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STRESS-DEFORMED STATE OF RIGGING PILOT STRUCTURES ON BASES CHARACTERIZED BY A COMBINATION OF BOND AND NON-COUPLED SOILS

Madatov Abdirakhim,
Candidate of Technical Sciences, Associate Professor of the Department of “Roads, Base and Foundations” of Samarkand State Architectural and Construction Institute, Uzbekistan
madatov.a55@mail.ru, +99897 936-06-10

Abstract
The work of trestle piling constructions on heterogeneous foundations characterized by a combination of connected and disconnected soils is examined in this article. The piling structure design approach for the relevant soil conditions is supported.

Key words: Heterogeneous bases, viscous deformations, creep threshold, elastic-visco plasticity, axial malleability.

Аннотация
В статье анализируются особенности работы эстакадных свайных конструкций на неоднородных основаниях, характеризующихся сочетанием связных и несвязных грунтов. Обосновывается расчетная схема свайных сооружений для рассматриваемых грунтов условий.

Ключевые слова: Неоднородные основания, вязкие деформации, порог ползучести, упруго-вязко пластичность, осевая податливость.

Аннотация: Мақолада боғланган ва боғланмаган грунтли асослардаги эстакада тоифасидаги свайли иншоотлар ишлашининг ўзига хосликлари таҳлил қилинган. Қаралаятган грунт шароитлардаги свайли иншоотларнинг ҳисобий схемаси асосланган.

Калит сўзлар: Бир жинсли бўлмаган асослар, қовушқоқ деформациялар, сирпанувчанлик чегарсидаги бўйлама куч, эластик-қовушкокпластиклик, бўйлама силжувчанлик.

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Introduction

Individual groups of piles resting on non-cohesive soils, while other piles along their whole length are on clay soil, are the most distinguishing elements of the operation of overpass pile structures on foundations characterized by a combination of cohesive and non-cohesive soils (Fig.1,c and d). In contrast to the previously described scenario (Fig.1,a), where all of the piles are in homogeneous soil [3,] the piles resting on detached rocks do not settle in time or only settle a little. In the case at hand, their subsidence over time is induced not by viscous deformations of the soils on which they rely, but by an increase in the active axial forces caused by the settling of other groups of piles, which are totally made of clay rocks.

Because reverse changes in the curvature of the elastic line of the girder are impossible in the case of a homogeneous clay foundation, the process of altering the stress-strain state of structures should be monotonous under the conditions considered. Piles resting on non-cohesive soils do not experience viscous displacements. The girder's deflections are caused by subsidence of only those groups of piles that do not reach the unconnected soils, and the position of these supports is practically stable over time (Fig.1, c and d). In this situation, the efforts in piles supported on non-cohesive soils only rise over time, while they decrease in the rest of the piles. This is due to the mobilization of the girder's elastic forces, which happens as a result of the deformation scheme indicated in Fig.2a. The method is more intense and takes less time, resulting in more rigidity, a larger number of non-displaceable pile supports, and a stiffer girder. Some manifestations of the aperiodicity of the process of changing the forces in the piles that do not reach the underlying cohesive soil can occur when there are a large number of spans in the cross-section of the structure and a small number of fixed supports at the same time, but they should be much smoother here than overpass structures on solid clay foundations.

The way of connecting the piles to the top structure determines the nature of the process of altering the stress-strain state of a structure over time under the specified engineering and geological parameters (embedding or hinge). The characteristics of structural work in these engineering-geological circumstances are more pronounced with rigid piling. All of the preceding appears self-evident and flows immediately from the fundamental laws of rod system statics.

