# Triaxial Compression Tests of Macrofragmental Soils

**Mirnyy A.Y.**, Lomonosov Moscow State University, Moscow, Russia
**Idrisov I.Kh.**, OOO “GEOTEK”, Penza, Russia

In accordance with GOST 25100-2020, macrofragmental soils are grained soils containing more that 50% particles larger than 2 mm, according to its granulometric composition. This definition includes a large number of soils of natural and technogenic origin, that are commonly found. But the presence of large inclusions significantly complicates the direct determination of these soils’ properties both by in situ and laboratory methods. Properties are often determined basing on the finely dispersed filler. For sandy filler this results in understating of stiffness, and for silty-loamed filler this fails to consider cohesion, since the structure of the filler becomes damaged. Technically, this approach is only valid when the mass content of the filler exceeds 40%. However, in this case 60% of coarse particles are not considered in the calculation.

This problem was more often examined by specialists in hydraulic engineering. And most frequently only exact soil type, assumed to be used as a dam material, was considered. Another area that requires determination of mechanical properties of macrofragmental soils of natural and artificial origin is construction of waste rock dumps and embankments. Thus, in civil engineering, the question of the mechanical parameters of macrofragmental soils determination has been studied extremely poorly.

Direct laboratory methods of determining the parameters of macrofragmental soils were sometimes used when designing hydraulic structures and nuclear power facilities. Instruments for compression, shear and triaxial testing of the samples up to 60 mm in diameter were available at the Iinstitute "Gidroproekt" and Vedeneev VNIIG. In particular, the team of authors of the Institute "Gidroproekt" with the involvement of Yu.K. Zaretsky developed recommendations for conducting such tests and interpretating their results. At present, such tests are not performed or are performed extremely rarely in Russia, according to the authors.

It is advisable to perform laboratory determination of mechanical parameters of macrofragmental soils with sandy and silty-loamed fillers in triaxial compression instruments. However, due to presence of coarse fractions, testing requires cells designed for samples of significant size. In accordance with GOST 12248, the sample diameter must be at least 6 times larger than a diameter of the largest inclusion. At the same time, absolute sample sizes are not specified in GOST, which allows to use any equipment according to this document.

OOO “GEOTEK” offers triaxial compression testing systems, that include a set of kinematic loading device with an ultimate vertical load of 500 kN, a lateral pressure supercharger with a maximum pressure of 2 MPa, control units, a type "A" triaxial compression cell for samples with a height of 600 mm and a diameter of 300 mm and a personal computer. One of them was delivered to the laboratory of SEC "Geotechnics" of the MSUCE in 2015. Despite the non-standard technical characteristics related to large sample size, absolute values of moving and vertical forces, this equipment meets the general requirements for configuration, design, measuring devices and calibration of systems for triaxial compression tests of soils according to GOST 12248. Nevertheless, the significant sizes of the sample bring some details to testing.

