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Experimental Studies of the Stress-Strain State of Rigid Sewer Pipes

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Abstract:
The purpose of the article is to study the stress-strain state of rigid underground pipes under various laying and loading conditions. Here attention is paid to testing pipes using a two-force scheme in underground conditions.

Keywords: Stress, strain, pipe, strength, soil.

Introduction

Currently, in the Republic of Uzbekistan, the installation of rigid pipes of round cross-section in underground conditions is carried out, from materials such as concrete, reinforced concrete, asbestos cement, plastic, etc., pipelines for water supply, sewerage, drainage and oil pipelines.

In industrial, civil and hydraulic engineering, rigid pipelines for various purposes, large diameter and small pipe diameters are becoming increasingly used.

In addition, with the development of technology and technology, the production of pipes from different materials is improving qualitatively and quantitatively.

The construction of closed drainage systems in water supply and irrigation conditions, including rigid pipes laid in the ground, is of great importance.

In this regard, it is necessary to conduct experimental research and develop methods for calculating rigid pipelines in underground conditions.

The main objective of this work is to study the strength of rigid underground sewer pipes. However, for the purpose of subsequent comparison of results, some of the pipes were tested in air using a two-force scheme.

Testing of pipes in air was carried out using a two-force scheme under pressure on a UMM-5 testing machine.

After preparing the pipe for testing, it was laid horizontally between wooden blocks. The bars with a cross section of 10x10 cm had a length equal to the length of the pipe. The surfaces of the bars were not specially treated and were left flat.

The load on the pipes was transferred in steps of 0.5 kN and the pipes were brought to destruction.

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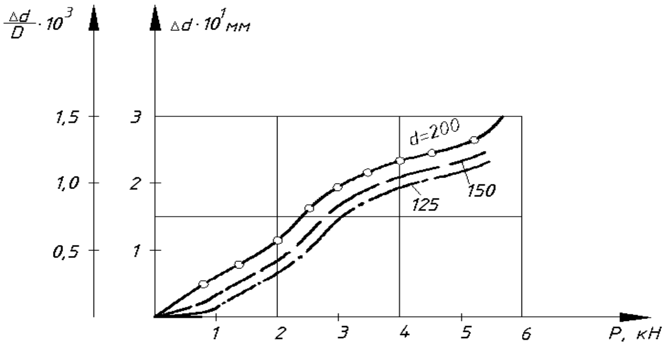
Based on the results of the experiment, graphs were constructed of the dependence of changes in the vertical and horizontal diameters of the pipe on the load Δd = f(P). In the graphs (Fig. 1), three areas of deformation can be distinguished. The area of elastic deformation is clearly expressed, the areas of conditional yield and hardening are weakly expressed.



The graph shows that the larger the diameter, the more significant the change in pipe diameters. The change in the vertical diameter of the pipe when testing it according to the two-force scheme is:

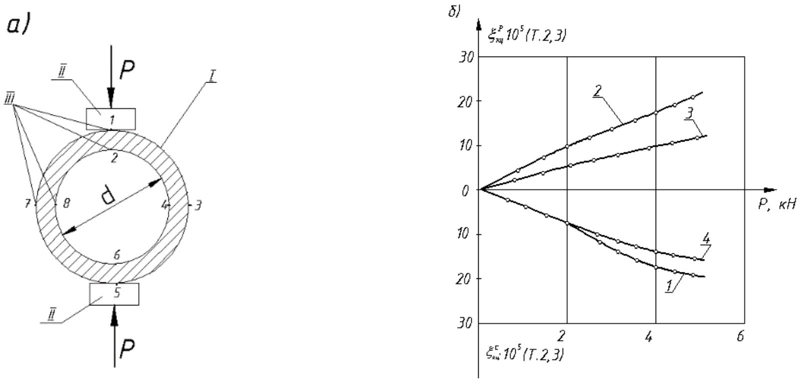
$$\Delta d = 1{,}788 \frac{P}{E}\left(\frac{r}{\delta}\right)^3; \qquad \xi_d = A\left(\frac{r^2}{\delta^3}\right), \qquad (1)$$

where, A are some constant numbers; r – pipe radius; δ – wall thickness.

In our experiments, the ratio $(r : \delta)^3$ for a large-diameter pipe is $(10 : 2{,}4)^3 = (4{,}166)^3$, for a small-diameter pipe $(10 : 2{,}4)^3 = =(4{,}166)^3$. And also the ratio $(r : \delta)^3$ respectively: $10^2 : 2{,}4^3 = 7{,}234$ and $6{,}25^2 : 1{,}8^3 = 6{,}698$. In formula (1), the reduction in the vertical diameter of the pipe is directly proportional to the ratios $(r{:}\,\delta)^3$ and $(r^2 : \delta^3)$, which corresponds to the test results shown in Fig. 1.

The results of testing pipes in air in the form of graphs of the dependence of the deformation of the pipe wall in the annular direction in stretched zones ($\xi^P_{кц}$) and in compressed zones ($\xi^C_{кц}$) on the load (P) are presented in Fig. 2.

Rice. 2. Loading a pipe according to the scheme of two forces in the air: a) loading scheme – I – pipe; II – bars; III – strain gauges; b) relative deformations for a pipe d = 200 mm.



