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Mutual influence of foundations on a homogeneous base

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ABSTRACT: The object of the study is heterogeneous substrates composed of water-saturated loess soils and a layer of loess soils of natural moisture, which are usually located in the upper part of the base. Field studies of the distribution ability of homogeneous and inhomogeneous bases composed of loess soils and the mutual influence of strip foundations arranged on them have been carried out. Layer-by-layer deformations along the depth of the bases, overpressures in pore water and the processes of their development in time are studied. Recommendations are given to reduce the mutual influence of foundations by means of special extinguishing slots.

KEY WORDS: subsidence loess soils, sedimentary funnel, mutual influence of foundations, distribution ability of the bases, quenching slot, water saturation of the soil.

I. INTRODUCTION

The design and construction of foundations and foundations of buildings and structures on loessial subsidence soils has always been a daunting task. It is known that out of the total number of building accidents due to failure of their foundations, at least half are precisely those territories occupied by subsidence soils.
In the Republic of Uzbekistan and other Central Asian states, loessial subsidence soils occupy a significant part of the territory.
Natural features of loessial soils are light yellow fawn color, low natural humidity, the presence of macropores visible to the naked eye, a significant content of dusty particles (fractions 60-70%), the ability to keep a vertical slope at natural humidity, lack of layering.
The absence of groundwater within the thickness of the ground preserves their most important property - subsidence. In the opposite case, as a result of moistening of the subsidence stratum with wash or ground water and the development of subsidence phenomena in them, loess soils undergo significant changes in structure and other characteristics and therefore lose subsidence properties.
Irrigated nature of agriculture, active irrigation of fields. Filtration from numerous canals and irrigation ditches, an abundance of new waterworks and reservoirs, leaks from communications - all this, as a result, leads to an intensive rise in the groundwater level. In Uzbekistan, it was noted that in many areas the groundwater level is steadily rising, although the lifting speeds in different areas are not the same. Basically, its value is 0.4 - 0.6 m / year. However, in some places of the Ferghana Valley, this speed reached 3 m / year. Such a rise in groundwater level has many negative sides. Two of them can be stopped. Firstly, in rising water there is a dissolution of a number of salts, usually included in the composition of the soil. Waters with saturated salts aggressively affect underground structures and especially foundations, destroying them gradually. This circumstance should always be taken into account when it comes to the durability of the construction. Secondly, rising, water turns sufficiently strong soils with a deformation modulus of E = 15 -18MPa into weak highly compressible soils with E = 1 - 5 MPa.
In Uzbekistan and other neighboring republics, rising water occupies one of two positions: it either reaches the day surface, or is established at a certain depth from it (2–3 m).
In the first case, a homogeneous water-saturated base was formed for the future structure, characterized by low bearing capacity and increased deformability.

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In the second case, we are dealing with a two-layer base, or, as it is most often called, a base with a weak underlying layer.
Water-saturated loess soils are one of the varieties of a large group of soft soils. Construction experience on them showed that they are not amenable to mechanical compaction, as well as chemical consolidation, based on the permeability of the fixing material into the soil.
There is reason to believe that hanging piles having a low bearing capacity under these conditions are unsuitable for them. Construction experience confirms the rationality of the use of plates (or cross tapes) on water-saturated loess soils.
The scientific novelty of the work is as follows:
- for the first time, the distribution ability of heterogeneous bases composed of loess soils at different locations along the depth of the groundwater level was studied;
- For the first time, the mutual influence of strip foundations on inhomogeneous bases was studied experimentally at various distances between their edges and increasing pressures;
- for the first time, measures have been proposed and implemented to reduce the mutual influence of foundations on a heterogeneous base in the form of a slit
The practical significance of the work performed is that it opens up the possibility of predicting the distribution ability of the bases, including a layer of water-saturated loess soil.
The research results can be used in the design and construction on the territory of Uzbekistan or in similar ground conditions in other regions.

II. SIGNIFICANCE OF SYSTEM

The issues of deformation of heterogeneous bases composed of loessial soils with an underlying water-saturated layer, and especially the distribution ability and mutual influence of foundations arranged on such bases, haven't been studied yet. Meanwhile, mass construction in the studied region, changes in hydrogeological conditions, an increase in land value, and as a result of this desire for a more compact distribution of residential buildings and small towns and villages, as well as workshops and other structures on industrial sites, make these problems very relevant. Existing regulatory documents don't contain any design provisions reflecting the specifics of the behavior of these bases under load. It seems to us unlawful to extend to them the principles of calculation developed for a wide set of weak water-saturated soils (silts, peat, peat and weak clay soils, etc.).

