UDC 629.563
DOI: 10.15587/1729-4061.2016.65264

ON THE POSSIBILITY OF APPLYING MODERN DESIGN SOLUTIONS OF OCEAN-TECHNICAL CONSTRUCTIONS FOR THE AZOV SEA SHELF

A. Zaiets
Assistant
Department of ship theory and design department
Odessa National Maritime University
Mechnikova str., 34, Odessa, Ukraine, 65000
E-mail: au.lopatnyova@gmail.com

Досліджено типи океанотехнічних споруджень для шельфу Азово-Чорноморського басейну. Виконано аналіз зарубіжного досвіду проектування та експлуатації океанотехнічних споруд в умовах мілководдя. Визначено льодові навантаження на підставі прогнозу реальних значень товщини льодових утворень. Виконано попередній аналіз вибору архітектурно-конструктивного типу океанотехнічних споруд з точки зору сприйняття льодових навантажень

Ключові слова: океанотехнічне спорудження, шельф Азово-Чорноморського басейну, лідостійки платформи, архітектурно-конструктивний тип

Исследованы типы платформ для шельфа Азово-Черноморского бассейна. Выполнен анализ зарубежного опыта проектирования и эксплуатации океанотехнических сооружений в условиях мелководья. Определены ледовые нагрузки на основании прогноза реальных значений толщины ледовых образований. Выполнен предварительный анализ выбора архитектурно-конструктивного типа океанотехнических сооружений с точки зрения восприятия ледовых нагрузок

Ключевые слова: океанотехническое сооружение, шельф Азово-Черноморского бассейна, ледостойкие платформы, архитектурно-конструктивный тип

1. Introduction

One of the main problems with the design of a platform for operation in ice, besides infrastructure and remoteness, is rather different properties of ice. Ice is not homogeneous and its properties are dynamic [1–3]. This complicates obtaining precise quantitative assessments of ice loads. Contemporary methods of design and estimation of constructions, used in the world practice, are based on the use of maximum values of ice load, obtained by the earlier observations [4–7]. This does not make it possible to estimate a real picture of the experienced loads, since in the last decade a change of the climatic conditions has been observed, including in the location of the designed ocean-technical constructions.

At present, the development of energy independence of Ukraine is a vital problem. This implies the exploration of hydrocarbons, in particular, on the Azov Sea shelf and design of the projects of ocean-technical constructions, capable to operate in ice conditions (Fig. 1).

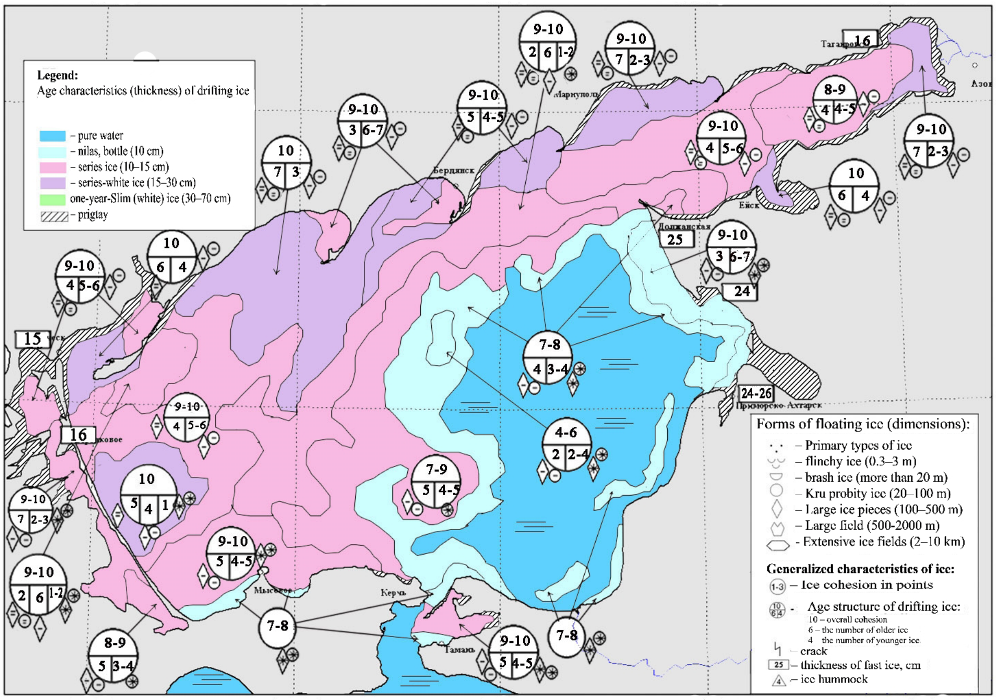


Fig. 1. Map of ice conditions in the Azov Sea in the winter of 2014 [8]

However, the absence of design proposals and recommendations during selection of the type of platforms for the year-round work under conditions of this shelf calls for conducting research and developing the recommendations for the initial stages of the design of ocean-technical constructions.

2. Analysis of scientific literature and the problem statement

During calculations of the ice loads in the early stages of design, they use normative values of the parameters of ice [9–11], but there is not a unified approach to the selection of these values.

In the paper [9], for calculating the ice loads, the maximum observed thickness of ice was used, which forms at the collision of ice formations, taking into account the rate of the flow. In the work [10] the thickness of ice, obtained according to empirical formulas is considered as the estimated thickness. The [11] examines the thickness of ice, obtained experimentally for the constructions with different angles of the slope of the base, without taking into account the real physical factors of the formation of sea ice. Some researchers propose to take maximally possible values out of existing series of observations as the estimated thickness [12, 13]. Others recommend introducing the most probable values into the calculations [14].

Despite the fact that in general existing ocean-technical constructions perform quite well under condition of correct estimation of the action of ice, there appears a number of problems both of technical and economic nature, caused either by unjustified or by overestimated values of the thicknesses of ice in the area of their installation [15]:

– absence of a long term forecast of the change in ice conditions, which would reveal sharp climatic changes, it does not provide full picture of the safety of the construction operation;

– incorrect orientation of ocean-technical constructions depending on the direction of ice drift can lead to incorrect estimation of the calculated ice load;

– presence of ice fracture around the drilling platforms is also an important factor, since the ice load from crushed ice is less than from a solid ice field.

