INVESTIGATION OF STRESS DISTRIBUTION DURING LARGE SCALE SHEARING TEST

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1. Introduction

In 2007 a great developing process began at the University of Miskolc. The Geotechnical Soil Testing Laboratory – part of Faculty of Earth Science and Engineering – started to build a large-scale shearing machine. The goal was to build a modular machine with various functions for geotechnical science. The main ways that we determined were the possibilities to the traditional direct shear tests with different box sizes, the ability to perform tribologic investigations (e.g., between geosynthetic materials and soil or waste) and enough space to build in innovated technologies, for example pressure sensors. The large size could help us to make investigations at a wider range of loads and make tests with larger grain size as well.

In this study we represent an innovative solution to the direct shearing tests. The paper focuses on two main parts: the first is the new large scale shearing machine with a flexible control system, and the second is the creation of a special measurement protocol to determine accurately the stress distribution in a large shear sample during testing.

2. Large scale shearing machine

The main difference between the traditional and innovated equipment is the size. Usually the samples used for shearing measurements are square-shaped 100 mm x 100 mm x 20 mm or rounded with 100 mm diameter. Our large shear box's dimensions are 400 mm x 400 mm x up to 300 mm, but we may also apply a shearing box of 700 mm x 700 mm x 700 mm (Figure 1). The normal load may rise up to 22 tons. These dimensions provide the abilities to carry out investigations on larger samples and reduce the distortions of mechanical parts of the equipment [2].

Figure 1. Large scale shearing machine (University of Miskolc)

2.1. Stress distribution in shear samples. The effect of sample height is one of the most problematic issues. The vertical load is applied through the loading plate on top of the sample, but this load produces not only normal but horizontal stresses also on the soil body (Figure 2). The normal stresses cause horizontal forces at the side wall of the shear-box, which results in some frictional forces. These frictional forces are proportional to the unknown normal stresses and surfaces. The normal force and naturally also the normal stresses decrease due to the frictional force, so the measured cohesions will be different from the real values (Figure 3).

Due to this fact we can never know exactly the normal stress at the shearing plane.

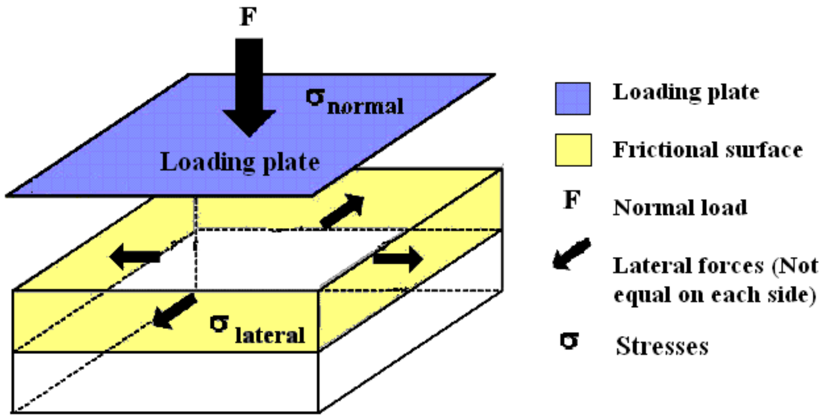

Figure 2. Scheme of surfaces and stresses causing side wall friction

To reduce this error two options are available:

- we have to reduce the surface of friction with reduction of sample height
- we have to measure or estimate the ratio of normal vs. lateral stresses [3].

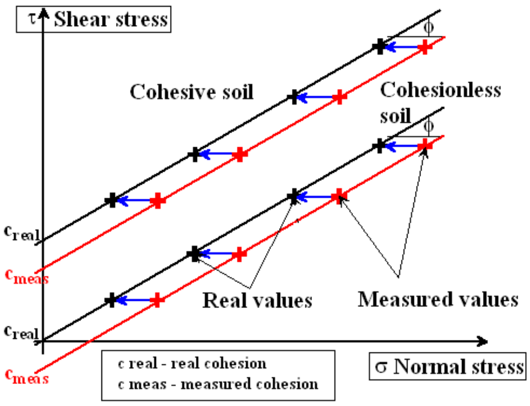

Figure 3. Theory of effect of friction on wall to the cohesion

2.2. Reducing of sample height. To reduce the frictional surface we can reduce the sample height in the shear-box. With height reduction (thinner samples) we can be sure that the normal stress due to applied load is close to that calculated (σ_n=F/A). This measurement results are closer to linear on σ-τ plane (Figure 4). Unfortunately the mentioned frictional error causes the reduction of "apparent" cohesion values, since during the measurement's evaluation we consider a higher normal stress than actually occurs.

