Experimental studies of the various soils bedding influence on the stress-strain state of a layered subsoil base of the slab foundation

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Abstract. The purpose of the study is to reveal the effect of the stress-strain state of the three-layer soil base of the slab foundation with a rigid underlying layer, which is heterogeneous along the depth of the ground. The main results of the study are obtaining relative deformations in the soil massif and the settlement of ground values of each layer. The results of experimental studies are obtained in the form of a deformation pattern of a layered base, distribution graphs of compressive stresses in the soil in depth and in a horizontal plane. The significance of the results achieved for the construction area is to establish the mutual influence of various soils on the stress-strain state of the laminate basement of the slab foundation. The presence of a dense top layer in a laminate base significantly increases its distribution ability. The stress distribution is proportional to the load-carrying capacity of the individual base layers. On the boundary between the layers, a jump in the compressive stresses may occur, which indicates the presence of shear deformations in the contact layer.
Keywords: slab foundation, layered soil base, rigid underlay.

1 Introduction

Qualitative and dependable forecasting of stress-strain state of ground bases is urgent problem of modern urban construction. Real soil properties, layered foundation irregularities in depth which influence on the processes in ground bases that occur under external loads, should be best reflected in the used analytical models [1-5]. The development of reliable computational theory of layered ground bases becomes a hot topic at the present time when necessity of the high-rise buildings construction with slab foundations [6-10] under adverse engineering-geological conditions in modern large cities can be observed.

As a result it becomes necessary to receive experimental data about stress-strain state of layered foundations that will become the blueprint for development of actual models of ground bases with different strength and strain characteristics [11-15]. In order to obtain data on stress-strain state, it is necessary to conduct experimental study of the models of slab foundations on layered heterogeneous foundations are required [16-21].

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2 Materials and methods

The tests were carried out on volumetric laboratory metal flumes with dimensions of 100x100 cm at the department of Foundations and basements, dynamics of structures and engineering geology of Kazan State University of Architecture and Engineering (KSUAE), general view of which is shown in Figs. 1, 2.

The model of layered foundation was formed by 3 layers of soil with different physical and mechanical characteristics, under which there was low-compressible layer. The height of three-layer foundation is 60 cm; the height of lower underlayer is 40 cm.

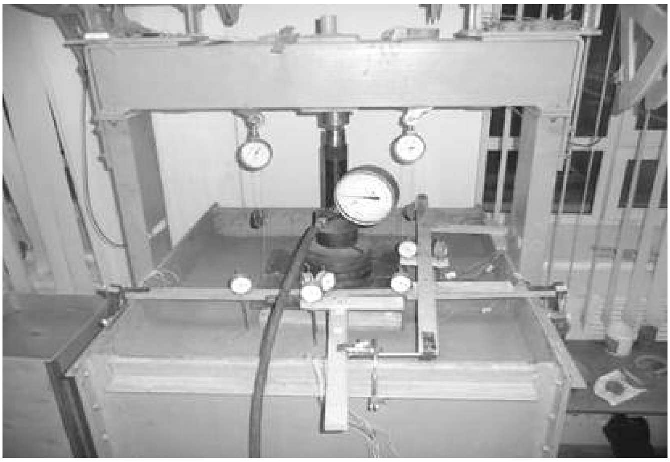

Fig. 1. General view of the laboratory flume under investigation.

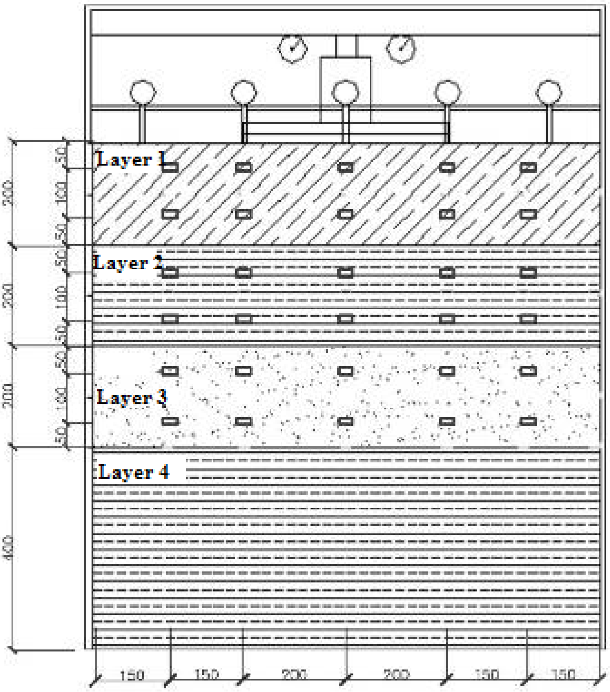

Fig. 2. Scheme of test and set-up of instruments.

