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Operation of Pipe Water Transmission Structure in Interaction with Subsiding Soil

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ABSTRACT

As is known, in compliance with all the requirements and recommendations of regulatory documents on the design of irrigation systems on subsident soils, deformations of the foundations of structures often significantly exceed the calculated ones, which can cause loss of operational suitability of irrigation structures. The above determines the need for further study of the features of the interaction of irrigation facilities with their subsidence bases. This article is devoted to this problem, in particular, to the study of the influence of stress redistribution in the moistened subsidence bases of tubular hydraulic structures on the stress state of their elements and the stress-strain state of loess subsidence bases of hydraulic structures in the Karshi steppe.

***Key words*:** humidity, process, deformation, horizontal expansion, flyer, priming, circuit, pressure depth, diameter zone, stamp, border.

I. Introduction

The increasing demand for improved irrigation systems in the world requires a more comprehensive and extensive study of the reliability and safety of hydraulic structures. In this regard, increasing the reliability during the operation of hydraulic structures of irrigation systems, and especially on subsident soils, is very important, because loess subsident soils are widespread on the globe, a significant part of loess rocks is located in Central Asia, including in the Republic of Uzbekistan. In these areas, in developed countries, including Australia, Asia, the UK, Europe, the USA, China, Russia, and special attention is paid to the development of effective methods for the design and construction of hydraulic structures.

Worldwide, special attention is paid to the research and development of hydraulic structures in irrigation systems aimed at studying, detecting and preventing damage, failures and accidents. In this regard, it is especially important to create a mechanism to ensure the reliability of irrigation systems and planned preventive maintenance and repair that meets modern requirements of innovative development.

Currently, large-scale measures are being implemented in the country to extend the service life of hydraulic structures on irrigation systems that are built and are being built on loess subsidence soils, to reduce damage from their breakdowns and failures, as well as to develop safety criteria.

A number of scientists, both in the Republic of Uzbekistan and abroad, were engaged in the problem of ensuring the reliability and safety of hydraulic structures of irrigation systems, including: M.A.Bandurin [13], D.R.Bazarov [3-4], M.R.Bakiev[11-12], Yu.S.Vasiliev and others [1], A.B.Veksler, V.A.Volosukhin[22], S.V.Zasov[14], B.D.Kaufman [16], Yu.M.Kosichenko [19], N.N.Frolov [27], and others.

The great importance is the reclamation of loess soils, which are fertile lands and occupy vast territories of the Russian Federation, but are located mainly in the arid regions of Russia, Ukraine and Central Asia, including in the Republic of Uzbekistan. However, the reclamation of these territories presents certain difficulties due to the specifics of the work of hydraulic structures on loess subsidence soils, which consists in the manifestation of significant and uneven deformations when the foundations are moistened.

One of the most important tasks of designing and constructing reclamation network structures on loess subsidence soils is to ensure their long-term trouble-free operation. Improving the methods of designing hydraulic structures on subsidence bases requires further study of very complex physical processes occurring in the foundations of structures during their construction and operation. This is confirmed by the fact that even if all the requirements and recommendations of regulatory documents on the design of irrigation systems on subsident soils are met, deformations of the foundations of structures often significantly exceed the calculated ones, which can cause loss of operational suitability of irrigation structures. Works are devoted to this problem [2], [5-6], [7-10], [14-15], [17-21], [23-26].

The above determines the need for further study of the features of the interaction of irrigation facilities with their subsidence bases, which is the main purpose of the research conducted by the author.

2. Methods

Typical epyura of jet attempts of loess soil to pressure of a diaphragm of tubular moving – difference, obtained during pilot investigations. The epyura corresponding to a diaphragm's lag on a pipe, as well as the duration of partial moistening of a diaphragm's foundation, are of particular interest for future investigation. In many instances, the practical epyura of loess soil jet attempts differs greatly from the predicted epyura.

The diaphragm is assumed to be a monolithic construction. This is the case if the seams joining the separate diaphragm plates are strong enough. The "freezing" of the diaphragm on the pipe necessitates the most effort at these seams. In this scenario, the force felt by one joint will be equivalent to:

$$N_s = Q_1 - P_a\, b\, l_1 \qquad (1)$$

where Q_1 is the weight of the diaphragm's extreme plate, kN; P_a is the average contact pressure between the extreme plate and the base; b denotes the breadth of the diaphragm plates in centimeters; l_1 is the length in centimeters of the longitudinal edge of the base of the diaphragm's extreme plate;

It can be assumed equal to the initial subsiding $P_a = P_{in}$, kN/sm^2 in the event of soaking the soil under the whole diaphragm; the friction force between the plates and the ground is very modest and goes to the safety margin in formula (1) is not taken into consideration.