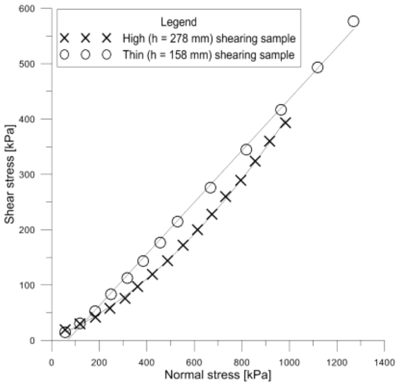

Figure 4. Effect of sample height reduction on Coulomb failure lines during shear tests

This can lead also to the measurement of "negative cohesion" in cohesionless soils (see Figure 3). In the case thatside wall friction force is not constant, an alteration in internal friction can also occur. Since parallel to the increase of the lateral forces there is also a decrease of contact surface due to soil compaction, the result of the two opposite procedures may cause either the increase or the decrease of the determined angle.

2.2.Measuring of stresses on the boundary. To measure the normal vs. lateral stresses function there are several ways. It is possible to build sensors into the side wall of the shearing-box, which can be one of the solutions. A sensoric measuring system was developed at University of Miskolc, Department of Earth Science and Engineering in 2011.

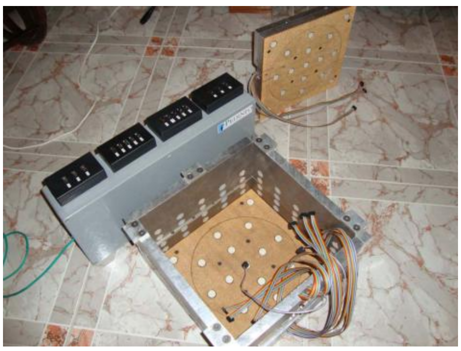

Figure 5. Parts of sensoric measuring system

This is an optional part of the large-scale shearing machine that makes possible to measure the stresses on the whole surface of shearing sample. The system consists of 82 pressure sensors (Figure 5). The measuring range of the stress sensors is 0 to 800 kPa. This means that the highest load we can apply on the surface (A = 1225 cm^2) is approx 10-12 tons due to the energy dissipation inside the soil sample body. This load range is high enough to simulate a number of processes that could occur in geotechnical practice.

In Figure 6 we can see a stress distribution map for a shear sample that is made from acrylate. This test was carried out in the early 1990s in Miskolc and the aim was to determine the stress zones in shear samples by optical techniques [4]. The investigation showed us that the stress distribution in the sample body is not homogeneous and a variety of effects deform it. The isobars help us to see the different stress zones.

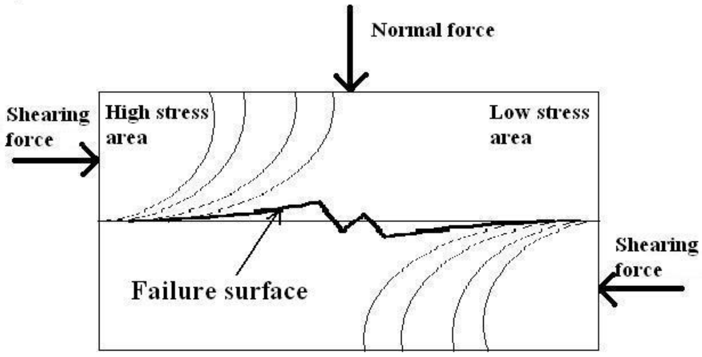

Figure 6. Stress distribution in a shear sample (reconstruction by authors)

Our research group aimed at a similar investigation. Thanks to the sensoric development on the large-scale shearing machine we could start the investigation. The measurement protocol was a traditional one, starting with a consolidation phase while the investigated soil compacted and next a shearing phase with horizontal movements.

The material used was a sandy agricultural soil in dry conditions. It comes from the investigation way of the Geotechnical Soil Testing Laboratory. We characterised loose agricultural soil with traditional geotechnical methods in laboratory, semi-laboratory and field situations.

Compaction behaviour of different soils mostly depends on its granulometry and moisture content level.. The sandy soil has an optional consolidation behaviour because if it is dry (w% = 1-2% m/m) we can reach the 80% of consolidation degree in a short time (a couple of minutes).