Three-layer foundation in experiments consisted of the following subsoils:

– soft sandy loam, non-subsiding, with the following properties: γ=1.7 g/cm^3, W=13 %, E=5,45 MPa, φ=12-14^0, c=1 kPa;

– clay loam, low-plasticity, non-subsiding, with the following properties: γ=1.89 g/cm^3, W=27 %, E=12.4 MPa, φ=19-21^0, c=10 kPa;

– fine sand, medium-weight, not enough saturated with the following properties: γ=1.65 g/cm^3, W=13 %, E=11 MPa, φ=14-16^0, c=2 kPa.

In all experiments semi-solid non-subsiding clay loam with the following properties was used as lower underlayer: γ=2.05 g/cm^3, W=16 %, E=38 MPa, φ=28^0, c=25 kPa.

The following four experiments, which simulate work of slab foundation based on three-layer ground base at rigid underlying layer, were conducted:

1-st experiment – layers order is described above;

2-d experiment: fine sand, medium-weight;

soft sandy loam, non-subsiding;

clay loam, low-plasticity, non-subsiding

3-d experiment: clay loam, low-plasticity, non-subsiding;

fine sand, medium-weight;

soft sandy loam, non-subsiding.

4-th experiment: fine sand, medium-weight;

clay loam, low-plasticity, non-subsiding;

soft sandy loam, non-subsiding.

We poured the subsoil in layers of 5cm into volume flume. After that it was spread and compacted by rectangular-sectioned rammer to predetermined value of density. Soil samples for physical and mechanical characteristics definition were drawn in every layer after soil compaction.

At prepared surface we set the model of slab foundation that represents reinforced-concrete slab with dimensions of 400x400x40 mm. The load was applied to the slab using a hydraulic cell under the block steps of 250, 500, 750, 1000, 1500 kg.

3 Results

During the experiments strains of ground bases were measured by ground sensors which were placed in the plan in two rows in every layer under the center of the slab (Fig. 2). Ground sensors readings were taken by means of AID-4 strain-gauge station. As a result we received relative rates of stress in soil in-situ and rates of settlement of ground in every layer.

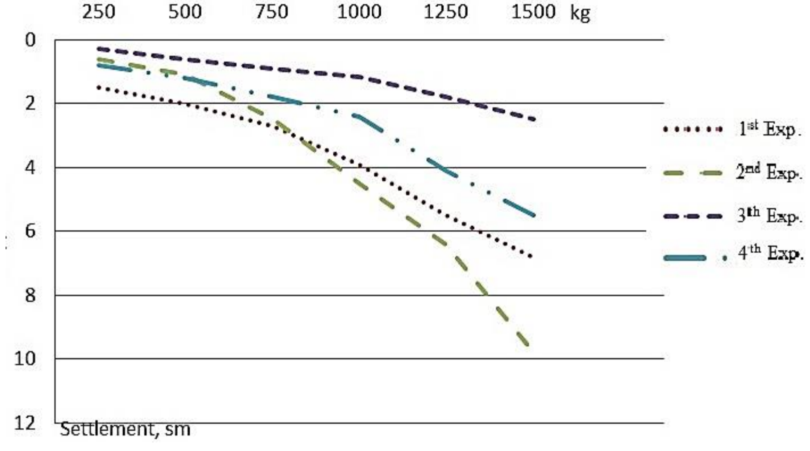

Fig. 3. Dependence of slab settlement on load.

