Stresses in subsidence bases of flutbet models under the moisturizing conditions

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Abstract. The practice of construction and operation of irrigation facilities on loess nodded soils shows that properly designed facilities, which are erected with high quality, can work for a long time without violating their operational suitability. At the same time, the specificity of the engineering and geological conditions of certain regions of the Republic of Uzbekistan, i.e. for strongly and inhomogeneous subsidence soils, it requires correcting some provisions of regulatory documents, to take into account the peculiarities of the stress-strain state of the "structure - subsidence base" system, which depends both on the structure of the hydraulic structure and the physical and mechanical properties of the soil changing during moistening. The specifics of the work of hydraulic structures consists that in the overwhelming majority of cases, their soil bases are moistened to the level of maximum water saturation. However, in the first time after the commissioning of the hydraulic structure, the soil mass is moistened unevenly, which affects the nature of the interaction between the foundation and the structure. The article presents the results of studying the patterns of stress variation in subsiding ground foundations in experimental studies of the stress-strain state of the loess bases of tubular crossings, which are widely distributed in irrigation systems of the south of the Republic of Uzbekistan.

1. Introduction
Hydraulic structures and their subsidence foundations accept various loads and effects that differ in origin, duration, recurrence, etc.

The peculiarities of the joint work of irrigation structures and their subsidence bases attracted the attention of many scientists. A great contribution to the study of this issue was made by the researchers Yu.M. Abelev, M.R. Bakiev [2], Balaev [3].., L.G V.P. Tsarev [4]., M.A. Bandurin [5], G.N. Vinogradova[6], V.A. Volosukhin [7], V.A. Dokin [8], G.A. Zhakapbaeva[9], S.V Zasov[10-11] and others.

The modern methods of design and construction of hydraulic structures on loess collapsible soils are based on the works of B.D. Kaufman, S.G. Shulman [12], Shakarna Saleh [13], A.A. Kirillov [14], G.A. Mavlyanov [15], A.L. Mariupolskiy [16], A.A. Mustafaev [17].

Field studies carried out by many scientists [23-24, 26-29.] showed that the subsidence of loess soil is characterized by sharply uneven vertical deformations, ground ruptures in the form of stepped subsidence cracks, the inclination and curvature of the surface of the subsidence funnel, and horizontal ground movements. These factors significantly complicate the working conditions of hydraulic structures on subsiding soils.

Currently, the bulk of hydraulic structures are designed without taking into account the specifics of joint work of hydraulic structures with their loess foundations. In many regions of the Republic of Uzbekistan, in...
the construction of irrigation facilities on loess soils, structures made of unified reinforced concrete parts are most widely used.

In particular, on the irrigation systems of the Amu-Kashkadarya Basin Administration, where the bulk of the research was carried out, structures made of reinforced concrete round pipes with heads made of the type of diving walls or in the form of reinforced concrete diaphragms have found the most widespread use. In the process of their construction, standard designs were used, developed for structures on non-subsiding soils.

Improving the reliability of hydraulic structures on collapsible soils can be achieved not only by improving their designs but also improving soil properties bases [10].

At present, the combined method of erecting hydraulic structures on collapsible soils is finding more and more widespread use. Structures with increased resistance to deformation are installed on a previously prepared foundation. This construction method can significantly improve the reliability and the operation of the hydraulic structure.

However, even at present, there are frequent cases of accidents of irrigation structures operating on subsidence soils. This indicates the need for further improvement of methods for designing such structures based on clarifying the features of their joint work with loess subsidence bases.

To study the distribution of stresses in the foundations of low-moisture loess soils in the considered objects of the Kashkadarya region, experimental studies of the stress-strain state of the loess foundations of pipe crossings-drops were carried out [18-22]. The peculiarities of the operation of tubular drops were studied using the example of temporary structures of the inter-farm distributor of the “Surkhan” massif, installed without preliminary preparation of their foundations [19].

2. Methods

Structural parts of the structures were equipped with control and measuring equipment - devices for measuring the displacements of parts of structures and layer-by-layer deformations of the soil, sensors for measuring contact stress along the edges of the head (GD-128 complete with station TSS-5) and stresses in the soil mass (M-70 v complete with station ISD-3).

The specifics of the interaction of the water-conducting parts of irrigation structures with subsidence bases are discussed in sufficient detail in the works [7-8; 10-11]. However, the presence of a large number of irregularities in the operation of the heads - diaphragms of tubular structures required the study of the features of work on collapsible soils and elements.

The design of the input and output heads of full-scale structures is made of three blocks of type B - 150 and OT-150 connected by welding embedded elements. The water-conducting part is made of pipes with socket joints of the TR-150 type, the length of the structure is 21 meters, the head is 1.5 meters, the inlet part of the channel and the damper are lined with reinforced concrete slabs, and the joints are monolithic.

In the process of work, a picture of the change in natural stresses in the mass of low-moisture loess soil in the bases of the dies was established when the latter was loaded up to 0.2 MPa.

