INVESTIGATIONS OF EARTHQUAKE RESISTANCE OF CONSTRUCTIONS INTERACTING WITH SOIL

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SYNOPSIS

The results of theoretical and experimental researches on the study of dynamic stressed-deformed state of underground constructions are given. The validity of founded seismodynamic theory of underground constructions of different appointment, underground tunnels, hydrotechnical and road constructions has been grounded. In theoretical preconditions the results of experimental researches on the study of physical nature of construction interaction with soil under the effect of static and dynamic (earthquake type) loads have been used.

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From point of view of the strength and the earthquake resistance the underground constructions are the structures of the frame type, all the elements of which are in contact with the surrounding soil. The elements' nodes have the encreased gabarits, the linear elements of different constructions may be met under the different angles.

The accurate solution of the dynamic problem of such a system under the earthquake wave propagation in soil meets the great difficulties. For instance, the task of the wave diffraction has been solved only for the simpliest bodies for the uniform wave. The approximation taken in the dynamics of ground constructions (the base moves as a whole rigid body) is not suitable as it many times reduces the stresses. The more accurate assumption that the construction everywhere firmly is fixed with soil i.e. the deformations of this construction are equal to that of the soil inside of the wave front, also may lead to mistakes.

In seismodynamic theory of complex underground constructions [1-5] the most expedient scheme of the combined soil deformation and the construction is taken: the spacial non-uniformity of the earthquake wave and the displacement of all the construction elements in regard to the soil are considered.

The stressed state of underground long constructions can be characterized by the dynamic coefficient n_{dyn}. It characterizes the effect of underground construction mobility in regard to the surrounding soil and is determined by the following expression

$$n_{dyn} = \frac{N_{max}}{N_{o,max}}, \quad N_{o,max} = A\,\omega_1\,B_{ud}, \quad \omega_1 = 2\pi/L, \qquad (1)$$

where $N_{o,max}$ and N_{max} - the longitudinal efforts respectively occuring in the construction or in the joint in the assumption that they are fixed in the soil and of the consideration of the mutual displacement effect;

A - the amplitude of the ground motion;

L - the length of the earthquake wave;

$B_{red} = \frac{B}{1 + B / K_N \ell}$ - the reduced construction rigidity;

B - the longitudinal construction rigidity;

K_N - the yielding coefficient of connections determined experimentally and

ℓ - the construction length between the connections (joints).

The force value N_{max} can be determined according to the seismodynamic theory of underground constructions [1] depending upon the different factors.

Considering that the main factor determining the real work of complex system of underground constructions is the surrounding medium - soil, the character of its interaction with construction has been studied. The test results show that this interaction possesses reologic properties and has a non-linear character. The tests conducted permitted to consider the motion of underground constructions in elastic, viscous-elastic and elastic-plastic soil.

The obtained equations describing the vibration of the complex underground systems have been reduced to the convenient form for calculation on the electronic computer.

The complex of universal algorithms and programmes for the solution of different concrete tasks has been worked out. The increase of the interaction coefficient with soil and hence that of the soil resistance to the pipeline motion lead to the decrease of relative pipeline displacement. The sharp change of soil properties along the pipeline route, especially in the region of complex joints, effects considerably on its interaction with pipeline. The increase of the joint mass without the change of its gabarits slightly effects on the dynamics of pipelines. The sufficient strong effect is revealed when the increase of the joint mass is related with the increase of its gabarits and hence of the resistance to the motion.

The dynamics of pipelines significantly depends upon the number $M = \frac{c_p}{a_T}$ (c_p and a_T - the velocities of wave propagation in the soil and in the pipe).

In the case when $M<1$ on the left and on the right from the joint the effect in the joints are equal; in the case when $M>1$ the stress jump considerably higher, the definite vibratory processes arise related with the natural pipeline vibrations.