III. METHODOLOGY

Our field experiments at the site, represented by a homogeneous thickness of loess soils, showed that on such bases the sedimentary funnel at the maximum possible loads P = (0.10-0.12 MPa), as a rule, was equal to the foundation width b and only in rare cases, it exceeded. Taking into account the insignificant distributive ability of the bases entirely composed of water-saturated loess soils, all series of experiments on the site were conducted by us only on heterogeneous bases.
In addition, very limited information was given by experiments in which the effect of the foundation loading process on the deformation of an unloaded foundation at various distances between them was studied. The absence of any loading on the foundation blocks did not allow them to sequentially settle as a sedimentary funnel exited under their sole. The blocks heeled in some places, but their deformation did not reflect the surface character of the sedimentary funnel.
Consequently, leaving this group of experiments without serious analysis, we investigated the mutual influence of the loaded foundations on an inhomogeneous base at various distances between them.
In fact, the experiments were carried out with two types of heterogeneous bases, when the roof of the water-saturated stratum was at a depth of $h = b$ and $h = 2b$. In each experiment, in addition, cases were considered when the distance between the loaded foundations was $l = 2b$ and $l = 3b$. The pressure range was the same as in previous experiments P = 0-0.12 MPa.
Let us consider the first group of experiments conducted on an inhomogeneous base with h = b and a distance between the edges of the foundations equal to $l = 2\ b$. The technique of loading the foundations was as follows. Knowing the features of the formation of a sedimentary funnel under various conditions, both in terms of the level of groundwater and loads, the left foundation No. 1 (if we look at our diagrams) was immediately loaded with a load of P = 0.08 MPa and maintained until the sediment was completely stabilized. In this case, the fixation of the formation of the sedimentary funnel and the position of the neighboring foundation No. 2 were carefully conducted. Then, foundation

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No. 2 was loaded to the same load, its sedimentary funnel was fixed, and then additional movements of the sedimentary funnel of foundation No. 1 when they merged in the intermediate zone. After stabilizing the movements from loading the foundation No. 2, the next stage was loading the foundation No. 1 and the procedure was repeated.

The mutual influence of the foundations was most clearly observed at a distance between them *l=2b* and P1 = P2 = 0.12 MPa. Despite the fact that at this position of the groundwater level in the soil, its distribution capacity is not very high, the load of the neighboring foundation increases by 5-8% the stabilizing sediment of the previously loaded foundation. The shape of the sedimentary funnel becomes domed. Extending them to a distance l = 3 b completely removes the mutual influence. In any case, it was not possible to fix it with available sufficiently accurate instruments at loads up to P = 0.02 MPa (see figure1).

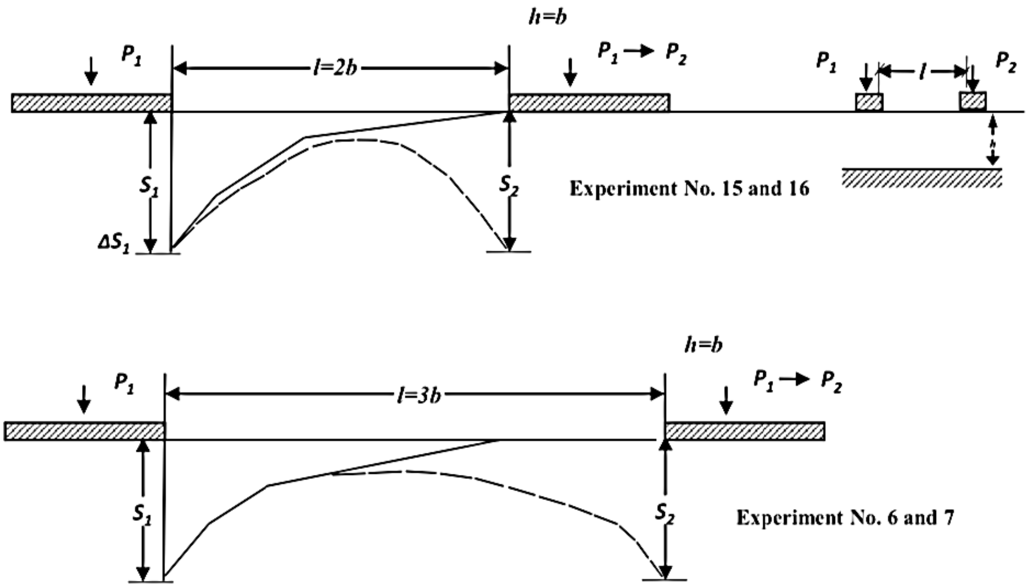

Fig.1. The character of the changing of the sedimentary funnel, due to the mutual foundations of the foundations on an inhomogeneous base at different distances between the edges of the foundations, pressure P = 0.12 MPa and h = 2b