3. Results and Discussion

The distribution of stresses along the depth of the base in the soil of natural moisture under the centres of round and square punches with an area of 1 m square is illustrated by curve 1 in Figure 1 and curve 1 in Figure 2. Due to the uneven distribution of stresses along with the contact of the stamp with the ground, their values under the centres of the stamps differ significantly from the average
Figure 1. Transformation of vertical stresses in the depth of the ground under the centre of the stamp (F = 1m square; R = 0.05 MPa).

Figure 2. Distribution of vertical stresses of natural moist ground (curve 1) and post-moisture along the square stamp axis (curve 2). F = 1m square, R = 0.1 MPa.

Figure 3 shows curve 1 which characterizes the relationship between two variables - the average pressure at the contact of the stamp with the ground and the relative depth of the core at the natural moisture content of the base.
Figure 3. The relationship between specific load and active zone depth on a 1m square surface circular stamp

Where $P$ is the average pressure at the contact of the hydraulic structures flat model (stamp) and its base: $H_{act}$ - core depth, $d_{sht}$ - die diameter

For the convenience of determining the depth of the core at a certain specified load on the stamp, it is more convenient to use expression (2), which characterizes the same curve 1 in Fig. 4 obtained from equation (1):

$$
\frac{H_{act}}{d_{sht}} = \sqrt{15.4P - 0.017} - 0.192
$$

and

$$
H_{act} = d_{sht}\left(\sqrt{15.4P - 0.017} - 0.192\right)
$$

Curve 2 in Figure 3 is constructed under the instructions of standards [25]. As can be seen from the figure, the zone within which the stress measured in the soil values exceed 0.01 MPa, at a given pressure on the ground they have a depth less than that calculated although the nature of curves 1 and 2 are similar. At low specific loads on the stamp (up to 0.05 MPa), the depth of the core is more than twice than obtained. With a higher specific load on the stamp, their ratio decreases slightly but remains rather large (more than 1.7 at $P < 0.2$ MPa).

These results are close to the results obtained at the Gorky Civil Engineering Institute when working with large monoliths of loess soils [9].

Curve 3 (Figure, 3) of the dependence $H_{act} = f(P)$ was constructed according to the data of [10] stamp tests of the bases. Such a foundation soil will undoubtedly have a more uniform structure and fewer rigid bonds than undisturbed soil. Therefore, the distribution of the measured stresses is close both to that obtained in the calculation by the elastic layer method [10], and to that calculated by standards [25].
In the process of soaking the soil of the bases of the models of the hydraulic structures floor bets, a significant transformation of stresses took place in it. At the same time, the depth of the core and the magnitude of stresses in the part of the soil mass located vertically directly under the stamp (in the so-called "bearing column") increased significantly.

As an illustration, Figure 1 shows the distribution of stresses in the base under the centre of a round stamp with an area of 1 m square transmitting a load on the soil of 0.05 MPa at different depths of the boundary of the wetting zone. In the course of the experiment, the stress concentration was noted at the border of the humid zone and the natural moisture massif (points 1 and 2 in Figure 1).

During the period of passage of the humidification boundary through a certain horizon, the stress values at this horizon are higher than after their stabilization and significantly exceeded by standards [25] (Figure 1).

When the humidification boundary moves into the depth of the massif, the stresses somewhat decrease (points 3 and 4 in Figure 1), and then they stabilize and become practically constant in time with a steady humidification contour

The stress values at the contact of the middle of the stamp with the base are less than the average pressure (P = 0.05 MPa) as a result of the concentration of stresses under the edges of the stamp.

As an illustration of what has been said (Figure 4) isobars of vertical stresses ($\sigma_z$) at the base of a round stamp with an area of 1 m square, transmitting pressure of 0.05 MPa to the base. The figure shows how the unevenness of the transfer of the load to the soil by the stamp affects the distribution of stresses in the soil mass.

![Isobars of vertical $\sigma_z$ and horizontal $\sigma_\theta$ stresses on the surface of a circular stamp, the average pressure on the ground under the conditions of the stabilization is 0.05 MPa.](image)

**Figure 4.** Isobars of vertical $\sigma_z$ and horizontal $\sigma_\theta$ stresses on the surface of a circular stamp, the average pressure on the ground under the conditions of the stabilization is 0.05 MPa.

4. Conclusion

The foregoing allows us to draw the following conclusions:

- the discrepancy between the calculated and the results obtained during stamp tests can be explained by the structural features of loess soils, which are dispersed anisotropic media;
- the experiments carried out showed that when calculating the core in loess low-moisture soils according to the generally accepted method, it is necessary to take into account the characteristics of these soils as the foundations of structures;
- the proposed design dependencies make it possible to clarify the depth of the active (compressible) zone in the foundations of structures erected on loess low-moisture soils and the peculiarities of the distribution of stresses in them.
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