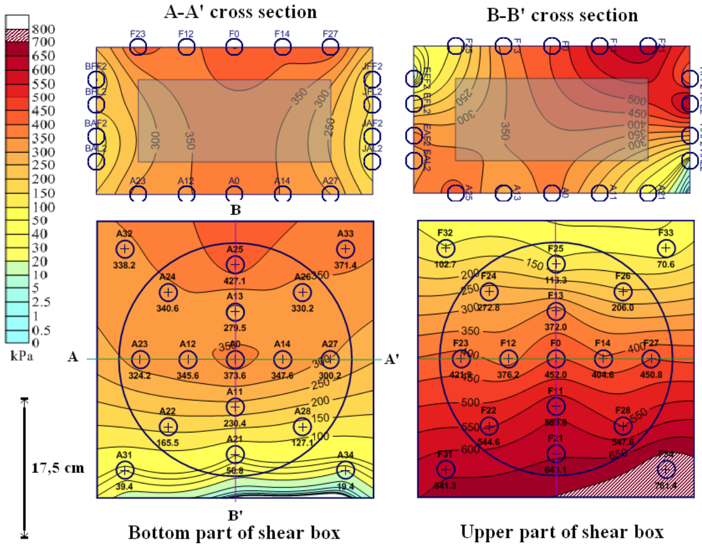

Figure 7. Stress distribution in large scale shear sample (pressure sensors)

Figure 7 summarises the results of a shearing test in an isobaric map. If we compare it with Figure 6 we can find significant similarities. The compaction zones are in the same places and the characteristics are the same. That means the stress zones that were measured in an acrylate sample are similar in grainy materials.

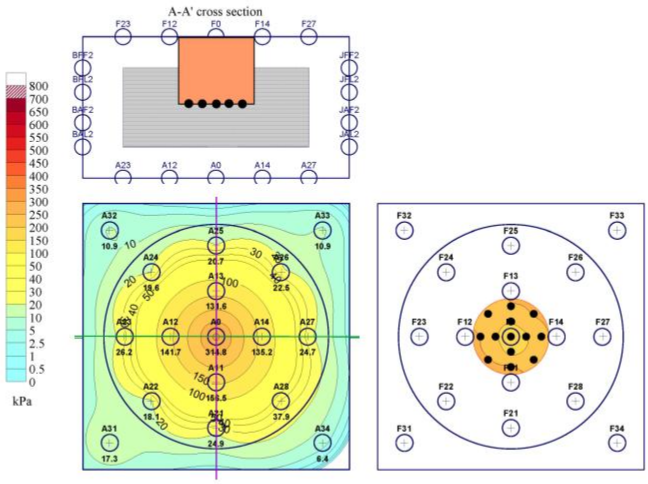

Figure 8. Stress distribution in an intender test (pressure sensors)

Another investigation was carried out with the sensoric system. It was an intender test, meaning that a rigid element was pushed into a pre-consolidated soil sample. The results provide a lot of information about the stress distribution (Figure 8). As we can see, the stress is not homogeneous on the contact surface of intender and soil [5]. Previous tests confirmed this behaviour; the root of causes come from the friction effects on the cylinder wall. These results could be useful in geotechnical piling technologies or bridge piers.

3. Conclusions

In the aspect of sample height we could say the following: as thin a sample as possible is to be used to reduce side wall friction or to make lateral stress measurements possible in the shearing box. In case the sample height is reduced too much, the boundary conditions at the top and bottom of the sample disturbs the processes inside the sample, therefore we have to find a compromise. In case of approx. 10 cm sample height at the highest vertical loads measurement results were already of acceptable side wall friction but without problems of effect of top and bottom are plates. The comparison of the stresses on several side-walls and the distribution character of stresses on the bottom plane give information on the initial homogeneity of the sample, which is a key issue due to the fact of skewing measurement results by such irregular errors.

Although a homogenous stress field is considered as an approximation there are large differences both inside the investigated sample and on the boundaries. It is not possible to measure the stress distribution inside the sample, but the measured values on the boundaries present a coherent picture of stress distribution that makes the estimation of in-sample stresses more accurate.

The measured parameters can be used as input parameters of further numerical simulations for soil characterisation that makes possible the control of determined constitutive law parameters. The measurement of real time distribution of stresses allows us to determine the character of energy dissipation that helps us to determine the transient geotechnical parameters. The determination of lateral vs. normal stresses gives an option to characterise the plastic Poisson ratio and its change during the compaction procedure.

Acknowledgements

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