In some cases and with continuous clay foundations, the considered features of the operation of overpass structures can be manifested, but when the piles are driven into the ground to significantly different depths, as is frequently observed at quayside

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embankments with steep berth slopes, bridge supports, and various flyovers (Fig.1,b). In these scenarios, a significantly raised creep threshold of deeply driven rear rows of piles can result in situations where the axial forces in the piles do not surpass the creep threshold within the possible redistribution range. As in the scenario outlined above, the piles remain static while other groups of piles driven to a shallower depth move over time. When the forces in the rear rows piles exceed the creep thresholds at certain points in time (then they move for a period of time and conditions are created under which the monotonic process of changing the stress-strain state of the system can become aperiodic for a period of time), an intermediate position is also possible; however, the aperiodic nature of the change in the forces in the structure will be significantly smoothed here.

In Fig.2,b shows the curves of stress variation (Δ σ) in the girder of the overpass structure in time (t), corresponding to all considered possible cases of soil stratification (Fig.1) within the pile foundation. Curve-I on the graph corresponds to bedding according to scheme-a (when all piles are immersed in homogeneous clay soil to the same depth), curve-2 according to scheme-b (if there is under the bridge or under the mooring slope on a homogeneous clay base), curve-3 according to the schemes - c and d (with a heterogeneous base, including weak clay soil).

The analysis leads to the conclusion that overpass constructions operating on heterogeneous foundations, particularly poor clay soils, have distinct characteristics that cannot be accurately characterized and expressed within the framework of the existing design model [4].

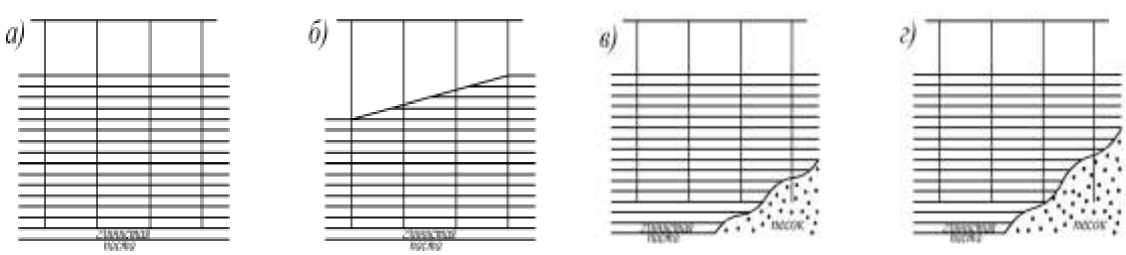

Fig. 1. Possible cases of soil conditions for the construction of pile structures

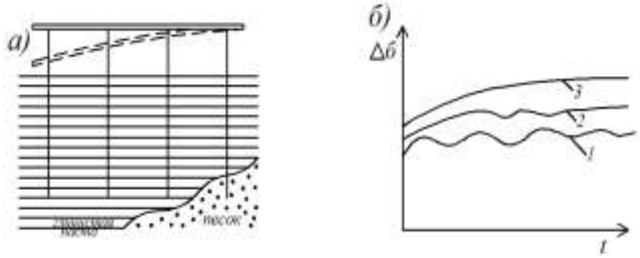

Fig.2. Diagram of the girder deformation of the structure with non-uniform foundations (a) and the stress change curves ($\Delta\sigma$) in the girder of the pile structure (b)

1 - corresponds to bedding according to the scheme - a (Fig.1); 2 - according to the scheme - b; 3 - according to schemes c and g.

Methodology for Conducting Research

Special laboratory studies were conducted at the beginning stage of examining the topic under consideration to identify the characteristics of the operation of overpass structures on heterogeneous foundations, including soils that deform over time [5, 6].

Experiments were conducted using three soil stratum systems, as illustrated in Fig. 3. One group of piles is embedded in sandy soil in the 1- scheme, while the other three groups are embedded in clay soil in the second. The number of pile groups in the sandy soil was equivalent to 2 and 3 in the second and third schemes, respectively.

In addition, experiments were carried out according to schemes 4 and 5 [6] to study the operation of overpass structures on a homogeneous clay base when they began under the overpass slope (Fig. 3). The slope under the elevated slope was taken equal to 1:2 (the slope of the slope to the horizon is $\alpha = 33^0$.

