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Evaluation of deformation properties of clay soils of technogenic structure under conditions of their performance in high embankment

Evaluation des propriétés de déformabilité des sols argileux à la structure technogénique en conditions de leur fonctionnement dans les hautes remblais

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ABSTRACT: Our investigations have shown that, when using the clay soils of moisture content higher than the optimum one in the high embankments (above 6 m), an individual design of such structure is required: evaluation of embankment stability and predication of final settlement and settlement in time. A new methodology for evaluating deformation properties of the clay soils of technogenic structure as well as a new design apparatus for predicting their settlement have been developed on the theoretical-experimental basis.

RÉSUMÉ: nos études ont montré que dans le cas de l'utilisation des sols argileux à l'humidité dépassant la valeur optimale dans les remblais hauts (supérieurs à 6 m) il convient d'élaborer des projets individuels de cette structure en tenant compte de l'évaluation de stabilité du remblai, de la prévision du tassement définitif et du tassement dans le temps. On a élaboré à la base théorique et expérimentale la nouvelle méthodologie pour évaluer des propriétés de déformabilité des sols argileux de structure technogénique ainsi que le nouveau appareil de calcul pour prévoir leur tassement.

1. INTRODUCTION

On the territory of Russia, a major part of cohesive soils in natural strata occur in the overwetted state due to climate conditions.

In recent years, builders have to use such soils in an ever increasing quantity in road embankments. The use of these soils in the working layer is rigidly restricted by specifications. However, a demand every so often arises in their employment for the subgrade portion underlying the working layer, particularly in the high fill construction. In these cases, the only possible way of using local clay soils is to lay them into the fill at natural moisture content. This is connected with a number of technical – and – economic reasons (expanding the road construction in the regions of excessive moistening, the lack of soils meeting the construction specification near construction sites, and an increase in transportation cost) as well as with environmental constraints. In addition, the use has to be made of the soils from overwetted cuts when embankments are built on rugged terrain, etc.

When the above soils are used in the road embankments of any height, an individual design is performed if an individual structure is substantiated by computation.

This is brought about by the necessity to solve not only problems of technology, laying in the fill, but also those of ensuring the stability and avoiding inadmissible settlements in the high embankments under their dead weight.

2. PECULIARITIES OF DEFORMATION PROPERTIES OF OVERWETTED CLAY SOILS

When designing an embankment structure, as a first approximation, it is possible to apply the theoretical apparatus developed for soft soils in the foundation. However, one should take into account that in the case of the embankment, we deal not with the natural soil structure, as is in the case of the foundation, but with the technogenic one that has been created in the process of technological operations at the embankment construction. The soil is subjected to the mechanical action during operations of its working out, transportation, and laying into the fill. On the one hand, the natural aggregates of lower strength disintegrate and, on the other hand, the newly created technogenic aggregates acquire an additional strength.

The technogenic structure created depends on conditions of soil occurrence, natural humidity as well as a type of construction equipment and a mode of its operation. The studies have shown that such structure influences the physical-and-mechanical properties of the soil and its behaviour under the action of various factors and in time. This especially holds true for the soils with a coefficient of moistening (the ratio of the initial moisture content to the optimum one at standard compaction) in the range of 1.1 to 1.5.

The above said proves that, when designing the embankment structure, it is required to apply the special theoretical apparatus that takes into consideration specific features of the technogenic structure and specific properties

of the soils of moisture content higher than the optimum one.

The multi-year studies of deformation properties of clay soils (Methodical recommendations 1986; Dobrov et al 1992; Kuzakhmetova 1994) with moisture content higher than the optimum one have shown that, under the conditions of compression tests, their relative deformation can be 0.01 to 0.2 depending on initial moisture content (in the range of 1.1 to 1.5 W_{opt}) and a magnitude of compaction load (0.02 to 0.5 MPa).

In addition, new regularities have been established for the process of settlement in time of such soils. They are conditioned by the technogenic structure, three-phase state, initial moisture content and density, and performance conditions (load magnitude and mode of application, drainage and a distance from the draining course). The difference between consolidation of the soils of technogenic structure and that of the soils of undisturbed structure is in the appearance of the new first stage of consolidation (pre-filtration stage). The rate of this stage development is governed by the compression of entrapped air and soil aggregates. One more difference is the appearance of a stage of the secondary filtration consolidation. The rate of its development is controlled by squeezing out loosely-bound water which movement departs from Darcy's law.

In a general case, the consolidation of the above soils (after conditionally-instantaneous settlement) can include four stages: pre-filtration consolidation, primary consolidation, secondary consolidation, creep consolidation (open system). The stages of consolidation are distinguished by a geometric feature when building a consolidation curve of type $\lambda=f(\lg t)$ where λ = relative deformation and t = time of its development

Depending on the initial state of the soil and a magnitude of the compaction load, the number of stages and their combination change.

For instance, variants can be as follows:

- pre – filtration consolidation and creep consolidation (closed system);
- pre – filtration consolidation, secondary consolidation, and creep consolidation (open system).

