THE METHODOLOGY AND FINDINGS OF STRESS STATE OF THE STRUCTURAL ELEMENTS SUPPORTING BLOCKS ON THE FIXED OFFSHORE PLATFORMS

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The paper deals with a methodology for assessing the state of stress of structural components support block fixed offshore platforms. On the basis of known formulas of structural mechanics analyzed stress state columns of horizontal zones, braces, and other elements of the bearing block fixed offshore platforms. The analysis revealed that the maximum stress experienced columns and struts. On the basis of the analysis made by the author, it was found that the fatigue life of the bearing block columns is about 20 years old, braces for about 25 years, and more horizontal elements 30. The author goes on an experimental study of fatigue life of elements supporting block of fixed offshore platform, the results of which will be published later.

Keywords: stress, offshore fixed platforms, pipe, fatique limit, life cycle, wave and wind loads, equivalent stress, zero elements, support block

Most of the support block of FOPs are in the complex stress conditions and often subjected to the combined action of bending, stretching, compression and torsion. Therefore, the assessment of the actual state of stress, taking into account the mutual influence of elements is complex and time-consuming task, effective solution which can be found by constructing computer model in the software package StructureCAD [1–5].

The study authors analyzed eight inspection reports of this type of platforms located on the continental shelf of the Black Sea, which clearly indicated that the greatest damage to the platform found in the zone of variable wetting located on (below) to 10 meters above sea level, and (above) 14 meters above sea level. This area is recognized as officially considering possible once in 100 years of extreme wave height of 13,9 m (1982 storm.). Yet in fact, it show that the authors of calculations "snip loads and impact on hydraulic structures", the wave height directly causes fatigue failure does not exceed 6,3 meters. And only the impact of extreme winds at a speed of more than 49 m/s can cause a wave height of 13,9 m. The author of an analytical study which showed that elements of the underwater part of the platform are large voltage value due to weight characteristics as a platform and a bending and torque from the wind and wave loads(WWL). In the absence of these voltage WWL loads are static and act FOPs columns along their axes. If the column is schematically considered as a beam clamped to one and one cantilevered end we can see that the maximum value of the order of 173 MPa occur at the point of load application conditional, and in point of attachment to the soil columns equal to about 250 MPa [1–5].

From this it follows that the maximum total stress value of the static and dynamic loads will be achieved as fixing portions to the ground, and in the immediate wave load application point. However, this is true only for columns. For the horizontal elements of the maximum stresses occur due to wave action, ice, and other dynamic loads, which reach their maximum values in the zone of alternating wetting. Dynamic loads in addition to them is redistributed from the load weight of the structure. Therefore, the greatest area of tension for braces can be identified only as a result of calculation.

To study the stress state of the reference block of FOPs is necessary to define the parameters of the wind, as the parameters of wave action (wave length, its height and period) are depending on wind speeds. Using official reference books, it was found that in the area of the Platform for Action of the wind, which can be classified according to speed:

Table 1

Characteristics of wind action in the vicinity of the installation of FOPs

Wind speed	The average value of the total hours given wind speed per year	The duration of one cycle, in hours	The number of cycles per year
10	1155	21	55
15	1040	20	52
20	153	17	9
25	36	12	3

Table 2

Features wave on Subottinskom field according to the project

Elements of the waves	Wind direction, rumba							
	W	SW	Yew	SE	The	C-B	C	NW
$\bar{h}$, M	5,2	6,3	6,3	6,3	4,8	2,8	2,3	2,9
$h_{1\%}$, M	11,7	13,8	13,9	13,8	10,8	6,5	5,3	6,8
$\bar{\tau}$, s	7,6	8,5	8,3	8,4	7,3	5,2	4,7	5,5
$\bar{\lambda}$, M	88	108	105	107	81	42	34	45

In addition to these values are also possible extreme values of wind speed causing wave effect, with different values of security that leads to an increase of wave height, and hence the magnitude of the wave loads. As an example, the parameters of the waves Subbotinskogo oil and gas field, with a maximum wind speed of 49m/s:

Analyze the factors causing stress state support block. All elements of the reference block can be divided into columns, the horizontal members and braces. If we analyze the supporting columns, in the absence of wave action considerable stresses are created in these racks it by gravity of their own weight, the weight of the equipment, marine fouling and other weight factors. It should take into account the specific feature characteristic of all hydraulic structures, namely buoyancy to the elements, immersed in an aqueous environment.

As we know from the course materials resistance, the state of stress of these elements subjected to compression or tension, is calculated as follows:

$$\sigma_p = -\frac{P}{F}, \quad (1)$$

where σ_p – *the compressive stress, P* – the longitudinal compressive force (gravitational force of its own weight columns, weight equipment, and other marine fouling. weighting factors), F – cross-sectional area of the pipe, which is calculated by the formula:

$$F = \pi\frac{\left(D^2 - d^2\right)}{4}, \quad (2)$$

where D – outer diameter of the pipe, d – the inner pipe diameter.