The main goal of laboratory research was to figure out what caused the stress-strain state of overpass structures to alter over time.

The functional link between stress σ in structures and time t in general form is described by the ratio

$$\sigma = f[\alpha(t), \beta(t), \Omega(t)],$$ as is well known[1,2],

here, $\alpha(t)$ is a function that represents the change in stresses in the structure as a result of the rheological properties of soils manifesting;

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$\beta(t)$ function that accounts for the structure's stress reliance on the dynamic mode of operation, which effect presents itself over time;

$\Omega(t)$ is a function that depicts the relationship between stresses and changes in the deformative characteristics of structural materials over time.

Due to the fact that the factors reflected by the functions $\beta(t)$ and $\Omega(t)$ have been studied more or less sufficiently, the task was to assess the effect of the factors taken into account by the function $\alpha(t)$in the range of variation of the parameters of the stress-strain state of the structure.

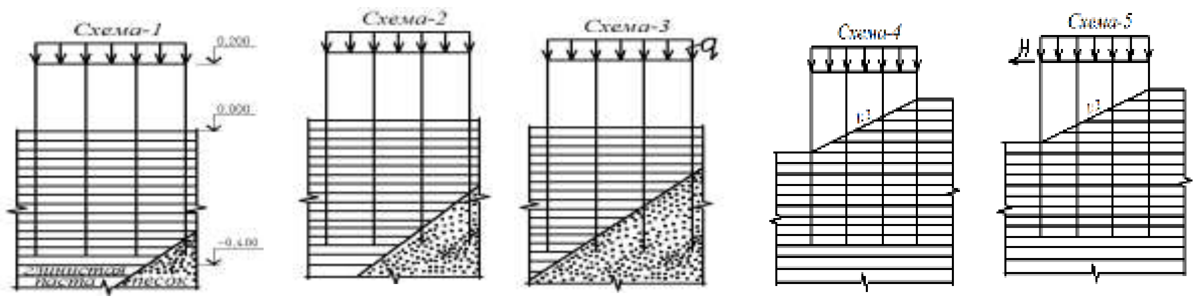

Fig. 3. Layering of soils in experiments

The performed experimental studies, which results are presented below, have shown that the function $\alpha(t)$ basically sets a monotonic decaying character of the change in σ; aperiodic fluctuations of efforts, characteristic of a homogeneous clay base [4], are not observed here, or are significantly smoothed out.

The goal of the laboratory research was:

-To research the impact of load intensity and position on the nature of the change in the structure's stress-strain state over time;

- Research into the effect of soil conditions (the number of pile groups embedded in non-creeping soil) on the process of altering structural stresses over time;
- Research on the effect of the girder's rigidity on the structure's operation over time;
- Research of the structure's performance on a homogenous basis that deforms over time at various depths of driving piles into the earth;
- Research of the structure's operation on a uniform basis that deforms over time at various depths of driving piles into the ground under the combined action of vertical and horizontal stresses;

Results

The findings of the research revealed that in the case of heterogeneous bedding of soils, the operation of the overpass construction differs qualitatively from that of a homogeneous clay soil.

The support of specific groups of piles on non-creeping soils causes the structure's contact with the base to take on a number of various characteristics. The most important are as follows:

-The absolute values of the axial displacements of the piles are significantly dependent on the number of groups of piles embedded in the creeping soil;

-Periodic fluctuations of efforts in piles, typical for a homogeneous clay base, are practically not observed here, or they turn out to be significantly smoothed;

- The absolute values of stress increment in structures are roughly 10%-30% higher than on a homogeneous base;

- The process of growing stresses is extended in time to a greater extent than in a homogeneous base.

The nature of the change in the stress-strain state of an overpass structure on a heterogeneous foundation, including soils deforming in time, are illustrated by the experimental graphs of the relative vertical displacements of the supports $\Delta_{i-j}= f(t)$ in time, shown in Fig.4-6 (Δ_{i-j}-the difference between the settlements of the *i*- and *j*-th supports for a period of time *t*).

