USE OF LOCAL CLAY SOILS OF INCREASED MOISTURE CONTENT IN EMBANKMENTS

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ABSTRACT
New scientific and practical developments are presented on predicting the embankment settlement when using clay soils of increased moisture content. They deal with taking account of the influence of soil structure on character of its natural consolidation in the embankment construction as well as considering more fully the soil performance in structure.

KEY WORDS
EMBANKMENT/ SOILS/ INCREASED MOISTURE CONTENT/ CONSOLIDATION

At present the extension of road networks is performed mainly in areas unfavourable for construction and under conditions when the use of non-standard soils is required.
For instance, the road builders sometimes have to construct embankments from local clay soils that do not comply with the requirements as per their moisture content because their initial moisture content is higher than their optimum and allowable ones. Such soils possess maximum abhesiveness, low strength, and high compressibility.
In this connection when they are employed as building materials, it is necessary to use not only special technologies but also appropriate structural solutions. It should be noted that technological properties of clay soils of increased humidity are studied to a greater extent than mechanical ones. However, due to the fact that there occur inadmissible deformations in the embankments built from clay soils of moisture content higher than optimum one (even in the case when the required density has been achieved), the scientists are forced to consider the behaviour of those soils and to evaluate their strength and deformation properties. It is especially urgent when applying the method of natural consolidation of soils of moisture content higher than an allowable one in the embankment body under loading from the weight of overlying layers.
The approach accepted for studying deformation properties of the above soils is of particular interest.
Specialists of the subgrade laboratory of Soyuzdornii have studied compressibility of clay soils of increased moisture content with taking into account their structure generated in constructing the embankment, i.e. in the process of technological operations, as well as the soil performance in the embankment (Kuzakhmetova,1994).
There are no yet analogues of similar studies in road science. It has been concluded that the created structure of clay soils in the embankment differs from the natural one in its composition, condition, and component location.
Therefore, a new notion of “artificially created or technogenic structure” has been introduced and a model of such structure has been developed.
Clay soils of technogenic structure according to the model consist of:
- technogenic aggregates formed from natural ones differing in shape, size, and strength of interconnections;
- bound water that is not continuous and has a changed composition as compared with natural one (similar to gaseous phase);
- entrapped air in technogenic and natural aggregates.

Determining a quantitative content of liquid and gaseous phases made it possible to conclude that the embankment soils of moisture content higher than optimum one are in a three-phase state. On the basis of the above model the theoretical and experimental investigations of deformation properties and regularities of static compaction of clay soils with technogenic structure have been conducted.

It is found that in the case of the increased moisture content of soils and their density below the required one, the soil layer settlement can amount 0.2-0.4 of its thickness. Detailed studies of character of the layer settlement in time have been carried out. New regularities of consolidation process of such soils have been established. These regularities are conditioned by the soil technogenic structure, three-phase state, initial moisture content, and density as well as by the regime of embankment construction and drainage conditions.

Distinction of consolidation of soils with technogenic structure from that of soils with natural (undisturbed) structure is in the appearance of the new first stage of consolidation (pre-filtration consolidation) and the second stage of filtration consolidation referred to as the second filtration consolidation. Thus, in the general case the clay soil consolidation in the embankment (after conventionally-instantaneous settlement) can involve four stages: pre-filtration, primary filtration, secondary filtration, and consolidation of volume creep. The rate of developing the above stages depends on:

- the first stage - moisture content, water squeezing from the surface, gas comperssion, elasticity of all components, technogenic aggregate compression, and natural aggregate repackage;
- the second stage – velocity of filtration of free water the movement of which is subject to Darcy’s law;
- the third stage – squeezing velocity of bound water the movement of which is subject to Darcy’s law;
- the fourth stage – visco-plastic shear of particles and aggregates in some soil volume.

A new pattern of developing the settlement in time of clay soils with technogenic structure, differing significantly from the traditional one, as well as peculiarities of soil performance in the structure made it necessary to work out a new theoretical apparatus and new criteria for evaluating conditions of soil performance (Kuzakhmetova, 2001).

The following consolidation parameters are proposed for practical calculations of the embankment settlement in time when using clay soils of increased moisture content:

- angular coefficient to the time axis (curve in semi-logarithmic scale) at the first and fourth stage;
- consolidation coefficient or index of consolidation degree at the second and third stages.

Generally the consolidation equation for clay soils of the embankment is as follows:

$$\lambda(t_i) = \lambda_{inst} + m' \lg\left(\frac{t_i}{t_{inst}}\right) + f_1(c_1, n_\varphi) + f_2(c_2) + m'' \bullet \lg\left(\frac{t_i}{t_\varphi}\right)$$

where

$\lambda(t_i)$- relative deformation at time t_i;

t_{inst}, t_φ – time of completing the conventionally - instantaneous settlement and secondary filtration consolidation, respectively;

m', m'' - angular coefficients to the time axis at the stage of prefiltration consolidation and volume creep consolidation, respectively;

c_1, c_2 – consolidation coefficients at the stage of primary and secondary filtration consolidation, respectively;

n_φ – water filtration path from a sample.

In this case, $t_i > t_{inst} > t_\varphi$. Stages of consolidation are distinguished by a geometric feature on consolidation curve of the type $\lambda = f(\lg t)$.

Since predicting the settlement we are interested in the beginning of porous water squeezing and filtration through the soil compacted, the initial gradient of filtration consolidation is proposed as such criterion rather than the initial gradient of water permeability. The initial gradient of filtration consolidation will be generated in soil under the action of the definite compaction load (soil weight) in every particular case. The load value can be determined from the results of consolidation tests of identical samples under various drainage conditions (Kuzakhmetova, 2001).

By comparing the load value found at the beginning of porous water mechanical squeezing out with the load acting at one or other embankment horizon, the zone where the soil performs under conditions of open system is determined. Beyond the above zone, the soil works under conditions of closed system. This means that predicting the natural consolidation of clay soils of increased moisture content is predetermined by the system in which the soil performs.

The character of system governs both methods of soil tests and the choice of design relationships. It’s quite clear that the introduction of the new evaluation criterion increases the accuracy of calculations of the time for achieving the required density-moisture content of soils as well as the required degree of their consolidation to exclude the embankment deformation inadmissible in magnitude and intensity, which, in its turn, predetermines the time of road pavement construction. The example of such design is given in (Kuzakhmetova, 2001).

Thus, developing the approach to the evaluation of structure of clay soils of increased moisture content, determining peculiarities of their consolidation process, proposing new criteria of soil performance in the embankment, and the new design apparatus for settlement prediction improve the reliability of individual design of high embankments from local non-standard soils, in particular it concerns the determination of soil layer thicknesses, their optimum position in the embankment, and the time of road pavement construction.

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