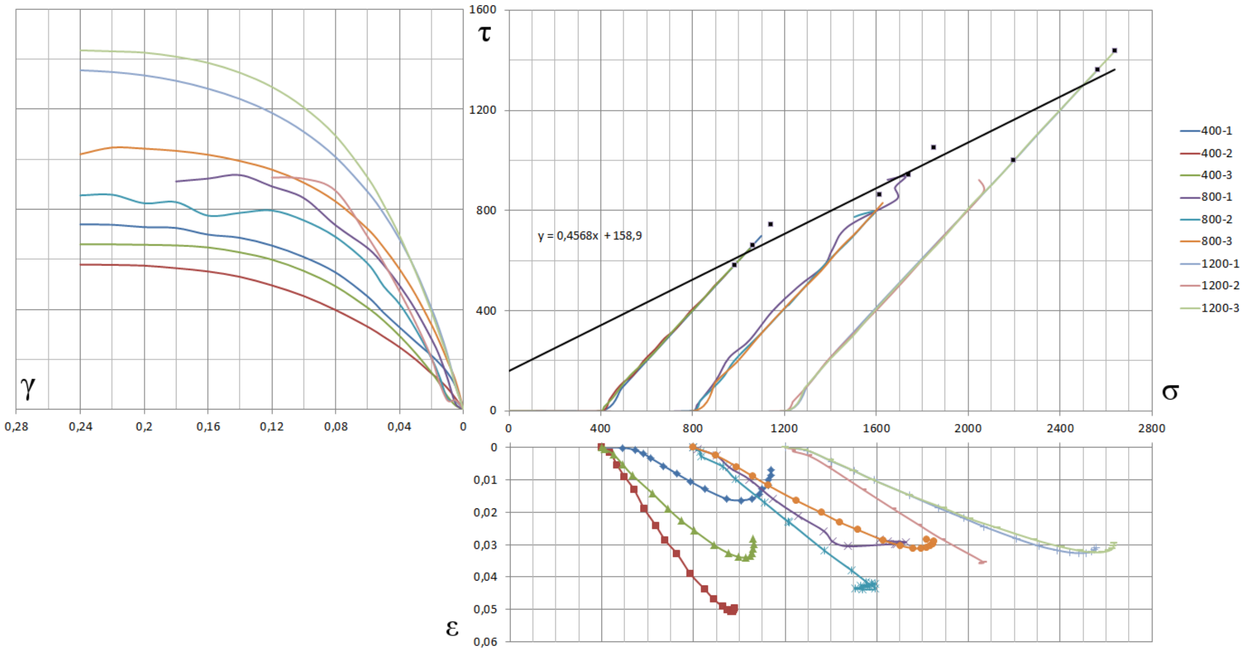
The cross-section area of the sample is 0.07 $m^2$, as a result of which the loading device should generate a considerable force to create stresses sufficient to destroy the sample even with relatively small side reduction. This, in turn, results in increasing requirements for strength of materials and intrinsic strains of the loading device. In addition, to achieve 15% of relative vertical strains, the piston stroke should not be less than 90 mm. These characteristics set limitations on the mechanism of loading device, without making it possible to use pneumatic and lever systems. This installation implements an electromechanical piston drive using a stepper motor.

Measuring radial and volumetric strains is rather complicated. The quality of the sample is recognized as satisfactory if volumetric strains do not exceed 4% during reconsolidation. Since the volume of the sample is 42 liters, in absolute terms, such strains correspond to a volume of 1.7 liters. These values make it impossible to use differential sensors to measure the volume of displaced liquid. In this regard, a 4.2-liter supercharger is used to create pressure in the cell. It is noteworthy that for artificially made samples this volume is not sufficient sometimes. During the test it is necessary to replenish the supercharger and correct the volume change when processing the results.

Similarly, a significant volume of the instrument cell (about 100 L) leads to its intrinsic volumetric strain, that is commensurate with volumetric strain of the sample. During the calibration with a metal blank instead of a sample, it is found that intrinsic strains of the cell and liquid are about 0,8L, of which only 80ml is due to the compressibility of the liquid.

Degassing of such a volume of liquid and the complete removal of air bubbles from the cell is a great difficulty. However, when processing test results in accordance with GOST 12248, it is necessary to take the volume at the stage of completed consolidation as initial sample volume. Thus, the quality of measurement of the volume change when deviatoric loading is crucial. Since the pressure in the cell is kept constant, the intrinsic compressibility of the liquid at this stage does not affect the measurement result. This does not imply that during the tests, degassing of the liquid and vacuum pumping of all channels can be disregarded, but the measurement quality can be considered as satisfactory, because the intrinsic volumetric strain of the liquid at the maximum pressure is only 80ml.

This equipment has been successfully used when constructing many hydraulic, nuclear power and industrial facilities. A comparison of various methods for determining the mechanical parameters of macrofragmental soils was also carried out, which showed that empirical methods cannot replace direct tests in any case.




An example of failure envelope of macrofragmental soil

Direct triaxial tests of macrofragmental soil allowed determining all mechanical properties of the soil, and a good convergence in the results was obtained after statistical processing. High cohesion is often observed due to structure of macrofragmental soils. Furthermore, this determination method is the only one that allows to determine the Poisson's ratio for macrofragmental soil, that significantly affects the formation of horizontal stresses in the soil body. Some disadvantages of this method are significant size of the samples and difficulties in their transporting, and as a result, the higher cost of the experiment. At the same time, refinement of strength characteristics increases the payback of this type of survey due to cost-effective design solutions.

OOO "GEOTEK" proposes the large scale soil triaxial apparatus for axisymmetrical triaxial tests of the samples of macrofragmental soils up to 300 mm in diameter. The system includes type "A" cells for creating triaxial stress state, and also the necessary equipment for implementation of vertical force action, cell and back pressure management. Tests are carried out in an automated mode with control of all test parameters in real time. Cells for samples of other sizes can be made on a special order.