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THE CALCULATION METHOD OF OIL-PRODUCTION CONSTRUCTIONS IN THE SEA SHELF FOR THE SEISMIC ACTIONS

Abstract

In the paper the method of calculation of oil-production constructions located on marine water areas for maintenance of their stability at earthquake is suggested.

As the initial data the accelogramms of the earthquake happened in the concrete region of the world or the known maximal value of acceleration of the earth surface are taken.

Oil-gas production constructions in the sea-shelf supposed for the maintenance in the seismic active regions of the world must be calculated for the action of seismic waves arising during earthquake and underground atom blast.

These investigations can be carried out with use of the equations of dynamics of constructions under the condition of substitution of the wave loading by the loading caused by accelerations of the ground surface. Let us consider, for example, the stationary sea platform. We model the piles of the platform as the equivalent stanchions immersed into the ground which rigid characteristics were investigated earlier in [1,2]. The platform itself is modelled as a many storey construction. We express the motion of the equivalent piles by two horizontal and one vertical components of acceleration of the ground surface. The general reaction of the construction for all three components of the acceleration can be determined as the sum for each component separately. Avoiding to repeat the calculation procedure for each component of the acceleration we will consider only the case when the motion of the ground happens in the perpendicular direction of the axis of the construction. In dynamic calculations the sea stationary platform, as it was above said, is modelled as a many storey construction with moveable zones.

The resistance forces connected with the motion of the construction in the water are not taken into account here. The resulting horizontal force acting to the most upper zone of the construction consists of the inertial forces and resistance forces caused with the inner friction of the construction. The resistance force is proportional to the difference of the velocities of the constructions. Therefore,

$$F_n = -m_n \ddot{u}_n - c_n(\dot{u}_n - \dot{u}_1). \tag{1}$$

The points above the letters mean the derivatives by time, where c_n is the coefficient of resistance. On the base of static methods the force F_n is connected with the relative displacement of the n-th zone

$$F_n = k_n(u_n - u_1), \tag{2}$$

where k_n is the corresponding coefficient of rigidity of the n-th zone. From (1)-(2) we obtain

$$\ddot{u}_n - c_n(\dot{u}_n - \dot{u}_1) + k(u_n - u_1) = 0. \tag{3}$$

Denoting the relative displacement by $u_N = u_n - u_1$ from (3) we obtain

$$m_n \ddot{u}_N + 2\beta_n \dot{u}_n + \omega_n^2 u_N = -\ddot{u}_1, \tag{4}$$

where β_n is the constant of damping of waves, ω_n is the circle frequency of natural oscillations of the n-th zone of the platform. They are expressed by the formulas:

$$\beta_n = 0{,}5 c_n / m_n; \;\; \omega_n^2 = k_n / m_n.$$

them the forms, we can complete the matrix of the relative displacements corresponding to the forms of oscillations:

$$[p]=U_{0j}(\lambda_i),\ (j=2,n;\ i=1,n). \qquad (10)$$

Introducing the new variables Q_{ii} such that $\{u\}=[p]\{Q\}$ the equation (9) can be written in the form:

$$[m']\{\ddot{Q}\}+2[\beta][m']\{\dot{Q}\}+[k']\{Q\}=\{F\}, \qquad (11)$$

where $[m']$ and $[k']$ are the diagonal matrices given by the expressions:

$$[m']=[p]^T[m][p],$$
$$[k']=[p]^T[K][p]=[m'][\lambda],$$

where $[\lambda]$ is the diagonal matrix whose non-zero components are equal to

$$\lambda_i;\ (i=\overline{1,n}),\ \{F'\}=[P^T]\{F\}.$$

The matrix equation (10) can be represented in the form of n independent equations with respect to Q_i and whose solutions are the expressions:

$$Q_n=\frac{l_n}{m'_n\omega_n}\int_0^t \ddot{u}_1(\tau)\exp[-\beta_n(t-\tau)]\sin\omega_n(t-\tau)d\tau,$$

where $l_n=\sum_{i=2}^{n}u_{0i}(\lambda_n)m_i$.

If the dependence $\ddot{u}_1(t)$ on time is known or received, then solutions will be obtained in the analytic form and the horizontal displacements of the separate zones can be calculated by (10).

By the maximal values of the horizontal displacements we can determine the corresponding to them maximal values of the vertical displacements and turn angles of all nodes of the construction. $\{v\}=[D][K]\{u\}$, where $[D]$ is the matrix known from the Theory of Elasticity.

Calculating the values of maximal stresses in the separate elements of the construction by the known methods we find the value of the effective stress. It should add to these values the stresses of natural weight of the construction. In the calculation practice it is not taken to sum these stresses with the stress of storm excitement. The calculation of the construction on the seismic and wave action at the same time would not be rather economic because of very small probability of coincide of these two unfavourable conditions.

As a numerical example

Let us consider the steel bar oil production construction and determine its reaction to the motion of the Earth surface at Earthquake. Let us assume, that the value of the real acceleration of the Earth surface at Earthquake in the region of see shelf (according to the data in [3]) is $G=2,5\,m/c^2$. For the sea stationary platforms of the mean type the matrix of the lumped masses $[m]$ (in tons) and rigidity $[K]$ (in Mega Newton's to meters) of the system have the following form:

$$[m]=\begin{bmatrix}200 & 0 & 0\\ 0 & 400 & 0\\ 0 & 0 & 622\end{bmatrix}$$

$$[k]=\begin{bmatrix} 240 & -230 & 50 \\ -230 & 440 & -200 \\ 50 & -200 & 150 \end{bmatrix}$$

After the corresponding calculations we obtain the values of the maximal acceleration of the construction caused by Earthquake

$$I_1 = 160{,}2 \cdot 10^{-3}\, m/\sec^2$$

$$I_2 = 1{,}73 \cdot 10^{-3}\, m/\sec^2$$

$$I_3 = 0{,}32 \cdot 10^{-3}\, m/\sec^2$$

The maximal horizontal displacements of the lower zone $u_1 = 0{,}093\, m$; middle zone $u_2 = 0{,}132\, m$; upper zone $u_3 = 0{,}1665\, m$. On the base of these data we calculate the values of the natural frequencies by the main forms of the oscillations: $\omega_1 = 5{,}43\, rad/\sec$; $\omega_2 = 20{,}3\, rad/\sec$, $\omega_3 = 43{,}8\, rad/\sec$.

Comparing these data with the possible ones it is possible to estimate the flexibility and stability of the construction at projecting the object.

Let us note that these results of the calculation have an illustrative character and give rely on validity of the suggested method.

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