All these factors are taken into consideration at designing ocean-technical constructions, which work under complicated ice conditions in order to reduce ice-breaking support to a minimum, taking into account the possibility of resistance to the action of ice load, which a drilling platform will experience from any direction.

Consequently, there is a need for improving the methods of the estimation of ice loads during designing and operating of engineering constructions for the Azov-Black Sea basin. In the papers [16, 17] the methods were examined and the methods proposed for forecasting real values of the thicknesses of ice formations, based on contemporary achievements of artificial intelligence. Possessing such data makes it possible to estimate real ice loads as well as give recommendations for engineers regarding the selection of an architectural-construction type of an ocean-technical construction.

3. The purpose and objectives of the study

The purpose of the conducted research was to determine the architectural-construction type (ACT) of an ocean-technical construction for the Azov Sea shelf taking into account real ice loads.

To achieve the set goal, the following tasks were solved:

– the type of ocean-technical constructions for the conditions of shoal and freezing sea was determined;

– the estimation was performed of the ice loads taking into account neural network forecast of the thickness of ice for the existing designs of ocean-technical constructions.

4. The study of the experience of applying different types of ocean-technical constructions for the conditions close to the shelf of the Azov-Black Sea basin

4. 1. Analysis and the application of foreign experience of designing and operating of ocean-technical constructions under the conditions of shallow water

For exploration and production of hydrocarbons under the conditions of shallow water, the following types of constructions were most frequently used by foreign petroleum companies [18–20]:

1. Ground islands

The use of artificial islands found particularly wide application in connection with the exploration of shallow fields in the Arctic shelf of the USA and Canada. Fig. 2 represents the distribution of the constructed ground islands depending on the depth of sea.

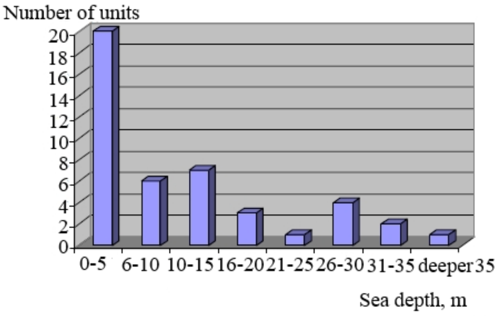


Fig. 2. Distribution of the constructed artificial ground islands by the depths of sea for the Arctic shelf of the USA and Canada

2. Ice islands

The islands, made by freezing in the seabed, are intended for a one-season drilling and were widely used in the Canadian Arctic because of the accessibility of the material for the core of the island and ease of the formation of the installation. Ice islands in comparison to the ground ones possess a number of advantages, especially with respect to ecological and economic aspects. Preparation time for construction is also shortened. It is not necessary to determine the location of quarries, to perform dredging work, to mobilize fleet or to design and produce contouring metal structures. The shortcomings include presence of fixed or very low-mobile ice cover, and also the time, spent on constructing the island, which substantially limits its use by time.

3. Self-elevating drilling platforms (SEDP)

With the aid of SEDP they conduct both exploration and operational drilling at the sea depths to 152 m, primarily from 60 to 120 m.

A special feature of the design of these installations is that they must possess the properties of both the floating object (when transporting) and the stationary water-engineering construction (when parked). Also there are transient states – the mode of embedment and extraction of supports from the soil.

Today in the world there are 557 SEDP units. This is approximately 52 % of the total quantity of elevating drilling platforms. The distribution of the quantity of operating SEDP by the year of their construction is represented in Fig. 3. As it follows from the given data, the overwhelming majority of SEDP are rather old, their age is more than 20 years. Such SEDP undergo modernization, as a rule, once per 10–15 years. Fig. 4, 5 present dynamics of the development of SEDP depending on the depth of handling of drilling site and depending on the depth of a well drilling.