__________ stabilized precipitation;

_ _ _ _ _ _ increase in sediment due to mutual influence of foundations

More clearly, the mutual influence was expressed in a heterogeneous base at *h = 2 b*. Here, an additional precipitate was observed both at *l = 2 b* and at *l = 3 b*. So, in particular, with the distance between the foundations *l = 2 b*, the increment in the sediment of the foundation No. 1 due to the loading of the foundation No. 2 was 17-20% of its initial settlement. In other words, if the calculated value of the foundation settlement No. 1 is close to the limit, according to the requirements of building standards and rules 2.02.01-83, the construction of a structure near it (foundation No. 2) will make the settlement of foundation No. 1 unacceptable and will need to be strengthened or adapt the building to excess movements. The shape of the sedimentary funnel remained domed.

With a change in the distance between the foundations to l = 3 b, additional precipitation due to mutual influence amounted to 6-8% of the previously stabilized precipitate, i.e. decreased, but remained significant (see figure 2)

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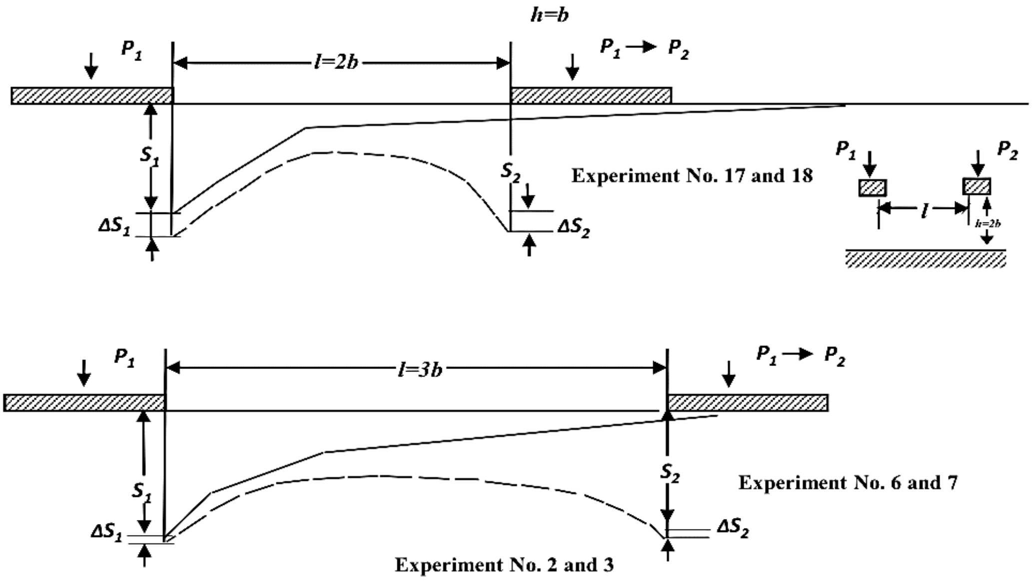

Fig. 2. The character of the changing of the sedimentary funnel, due to the mutual foundations of the foundations on an inhomogeneous base at different distances between the edges of the foundations, pressure P = 0.42 MPa and h = 2b
__________ stabilized precipitation;
_ _ _ _ _ _ increase in sediment due to mutual influence of foundations

IV. EXPEREMENTAL RESULTS

It was experimentally found that the main reason for the growth of the foundation sediment under the conditions of stabilized deformations is the increase in their base of pore pressures, the value of which was measured during loading of the foundations (see fig. 3.). Analyzing successively the results of the performed experiments, we can draw the following conclusions:
- in those cases when the sedimentary funnel, when the foundations interacted, crossed the edge of the foundation and spread under its sole, there was an increase in the settlement of foundations from 5 to 20% of its stabilized value;
- with rigid foundations, a pronounced roll towards the loadable foundation was observed;
- the sedimentary funnel in all cases of mutual influence of the foundations (at l = 2b and 3b) increased in depth, even if this mutual influence did not affect the foundations at all;
- increments in the sediment of the soil surface in vertical sections at mirror-opposite points are not always equal even at equal pressures at the level of the soles of mutually affecting foundations, which can be explained by some heterogeneity of the soil and, possibly, the accuracy of fixing the movements.