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It is clear from the graphs that the deformation on the tensile surface of the wall at the ends of the vertical diameter (points 2 and 6) of the pipe is greater than at the ends of the horizontal diameter (points 3 and 7) of the pipe under the same loads. The deformations in the compressed zones of the pipe wall surface (points 1 and 4) are almost the same (Fig. 2, b). The first circumstance is explained by the fact that the calculated bending moment under the load application point is much greater than in the sections at the ends of the horizontal diameter (ratio 0.318:0.182). The deformations in the compressed zones are almost the same because in the section at the level of the horizontal diameter the action of the moment is accompanied by the action of a longitudinal compressive force.

Dependence of relative deformations on load $\xi = f(P)$ in Fig. 2 is close to linear.

Cracks appear at loads that are approximately 0.8 times the breaking load, first on the inner surface of the pipe wall in a vertical section and later on the outer surface in a horizontal section, which corresponds to the outline of the moment diagram. The destruction of the pipe occurred by breaking it into four parts.

In some works, the deformation capacity decreases with increasing their diameter, which has not received proper stretching. In our tests, it turned out that the larger the pipe diameter, the less deformation of the pipe wall under the same loads.

To identify the role of the elastic resistance of the soil on the strength of pipes tested according to the two-force scheme, it was decided to also conduct tests for pipes immersed in the ground.

The pipes were placed in a box between wooden blocks and then backfilled. At the same time, the ends of the pipes were protected with gaskets so that the internal cavity of the pipe was free of sand.

Tests of pipes with a diameter of 150 and 200 mm were carried out in uncompacted and compacted soil.

The load on the pipes was transferred in steps of 1 kN and the pipes were brought to destruction.

Just as in the experiments with pipes in air, in these experiments the change in pipe diameters was more significant for large-diameter pipes.

Graphs of changes in the vertical and horizontal diameters of pipes d = 200 mm and d = 150 mm depending on the load are shown in Fig. 1.

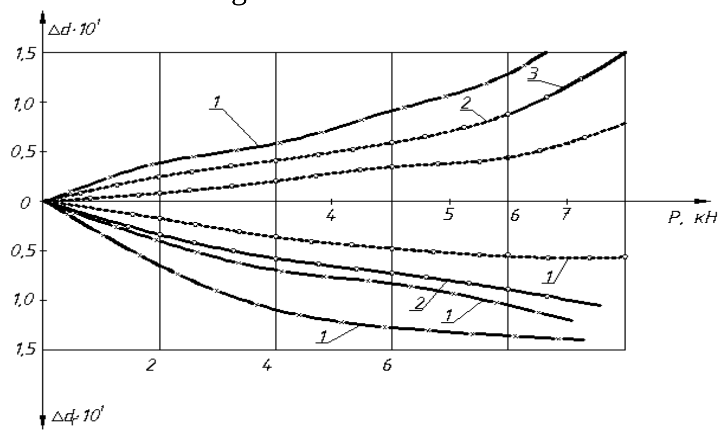

Fig.1. Change in the vertical and horizontal diameter of the pipe in mm depending on the load. 1 and 2 - d = 200 mm in uncompacted and compacted soils, respectively 3 and 4 d = 150 mm.

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The graph shows that in compacted soil the deformation of the vertical diameter of the pipe is 1.5 times less than in uncompacted soil under the same loads.

Graphs of changes in pipe diameters d = 200 mm, with varying degrees of soil compaction ($\gamma = 14{,}1 кН/м^3$ and $\gamma = 16{,}8 кН/м^3$), as well as in the absence of soil (in air), are shown in Fig. 2, b.

The graph shows that the deformation of the diameters of a pipe laid in the ground is reduced by more than half compared to a pipe outside the ground under the same loads. When soil is compacted, this difference increases to 3.5 times.

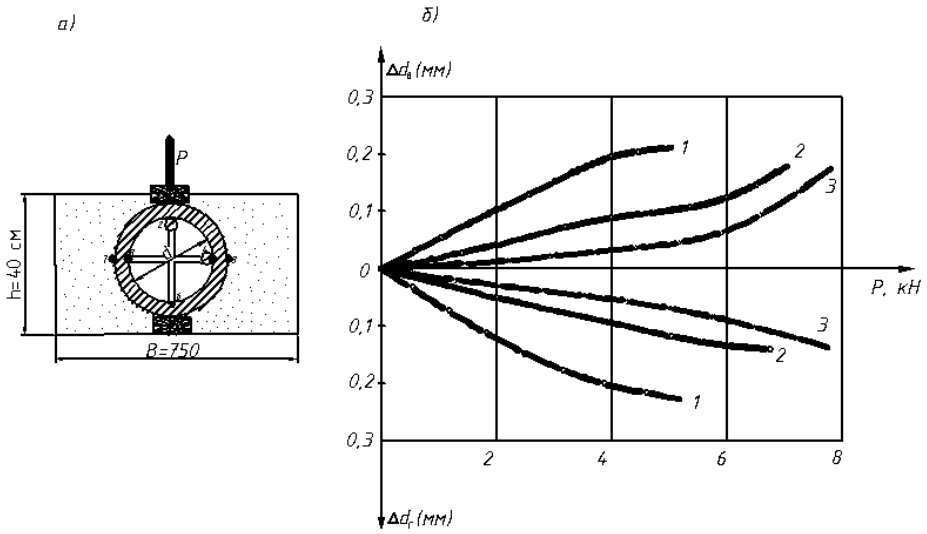

Рис.2

Our experiments have shown that to destroy a pipe buried in the ground, a load 1.5 times greater than for a pipe in the air was required, and with soil compaction, this ratio increases and reaches 2.

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