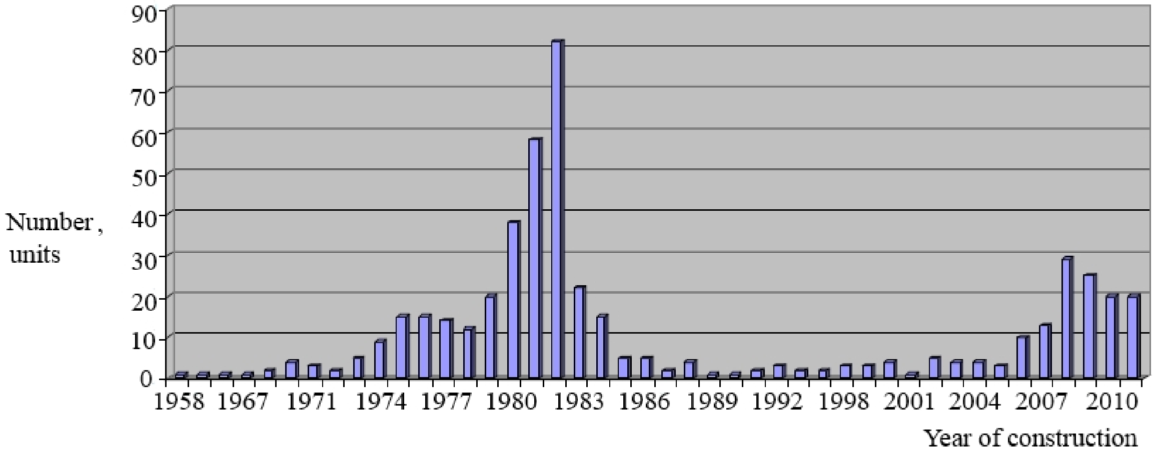
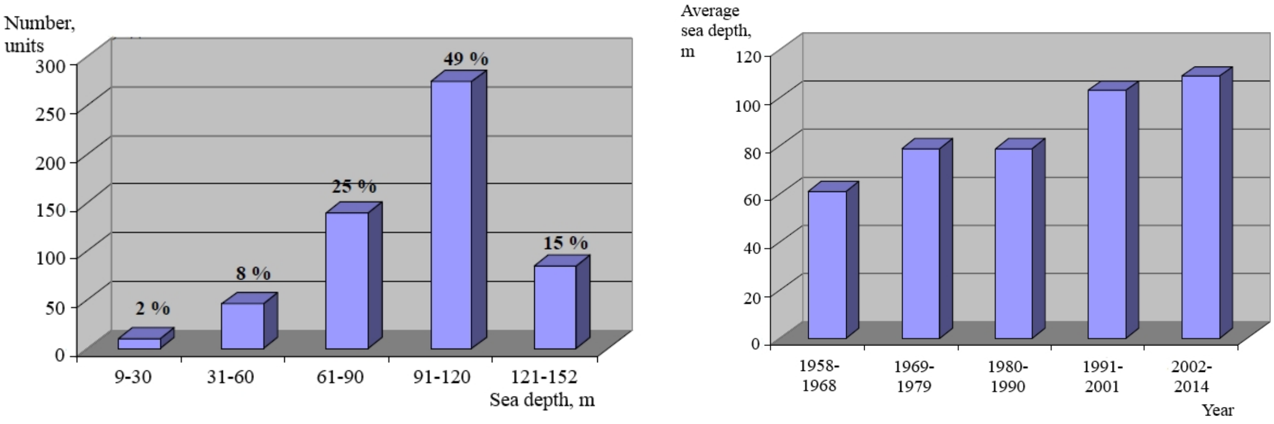
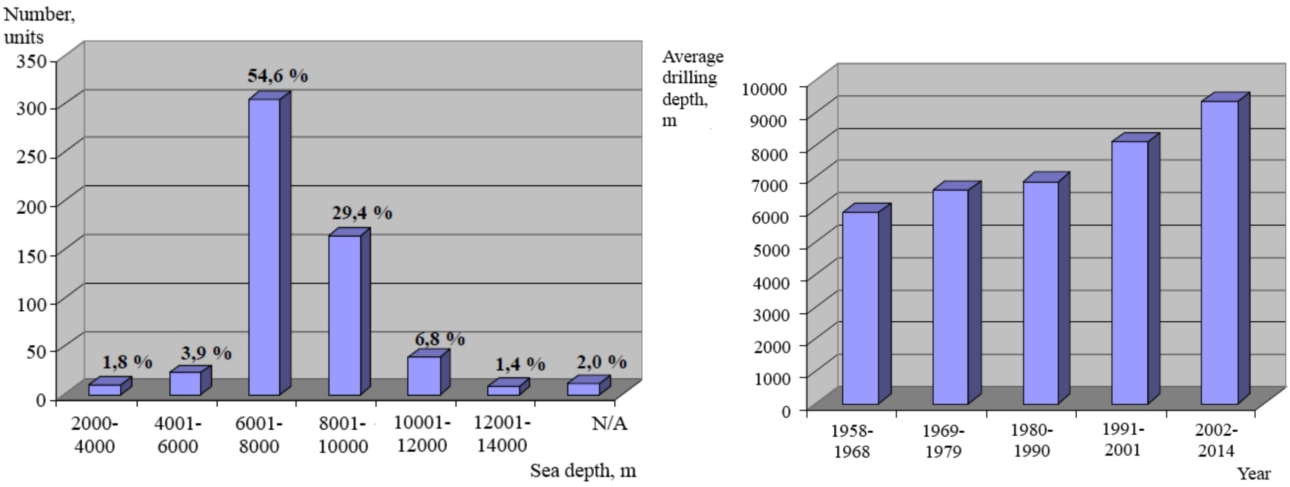


Fig. 3. Distribution of the quantity of operating SEDP by the year of their construction



a *b*

Fig. 4. Dynamics of development of SEDP depending on the sea depth: *a* – distribution of SEDP by the sea depth; *b* – trend of SEDP development by the sea depth



a *b*

Fig. 5. Dynamics of development of SEDP depending on the depth of a well drilling: *a* – distribution of SEDP by the sea depth; *b* – trend of SEDP development by a characteristic – well drilling depth

It is evident from the given figures that there is a tendency of an increase in the average sea depth and an increase in the depth of well drilling with SEDP.

4. Ice resistant stationary drilling platforms

In the 80s of the twentieth century foreign companies designed technical proposals of structures and methods of construction of ice resistant stationary platforms (ISP) for the development of oil fields on Sakhalin Island. At the end of the 90s the application of ISP became actual (there appeared more than hundred constructions) in connection with the exploration of fields in the Sea of Okhotsk and the Beaufort Sea, and also with exploring the Arctic part of the shelf of Canada.

At present ISP constructions continue to be improved [21, 22].

Let us examine the applicability of these types of constructions for the Azov Sea shelf.

1. Ground islands. The main received load is ice. But because of their own weight, the ground islands produce a significant effect on the foundation. This load exceeds ice, practically by three times. Most of emergencies, connected with the ground islands: destruction and the erosion of the mound of an island. Taking into account soft and "creeping" ground of the Azov Sea, creation of a ground island will be a complicated engineering problem, and also will have high economic costs.

2. Ice islands. They are formed by the layered thickening of natural ice cover. Setting up of such platforms in the Azov sea is impossible because of the absence of year-round ice.

3. Self-elevating floating drilling platforms. The platforms with the supporting mats are used for the soft ground. Using of SEDP at the depths to 30 m composes only 2 % of the total number of SEDP, therefore, applying this type of platforms is possible, but it is not expedient.

4. Ice resistant stationary platforms (LSP). Taking into account special features of the soft ground in question, the stationary platforms with the pile base are examined. Of special interest are the ice resistant gravitational platforms, capable of maintaining wind, wave and high ice loads. Depending on the sea depth, there can be 4 types of them:

– the caisson is the base;
– the monokon is the base;
– with a multicolumn base;
– "lightweight design".

Of the enumerated above, let us select ice resistant stationary platforms for consideration.

4. 2. Requirements, put forward at selecting the optimal variant of an ISP construction

The assessments of parameters and economic indicators of the considered technical solutions require specific approaches depending on the level of development (technical proposal, technical and economic substantiation, draft and working designs, etc) and sufficient information. Selecting the main variant of the technical solutions is easy with complete informativeness.

Lack of the information is perceived as a rule in the stages of technical proposals, and therefore it is necessary to carry out assessment by expert evaluation and to select the main variant of proposed technical solutions based on its results.

