Determination of calculating stresses on the depth of loess grounds of hydraulic structures

R Xujakulov, M Rahmatov, E Nabiev and M Zaripov

Karshi Engineering and Economic Institute, 180100, Kashkadarya, Uzbekistan

E-mail: rustam868793@mail.ru

Abstract. The processes of deformation and moistening of subsiding soils are closely related to each other. On the one hand, the deformations of subsiding soil depend on the degree of its moisture content, and on the other hand, they seriously affect the regularities of the process of moistening the massif. In connection with this, the improvement of methods for calculating the deformations of loess bases of hydraulic structures requires a thorough study of the process of moistening the massif and the influence on this process of the specifics of the impact and irrigation structures on the soil. The article presents the results of studies to determine the stresses on the depth of the loess bases of hydraulic structures in the Karshi steppe. It was established that the lateral pressure coefficient reaches its maximum during the period of the most intense manifestation of subsidence in the layer under consideration.

1. Introduction

The nature of the moistening of the loess foundations of the hydraulic structures depends both on the soil conditions of the site, and on the type of structure, the pressure transmitted by the structure to the ground, the width of the water and its pressure, etc. Two types of structures can be distinguished by the nature of the moistening of their bases:

Type I - structures, during the period of operation of which their foundations are constantly moistened for a long period. Such structures should include drops, swift currents and other structures on the canals, as well as the canals themselves. During the operation of such structures, a significant amount of moisture enters their foundations;

Type II - structures from which water enters the ground only by accident, for a short time as a result of damage to their structures. These are pipes, trays, channels in impervious clothing, as well as other water sources that have a very small area of the water, etc.

In the foundations of type I structures, the subsidence toll is wetted intensively and completely. In case of accidents of type II structures, the soil massif is moistened not to full water saturation, and usually, a suspended moistening loop is formed.

Within the humidification contour, the soil content varies from natural (at the border of the wetted zone) to close to full water saturation near the water source.

The process of filtration moistening of soils, including subsidence soils, has been studied by many authors: M.R. Bakiev [1-2], M.A. Bandurin [3], A.M. Budikova, N.N. Frolov, O.N. Chernykhy [4-6], S.N. Belyakova [6-7], A.V. Varyydin [8], A.G. Vasilevsky [7], A.B. Veksler, D.A. Ivashchintsev, D.V. Stefanishin [8], V.A. Volosukhin [9], G.A. Zhakapbaeva [10]. In particular, it is noted that for
sources of moisture of any shape in terms of having approximately the same depth of filling, the rate of soil wetting is proportional to their transverse dimensions. At the same time, when the soil is soaked from sources of moisture that have approximately the same width and depth of filling, but a different shape in plan (in one case, compact, imitating construction pits, and in the other elongated, representing sections of channels), the intensity of soil moisture is different. In the second case, it is slightly higher.

As shown earlier in the analysis of the works of several scientists A. Dzhumanazarova [11], D.V. Dokin, S.V. Zasov, R. Xujakulov, S.V. Zasov [14], B.D. Kaufman, B.D. Kaufman, S.G. Shulman [16], Yu.M. Kosichenko, F.V. Matveenkov, R. Xujakulov, I. Inoyatov, A.A. Sozaev, V.M. Fedorov, O.M. Finogenov, S.N. Belyakova, O.R. Krupnov, R. Xujakulov [17–37] failure to take into account the anisotropy of the properties of wetted collapsible soils, as well as the formation of two layers with different physical and mechanical properties in them leads to a discrepancy between the calculated and actual values of the subsidence of loess soil, R. Xujakulov, M. Zaripov, R. Xujakulov, E. Nabiev, R. Xujakulov, E. Nabiev [24-28].

The values of vertical stresses along the depth of the bases under the centres of the dies undergo significant changes in the process of moistening. If their values measured at natural soil moisture \( \omega = (8-10)\% \) are much less than those calculated following the instructions of KMK 2.02.02-98, then after moistening the base at \( \omega = (25-30)\% \), they exceed. This cannot tell the accuracy of calculations of the values of settlement and subsidence, as well as the strength and stability of the foundations. Proceeding from this, the authors researched the massifs "Samarkand", "Turkmenistan" and "Surkhan" of the Karshi steppe R. Frier [19], R. Xujakulov, M. Zaripov, R. Xujakulov, E. Nabiev, R. Xujakulov, E. Nabiev; O.M. Finogenov, S.N. Belyakova, O.R. Krupnov [35-40].

2. Methods

In the course of soaking the loess bases of the stamps, the process of transformation of the lateral pressure in the soil mass was studied. It was found that the value of lateral pressure in collapsing soils reaches the highest value at the moment when the soil is moistened on the studied horizon and the bonds between its particles are destroyed.

At the moment of deformation of the soil, many rigid bonds are broken in it and, before the formation of new soil particles, they have an increased ability and movement, which somewhat brings its properties closer to those of a liquid. Besides, the pore volume of the soil in the process of deformation rapidly decreases, with an almost constant weight moisture content, which can lead to an increase in the degree of moisture content and an increase in pore pressure by some degree.

After attenuation of the deformation process and the investigated soil layer, the value of the lateral pressure decreases. The decrease coincides in time with the fall of both the vertical and horizontal components of the stress tensor. After the stabilization of stresses in the soil mass, in the bases of the dies, it remained practically constant at moisture content.