The necessary cutting area of the diaphragm plate weld will thus be equal to:

$$F_s = \frac{N_s}{R_s}, \text{sm}^2$$

where Rs is the estimated shear material cut resistance in kN/sm$^{2.}$

3. Results and Discussion

The diaphragm can be approximated as a beam with a large h/b ratio according to the scheme illustrated in Fig. 1 and matching to the aperture period of the diaphragm if the integrity of the joints connecting the cap plates is assured.

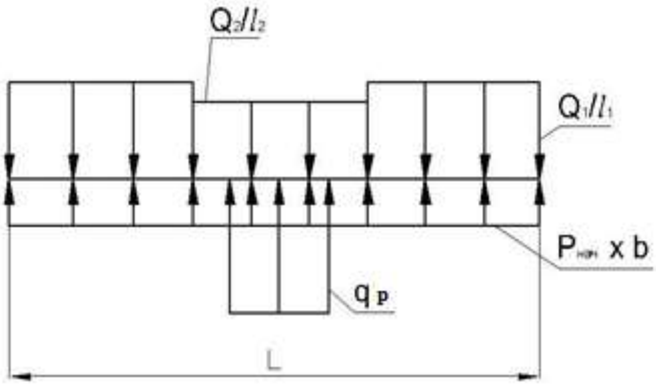

Figure 1. The diaphragm's design schematic corresponds to the scenario when it is suspended from a water supply pipe.

It is feasible to assume the soil repulse reaction evenly distributed and equal to P nach with a degree of precision suitable for practical applications. Based on the above, the diaphragm's maximum bending moment in the situation of its hanging on the water supply pipe will be important:

$$M_1 = \frac{Q(l_1 + l_2) - P_{in}(l_1 + \frac{l_2}{2})^2}{2} + \frac{Q_2 l_2 - q_p d_p^2}{8} \qquad (2)$$

where l2 is the length of the longitudinal face of the base of the diaphragm's middle plate, in cm; qtr is the intensity of the repulsing a pipe response, in kN/sm^2; $Q_2$is the weight of the middle plate, in kN; and dt is the pipe's diameter, in mm.

When $l_1 = l_2 = l$, as is frequently the case, formula (2) looks like this:

$$M_1 = \frac{l^2(8q_1 + q_2 - 9P_{in}в - q_p d_p^2) - q_p d_t^2)^2}{8}$$

According to structural mechanics, the intensity of the pipe's reactive forces may be determined as follows:

$$q_p = \frac{2Q_1 + Q_2 - 3P_{in}bl}{d_p}$$

It should be emphasized, however, that the aforementioned formulae are only true if the soil is wetted across the full region of diaphragm contact with the base. In reality, this is true if the water distribution along the diaphragm's contact with the ground away from the structure's axis fulfills the following criteria:

$$\frac{B}{2} + (H + h_2)tg\beta \geq \frac{L}{2} \quad (3)$$

where B is the width of the soaked area, m; L is the span of the tip - diaphragm, m; β- spreading angle of filtering moisture and vertical, for loess loams β= 50^0, for loess sandy loops = 35^0; H is the water pressure in the channel, m; $h_2$is the distance between the bottom edge of the diaphragm and the bottom of the reservoir. If this criterion (3) is not met, there is a concentration of contact stresses under the tip's edges, which rest on non-wetted soil.

Figure 2 depicts the design schematic for this manner of diaphragm functioning. The reactive efforts of the non-wetted section of the base are replaced by intensified reactions A and B, which match to the diaphragm's severe circumstances. Reactions A and B are calculated using the system's equilibrium equation in the normal way.Fig. 2. Design diagram of the diaphragm, corresponding to the case of the support of its edges on non-humid soil.

The reactive pressure of the pipe may be ignored because it is insignificant in this situation.