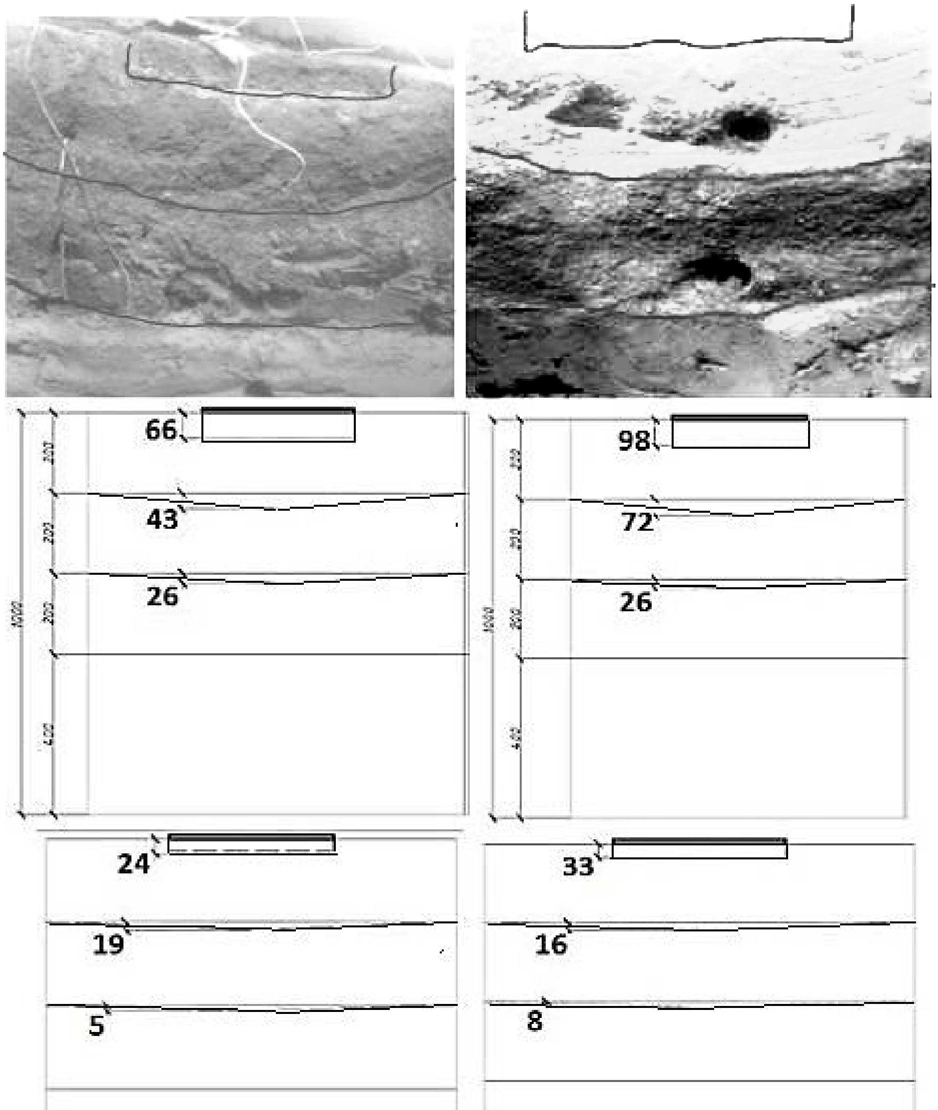

Fig. 4. Section of three-layer ground base in the center of slab model and form of strain of layered ground base in 4 experiments.

Comparing slab settlement received in 4 experiments (Figs. 3, 4) we can see that minimal settlement was received in the 3^d experiment and amounts 24 mm, maximum – in the 2^{nd} experiment – 98 mm, in the 3^d and 4^{th} experiments rates of settlements differ slightly and are 24 and 33 mm, respectively. The largest value of settlements of slab foundation model appeared in the presence of fine sand or fine sandy loam as underlaying layer. The place of more solid layer – low-plasticity clay loam – has major importance: the closer to surface it is placed, the less is the settlement. It means that solid upper layer in layered foundation largely increases distributing capacity of full compressible layer.

During all experiments (Figs. 5, 6) in the upper two layers at all steps of loading the epure of stress distribution in the subsoils in horizontal direction has classic view of distribution, videlicet saddle-like form; in the 3^d layer that is deeper, the epure of stress has cusp form; and only during the experiment №3, where layers are arranged from up to down from most firm to less firm, the epure changes its form from saddle-like to cusp one.