The main fundamental conditions of the procedure of selecting optimal variant consist in the fact that the number and the technical essence of criteria for the expert estimation depend on the nature of the constructions of platforms, natural climatic conditions of the area of construction and the availability of necessary shore infrastructure.

The main criteria, which influence the selection of the type and construction of ISP [23]:

– contemporary level of the development of designing;
– the degree of automation of production-engineering operations;
– ISP autonomous capacity;
– susceptibility to critical conditions;
– resistance to external influences;
– reliability of the supporting part of the platform structure;
– safety during operation of a platform.

5. Determining ice loads on the existing types of platforms

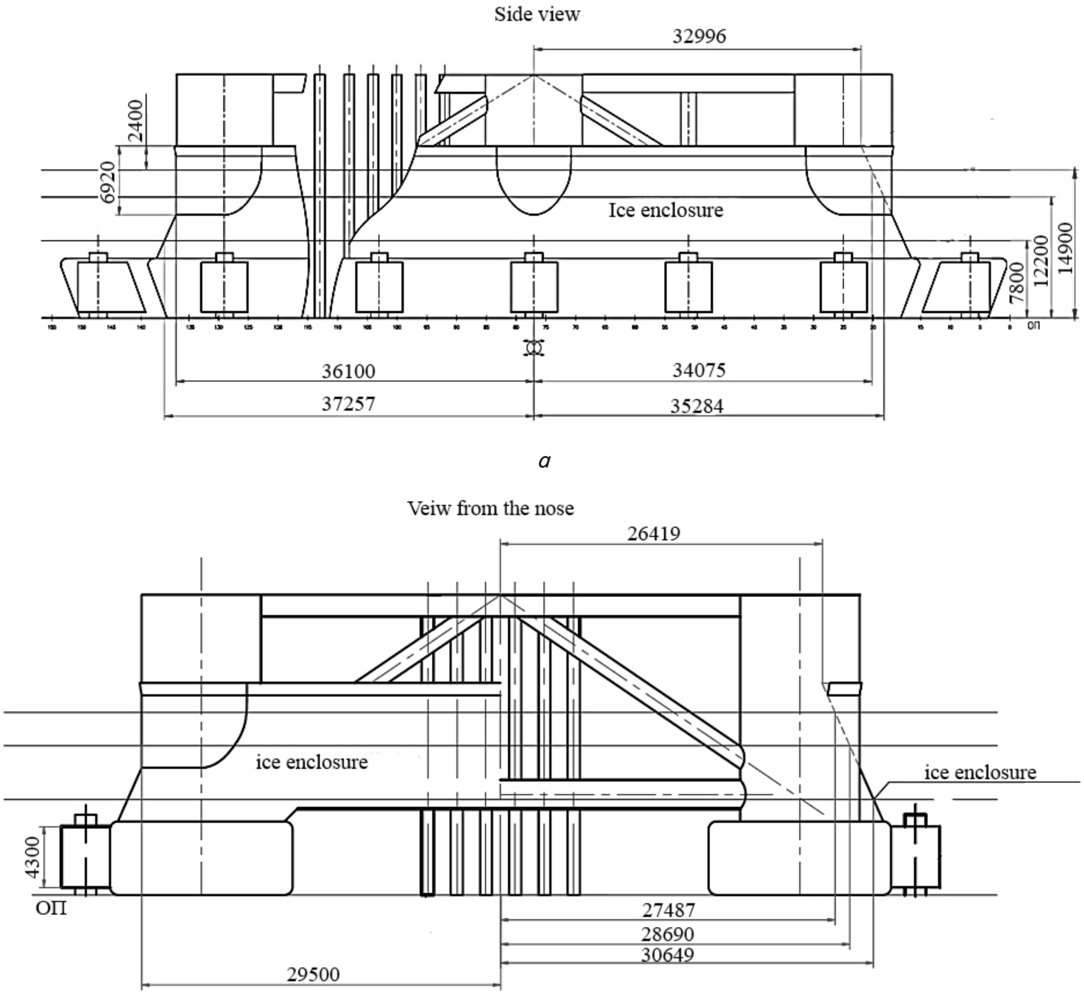
5. 1. Assumptions for the selection of the type of ocean-technical constructions that take into account special features of the considered region

To fulfill preliminary estimation and selection of the architecturally construction type of an ocean technical structure for the Azov Sea shelf, we selected several criteria, namely: contemporary level of design and the estimation of the criterion of perception of one of the main component of the received total load – of ice. As the platforms to consider we selected already existing and successfully performing platforms ISP-1 (ice resistant stationary platform, which contains 6 t of stabilizing columns of cylindrical type that rest on two pontoons) [24] and SMSIP (ice-resistant stationary dock, the base of which is a mono support block and the bottom base is the pontoon) [25]. The selection of such platforms was carried out also by taking into account the similarity of operating conditions: shoal, the weak upper layer of soil, etc.

To fulfill preliminary analysis of the selection of the architectural construction type of an ocean technical construction, we formulated the following assumptions:

1. Sea depth in the promising and existing places of hydrocarbons exploration is 8–12 m [26].
2. Year-round extraction.
3. The upper layer of weak silty soil comprises: on the western coast 4–5 m, the middle part of the sea – 7 m.
4. Extreme wave height is 3 % of reserve, the recurring period: 1 in 100 years – 4,3 m.
5. Extreme high tide with a surge of 3,34 m.
6. Absence of steady shore ice.
7. Thickness of the ice in winter period. Taking into account the maximum values of the thicknesses of the ice, according to the ice observations from December 2007 to March 2016, the maximum thickness of the ice in the following 10 years was forecasted with the application of neuron networks, which is 0,298 m (Fig. 6, 7) [17].

