rest on the formed solid foundation, which increases their bearing capacity.

Disadvantages of supports. Despite the advantages, this method also has one significant drawback, which is that during grouting, an excessive amount of water gets into the soil along with the suspension. As a result, the groundwater level rises for some time, which, over time, stabilizes. [2]

Conclusions. Thus, each of the considered methods has its own advantages and disadvantages, thanks to which it can be used in certain cases. It should also be noted that for the installation of soil-concrete piles, special equipment is needed and specialists who must monitor it, therefore, only specialized organizations can deal with the installation of the above piles.

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UDC 624.04

RESEARCH OF FORCED VIBRATIONS OF AN ELASTIC MECHANICAL SYSTEM WITH ODF UNDER THE ACTION OF THE HARMONIC LOAD

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Annotation. Earthquakes, wind, and shock waves from explosions cause considerable deformations, displacements, and strains in buildings and structures that depend on time and can lead to destruction of the structures. In addition, the mechanisms and machines located in industrial buildings also cause similar deformations and displacements due to the fact that these mechanisms and machines have unbalanced rotating parts, or they themselves are mechanisms of impact (hammers, presses, etc.). Impact mechanisms can also be located near the structure (for example, drop-hammer for driving piles).

Fig. 1. Earthquake impact.

In this case, their influence is transmitted through the soil. The effects that cause variable in time deformations, displacements and stresses will be called dynamic. Investigation of the resulting oscillations in structures is an important engineering task [1-2].

Relevance. Problems of studying the occurrence of oscillations in different machines and mechanisms: cranes, cars, trains, etc. also constitute a large class of engineering problems.

To simplify the solution of these engineering problems, it is necessary to schematize both the object itself (i.e. to build its simplified model) and the dynamic impact on it (i.e. replace it with a slightly simplified, but taking into account all significant effects caused by real impact).

Fig. 2. Wind impact.

The combination of model, object and schematic dynamic impact will be called the dynamic model of the corresponding engineering problem.

Consider the case where the simplest elastic mechanical system with ODF is affected by the disturbing force $\boldsymbol{F}(t)$ (Fig. 3). The basic dynamics equation looks like this:

$$ma = R + F + P + N \tag{1}$$

Project it on the *x*-axis and taking into account (1), we obtain:

$$m\ddot{x} = -cx + F(t) \tag{2}$$

This is the differential equation of the forced vibrations of the simplest elastic sys-tem with the ODF.

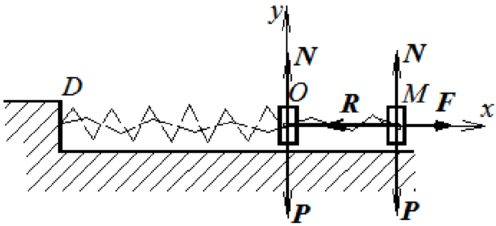

Fig. 3. Forced vibrations.

Dividing both parts of equality by *m*, we obtain:

$$\ddot{x} + k^2 x = \frac{1}{m} F(t) \tag{3}$$

Here, $k = \sqrt{c/m}$. Consider the forced motion of an elastic mechanical system with the ODF in the case when the force ***F***(t) is harmonious:

$$F(t) = G\sin(pt + \delta) \tag{4}$$

Then equation (3) will look like this:

$$\ddot{x} + k^2 x = H\sin(pt + \delta) \tag{5}$$

($H = G/m$).The total solution of a linear inhomogeneous differential equation (4) is equal to the general solution of a corresponding homogeneous differential equation adding to a partial solution of equation (4):

$$x(t) = x_{gen}(t) + x_{pr}(t) \tag{6}$$

According to (1):

$$x_{gen}(t) = A\sin(kt + \alpha) \tag{7}$$

The partial solution that determines the forced steady vibrations of an elastic mechanical system, with $p \neq k$, will be sought in the form:

$$x_{pr} = B\sin(pt + \delta) \tag{8}$$

Substituting (7) into (4), we obtain:

$$B = \frac{H}{k^2 - p^2} \tag{9}$$

The graph of the dependence of *B* on *p* is shown in Fig. 4. Substituting

(7) - (9) into (5), we will have:

$$x(t) = A\sin(kt+\alpha) + \frac{H}{k^2 - p^2}\sin(pt+\delta) \tag{10}$$

moreover, the constants *A* and α are determined from the initial conditions.

It follows from (9) that at *p* = *k* the amplitude *B* of the steady-state oscillations becomes infinitely large. The equality of the frequencies of a point free oscillations and the driving force is called resonance. A particular solution to equation (8) in this case should be sought in another form, namely:

$$x_{pr} = Bt\cos(kt+\delta) \tag{11}$$

From (11) we find:

$$\begin{aligned} \dot{x}_{pr} &= B\cos(kt+\delta) - kBt\sin(kt+\delta) \\ \ddot{x}_{pr} &= -2kB\sin(kt+\delta) - k^2 Bt\cos(kt+\delta) \end{aligned} \tag{12}$$

Substituting (11) – (12) into (3), we obtain:

$$B = -H/2k \tag{13}$$

Thus, the particular solution of equation () takes the final form:

$$x_{pr} = -\frac{H}{2k}t\cos(kt+\delta) \tag{14}$$

the graph of which is shown in Fig. 4.

