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WHITE PAPER 2. SEISMODYNAMICS OF GROUND/ABOVEGROUND PIPELINES AND EXTENDED STRUCTURES ON RIGID AND DEFORMABLE SUPPORTS: MODELING AND THEORIES OF SEISMIC RESISTANCE

Section 1. The reaction of a ground/aboveground pipeline (extended structure) to an earthquake: the current state of the problem

A much smaller number of works are devoted to the problem of seismic behavior of aboveground pipelines than to a similar problem for underground pipelines. One of the reasons for this is due to the fact that aboveground pipelines are less widespread than underground ones. At the same time, the existing aboveground pipelines are mainly power pipelines (gas and oil pipelines), and their destruction in an earthquake can lead to ecological disasters. Therefore, research in this area is of great scientific and practical importance. However, due to serious mathematical difficulties in setting and solving problems about a seismic response of such a complex structure as an extended pipeline located on rigid or deformable supports, only very approximate engineering methods for calculating this response exist in the literature.

The fundamentals of one of the common engineering methods for calculating an aboveground pipeline for seismic effects are presented in [1], in which the pipeline is considered as a multi-span beam on point supports. Such a beam is replaced by a discrete system considering that the masses of the pipeline spans are located at the nodes, - the points of contact of the supports with the pipeline, and the interaction between the masses (deformation of the pipeline spans) and the interaction of the masses with the soil through the supports are modeled by elastic springs. The system of differential equations of oscillations of the resulting discrete model is solved numerically.

However, these studies have significant disadvantages. They do not take into account the mutual influence of movement and /or deformation of the supports and sections of the pipeline between the supports caused by the seismic movement of the footings of the supports embedded in the ground. In addition, the numerical calculation of the movement of the selected node (one element of the discrete model) is carried out taking into account the influence on it, at best, only the two nearest pipeline spans (local analysis). Thus, a "global" model for calculating an extended or infinitely long (trunk) pipeline on many supports or a periodic system of supports (rigid or deformable) has not yet been proposed. Only on the basis of such a "global" model can the problems of seismic resistance of such extended structures under the influence of long seismic waves be posed and effectively solved, as well as qualitative effects of the behavior of such structures are identified.

Section 2.The behavior of extended aboveground structures on rigid and deformable supports (pipelines, bridges) during an earthquake: new models and mathematical theories of earthquake resistance