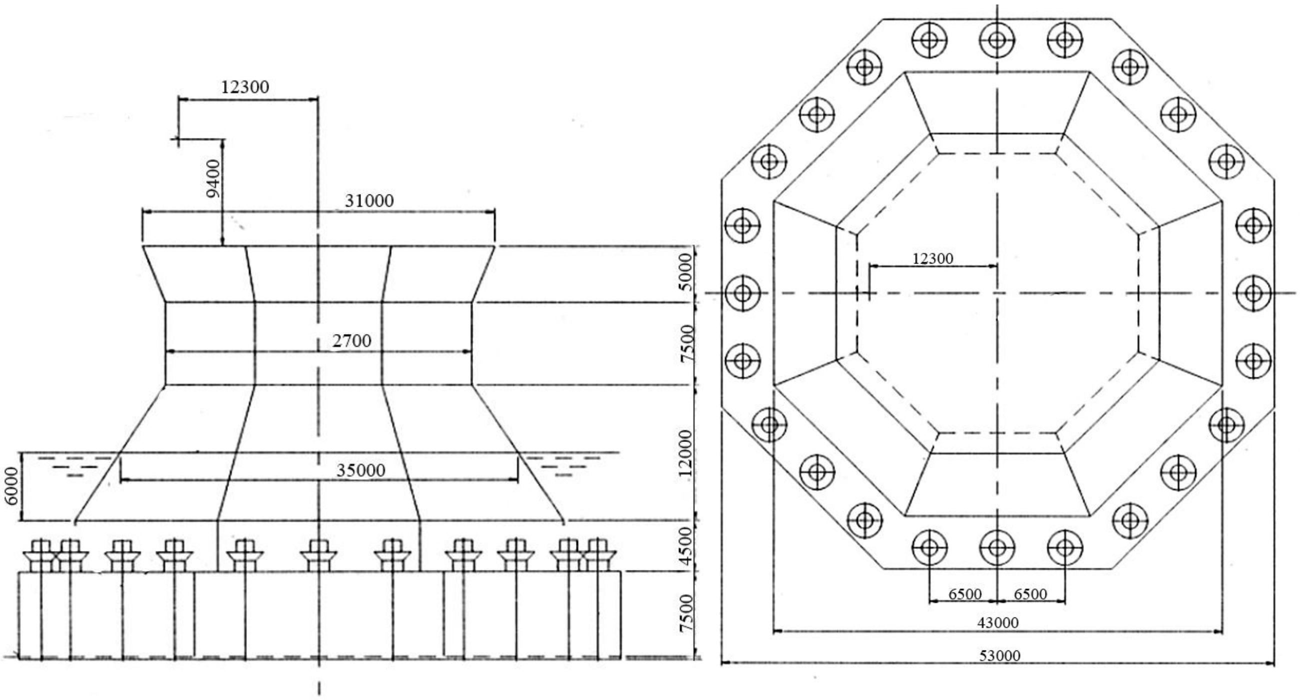
Characteristics and data for calculating the ice load are in Table 1.



a

b

Fig. 6. General view of the ISP base: *a* — side view; *b* — form from the nose



a *b*

Fig. 7. General view of the SMSIP base: *a* — side view; *b* — top view

Table 1

Data for calculating the ice loads for the Azov-Black Sea basin [24–26]

Parameters	Values
Gravitational constant g, m/s^2	9,81
Water density ρ_w, kg/m^3	1025
Air density ρ_a, kg/m^3	1,225
Maximum speed of the wind V_w, m/s	26
Maximum depth of setting the platform d, m	12
Ice parameters	
Coefficient of the friction μ	0,20
Ice density ρ_i, kg/m^3	900
Bending strength of ice σ_f, kPa	500
Modulus of elasticity E, GPa	5
Poisson ratio ν	0,3
Thickness of ice h, m	0,298
ISP parameters	
Width of the platform	
the board B_b, m	70,0
the nose B_n, m	63,0
Angle of the slope of the face α, degree	66
SMSIP	
Width of platform at the level 8, m	43
Width at the level 12, m	41,8
Angle of the slope of the face α, degree	56,3

Let us examine the methods of calculating the loads for the construction with a vertical board.

5. 2. The method of calculation of ice load according to the Rules of the Sea Register of Navigation (RSRN) [5]

During the interaction of a single-support platform with vertical boards with the moving field, the comparison of the global loads, which correspond to the mode of the cutting, is carried out (1):

$$F_{x1} = mK_L K_V \sigma_c D^{0,85} h^{0,9}, \quad (1)$$

where m is the coefficient of the form of a support in the plan of the direction of the motion of ice (for the constructions of circular cross section and polygonal cross section m=0,9; for the constructions of rectangular cross section m=1); σ_c is the uniaxial compression strength of ice, MPa; K_L is the coefficient, which is calculated by (2), considering the influence on the load from the ratio between the field square A_i (equivalent diameter of the field $D_1 = 2\sqrt{A_i / \pi}$) and the diameter of the construction D;

$$K_L = \begin{cases} 1, \text{ if } D_1 / D \geq 10, \\ 1 - 0.0667(10 - D_1 / D), \text{ if } 10 > D_1 / D > 3, \\ 0.6, \text{if } D_1 / D \leq 3, \end{cases} \quad (2)$$

where K_V is the coefficient, which considers the speed of the motion of ice V and its thickness h, and it is determined by (3).

$$K_V = (1{,}6 - 20V / h), \text{ if } V / h < 3 \cdot 10^{-2},$$
$$K_V = 1, \text{ if } V / h \geq 3 \cdot 10^{-2}, \quad (3)$$

5. 2. 1. Procedure of calculation of the ice load according to ISO 19906 [4]

Determining the total load on the construction, caused by splitting ice. When splitting of the ice occurs next to the construction, the total load of the ice perpendicular to the surface F_G, can be expressed as (4):

$$F_G = p_G \cdot A, \quad (4)$$

independent of the limiting mechanism, where p_G is the pressure of ice, averaged to the nominal area of the contact, connected with the total load; A is the nominal area of the contact.

The nominal area of the contact is the projection of the surface of the intact ice formation on the construction.

For the flat ice, layered ice or frozen layer of ice-hummocks, the nominal area of the contact is (h–w), where h is the thickness of ice, and w is the width of the contact with the construction.

In this case the expression is used (5):

$$F_G = p_G \cdot h \cdot w. \quad (5)$$

For interactions with the large ice formations the nominal area of the contact is the design contact area of an ice formation with the surface of a construction for the given penetration in the ice. When the mechanisms of limiting stress or maximum motion power are determining, the nominal area of the contact can be constant for the full interaction or have (by hypothesis) a significant magnitude.

For the situations of maximum energy, the design area usually increases during the process of interaction in accordance with the forms of the ice formation and the construction.