The maximum bending moment in the diaphragm's mid span will be expressed as follows:

$$M_2 = \frac{(9P_{in}bl + 4Q_1 - 5Q_2)l}{8} \quad (4)$$

The aforementioned formulae (2) and (4) relate to the diaphragm's extreme modes of action. If a large portion of the diaphragm's base is not wetted, the design plan will take the shape depicted in Fig. 3.

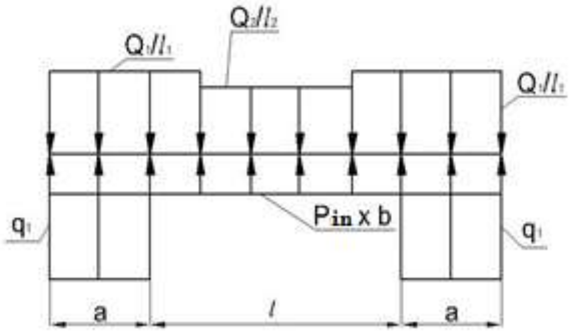

Figure 3. The picture shows a design schematic of a diaphragm for a partially wet soil.

The length of the non-wetted area for a narray of soil with a steady moisture contour can be determined by the formula:

$$a = \frac{L}{2} - \frac{B}{2} - (H + h_2) tg\beta \quad (5)$$

where B is the width of the water mirror in the associated pool and h is the distance between the lower face of the tip - the diaphragm - and the reservoir bottom.

The wet portion l of the head-base diaphragm's will be measured in centimeters.

$$\ell = L - 2a = 2\ell_1 + \ell_2 - 2a$$

The maximum bending moment in the diaphragm, according to the design approach given in Fig.4.6, is equal to:

$$M_3 = \frac{Q_2 l_2 - P_{in} l^2 b}{8} + \frac{Q_1 (l_1 + l_2) - q_0 (a + l) a}{2} \quad (6)$$

where q_0 is the non-humid component of the diaphragm's base response intensity (n/sm).

The diaphragm of three plates has a moment when $l_1 = l_{,2} = l$, but not if $Q_1 \neq Q_2$.

$$M_3 = \frac{Q_2 (2a - 5l) + 4Q_1 (a - l) + 3P_{нач} вl - 2a)}{8} \quad (7)$$

If the weight difference between the average and extreme plates is small, the formula appears:

$$M_3 = \frac{3}{8} (P_{in} вl - Q)(3l - 2a) \quad (8)$$

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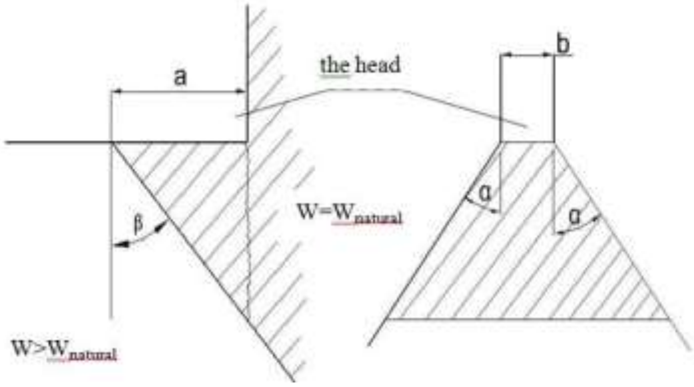

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Figure 4. The picture shows how the tip-diaphragm is supported on the moist ground wedge.

An isosceles trapezium with an upper base equal to the diaphragm thickness can be used to depict the shear area. The height of the trapezoid is equal to $h = a/tg\beta$ in line with the designations used in Fig. 4. The trapezium's bottom base is the following size:

$$b^1 = b + 2htg\alpha = b + \frac{2atg\alpha}{tg\beta}$$

where denotes the angle of dispersion of pressures in the soil caused by the action of an extra load. Based on this, the area of the trapezoid will be equal to:

$$F_{cd} = (\frac{b + b'}{2})h = \frac{ab}{tg\beta} + \frac{a^2 tg\alpha}{tg^2\beta}$$