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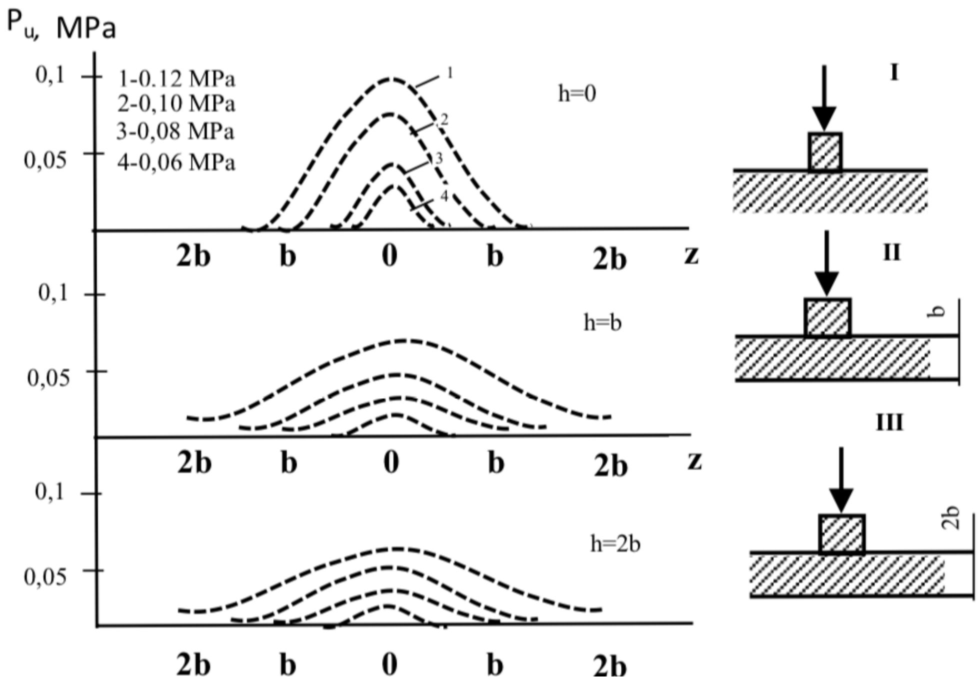

Fig. 3. The distribution of pore pressure in the base with different depths of the water-saturated layer

As we have already noted, during the construction of new buildings in cramped urban conditions, as well as in conditions of land scarcity or its high cost, it often does not seem possible to remove them from each other due to the mutual influence of foundations.

However, as our studies have shown, the close placement of buildings can cause them to excess deformations (heelings, sediment, etc.), requiring the transition to other, more expensive types of foundations or the use of other engineering solutions that reduce or exclude the mutual influence of foundations.

However, many well-known events are technically or economically impossible. In particular, the elimination of interference by means of a sheet pile wall is sometimes difficult to implement, since this requires only special equipment.

In connection with the foregoing, it required the use of technical solutions with a number of qualities that would make them reliable, cheap and practically feasible.

From this point of view, in our opinion, the most suitable solution would be to create a deep cut in the soil that extinguishes the transmission of movements in the soil. It is known that in some countries, cuts in soils are sometimes used to damp vibrations when tamping soil in the vicinity of operating facilities.

The field cut was carried out using a boron machine. The width of the slot was S = 0.4 m. Its depth was taken equal to $h = 1.2\ b$. Special experiments on the selection of the optimal depth of the slot were not set. The depth of the slot, adopted in the first experiments by a voluntary order, removed any mutual influence of the foundations on each other. We deemed this depth optimal. Naturally, special experiments could refine this parameter.

In the field, in experiments No. 6 and No. 7, as well as No. 17 and No. 18, we experimentally investigated the effect of a vertical slot on the distribution ability of heterogeneous bases. The slot in all cases was filled with coarse sand. For both cases, when the distance between the edges of the hard dies was l = 2 b and l = 3 b, the presence of a slot completely excluded the transfer of displacements beyond the slot. Surface marks at the edge of the slot recorded zero movement. At the same time, the presence of a slot filled with sand did not affect the size of the stamp precipitation.

Plots of displacements of the soil surface in the presence of vertical slots in Fig. 4.