In addition to compressive forces resulting from the forces of gravity on the structural elements of the FOP in the horizontal direction are different loads (wave, wind, etc.), the amount of which is denoted q. Note that in accordance with SNIP “Loads and effects on hydraulic structures” for the vertical elements may submit a wave as a concentrated force load with a specific coordinate, measured from the surface of the sea, or as unevenly distributed load.

Consider a beam *AB*, is rigidly fixed on the one hand and on the other hand pivotally (analog column FOP reference block). On *AB* are uniformly distributed load q and longitudinal compressive force P.

Assume that the deflection of the beam relative to the size of the cross section can be ignored, then with a sufficient degree of accuracy in practice it can be assumed that after the longitudinal deformation force P will cause axial compression of a beam. Using the method of addition of forces, we can find the normal stress at any point of each cross section of the beam as the algebraic sum of the voltages induced by the load P and q.

The greatest tension is in the upper section fibers, where both types of deformation cause contraction; in the lower fibers may be either compressive or tensile, depending on the numerical values of voltages σ_p and σ_q. Since the voltage of the power P in all sections are identical and evenly distributed, the dangerous fibers are the most strained by bending. These are the extreme fiber section with the greatest bending moment. For them, according to, the maximum stress from bending and compression is calculated as follows:

$$|\sigma_{max}| = |\sigma_1| = \left|\frac{P}{F} + \frac{M_{max}}{W}\right|, \quad (3)$$

where W – axial section modulus of the pipe.

Let us consider to horizontal zones. Calculations have shown that horizontal belt loaded in most cases considerably less than the column and bracing. And only in the zone of variable wetting magnitude of these stresses reach their maximum values close to the values of maximum stress in the columns and diagonals. Scheme loads elements arranged horizontally is also changed. In the absence of wind and wave loads, weight loads will no longer play so important in the formation of the state of stress in the case of an element with a column or brace. Thus, from the column depending on the direction of the beam may be formed as a wave twisting and bending moments, which in some cases can act simultaneously. Horizontal belt in the areas of attachment to the columns on both sides are fixed rigidly – welding.

The formula for determining the value of the rated voltage of the bending moment in this case, will have the form:

$$\sigma_0 = \sigma_z + \sigma_x + \sigma_y = \frac{P}{F} + \frac{M_x}{I_x} \cdot y \pm \frac{M_y}{I_y} \cdot x, \quad (4)$$

Where M_x, M_y – components of the bending moment, H/m^2, *x*, *y* – M_x vector does not change its direction.

$I_x = I_y$ – moments of inertia of the cross-sectional

In this case, $x = y = r_{outer}$, where r_{outer} – the radius of a horizontal cross wall member having an outer diameter D, mm.

The analysis showed that all the forces and loads acting on the bracing support block in many ways similar load horizontal elements, except for the presence in them of significant longitudinal forces due to the forces of gravity. Therefore, the previously described methods for the evaluation of the stress state of the columns and horizontal elements are similar to methods for assessing the state of stress braces.

It is important to stress the issue of assessing the state of the platform. According to the author, it is advisable to solve this problem by means of modern theories of strength to help you find the value "equivalent" voltage. To solve this problem we allocate about a point of the component of the reference parallelepiped block with edges infinitesimal length. On the faces of the elementary parallelepiped in general can act normal and shear stresses. The set of voltages at various sites, passing through the point is called a strained state of the material at the point. It is proved that you can be placed in a box space that it faces will be only normal stresses. These faces are called the major sites, and stress to them – the principal stresses. The greatest principal stress σ_1 is designated, the smallest – σ_3, and intermediate – σ_2.

After finding the values of the invariants of the stress tensor and the solution of a cubic equation with subsequent determination of the values of the principal stresses can be obtained according to the fourth equivalent stress theory of strength by the formula:

$$\sigma_{eq} = \frac{1}{\sqrt{2}} \sqrt{(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2}. \quad (5)$$

Table 3

The values of equivalent stress elements supporting block at various combinations of loading and different design solutions

Load combination	Non-sections of the support unit to FOPs														
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
	The values of equivalent stress, MPa														
	Columns					Horizontal Belt					Bracing				
K_1	45	43	18	32	51	6	7	32	17	20	77	50	104	112	114
K_2	169	168	65	91	89	35	48	82	119	27	209	198	267	344	290
K_3	250	242	115	197	173	71	75	92	250	182	208	186	206	196	320
The values of equivalent stress in the case of 1 (no braces and horizontal belt), MPa															
K_1	158	159	310	367	508	–	–	–	–	–	–	–	–	–	–
K_2	294	464	1092	1416	1573	–	–	–	–	–	–	–	–	–	–
K_3	2147	1283	1722	2673	2314	–	–	–	–	–	–	–	–	–	–
The values of equivalent stresses Case 2 (no braces only), MPa															
K_1	273	247	243	365	409	11	275	261	266	16	–	–	–	–	–
K_2	1213	901	972	1213	1345	93	448	312	358	2	–	–	–	–	–
K_3	1771	1361	1375	2141	1954	290	2666	2658	2294	82	–	–	–	–	–
The values of equivalent stress for the case 3 (missing only the horizontal belt), MPa															
K_1	72	55	26	30	90	–	–	–	–	–	79	32	75	127	51
K_2	313	275	138	143	186	–	–	–	–	–	287	252	229	392	28
K_3	450	405	203	211	123	–	–	–	–	–	235	23	306	256	60