When the soils are layered according to scheme 1 (Fig. 4), the increase in the relative displacements of pile supports $\Delta_{i-j}= f(t)$ has a monotonous decaying character. Some exceptions are observed on some curves $\Delta_{i-j}= f(t)$ for their initial sections when the model is loaded, which is caused by the influence of the instantaneous settlement increments (see on the eg. Δ_{1-0} in Fig.4,b). (On the graphs, value $\Delta_{1-2}$is the difference between the displacements of supports №1 and №2; Δ_{2-3} is the difference between the displacements of supports №2 and №3, etc.).

Under soil conditions according to scheme 2 and 3, the noted pattern is generally preserved (see Fig.5 and 6). Here, however, some decreases in the relative speed of movement of the supports are observed at the second and third stages of loading (Δ_{1-0} in Fig. 5, b and c).

In order to study the effect of the stiffness of the girder on the nature of the change in the stress-strain state of structures, we carried out at two of its stiffnesses (EJ_1 and EJ_2).

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The experimental results shown above in Figs.4,5 were obtained with the girder stiffness EJ_1=0,120 GPa.см^4.

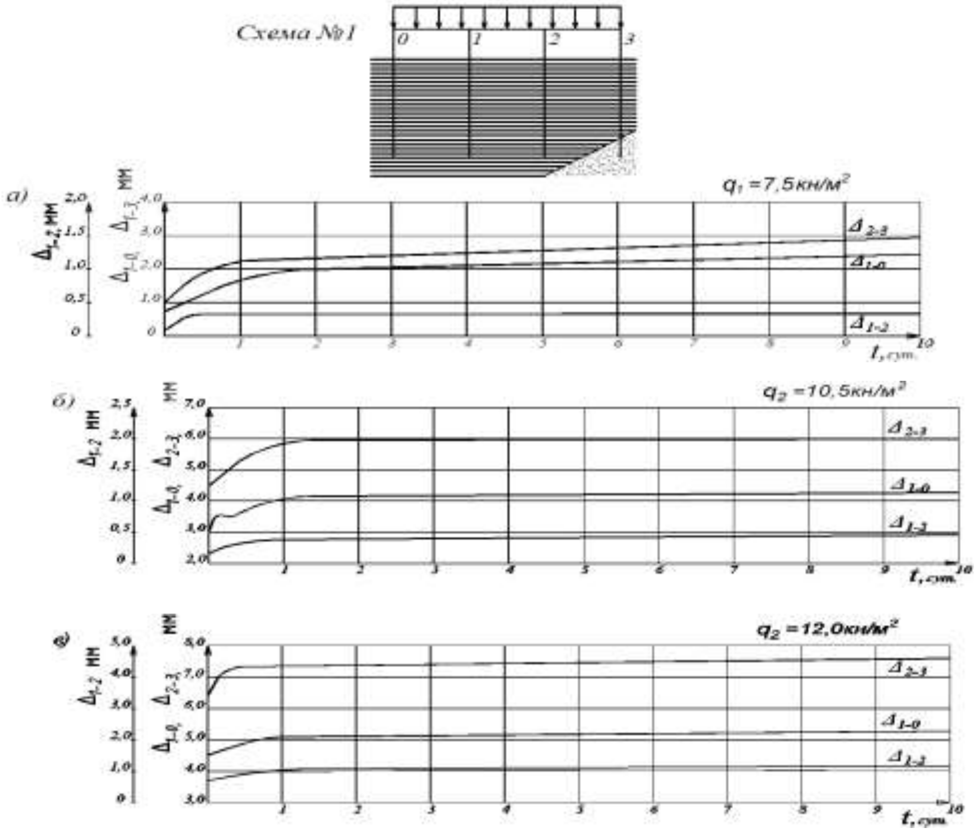
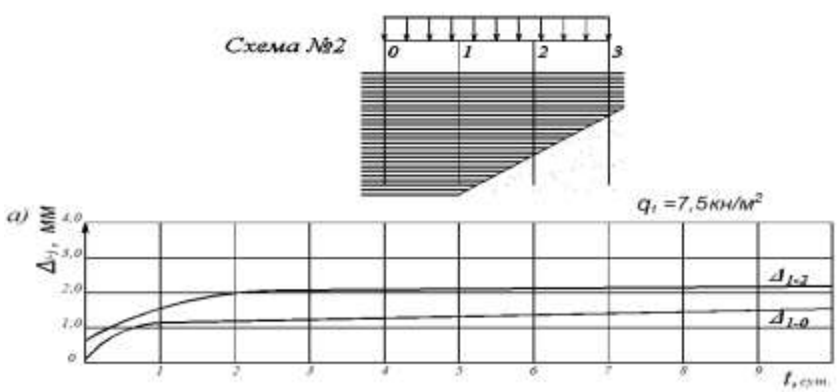