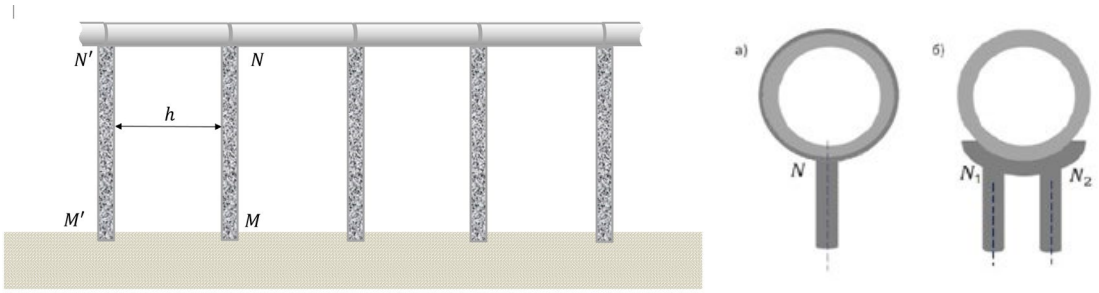

Fig. 1

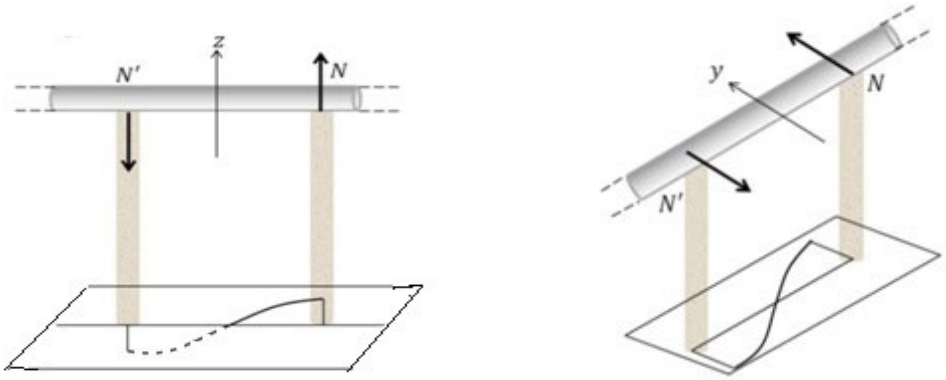

Fig. 2

1). Quasi-static theory of seismic resistance of an aboveground pipeline on rigid (non-deformable) supports (Fig. 1). Derivation of maximum values for displacements and stresses in cases of longitudinal and transverse (Fig. 2) pipeline vibrations. The found maximum values in many cases (excluding cases of resonance) serve as upper limits for the named values for deformable supports.

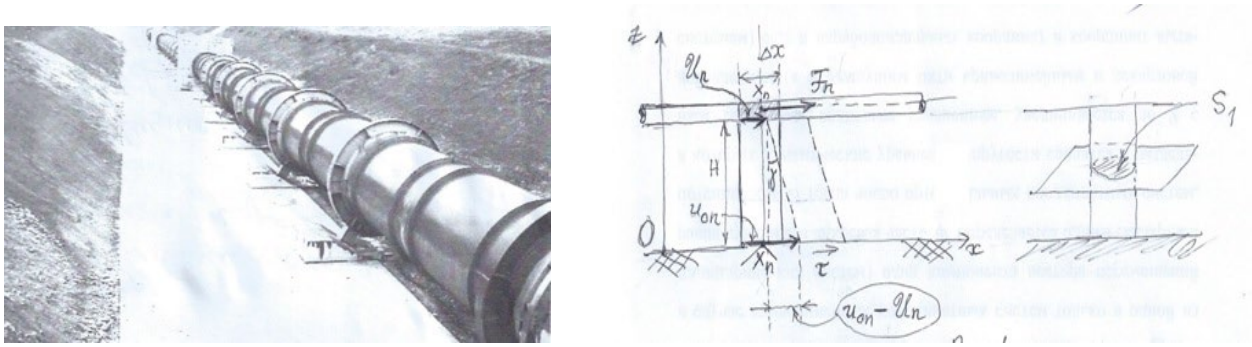

Fig. 3

2). The theory of seismic resistance of an aboveground pipeline on short supports subject to shear deformation (Fig. 3). Construction of a discrete model describing the longitudinal movements of

an aboveground pipeline with such supports. Derivation of the averaged equation of longitudinal vibrations of the pipeline by the transition to a continuous system. Formulation and solution of problems on longitudinal oscillations of an infinite pipeline for subsonic and supersonic regimes. Investigation of the possibility of resonance, and derivation of the criterion of seismic resistance of the pipeline.

3). Construction of a discrete model of a pipeline in the form of a linear chain of concentrated masses with its transverse vibrations, when the forces of interaction between the masses are determined not by elastic springs as in the previous case, but by elastic beams (connecting the masses) when they bend. Transition to a continuous system and derivation of the averaged equation of forced bending vibrations of the pipeline. The solution of the obtained equation in the case of steady oscillations of an infinite pipeline and calculation of the maximum values of moments and cutting forces arising in the pipeline during seismic vibrations of the soil.

4). The case of deformable supports working on tension-compression: calculation of the forces acting on the pipeline during vertical seismic movements of the soil. Construction of a discrete model and transition to a continuous system in relation to bending vibrations of an aboveground pipeline with vertical movement of supports. Formulation of earthquake resistance criteria in this case.

5). Deformable supports are subject to bending during seismic movements of the soil (beams as supports). Modeling of longitudinal seismic vibrations of an aboveground pipeline, on beams as supports, subject to bending by a discrete system. Transition to a continuous system and derivation of the averaged equation of the longitudinal movements of the pipeline. Formulation and solution of problems on longitudinal vibrations of the pipeline on the beams as supports for subsonic and supersonic modes.

6). Transverse (bending) vibrations of an aboveground pipeline on deformable supports as beams: a discrete model and the derivation of the averaged equation of transverse vibrations. Formulation and solution of problems on seismic flexural vibrations of an infinite pipeline; conditions of seismic resistance.

References

1. *Anderson J.C., Johnston S.B.* Seismic behavior of above-ground oil pipelines // Earthquake Engineering and Structural Dynamics. 1975, Vol. 3. P. 319-336.