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Study of the Deformability of Bulk Soils at Increased Stresses

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ANNOTATION: In the article the question of the influence of the stress level on the deformability of loose soils is considered. The results are presented, analysis and comparison of the results in compression, shear devices and in triaxial compression devices are made.

ANNOTATION: This paper is devoted to the study of the peculiarities of the deformation of fractured soils when exposed to high values of stress. The article examines the results of experiments conducted on various instruments and draws appropriate conclusions.

KEYWORDS: Deformability, stress, crushing of sand particles, dilatancy (volumetric deformation due to tangential stresses), crushing of mineral particles of the skeleton, elastic compressibility of the constituent components of the soil, stress level, loose soils.

KEYWORDS: Deformation, stress, fracture of sand particles, dilatation (volumetric deformation under the influence of applied stresses), fracture of mineral particles of the soil skeleton, elastic compression of soil components, stress values, fractured soils.

In soil mechanics, there is no generally accepted classification of stresses. We propose the following classification of stresses: stresses up to 1.0 MPa are called low; from 1.0 to 10.0 MPa - increased; from 10.0MPa to 100MPa-high; 100 to 1000MPa is very high.

The construction of high dams, multi-storey buildings, and the construction of deep foundations requires the study of the deformability of soils in the stress range up to 10.0 MPa, and solving the problems of geomechanics and behavior of soils during blasting operations requires studying the characteristics of the behavior of soils at stresses above 100 MPa.

... Compression studies of sandy soils at stresses up to 50.0 MPa showed the fact of crushing of sandy particles. Particle crushing is accompanied by a characteristic crackling sound.

Investigations in shear devices show that shear at normal stresses up to 2.5-3.0 MPa occurs at critical porosity. At the same time, dense sands are loosened and loose ones are compacted, while shear at normal stresses greater than 3.0 MPa proceeds differently. Sandy soils, regardless of their initial density, are only compacted. This process is explained by the destruction of the sThe influence of the stress level, both from the point of view of the physical characteristics of deformation and the development of the stress-strain state, is most fully studied in triaxial tests.

There are three phenomena that are characteristic and have a great influence on the deformability of sandy soils:

- 1) Dilatancy (volumetric deformation due to shear stresses),
- 2) crushing of mineral particles of the skeleton,
- 3) elastic compressibility of the constituent components of the soil.



The phenomenon of dilatancy of granular materials discovered in 1884 by O. Reynolds is one of the most important properties of soils that affect their deformability.

The initial state and mineralogical composition of soils have a great influence on the dilatant properties of soils. The more dense samples in the initial state correspond to more intensive loosening in the limiting state. Loose, in the initial state, samples can collapse without loosening.

With an increase in the stress level, particle fragmentation is observed, which affects a decrease in the intensity of dilatancy. At lateral pressures in the stabilometer up to 0.1 MPa, the destruction of particles is practically not observed. However, with an increase in the lateral pressure to 1.0 MPa, a change in the grain size composition is already observed. Crushing increases significantly with increasing lateral pressures up to 10 MPa. At high lateral pressures, dilatancy practically disappears in both dense and loose sands, so in both cases dilatancy is suppressed by intense fragmentation of particles.

One might think that, in comparison with the crushing of particles, the effect of their elastic compressibility on the deformability of soils is much less. However, as the results of experiments show, with an increase in the level of stresses, an increase in the elastic deformations of particles and the formation of local microplastic zones at the points of contact greatly facilitates the movement of particles and decreases the angle of internal friction.

Thus, the crushing of particles and their elastic compressibility increase the deformations of the soil and reduce the intensity of loosening in the limiting state and grains themselves.