Fig. 4 Graphs $\Delta_{i-j} = f(t)$ for operation scheme №1 (crossbar stiffness EJ_1=0.120 GPa см^4)



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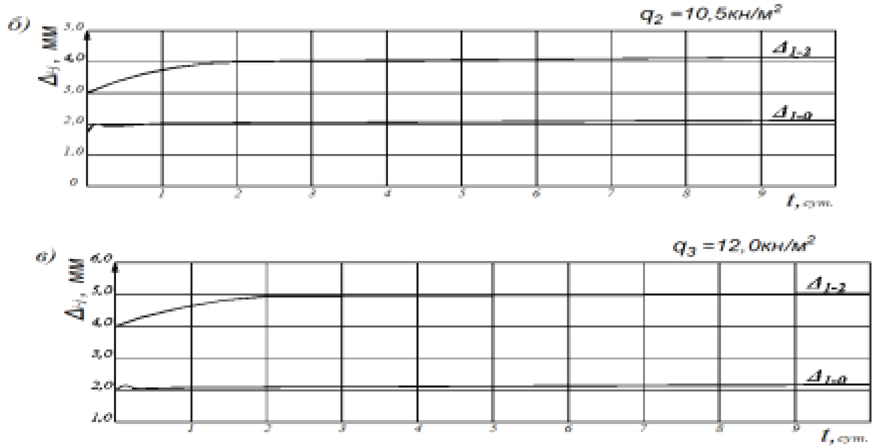

Fig.5 Graphs $\Delta_{i-j}= f(t)$for operation scheme №2 (crossbar stiffness *EJ₁*=0.120 GPa.см^4)