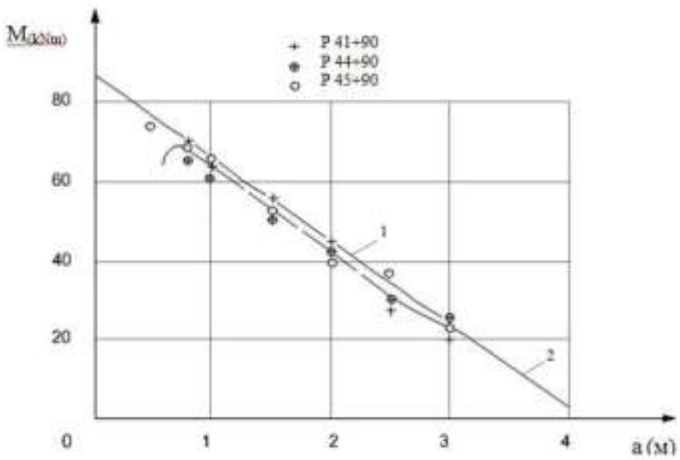

Figure 5. Graphs illustrating the change in the maximum bending moment in the tip of the crossing differential as a function of the parameter "a": 1- according to the formula (8); 2- based on experimental data

With some assumptions, the weight of the plates is viewed as moist loess soil over the whole region of the diaphragm's base. The pressure on the shear regions beneath both edges of the diaphragm corresponds to the difference between the weight of the diaphragm and the entire reaction of the wetted soil. The findings of soil laboratory tests can be used to calculate its value. $C = 0.005 - 0.05$ *MPa* for loess low moisture soil.

$$2Q_1 + Q_2 - P_{in} b(2l_1 + l_2) = 2F_{cd} c \qquad (9)$$

where C denotes the particular cohesiveness of natural moisture in

Internal ground friction is ignored since it is a very minor number that contributes to the safety margin. By expressing F_{cd} with the parameter "*a"* we may determine the boundary value at which equation (6) will be true.

$$Q_1 + 0,5Q_2 - P_{in} bl_1 - 0.5P_{in} bl_2 = \frac{abc}{tg\beta} + \frac{a^2 ctg\alpha}{tg^2\beta} \qquad (10)$$

o so, we solve the equation for "a" by inserting the beginning data for the tubular differential P 45 + 90, whose operation was investigated throughout the experiment:

$в=0,25m; C=40кN/m^2; \omega=11\%; Q_1=50кN; Q_2=40кN; P_{st}=25кN/m^2; L=9m;$

The result is that weget the value a=0.68*m.*

In Fig. 6, the graphs of the maximum bending moment in the diaphragm of a one-point differential, computed by the formula (7) and estimated on the basis of experimental contact stress diagrams, on the value of the parameter "*a*" are shown for comparison.

The bulk of experimental points are below the theoretical dependency, as shown in fig. 6: the average difference is 2.4 *kNm,* which is barely 3% in the area of maximum bending moment values. The experimental points' standard deviation from the straight line is 2.7 *kNm*.

The cleaving of the soil without moistening under the margins of the tip was determined experimentally at "*a*" = 0.4 - 0.7 *m,* which is near enough to the theoretically calculated value of this parameter. The strains on the diaphragm's contact with the base will match to the schematic in Fig.1. *g)* and the scheme in Fig.1. after cleaving the wedges of soil without moisture.

The inner edge of the differential head is affected by the pressure of the bulk compacted earth. This pressure on the diaphragm is of the following magnitude:

$$q = \varphi \cdot \rho \cdot h \qquad (11)$$

where the lateral pressure coefficient is; *h*– depth from the embankment's surface, *m*; - specific bulk soil, kN/m^3.

In this scenario, the diaphragm operation design diagram can be depicted as a console of unit widths with embedment at the level of the channel bottom concrete anchoring (Fig. 7).

A significant depth of embedding and the presence of a pipe solidly linked to the diaphragm assure fastening reliability.

The height of the mound, hn (Fig. 6 and 7) corresponds to the length of the console:

$$h_H = h_1 - h_2 - h_3 \quad (12)$$

Where h_3 is the height of the diaphragm plate portion above the ground level. Take $h_3 = 0$ as an example, which corresponds to the safety margin.

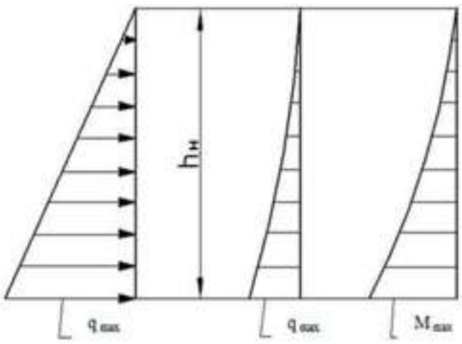

Figure 6. Design concept for the diaphragm's work from the dirt pile on the water supply pipe's side.

