loads are the main impacts on hydraulic engineering structures in arctic conditions.

2. Analysis of the maximum loads from waves and ice in the Arctic in the process of interaction with structures with dimensions of $20 \times 20$ m and $40 \times 40$ m is done, as a result of which the dependencies of the tipping point on the depth for structures are obtained, as well as the dependence of the moment on the width of the structure.

3. The obtained dependences make it possible to conclude that with the dimensions of the structure $20 \times 20$ m at the same depths, the average overturning moment for the ice load is higher than for the wave load by 1.2 times. Considering the construction of $40 \times 40$ m in size for the same depth, an inverse relationship appears. The average overturning moment for the wave load is 2.7 times higher than for the ice. With an increase in the size of the structure from $20 \times 20$ m to $40 \times 40$ m, the average tilting moment for the ice load increases 1.5 times, for a wave load, a significant increase of 4.8 times occurs. Thus, it can be concluded that for regions with significant wave heights, structures with a small cross section are preferred, which avoids large loads from waves.

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