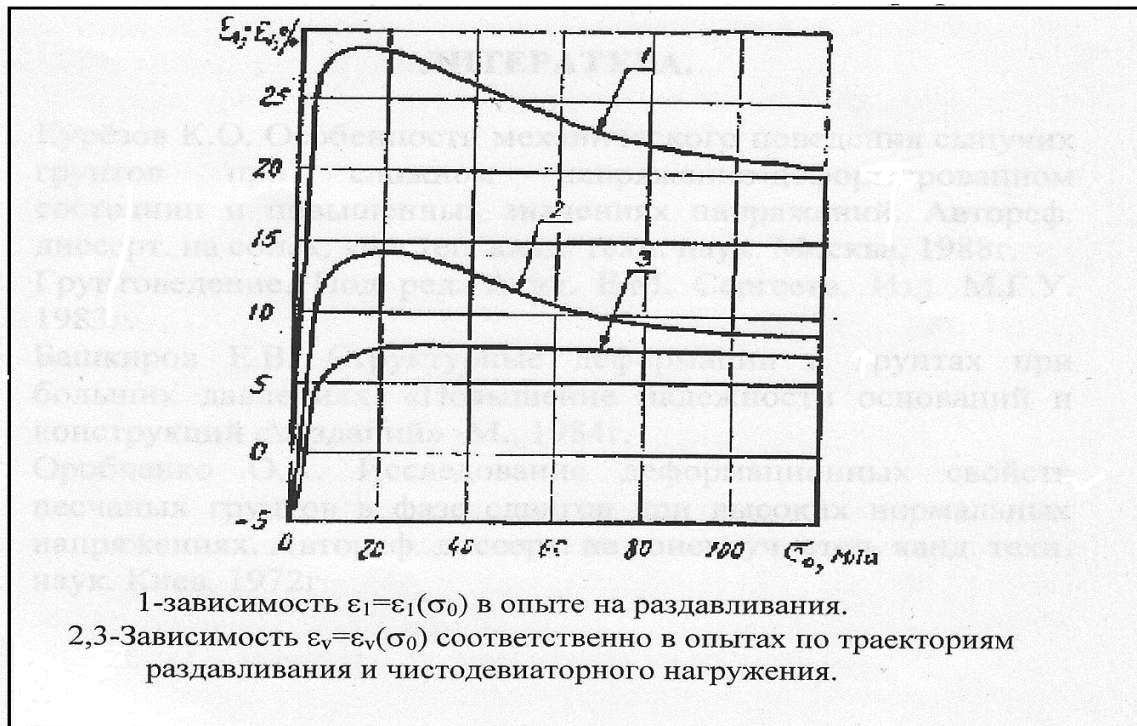
The results of some studies show significant changes in the deformability of sandy soils of different initial density with an increase in the level of acting stresses. Loose sand at lateral pressures of 0.7 MPa is destroyed by loosening, and an increase in lateral pressures up to 7.0 MPa leads to intensive compaction. With a further increase in lateral pressures to 28 MPa, the increment in volumetric deformation is insignificant. Dense sand at lateral pressures of 0.7 MPa collapsed with intense loosening, and an increase in pressure to 3.5 MPa led to a slight compaction during destruction. A further increase in lateral pressures caused the crushing of sand particles and the samples collapsed with intense compaction.

Experiments show that volumetric deformations under deviatorial loading are greater than under hydrostatic compression, and this difference increases with increasing stress levels.

The question of the influence of an increase in stresses on the value of axial and volumetric deformations during fracture was studied. Ultimate (axial and volumetric) deformations under conditions $b_2 = b_3 = \text{const}$ increases with an increase in the average stress and reach maximum values at $b = 10.0$ MPa. With a further increase in stresses, the limiting strains (axial and volumetric) decrease. With purely deviatorial loading trajectories, an increase in ultimate strains during fracture to values of $b = 10$ MPa is also observed, and with a further increase in stresses, they remain unchanged.

The dependence of the axial and volumetric deformation of sand during fracture on the value of the average pressure is shown in Fig. This character of the curves is explained as follows. With an increase in average stresses up to 10-20 MPa, contact stresses increase and, being greater than the strength of the particles themselves, cause their crushing. This leads to a decrease in the average grain diameter and a sharp decrease in contact stresses to a value comparable to the strength of the particles. The effect of crushing on shear and volumetric deformations decreases and the maximum values of volumetric and axial deformations tend to constant values during fracture.

This character of the curves is explained as follows: With an increase in the average stress to 10-20 MPa, the contact stresses increase and, being greater than the strength of the particles themselves, cause their crushing. This leads to a decrease in the average grain diameter and a sharp decrease in contact stresses to a value comparable to the strength of the particles. The effect of crushing on shear and volumetric deformations decreases and the maximum values of volumetric and axial deformations tend to constant values during fracture.



An increase in the level of stresses significantly affects the deformability of the soil and up to the limiting region. The relative role of the loading trajectories and the influence of the type of stress state decreases; therefore, the degree of uniqueness of plastic deformations from the combined action of the two basic invariants b and b_i increases. The calculated dependences defining deformations approach simpler ones, since the physical law of deformability is simplified.

As can be seen, there is a different opinion about the influence of an increase in the level of stresses on the deformability of soils in the prelimit and in the limiting state, which indicates the need for further study of these issues. In conclusion, we note that extrapolation of the data for determining the deformability obtained at stresses of 0.3-1.0 MPa to the case of describing the deformability at stresses of 10-15 MPa cannot be recommended when solving practical problems of soil mechanics in modern large-scale hydraulic engineering and power engineering.

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