Pressure of ice p_G, often the most important parameter during the design of the protection of constructions from ice loads. The pressure, connected with the total load, is subjected to the effect of temperature of ice, nominal area of the contact, form or ratio of the dimensions of the area of the contact, nature of the contact, relative speed and displacements between ice and the construction, and also the pliability of construction. Since the pressure of ice can considerably change in time, maximum values will usually depend on the averaging time.

Determining total pressure for the sea ice.

The information, obtained from the measurements on a full-scale model in Cook Bay, the Beaufort Sea, the Baltic Sea and the Bohai Sea [25, 26], was used for determining the upper value of the border of ice load for the scenarios, when one-year and multi-year ices acted on a construction. The data were also used in order to analyze how the thickness of ice and the width of construction influence total ice load. Based on these studies, the total pressure of ice can be determined from (6):

$$p_G = C_R \left(\frac{h}{h^*} \right)^n \left(\frac{w}{h} \right)^m, \quad (6)$$

where p_G is the overall average ice pressure in MPa; w is the project design width in m; h is the thickness of the ice cover in m; h* is the reference thickness 1.0 m; m is the empirical coefficient (=–0,16); n is the empirical coefficient; $n = -0{,}5 + h/5$; for h<1,0 m; $n = -0{,}30$ n=–0,30; for h>1,0 m; C_R – is the strength coefficient of ice in MPa.

5. 2. 2. Author's technique by K. N. Shkhinek. Loads on a single-support platform with vertical prismatic boards [6]

Load from the flat ice field and the field of rafted ice.

With interaction of an ice field with the platforms, the load depends on many factors and, in particular, on the form of ice fracture, which can occur through the loss of stability of the field, its bend and splitting or a plastic flow. The largest loads correspond to the plastic flow and splitting, which further are considered as the main ones. With the probabilistic estimation, it is necessary to examine all possible types of ice destruction.

Loads with the first encounter of a platform with ice and with subsequent interactions differ considerably. The load, which appears with the first interaction, should be used with the calculation of general strength and stability in quasi-static approximation. Loads with subsequent interactions must be considered at evaluation of the dynamics of a platform, estimation of loads with the resonance occurrence and in calculating the fatigue failure.

Loads with initial interaction with the moving field with the efficient diameter $D_1 = 2\sqrt{A/\pi}$ (A – square of the field on the plan, m^2) that exceeds the diameter of a platform by more than 20 times, the global horizontal load (MN) is determined by the formulas (7), (8):

$$F_{xil} = mKA_1R_c, \qquad (7)$$

where K is the coefficient, which considers the form of the stressed state of a field near a platform

$$1+4/(1+D/h_1)\begin{cases}\text{if } 3<D^*/h_1<9,\\ 1{,}85-0{,}05D/h_1, \text{ if } 9<D/h_1<17,\\ 1{,}0, \text{ if } D/h_1>17,\end{cases} \qquad (8)$$

where * is the seas with clearly expressed change in the water level, the diameter (maximum transverse size) of a platform should be taken with regard to its increase due to the ice freezing.

A_1 is the real contact area, equal to

$$\begin{cases}Dh_1, \text{ at } V/h_1<0{,}001c^{-1},\\ Dh_1e, \text{ at } 0{,}001<V/h_1<0{,}3c^{-1},\\ 0{,}55\cdot Dh_1e, \text{ at } V/h_1>0{,}3c^{-1},\end{cases} \qquad (9)$$

where m is the coefficient of the form of a support on the plan in the direction of ice motion

For the constructions of circular cross section m=1. For the constructions of polygonal cross section m=1, if the angle β between the bisector of the angle of the platform, exposed to ice motion, and the direction of the motion of ice exceeds ±15°. At the angle $|\beta|<15°$, the coefficient m is determined by the formula (10):

$$\begin{aligned}&m = m1+\frac{\beta}{15}(1-m1) \text{ at } 0<|\beta|<15°,\\ &m=1 \qquad\qquad\qquad \text{at } |\beta|>15°,\end{aligned} \qquad (10)$$

where m1 is the parameter, determined according to Table 2 depending on the value of wedge angle α_1.

Load distribution from flat and hummocky ice is assumed to be uniform in the contact area.

If a global load from a separately moving field (or separate ice formation, for example, surfaced grounded hummock) is of interest, and if the effective diameter of this field $D_1 = 2\sqrt{A/\pi}$ is less than 20 diameters of the platform D, then its stop near the construction is possible. In that case, besides the load F_{xil}, the load F_{xi2} is determined, MN according to the formula (11):

$$F_{xi2} = 0{,}93D_1h_1\left(\frac{\gamma_i D}{g(D+D_1)}\right)^{0{,}33}(R_cV)^{0{,}66}. \qquad (11)$$

If the load, determined by the formula is less (7) than by the formula (11), then the load, determined by the formula (11), is accepted as normative.

If the load by the formula (11) is less than by the formula (7), and the ice concentration is less than 6/10, then (7) is assumed as normative (of the considered ice formation). If the load by the formula (11) is less then that by the formula (7), and the ice concentration is higher or equal to 6/10, then the load (12) is taken as normative:

$$F_{xi3} = 1{,}1mKDh_1R_c. \qquad (12)$$

Based on the forecast of the thickness of ice formations with the application of neuron networks, we will obtain the values of ice loads, represented in Tables 3, 4.

Table 2

Values of coefficient m1 depending on the value of wedge angle α_1

α_1	75	90	120
m1	0,52	0,6	0,71

Table 3

Horizontal ice load on ISP 1 with the thickness of ice 0,298 m

Direction of the load action	RSRN	ISO 19906		Method by K. N. Shkhinek
		Theory of plasticity	Bend of elastic beam	
board	12,0 MN	6,39 MN	4,65 MN	16,1 MN
nose	10,2 MN	5,77 MN	4,19 MN	14,4 MN

Table 4

Horizontal ice load on SMSIP with the thickness of ice 0,298 m

Sea depth	RSRN	ISO 19906	Method by K. N. Shkhinek
8 m	8,9 MN	3,4 MN	12,72 MN
12 m	10,86MN	5,4 MN	17,6 MN

In further calculations of the total load on the construction, we will use the ice load, obtained by the author's method of K. N. Shkhinek, because this method gives the most realistic values of the loads, confirmed by experiments in the A. N. Krylov CNI experimental pool [24, 25].