In this connection there arises a need for introducing a criterium for evaluating conditions of the development of filtration consolidation. As such criterium, the author proposes to apply an initial gradient of filtration consolidation ($i_{i.f.c.}$) instead of an initial gradient of filtration i_0 . This gradient will be created in the soil under compaction load $P=P_{i.f.c.}$, under the action of which the structural compression strength of soil (P_{str}) is exceeded and simultaneously a gradient of head, $i_{i.f.c.}$ higher than i_0 , develops in pore water. In this case the primary filtration consolidation and the secondary one will occur. For two-phase soils a value $P_{i.f.c.}$ is close to a value P_{str} while for three-phase soils $P_{i.f.c.} > P_{str}$. For the investigated clay soils of increased moisture content, the values of $P_{i.f.c.}$ obtained are in the range of 0.075 to 0.25 MPa depending on the initial moisture content.

For the first and fourth stages of consolidation a parameter "m" is proposed as a consolidation characteristic. It presents a slope angle of a rectilinear part of relationship $\lambda = f(\lg t)$ to axis of time. For the second and

third stages a coefficient of consolidation "c" is proposed as a consolidation characteristic. The parameter "m" can vary from 0.001 to 0.01 and the parameter "c" from 0.01 to 0.1 cm^2/min .

In the process of our study a need was established to simulate in the experiment the following: initial structure of soil, its initial density-moisture content, and conditions of its performance in structure (a regime of the embankment construction, an open or closed system, a gradient of pore water squeezing out). As a result, a scheme for the embankment design should be made up taking into consideration: stressed-strained state of soil in the embankment, stress value under dead weight, gradient of water head, a distance of the design layer from the drainage one, conditions of the open or closed system.

The most complete consideration of conditions of the soil performance in the embankment structure during an experiment allows to increase an accuracy of the evaluation of soil deformation properties. The most detailed scheme of the embankment design permits to improve the reliability of computations of possible deformations.

Let's consider an embankment structure 15 m high. Its working layer is 1.5 m, sandy loam layer – 1.5 to 5 m; clay soil layer of increased moisture content – 5 to 10 m; sandy loam layer – 10 to 15 m. The load on the surface of the clay soil layer from the overlain soil weight is $P = 0.1$ MPa and the load in the bottom is $P=0.2$ MPa. The structural compression strength of clay soil (P_{str}) is 0.1 MPa. This means that the active zone of the embankment, where soil compaction will take place because $P > P_{str}$, includes a clay soil layer of 5 to 10 m. According to the existing methods (Methodical recommendations 1992) the way of water filtration from the above layer is 5 m. However, it is the author's opinion (Kuzakhmetova 1994; Kuzakhmetova 1998) that conditions for mechanical squeezing out of pore water can be created not in all cases and not through the whole layer. So, at a definite moisture content and density of the soil, $P_{i.f.c.}$ can be 0.15 MPa. In this case, only in a portion of the layer from 7.5 to 10 m, the conditions will appear for development of the filtration consolidation (the open system). The filtration path of water will be 2.5 m. A part of the above layer from 5 to 7.5 m in the active zone will present the closed system. It is apparent that for these systems different formulae should be applied to predict the time of completing the intensive part of consolidation. In addition, for such difference in values of the filtration path one will obtain essentially different time periods of completing the intensive part of consolidation. This example proves the necessity to introduce a new criterium for predicting the embankment settlement.

When forecasting the time of the settlement development, it is required to take account of the variability in consolidation characteristics of clay soils (c) in the process of static compaction as well as the variability in layer thickness, and hence, in the filtration path of squeezed – out water (H_f). The simplest way of considering the above is to apply, in the existing formulae for settlement computation, not initial values of c and H_f but the average ones between the initial and final values obtained during the compaction under the design load.

3. PRINCIPLES OF PREDICTING THE SETTLEMENT OF OVERWETTED CLAY SOILS

The above recommendations make a part of those proposed in the new methodology for predicting the settlement of the embankments of clay soils of moisture content higher than the optimum one.

The main principles of the embankment design method that concern the settlement prediction are as follows:

1. Obtaining comprehensive information on soil composition, state and properties, including those at the time of construction, on the basis of engineering – geological investigations.
2. Evaluating conditions of the soil performance in the structure based on the preliminary design of its geometric dimensions, design elevation, and layer position.
3. Determining indices of physical-and-mechanical properties on specimens of specified moisture content and density as well as by simulating the soil performance in the embankment structure.
4. Adopting the embankment structure based on the conditions of its stability. Separating the active zone.
5. Separating the parts in the active zone that perform under conditions of the open and closed systems.
6. Separating the design layers that are characterised by the same stressed-strained state in order to assess their settlement.
7. Computing the final settlement of the embankment and its development in time.
8. Determining the terms of road pavement construction based on the time when an admissible intensity of the settlement is achieved.

These are the basic ways of considering the peculiarities in the deformation properties of the clay soils of technogenic structure and moisture content higher than the optimum one when predicting their settlement. They allow to improve the reliability of the design of the embankment structure and to ensure the normal performance of the latter.

References

- Dobrov E.M., Lvovitch Yu. M., Kuzakhmetova E.K. et al. 1992. Clay soils of increased moisture content in road construction. M, Transstroy.
- Kuzakhmetova E.K. 1994. Present-day methods for predicting the settlement of soft soils in the foundation of engineering structures and in these structures themselves. Issue 7. M. Informavtodor.
- Kuzakhmetova E.K. 1998. Improvement of the quality of individual design of road embankments. Transportnoye Stroitelstvo № 8, M.
- Methodical recommendations on working out cuts in clay soils of moisture content higher than the optimum one and the use of these soils for road embankment construction in road-climatic zones II and III. 1986. M., Soyuzdormii.