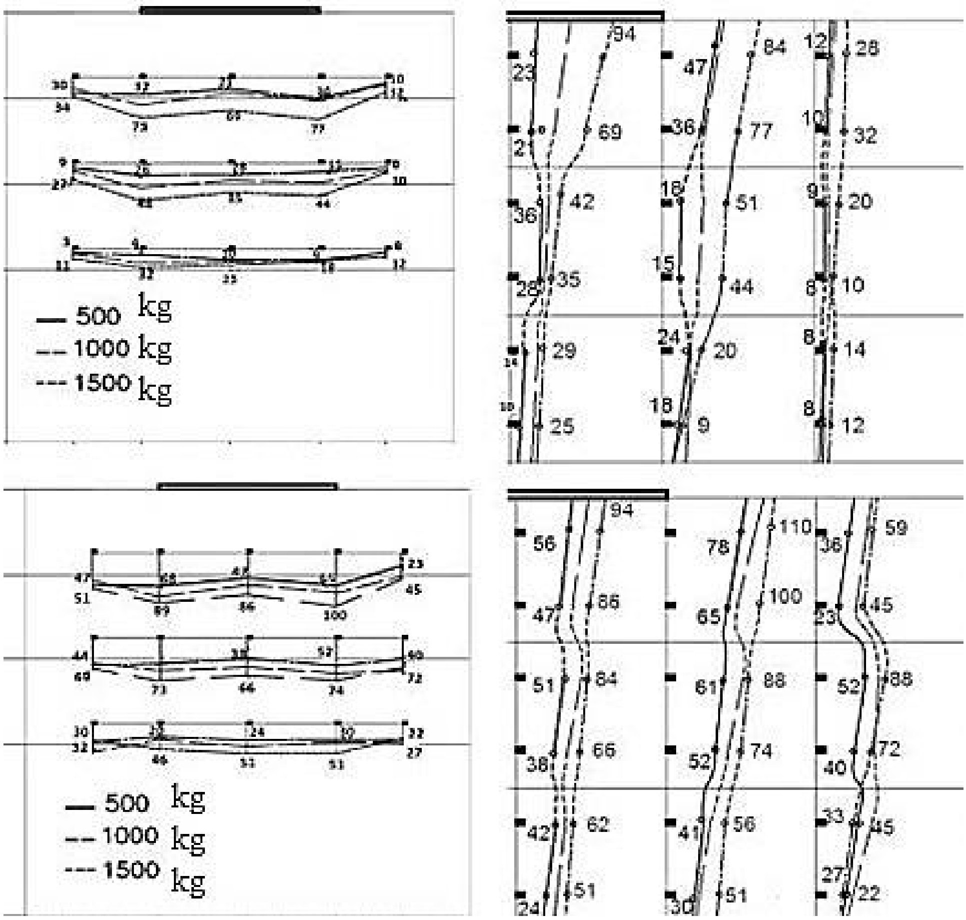

Fig. 5. Stress epures in horizontal and vertical directions in the subsoils under the slab foundation model in 1st and 2nd experiments.

The highest rates of strain up to 140 kPa appear at underlaying layer of slab foundation if it is the most non-rigid ground – clay loam (experiment No 3). In this case of three-layer ground base a high rate of strain can be observed also at other layers: up to 113 kPa in the 2nd layer and up to 110 kPa in the 3d layer. During the experiment №4 where settlement was also small, maximum stresses in layers were observed from up to down: 122 kPa, 137 kPa, 90 kPa. During the experiments #1 and #2, where settlement was 2-3 times more, maximum stresses in layers were smaller (from up to down) by 55% (84 kPa) and 18 % (110 kPa), by 145 % (51 kPa) and 42 % (88 kPa), by 212 % (32 kPa) and 79 % (56 kPa).