The propagating wave effect duration significantly effects on the dynamics of pipelines. Under the typical duration $\tau_0 = 10 \div 30$ ($\tau = \frac{c_p t}{\ell}$; t - time, ℓ - the pipeline length) the joint-longitudinal pipeline interaction is the local and the removed parts effect on the intensity (strain). For the impulses of the small duration $\tau_0 \cong 0$ [1] the joint-end sections interaction is significant and in the design the number of freedom degrees must be increased as during the impulse propagation through the joint zones the elastic wave reflection from the edge pipeline sections effects on the intensity (strain).

Fig. 1 shows the consideration effect of viscous properties of pipeline contact with soil and elastic fixing of pipeline ends upon the value n_{dyn}. From these curves it is seen that the consideration of viscous contact properties leads to the essential decrease of dynamic force effecting on the joint. Elastic fixing strongly effects upon the displacements and stresses of pipes.

On the base of seismodynamic theory of underground constructions the methods of design of underground tunnels [6] and also that of the stations of column type on the dynamic effects have been worked out. The results of calculations show that maximum values of stresses and bending flexure moments occuring in the casings are 15-20 % more than the results obtained by static methods. This fenomena especially is revealed for the loose and soft soils.

Using the results of the above written tests the earthquake loads in multistoreyed buildings and constructions on the linear-yielding base have been determined. In this case for the determination of the load the correction factor ε_{ij} has been introduced.

Fig. 2 shows the value ε_{ij} depending upon $\mu_0 = \frac{K}{K_0}$ (K and K_0 - the rigidities of elastic elements and of the base) where $\alpha = \frac{M}{\rho F h}$ (M, ρ, F, h - mass, density, the cross section area and the height of storeys respectively).

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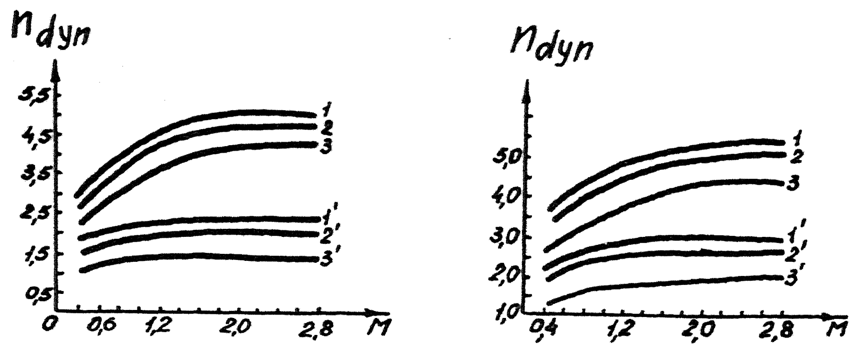

1 - Pipeline Ends are Removed from Joint to Infinity
2 - the same with consideration of Visco-elastic Contact
3 - Pipeline Ends on Finite Distance from the Joint
1'-3' for the Joint, 1-3 for the Pipe

Fig. 1. Influence M on Dynamics of Pipeline under Rigid Jointing ($N = 11$, $\tau_o = 30$, $x_1 = x_2 = 0.5$)

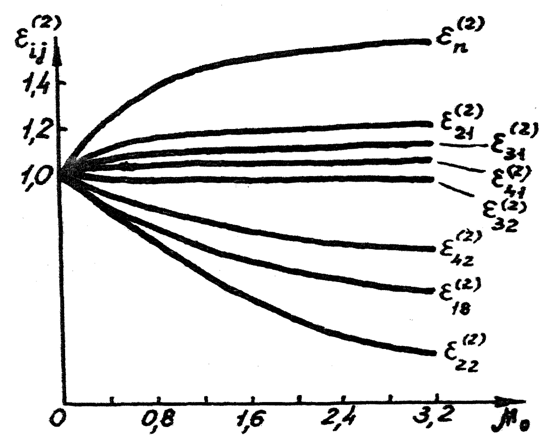

Fig. 2. Dependence of Correction Factors of the First and Second Vibration Forms of Four-Storeyed Buildings upon μ_o under $\alpha_o = 0.2$, $\alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = 1$