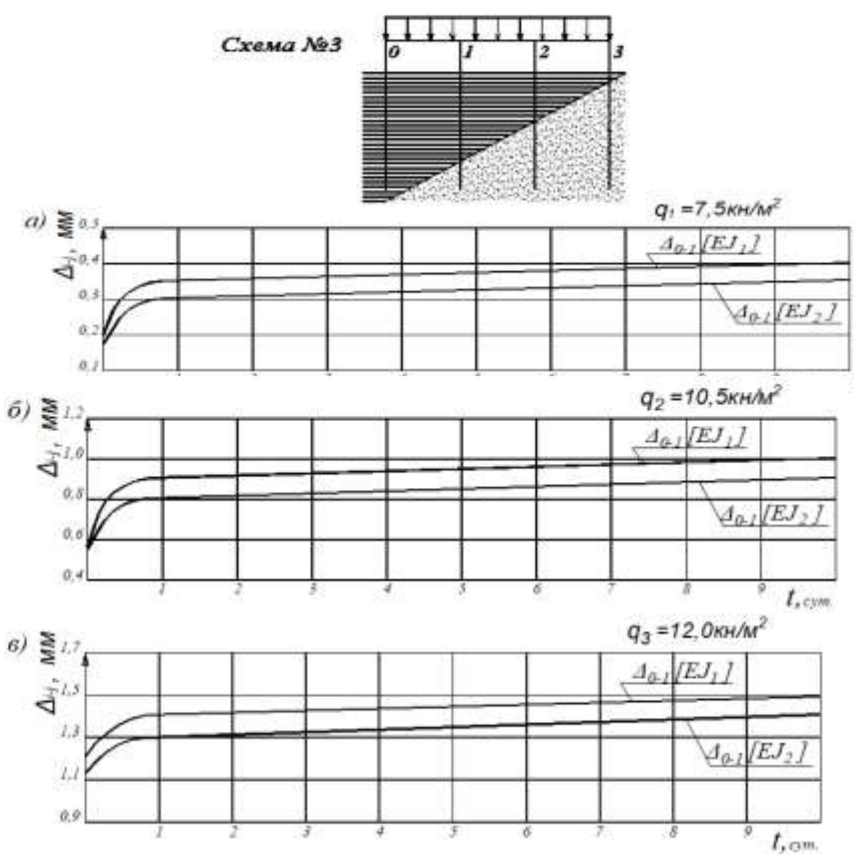

Fig. 6. Graphs $\Delta_{i-j}= f(t)$ for operation scheme №3 (crossbar stiffness EJ_1=0.120 GPa. см^4 and EJ_2=0,280 ГПа.см^4)

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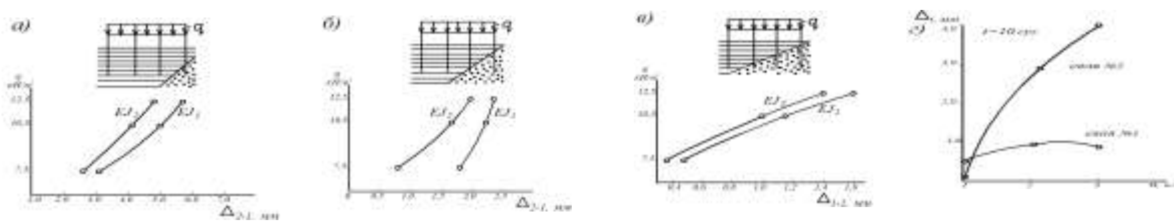
The results of the experiments carried out with the girder stiffness EJ_2=0,280 GPa.cм^4 (Fig. 6) showed that the above-mentioned patterns are also preserved for all experimental schemes, but the growth rates of the relative displacements of the supports are noticeably reduced.



n- number of pile groups in clay

Fig. 7. Graphs $\Delta_{i-j}= f(t)$ (a, b, c), respectively, for the 1st, 2nd and 3rd schemes of soil conditions shown in Fig. 3 and graphs Δ_i=f (n) (g).

The findings of laboratory studies presented in Fig. 4-7 reveal a strong nonlinear relationship between the absolute value of the supports' settlement - (Δ) and the number of groups of piles resting on the soil deforming over time - (n) (see Fig. 7). The rate of increase in settlement over time is determined by the value of (n) and varies between pile groupings. As a result, the difference in the settlement of neighboring supports varies with time, generating redistribution and an increase in bending stresses in the girder and axial forces in piles, according to the rules of statics.

Conclusion

The axial forces in particular groups of piles and the stresses in the grillage greatly rise with time due to the viscous subsidence of pile supports in time-deformed soil, as indicated by the findings of experimental studies of pile systems on heterogeneous foundations. The issues that must be considered in the design scheme for overpass structures on heterogeneous foundations, especially clay soils that deform over time, are covered in the following chapters:

- Fundamentally different axial compliance in pile groups that are fully in creeping soil versus those that are resting on non-creeping soil (the latter does not vary with time under a constant load);

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- The creep threshold of piles is dependent on the depth of their immersion in the earth (if there is an elevated slope beneath);
- All pile groups' initial elastic deformations.

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