Consider the stress state of the bearing block fixed offshore platforms for example, SMEs, installed on Subottinskom field. The practice of design and operation of these platforms show that the inclusion of interference of various elements of the platform is an extremely difficult task. For the analysis of the stress state of the platform it was built a computer model in the software package StructureCAD. An analysis of the state of stress is more convenient to hold, calculate the values of equivalent stresses for each element. To evaluate the stresses arising in the elements of the platform model was loaded with loads affecting its fatigue failure, it were asked: the load of its own weight, the weight of the equipment and marine fouling, buoyancy aquatic environment (a combination of loads to K_1) and the load from the wind -wave exposure. Moreover, to account for interference elements, the direction of the wind and wave load set as the X-axis (the combination of loads to K_2), and in direction at an angle of 45 ° to the axis X (the combination of loads to K_3). The magnitude of the wave load was chosen corresponding wave action 1% security. Structurally, the platform is a truss structure of pipes, and has five sections, each of which height is approximately ten meters. And an additional section located above the discharge area at a height of about 6 meters above sea level and is of considerable interest for the study of the processes of fatigue failure. The study produced the following results (Table 3). Analysis of the columns supporting the FOP block indicates that the maximum equivalent stress (ES), resulting in the columns of the bottom sections (section № 1) an outer diameter of 720 mm and a wall thickness of 20 mm, appear at the impact of wind and wave loads at an angle of 45 degrees and is 250 MPa. This proves the fact that the tension in the column are not only on the factors of weight, but also on the wind and wave action, as a result of which there are significant bending and torsional moments. In the second section of the maximum stress also occurs when wind and wave loads at an angle of 45 degrees and slightly differing from the bottom and is 242 MPa, and in the absence of wind and wave loading 43 MPa. The following third section, the maximum voltage occurs under the same conditions as the first two sections, but is already significantly smaller amount of 115 MPa. In the absence of the impact of the magnitude of the voltage is only 18 MPa. Such a voltage drop is caused by the fact that in this zone is significantly redistributed weight load on the struts. Next to the columns in the zone of alternating wetting, increasing the value of the maximum equivalent stress, which is associated with a structural feature of the platform and the project caused a decrease in cross-sectional area as a result of the use of pipes with wall thickness less than 25%, as well as higher values of wind-wave load in this area. In the area of influence of the atmospheric wave action is reduced slightly, but the action of bending and twisting moments do not stop, and the maximum value of ES is 173 MPa. And in the absence of the value of wind and wave ES reaches 51 MPa. This increase in value is due to the design of the ES platforms and due to the fact that this element of the column is not inclined, like the previous ones, and the vertical. Besides that, this section there are no braces. Analysis of horizontal zones (HZ) farms, made of pipes with diameters 420 mm and a wall thickness of 12 mm, has shown that the minimum voltage at wind and wave loads condition of 75 MPa is reached in the HZ situated in the bottom zone. Then, in the second zone, there is a slight increase in the amount of equivalent stress. In the third zone, with an increase of wind and wave loads, 22% stress value increases, the maximum values of ES reaches 92 MPa. Structurally and at atmospheric splash zones horizontal members 325 are made of tubes with diameter 12 mm wall thickness, which reduces the cross-sectional area. However, in these zones wave load reaches its maximum value, so values of stresses in these zones do not differ from the third zone. Let us analyze ES arising brace. In the absence of WWL ES values in braces significantly exceed those values in the columns and horizontal elements. This suggests that the effect of the combination weight loads significantly redistributed with columns and diagonals on the HZ. The maximum values of ES achieved with the combination K_2, preserving the value of the order of 200 MPa, and gradually increasing with the increasing activities of WWL, reaching its maximum in the zone of splash, and then greatly reduced in the atmospheric zone.

Considerable practical interest is a study on SOP support block so-called “zero” elements, i.e, unloaded items [1–5]. The calculation of equivalent stress values for the two cases: 1) no support block braces and horizontal elements; 2) in the reference block is not only bracing; 3) in the reference block is not only horizontal belt. Develop appropriate given the three cases computer models and calculations of maximum values of equivalent stress. If you create a platform composed exclusively of the columns, in the absence of WWL stresses occurring in them, will not exceed the allowable stress for steel 17G1S from which the column equal to 252 MPa.

However, with WWL for combinations of loading K_2 and K_3 voltage values significantly exceed the allowable stress. For the case № 2, wherein the columns are connected by horizontal belts, the first and second sections of the columns occurs even slight increase in the values ES, due to additional torque. In the third, fourth and fifth sections of a reduction in the value of ES. This voltage in horizontal zones platform under WWL significantly exceed the level of allowable stresses. The situation greatly changes the introduction of braces, which redistribute a significant part of the load and reduce the operating voltage to almost the allowable stress level, even in the absence of horizontal belts. Thus, we can conclude that the diagonals are playing an increasingly important role in reducing the stress state of the platform than the horizontal elements.

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