Figure 1 shows the isobars of the lateral pressure coefficient at the base of a round stamp with an area of 1m², transmitting pressure of 0.1 MPa to the ground, after stabilizing deformations in the soil mass.
Figure 1. Lateral pressure isobars in the subsidence base of a round die, transmitting pressure of 0.1 MPa to the ground, after stabilization

As can be seen from the figure, it has the greatest value in the upper soil layer under the stamp. The value of the lateral pressure coefficient decreases with depth. The maximum value of the coefficient of the stamp alone is slightly higher than 0.5.

3. Results and Discussion
The lateral pressure coefficient obtained from the experimental data is of greater importance under the edges of the stamp than under its central part, which corresponds to theoretical assumptions.

Figure 2 shows the curves characterizing the stresses in the soil mass of the base of a round stamp with an area of 1 m square, which transfers pressure of 0.1 MPa to the soil. Curve 1 was obtained by calculation under the instructions of KMK 2.02.02 - 98.
Figure 2. Stresses in the soil mass (curve of dependence of $\sigma$ on H/R) under a round stamp with an area of 1 m$^2$ transferring to the ground load 0.1 MPa

Curve 2 is plotted taking into account the stress concentration due to the anisotropy of the loess soil, which has a moisture content $\omega = (26-29\%)$. To plot curve 2, the stresses were calculated using the formula:

$$\sigma'_x = \sigma_x K_x$$  \hspace{1cm} (1)

where

$\sigma_x$ - stresses determined by KMK 2.02.02 - 98

$K_i$ - concentration factor calculated using the formula recommended by N.A. Tsytovich [13].

$$K_x = \frac{E_z}{E_y}$$  \hspace{1cm} (2)

Here $E_y$ and $E_z$ - the modulus of soil deformation when a load is applied, respectively, in the horizontal and vertical directions. They were determined by the results of compression tests of samples taken from the studied soil horizons from the bases of the stamps.

When determining the stress concentration factor based on the results of compression tests of loess subsidence soils in the southeastern part of the Karshi steppe, under a load of up to 0.2 MPa, we obtained average values of $K_x = 1.10-1.66$ (depending on the load and soil deformability).

The $K_x$ values depending on the depth of the considered soil horizon according to the data of our experiments are shown in Fig. 3.
Figure 3. Change in the stress concentration factor due to the anisotropy of the studied soil along with the depth of the massif deformations. Die diameter 1.12 m.

Curve 3 (Fig. 3) was constructed by us based on experimental data for the case of stabilization of stresses in the soil mass after its moistening. In order to exclude the influence on the value of $\sigma_z$ of the unevenness of the transfer of pressure stamps to the soil, here are given the averaged values of vertical stresses at the considered horizons in the bearing column of the soil.

As can be seen from the figure, curves 2 and 3 have very close outlines. Calculation and measurement of stresses in the soil layer $H < 0.5$ P is a problem. This is due to the unevenness of the actual pressure distribution over the contact between the die and the base. Also, in the process of wetting the base of the stamp, the nature of the interaction between the stamp and the soil is constantly changing.

Fig. 4 shows diagrams of the maximum values of vertical stresses arising in the soil mass. The concentration of stresses takes place in each soil horizon at the moment of moisture passing through it (at the contact with a rigid underlying unmoistened layer).
Figure 4. Vertical stresses in subsidence bases of square stamps in fractions of the average pressure in contact of the stamp with the ground

Curve 2 (Fig. 4) characterizes the maximum stresses $\sigma''z$ at the horizons recorded by instruments. The $\sigma''z$ values can also be expressed by the formula:

$$\sigma''z = \sigma'z K'_x = \sigma_z K'_x K'_z$$  \hspace{1cm} (3)

where $K'_x$ – the stress concentration factor at the border of the wetted zone.

Most simply and conveniently, $\sigma''$ can be determined by the formula:

$$\sigma''z = \alpha P$$  \hspace{1cm} (4)

The table under consideration shows the experimental values of the coefficient $\alpha$ for a low-moisture loess base; for soaked soil at the end of the process, stress stabilization; in the process of water infiltration into the ground at the border of the wetted zone, where maximum stresses arise.

Experiments have shown that the difference in the values of $\alpha$ in the accepted range of loads and for a certain configuration of the stamp is insignificant. Their tabular values were determined as the arithmetic means of the values obtained in experiments with different loads on the punch, but with its constant shape.

In cases for $H > 3.5 R$ ($H > 1.75 V$), the stress in the soil from the action of the additional load becomes rather small. When calculating soil deformations to take this allows a sufficient degree of accuracy for practical purposes:

$$\sigma''z = \sigma'_z = \sigma_z$$  \hspace{1cm} (5)

4. Conclusion

The foregoing allows us to draw the following conclusions:

the depth of the core in the foundations of structures erected on loess soils of natural moisture is much less than that calculated following KMK 2.02.02 – 98;
stresses at the contact of a flat model with a subsidence base have concentration zones where their values significantly exceed the average pressure of the stamp on the ground;

the stressed state of the soil massif of the base of the structure model is transformed in the process of the moisture front advancing into the massif depth. In this case, there is a concentration of stresses in the soil layer at the border of the wetted in the non-wetted zones, the moisture content of which corresponds to the initial subsidence;

after stabilization of stresses at the base of the structure, the values of the lateral pressure coefficient, even under the condition of a high degree of soil moisture, are significantly less than unity;

the lateral pressure coefficient reaches its maximum during the period of the most intense manifestation of subsidence in the layer under consideration.

the stress state of the loess foundations of hydraulic structures depends on several factors and which should include the nature of the massif moistening, anisotropy, as well as other physical and mechanical properties and features of loess soils.

to determine the stresses in the foundations of structures, a special table can be used, taking into account the above factors and compiled based on experimental data.

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