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Original Research Article

Comparison of sandy soil shear strength parameters obtained by various construction direct shear apparatuses

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ABSTRACT

An analysis of test results performed by common type of direct shear apparatuses shows that normal stress on the shear plane of soil sample is not equal to vertical component of distributed external load applied to the top of soil sample. Performed measurements cleared that only 65–85% of total vertical load is transmitted to the sample shear plane. Thus, determining of the soil shear strength depends on shear apparatus construction, i.e. on actual magnitude of vertical load transmitted to the shear plane. The paper presents an analysis of shear strength parameters of sand determined by two different construction of direct shear apparatuses with movable lower shear ring. The soil shear strength parameters by employing direct shear apparatus SPF-2 have been obtained under constant vertical load and measuring the vertical load at different positions, namely: at the bottom and that of at the top of soil sample, respectively. The soil strength parameters by employing the universal shear testing device ADS 1/3 were determined under two conditions, namely: by maintaining constant soil volume and that of for constant vertical load, respectively. In both cases the vertical load was measured at the top of soil sample.

1. Introduction

At present the direct shear and triaxial tests are the most common laboratory tests for determining soil shear strength parameters. Direct shear test is the most widely applied method in Lithuania. Direct shear and triaxial tests are widely applied in other countries [1,2]. An angle of internal friction φ (°) and a cohesion c (kPa) are the shear strength parameters of the Mohr – Coulomb strength criterion, generally being identified by the above listed methods.

Direct shear test is simple and relatively cheap method for determining the soil shear strength parameters. The construction of apparatus is not complicated, the test is fast to perform, the output data can be relatively easily processed to obtain the necessary parameters. Therefore the direct shear apparatuses are widely applied in an engineering practice and for research aims [5,11,16,20]. Despite an attraction of the method, the obtained experience and recognized factors leading to many inaccuracies (as e.g. discrepancy to introduced assumptions, boundary conditions, etc.) raise a

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necessity for deeper analysis and subsequent improvements to ensure the more reliable and adequate testing and data processing methods using this technique [4,18]. The efforts are applied to eliminate/reduce an influence of unexpected factors, that influencing the accuracy of shear strength parameters to be determined [3,9,15,17]. But one can face the cases when the tools being employed to eliminate negative above mentioned factors of applied apparatuses induce the new additional negative factors.

The main mentioned negative factors met in practice of determining strength parameters via the usual direct shear apparatuses can be listed as follow: non-uniform stress and strain distribution in sample; the vertical compressive load applied on the top is not completely transferred to the sample; the actual distribution of normal load on shear plane is unknown; the testing conditions do not imitate a soil sample behavior in ground; one cannot perform the test under the constant volume condition [10,19,21]. The distribution of stresses in sample applying the direct shear box depends on: the way of vertical load transmission; the position of the movable part of shear ring; the horizontal displacement of the movable part of the ring; the shape and stiffness of the loading plate; the clearance between the upper and the lower rings of the box [3]. Generally it is assumed that vertical load applied onto the top of shear box specimen is completely transmitted to the soil shear plane. Hence the frictional force mobilized between the specimen and that of the vertical walls of the shear box is not taken into account [12,13]. It is obvious that the above listed reasons influence to the accuracy of determined actual soil shear strength parameters. All the above factors finally result that shear strength parameters to be either underestimated (for contractant soils) or overestimated (for dilatant soils) [6,7,14,22].

The performed by authors measurements of normal stress in the shear plane showed that it is of 65–85% magnitude of vertical force applied on the top of the sample. The tests have been performed by direct shear apparatus SPF-2 with movable lower shear ring. The normal stress magnitude on the shear plane also depends on the magnitude of horizontal displacement (varying from zero till the fixed magnitude) of movable part of shear box during the testing procedure. The testing procedure was stopped when the following requirements have been reached, namely: the horizontal displacement reached 6 mm, and the normal stress on the shear plane exceeded 10% of normal stress being developed on the top of the dense sample. The vertical load to the soil sample was applied via the loading plate by using the special lever mechanism. When the horizontal (lateral) force is applied, the soil in the front of an upper ring is lifted, and in the contrary side of upper ring the soil moves down. The tangential stresses being developed at internal surface of upper ring front is much larger the ones being developed at the internal surface of the contrary side of the upper ring. The developed frictional forces between ring and sample will be larger in the front of the upper ring.

So one can conclude, that the soil shear strength depends on construction of the shear apparatus. Hence aiming to reduce the influence of shear apparatus construction on experimentally determined shear strength parameters, one should manage the actual regularity of normal stress distribution in shear plane.

The performed investigation is assigned to an analysis of determined shear strength parameters of sandy soil being obtained with two different constructions of direct shear apparatuses with movable lower shear ring. The tests with apparatus SPF-2 have been performed under constant normal stress and by measuring the vertical load at the top and at the bottom of the sample, respectively. The direct shear tests with apparatus ADS 1/3 have been performed under two conditions: by maintaining the constant soil volume and by measuring the vertical load at the top of soil sample, and that of by applying the constant vertical load and by measuring the vertical load at the top of soil sample, respectively.

2. Construction of employed direct shear apparatuses

The shear tests with modified standard apparatus SPF-2 have been performed at Laboratory of Department of Geotechnical Engineering of Vilnius Gediminas Technical University. Modification of apparatus has been developed via implementing a vertical load measuring system at shear plane. The principal scheme of employed apparatus is given in Fig. 1.

When applying the modified direct shear apparatus SPF-2 it is possible to measure not only the vertical compressive force applied onto the sample, but also the normal stress transferred on the shear plane. For determining the normal force acting on the shear plane the load transducer is placed onto the lower ring. One can also perform the test under the constant volume. The cut cone loading plate, that reducing probability of contact between ring and loading plate, is employed. The loading plate can freely tilt.

The vertical load is transmitted to the sample via a hinge transmission applying the lever mechanism. Such method of loading ensures constant vertical load magnitude on the top of sample i.e. developing constant normal stress per whole loading history. During test the normal load is measured at the bottom of the sample. The sample is sheared by moving with a constant velocity the lower part of the ring. Thus, the shearing velocity is controlled and the lateral force is permanently measured.

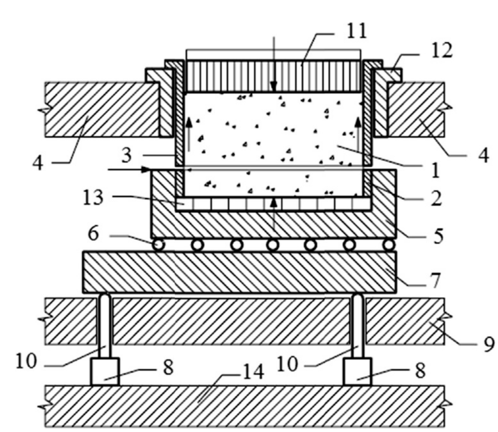

Fig. 1 – Principal scheme of modified shear box apparatus SPF-2: 1 – soil; 2 – lower ring; 3 – upper ring; 4 – fixed support; 5 – movable part of apparatus; 6 – bell track; 7 – lower part of apparatus; 8 – load transducers; 9 – table of apparatus; 10 – supports; 11 – loading plate; 12 – fixator; 13 – porous stone; 14 – plate of support.