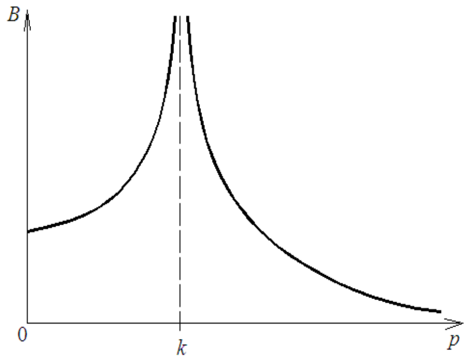

Fig. 4. Vibration frequency graphs.

It can be seen from the figure that the motion has vibrational character, and the amplitude of the vibrations is continuously increasing. In such cases, they say that there is an "excitation" of vibrations.

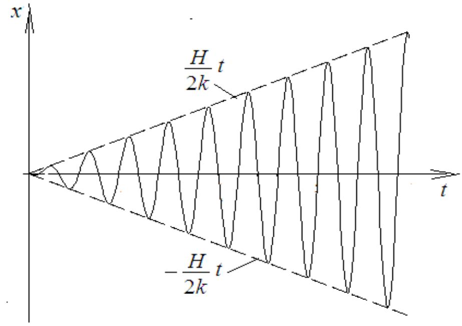

Fig. 5. Resonance.

Conclusions and results.

Given data:

m_1 = 7 T, l = 7 м, q_{11}= 6,325 10^{-3} м/kN

$q_{1,0}$ = 0,7 м, $V_{1,0}$ = 0,4 м/s

G_1 = 8 kN, p =20 s^{-1}

<u>STAGE 1.</u> RESEARCH OF FREE VIBRATIONS OF ELASTIC MECHANICAL SYSTEM WITH ODF.

Assume, that $m_2 = 0$. Then the system shown in Fig. 6, will have only one degree of freedom [1] with a generalized coordinate q_1.

The $m_1 = 7$ *T*, $m_2 = 0$.

$$K_1 = \frac{1}{q_{11}} = 158 \text{ кN /м} \qquad (15)$$

$$k_1 = \sqrt{\frac{K_1}{m_1}} = 4{,}75 \;\; c^{-1} \qquad (16)$$

$$\nu_1 = \frac{k_1}{2\pi} = 0{,}8 \text{ Hz} \qquad (17)$$

$$T_1 = \frac{1}{\nu_1} = 1{,}25 \text{ c} \qquad (18)$$

We find the amplitude and the initial phase of the vibrations:

$$A_1 = \sqrt{q_{1,0}^2 + \frac{V_{1,0}^2}{k_1^2}} = 0{,}7 \; m$$

$$\operatorname{tg}\alpha_1 = \frac{k_1 q_{1,0}}{V_{1,0}} \qquad (19)$$

$$\alpha_1 = \operatorname{arctg} \alpha_1 = 1{,}45 \text{ rad} \qquad (20)$$

The equation of the material point M_1 motion has the following form:

$$q_1 = A_1 \sin(k_1 t + \alpha_1) = \quad 0{,}7\sin(4{,}75t + 1{,}45). \tag{21}$$

STAGE 2. RESEARCH OF FORCED VIBRATIONS OF AN ELASTIC MECHANICAL SYSTEM WITH ODF UNDER THE ACTION OF THE HARMONIC LOAD.

The elastic mechanical system is affected by a variable force $\boldsymbol{F}_1$ (t), harmonically dependent on time, applied at point M_1 and directed along the axis q_1:

$$\mathbf{F}_1(t) = \mathbf{G}_1 \sin pt \tag{22}$$

$$H_1 = G_1/m_1 = 1{,}14 \text{ m} \tag{23}$$

The amplitude of the forced vibrations is determined by the formula:

$$B_1 = \frac{H_1}{k_1^2 - p^2} = 0{,}003 \text{ m} \tag{24}$$

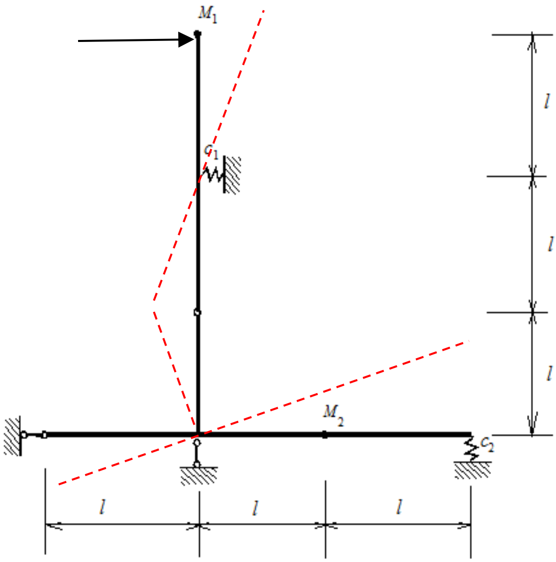

Fig. 6. Force action.

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