6. Determining the thickness of ice belt and linear load considering the depth of setting up an ocean technical construction

According to RSRN, the value of an ice belt is calculated by the formula:

$$l = \Delta_{100} + 2\alpha_1h_{c100}, \qquad (13)$$

where Δ_{100} is the maximum spread of a change in sea level relative to average level, m, occurring once per 100 years; α_1 is the safety coefficient, $h_{c,100}=0,298$ is the thickness of a consolidated layer of ice-hummock (in the absence of ice-hummocks, the thickness of flat or rafted ice), m.

According to (13), $l = 3,34 + 2 \cdot 1,1 \cdot 0,298 = 4,0$ m.

The vertical component of a global ice load from flat or rafted ice on the support of a conical shape is determined by the formula (14):

$$F_v = \frac{F_h}{tg(\beta + arctgf)}. \tag{14}$$

Taking into account the lengths of load distribution at the levels of each platform, we will obtain:

– for the horizontal linear loads (15):

$$g_h = \frac{F_h}{L}, \tag{15}$$

– for the vertical linear loads (16):

$$g_v = \frac{F_v}{L}, \tag{16}$$

where L is the length of ice enclosure, which receives the load along DP of the installation and across DP of the installation.

The obtained values of the linear loads are represented in Tables 5, 6.

Table 5

Calculated values of linear loads for ISP

Level of application	Board		Nose	
	12000	8000	12000	8000
F_h , kN	16100	16100	14400	14400
F_v , kN	7092	7092	6343	6343
L , m	68	70	61	63
g_h , kN/m	237,0	230,0	236,1	228,6
g_v , kN/m	104,3	101,3	104,0	100,7

Thus, by applying forecasting of the real thickness of ice formations and the methods of determining ice impact, the real ice loads on the considered types of ocean-technical constructions were calculated. As can be seen from Table 5, 6, the values of the ice loads, including linear load, rendered on ISP are less than those on SMSIP. From the point of view of the perception of external loads, an ocean technical construction, which has ISP ACT will be less subjected to suffering from ice loads. In future we plan to conduct stability analysis of these types of constructions on the ground, as well as the estimation of economic indicators.

Table 6

Calculated values of linear loads for SMSIP

Level of application	12000	8000
F_h , kN	17600	17600
F_v, kN	11655	11655
L, m	41,8	43
g_h, kN/m	421,1	409,3
g_v, kN/m	278,8	271,0

7. Conclusions

1. The calculation of ice loads was performed by taking into account the forecast of the thickness of ice formations, executed with the use of neural network analysis and bases on the observations of the ice mode from 2007 to 2015. The thickness of ice formations was taken equal to 0,298 m. The calculation of ice loads was carried out by three methods: Rules of the Sea Register of Navigation, ISO 19906, the author's method of K. N. Shkhinek. The closest to the values, obtained during experiments in the experimental pool, are the values of the ice loads, calculated by the author's method of K. N. Shkhinek, which subsequently are used as estimated at determining the total load on the ocean technical constructions. Since the values, obtained by the author's method of K. N. Shkhinek are the closest to those obtained in the experimental pool, then the estimated calculation is considered the value of the horizontal ice load $F_h = 16,1$ MN.

2. Analysis of the foreign experience of the use of different types of ocean-technical constructions, taking into account the calculated operational parameters, made it possible to determine that the suitable type of ocean-technical constructions for the exploration of the Azov Sea shelf is an ice resistant stationary platform of gravitational type. Upon performing the calculation of ice loads and the value of linear load, a recommended architectural-construction type of the platform is an extended structure with inclined front face at the level (depth) of sea of 8,0 m, and at the depth of 12,0 m is an extended structure with a combination of inclined sections and vertical parts of the columns on the front face.

References

1. Fedorenko, A. V. Osobennosti ledovogo sezona 2007–2008 gg. na Azovskom more [Text] / A. V. Fedorenko // Trudy Gidromettsentra Rossii. – 2009. – Vol. 343. – P. 88–99.
2. Borovskaya, R. V. Osobennosti ledovykh usloviy Azovskogo morya v zimniy period 2011 – 2012 gg. [Text] / R. V. Borovskaya // Sistemy kontrolya okruzhayushchey sredy. – 2012. – Vol. 17. – P. 123–127.
3. D'yakov, N. N. Sovremennyye izmeneniya ledovitosti Azovskogo morya [Text] / N. N. D'yakov, T. U. Timoshenko, A. A. Belogudov // Geoinformatsionnyye nauki i ekologicheskoye razvitiye: novyye podkhody, metody, tekhnologii». – 2013. – Vol. 2. – P. 77–82.
4. ISO 19906:2010 – 2010 [Text]. – Petroleum and natural gas industries – Arctic offshore structures. – introduced. 14.12.2010. – 474 p.
5. Pravila klassifikatsii, postroyki i oborudovaniya plavuchikh burovykh ustanovok i morskikh statsionarnykh platform [Text]. – Rossiyskiy morskoy registr sudokhodstva, 2014. – 483 p.