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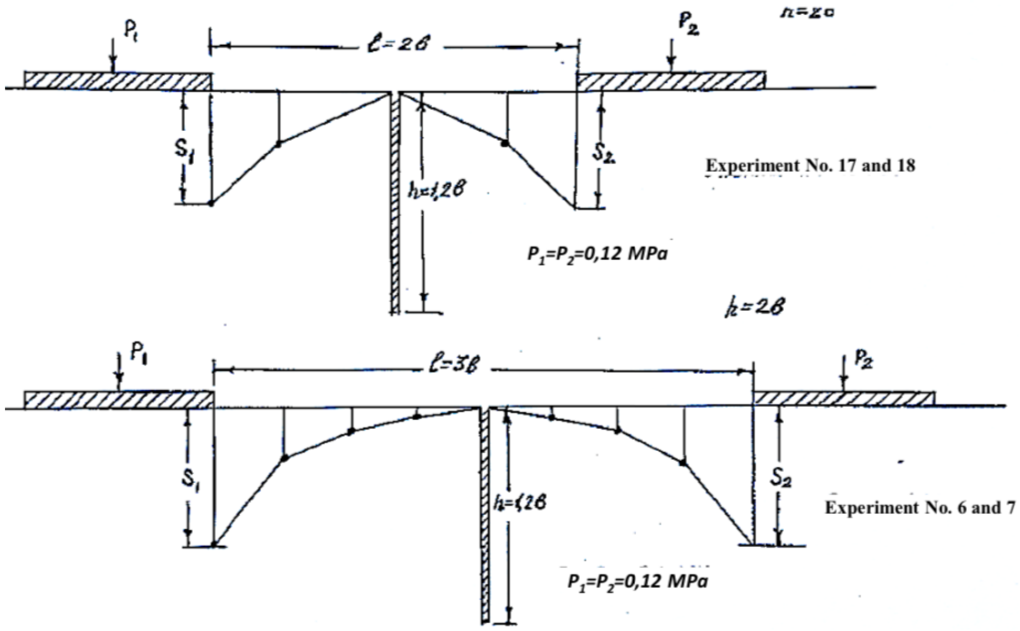

Fig. 4. The effect of vertical cuts on the distribution capacity of heterogeneous bases

Findings:

1. In a water-saturated homogeneous loess base, an increase in the sedimentary funnel with increasing load was observed only up to a pressure of P = 0.1 MPa and did not exceed *1.0 b*. A further increase in the load led to the penetration of the stamp into the soil, an active increase in its sediment and the practical termination of the growth of the sedimentary funnel.
2. The deepening of the weak water-saturated layer relative to the day surface led to an increase in the distribution ability of the heterogeneous base at $h=b$ by *1.5 - 1.8* times, and at $h=2b$ - by 2.7 - 2.9 times, to a decrease in the value sediment and to a more gentle development of a sedimentary funnel outside the stamps.
3. Comparison of experimentally measured sedimentary funnels with values calculated from models of elastic half-space and a base of finite thickness showed that the settlement of the surface of a homogeneous water-saturated base is best described by a model of a base of finite thickness. For an inhomogeneous base, a model of elastic half-space is better suited, although theoretically the attenuation of sediment along it passes at infinity.
4. The size of the compressible thickness along the depth of the base is directly dependent on the location of the roof of the water-saturated soil layer. At P = 0.06 - 0.12 MPa and $h = 0$, the depth of the compressible stratum was in the range (1.5 - 2.0) b, which is 2 - 3.5 times less than the calculated one. At $h = b$ in the same pressure range, the compressible stratum increased to (1.7 - 3.0) b, at h = 2 b its value reached (1.75 - 3.7) b and was 1.5 times smaller estimated.
5. In the upper zone of a homogeneous water-saturated base equal to the width of the foundation, more than 70% of deformations were formed. With a decrease in the level of the roof of soft soil to $h = b$, this concentration in the same zone decreased to 58%, and at $h = 2$ b to 50%.
6. Pore pressure at various depths of homogeneous and heterogeneous bases also recorded an increase in the distribution capacity of the base as the roof level of weak water-saturated soil decreases.
7. The main reason for the growth of sediment foundations in the conditions of stabilized deformations is the increase in their bases of pore pressures.
8. An increase in the sediment of the foundations (from 5 to 20%) of its stabilized value occurred in those cases when the sedimentary funnel, when the foundations interacted, crossed the edge of the foundation and spread under its sole.

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