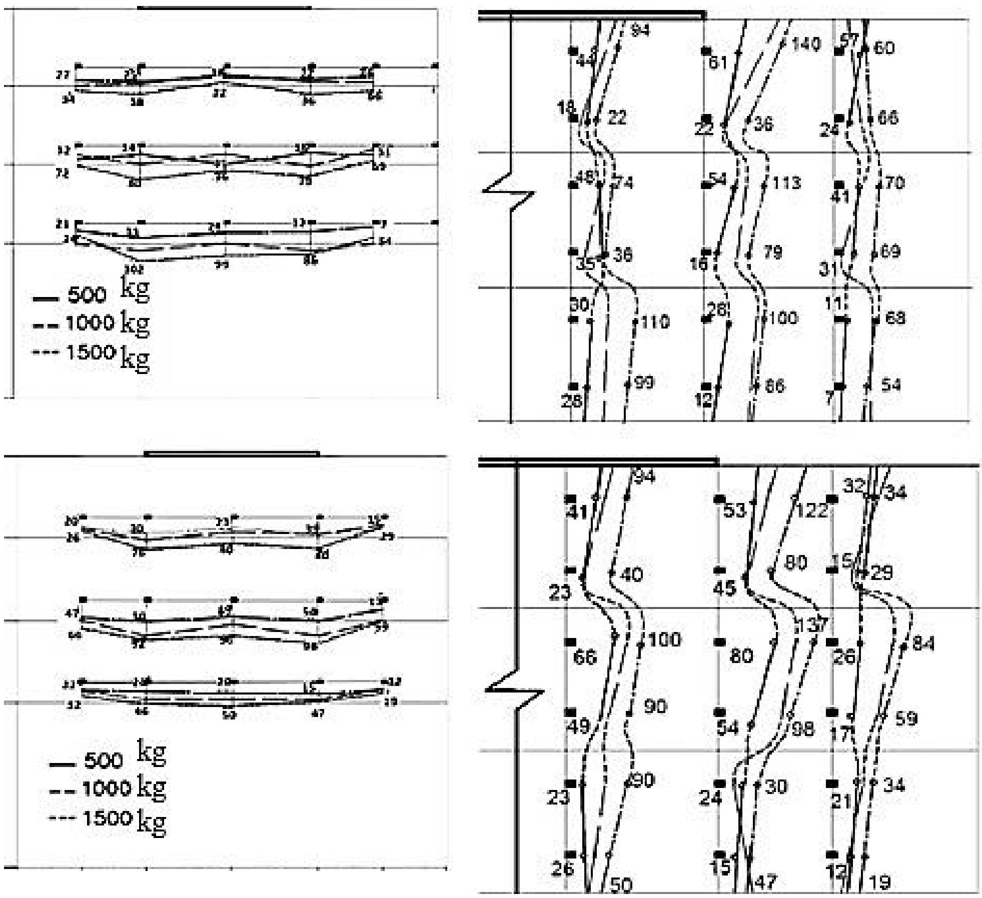

Fig.6. Stress epures in horizontal and vertical directions in the grounds under the slab foundation model in 3th and 4th experiments.

4 Discussion

After stress epures of all 4 experiments were analyzed (Figs. 5, 6) we can conclude that stress distribution in layered foundation differs from accepted scheme peculiar to homogeneous foundation.

By the nature of compressive stress distribution (Figs. 5, 6) we can observe that in every geologic layer stress decreases in depth and in the underlying layer in the majority of experiments stress increase can be seen in comparison with upper layer, in other words on the border between layers the leap as stress fluctuation appears that is indicative of shearing stress in contact layer. At the same time, the more these strains, the higher the contact layer is and the more efficiently the compressive stress is redistributed in the layered foundation which leads to less settlements of slab foundation model. During the experiment №1 (settlement is 66 mm) compressive stress changes in all three layers almost according to linear law. During the experiment №2 (settlement is 93 mm) stress under the center and on the edge of slab changes according to linear law in all depth of foundation and outside of slab there is a stress fluctuation by two times more in the 1st and 2nd layers. During the experiment #3 (settlement is 24 mm) stress fluctuation appears in two contact layers in the center and on the edge of slab by 3.05÷3.36 times more and by 1.27÷3.14 times more respectively, outside of the slab there is no stress fluctuation. During the experiment №4 (settlement is 33 mm) stress fluctuation can be observed only between the 1st and 2nd layers by 1.71÷2.9 times more all along the contact line.

5 Conclusions

1. In multilayer ground bases of slab foundations with a significant difference in strength and stress-related characteristics, compressive stress changes in depth according to the scheme that differs from accepted scheme inherent in homogeneous foundation. Stress not only decreases with depth but also can increase at the contacts of lithologically different layers.

2. Stress fluctuation in vertical epures, which can be seen in the place of one layer to other crossing, shows shearing stress in contact layer.

3. Depending on the stratal configuration of different subsoils stress-strain state of layered ground base is variable in wide range.

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