6. Loset, S. Vozdeystviye l'da na morskiye beregovyye sooruzheniya [Text] / S. Loset, K. N. Shkhinek, O. Gumestad, K. Khoyland. – SPb: Izd–vo «Lan'», 2010. – 272 p.
7. API RP 2N. Recommended practice for planning, designing and constructing structures and pipelines for Arctic conditions [Text]. – Amer: Petroleum Inst. Bulletin. – Dallas, 1995. – 435 p.
8. Yedinaya gosudarstvennaya sistema informatsii ob obstanovke v mirovom okeane [Electronic resource]. – Operativnyy modul' YESIMO. – Available at: http://193.7.160.230/web/esimo/azov/ice/ice_azov.php
9. Yang, Y. Dynamic Response Analysis of an Offshore Gravity Platform under Ice Load [Text] / Y. Yang, Y. Wang, R. Li, N. Liu, X. Wang, X. Zou // EJGE. – 2012. – P. 685–698.
10. Uvarova, T. E. Normative procedures of global ice loads calculation [Text] / T. E. Uvarova, E. E. Pomnikov, G. R. Shamsutdinova, A. S. Narkevich, V. V. Protsenko // Vestnik MGSU. –2012. – Vol. 10. – P. 122–127.
11. Marchenko, A. Modelling of Ice Piling up Near Offshore Structures [Text] / A. Marchenko // 20th IAHR International Symposium on Ice, 2010. – P. 286–298.
12. Hirdarisa, S. E. Loads for use in the design of ships and offshore structures [Text] / S. E. Hirdarisa, W. Baib, D. Dessic, A. Ergind, X. Gue, O. A. Hermundstadf et. al. // Ocean Engineering. – 2014. – Vol. 78. – P. 131–174.
13. Liang, L. Dynamic Interaction between Ice and Inclined Structure [Text] / L. Liang, K. N. Shkhinek // Magazine of Civil Engineering. – 2014. – Vol. 45, Issue 1. – P. 71–79. doi: 10.5862/mce.45.8
14. Ziemer, G. Influence of Structural Compliance and Slope Angle on Ice Loads and Dynamic Response of Conical Structures [Text] / G. Ziemer, K.-U. Evers, Chr. Voosen // ASME 2015 34th International Conference on Ocean, Offshore and Arctic Engineering. – 2015. – Vol. 8. – P. 37–44. doi: 10.1115/omae2015-41769
15. Kim, E. Discussion of assumptions behind rule-based ice loads due to crushing [Text] / E. Kim, J. Amdahl // Ocean Engineering. – 2016. – Vol. 119. – P. 249–261. doi: 10.1016/j.oceaneng.2015.09.034
16. Zayets, A. Yu. Garantosposobnost' okeanotekhnicheskikh system [Text] / A. Yu. Zayets, V. A. Kramar' // Naukovo-tekhnichnchiy zhurnal Radioyelektronni i komp'yuterni sistemi. – 2014. – Vol. 6, Issue 70. – P. 7–11.
17. Dushko, V. R. Mnogofaktornyy podkhod dlya rascheta ledovykh nagruzok s pomoshch'yu neyronnoy seti [Text] / V. R. Dushko, V. A. Kramar', V. V. Al'chakov, A. Yu. Lopatneva // Sovremennyye problemy prikladnoy matematiki, informatiki, avtomatizatsii i upravleniya, 2014. – P. 145–150.
18. Khalikova, D. F. Metodika opredeleniya arkhitekturno – konstruktivnogo tipa i glavnykh razmerennoy SPBU dlya bureniya poiskovo-razvedochnykh skvazhin v usloviyakh melkovod'ya [Text] / D. F. Khalikova, O. Ya. Timofeyev, G. K. Krupnov. – RAO/CIS Offshore, 2011. – P. 493–498.
19. Adamyants, P. P. Proyektirovaniye obustroystva morskikh neftegazovykh mestorozhdeniy [Text] / P. P. Adamyants, Ch. S. Guseynov, V. K. Ivanets. – Moscow: OOO «TsentrLitNefteGaz», 2005. – 496 p.
20. Bekker, A. T. Veroyatnostnyye kharakteristiki ledovykh nagruzok na sooruzheniya kontinental'nogo shel'fa [Text] / A. T. Bekker. – Vladivostok: Dal'naukayu, 2004. – 346 p.
21. Guseynov, Ch. S. Osvoyeniye melkovodnykh neftegazovykh mestorozhdeniy arkticheskogo shel'fa s ispol'zovaniyem ledostoykoy statsionarnoy platformy na monoopore [Text] / Ch. S. Guseynov, A. A. Musabirov // Sovremennyye tekhnologii osvoyeniya mestorozhdeniy uglevodorodov na sushe i more. «GEOPETROL' – 2012», 2012. – P. 851–852.
22. Musabirov, A. A. Proyektirovaniye morskoy ledostoykoy samopod"yomnoy platformy dlya zamerzayushchego melkovod'ya [Text] / A. A. Musabirov // Trudy Rossiyskogo gosudarstvennogo universiteta nefti i gaza imeni I. M. Gubkina. – 2012. – Vol. 1. – P. 60–66.
23. Vyakhirev, R. I. Obustroystvo i osvoyeniye morskikh neftegazovykh mestorozhdeniy [Text] / R. I. Vyakhirev, B. A. Nikitin, D. A. Mirzoyev. – Moscow: Izdatel'stvo Akademii gornykh nauk, 1999. – 373 p.
24. Opredeleniye global'nykh ledovykh nagruzok na ledostoykuyu statsionarnuyu platformu (LSP) na baze BPNK «Shel'f-7» na osnove model'nykh ispytaniy v ledovom opytovom basseyne [Text]. – Nauchno tekhnicheskiy otchet, 2005. – 75 p.
25. Opredeleniye global'nykh ledovykh nagruzok na statsionarnyy morskoy ledostoykiy otgruzochnyy prichal na osnove model'nykh ispytaniy v ledovom opytovom basseyne [Text]. – Nauchno tekhnicheskiy otchet, 2005. – 50 p.
26. Kos'yan, R. D. Nauchnoye obespecheniye sbalansirovannogo planirovaniya khozyaystvennoy deyatel'nosti na unikal'nykh morskikh beregovykh landshaftakh i predlozheniya po yego ispol'zovaniyu na primere Azovo-Chernomorskogo poberezh'ya [Text] / R. D. Kos'yan // Federal'noye gosudarstvennoye byudzhetnoye uchrezhdeniye nauki Institut okeanologii im. P. P. Shirshova. Rossiyskoy akademii nauk (IO RAN), 2013. – P. 1103–1317.
27. ISO 19906:2010 [Text]. – Appendix B. Petroleum and natural gas industries. Arctic offshore structures, 2010. – 102 p.
28. Wise, J. L. Superstructure icing in Alaskan waters, Environmental Research Laboratories [Text] / J. L. Wise, A. L. Comisky. – Special Report, US NOAA, Boulder, USA, 1980.
29. Weeks, W. F. The Growth, Structure and Properties of Sea Ice [Text] / W. F. Weeks, S. F. Ackley. – USA CRREL Monograph 82-1, Hanover, USA, 1982.