The load on the console, as distributed by the law of the triangle, has a maximum intensity at the embedment, which may be calculated using the formula for the conditional cut-out strip of unit width:

$$q'_{max} = \varphi\rho h_н, \text{кN/m} \quad (13)$$

In the embedment portion, the diaphragm experiences the greatest bending moment due to the action of the dirt pile.

$$M_{H(\max)} = \frac{q'_{\max} h_H^2}{6} = \frac{\varphi\rho h_H^3 1m}{6}, \text{ кN/m} \quad (14)$$

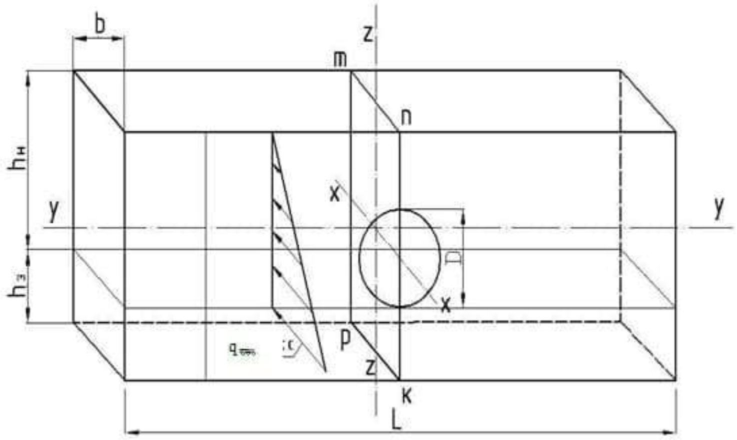

Figure 7. Head-end diaphragm diagram

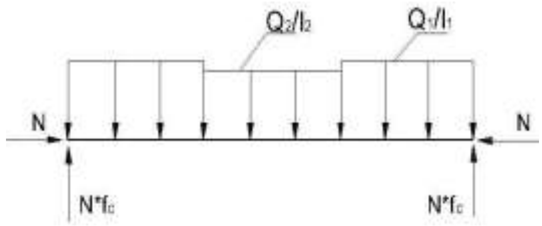

Figure 8. Diaphragm design schematic for the situation of a mound of dirt on its side faces.

4. Conclusions

1. Field studies conducted by many scientists have shown that the subsidence of loess soil is characterized by sharply uneven vertical deformations, soil ruptures in the form of stepped subsidence cracks, the slope and curvature of the surface of the subsidence funnel, horizontal movements of the soil. These factors significantly complicate the working conditions of hydraulic structures on subsident soils.
2. Currently, the bulk of hydraulic structures are designed without taking into account the specifics of the joint work of hydraulic structures with their loess bases.
3. In many regions of the Republic of Uzbekistan, when erecting irrigation structures on loess soils, structures made of unified reinforced concrete parts are most widely used.
4. In particular, on the irrigation systems of the Amu-Kashkadarya basin management, where the bulk of the research was carried out, structures made of reinforced concrete round pipes with heads made according to the type of diving walls or in the form of reinforced concrete diaphragms found the most widespread use. In the process of their construction, standard projects developed for structures on non-sedimentary soils were used.
5. Based on statistical processing of the results of the survey of existing irrigation systems, it can be concluded that for certain types of hydraulic structures erected on loess soils, it is necessary to take into account the specifics of their interaction with the base at the design stage. This need is caused by the specifics of moistening the soil of the base, as well as the

peculiarities of transferring pressure to the soil mass by structures of various designs.

6. Based on the above, it should be concluded that the diaphragm heads of tubular irrigation structures operating on loess filler soils can be in different loading conditions depending on the nature of the moistening of the base and the features of interaction with the water supply elements (Fig. 7-8).
7. At the same time, the specific stress state of the heads depends both on their mass and geometric dimensions, as well as on the physical and mechanical properties and the condition of the soils of the bases. This indicates the need to determine the most dangerous state of the diaphragm at the design stage in accordance with the proposed calculation formulas and schemes.

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