CASE STUDY: BACK PRESSURED SHEABOX

USER: PETERIS SKELS, RESEARCHER, KASPARS BONDARS D.Sc., LEADING RESEARCHER, RIGA TECHNICAL UNIVERSITY

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Website Link:
www.rtu.lv

GDS Instruments
Unit 32 Murrell Green Business Park
London Road, Hook
Hampshire,
RG27 9GR, UK

T: +44 (0)1256 382450
F: +44 (0)1256 382451
E: info@gdsinstruments.com
W: www.gdsinstruments.com

THE PROBLEM

Peteris Skels and Kaspars Bondars from the Riga Technical University (RTU) set out to examine slope stability and landslide triggering mechanisms in colluvial soil in deep river valley slopes. Most of the landslides in Latvia evolve in deep river valleys after heavy consecutive rainfall in Autumn or rapid snowmelt in Spring (Latvian Geological Survey, 2003). The change in groundwater flow and levels effect, the stress state in the soil and creates seepage pressure. Soil is divided into saturated and unsaturated zones. Unsaturated soil parts after water infiltration or exfiltration, intense rainfall or melting snow can lead to the soil becoming saturated, thus the pore pressure will increase and the effective normal stress will be reduced, therefore reducing the shear resistance. However, it is important not only to evaluate groundwater fluctuations and pore pressure changes, but also other factors such as slope topography, soil stratigraphy and geomorphology.

SITE INVESTIGATION

The investigated site was located in the Abava-Slocene valley, which spans between the town of Tukums and the village of Renda. The cross-section of the valley is asymmetrical with mainly erosional terraces present. The valley slopes are dissected by numerous gullies and valleys of tributaries, particularly in the section between the towns Kandava and Sabile. The soil within the study area contains Upper Devonian sandstones, clay, and dolomite layers, while glacial till lays on the top of the slope and colluvium of varying depth (1.5m-14m) cover the sloping part of the valleys.

In 2014 after a period of persistent rainfall, a landslide developed during the construction of the P130 motorway, in the upper part of the Abava river valley between Sabile and Kandava. The soil samples taken for testing came from the bottom of the cracks which, were approximately 2m deep and 2m wide. Physical and laboratory tests were carried out on these samples.

Figure 1. Soil embankment next to the P130 motorway.

Alongside the physical and laboratory testing of the soil, the historical background of this site was explored. A very important fact about this particular section of the Abava river valley was identified. In the 1960's during road construction, the soil deformation on the slope was recorded and it was decided to stabilize the slope foot with concrete walls (Latdoravtoprojekt, 1962). This confirmed that not only peak shear strength, but also residual strength would be essential to measure in the laboratory.

Physical soil tests were performed from trimmings and material left from the block samples. These tests were carried out in order to identify and classify the soil and evaluate the physical soil parameters for further landslide analysis with analytical and/or numerical methods. The following physical tests were performed: Moisture content according to LVS EN ISO/TS 17892-1; Soil density according to LVS EN ISO/TS 17892-2; Particle density according to LVS EN ISO/TS 17892-3; Particle size distribution according to LVS EN ISO/TS 17892-4; Determination of Atterberg limits according to LVS EN ISO/TS 17892-12.

At the RTU soil mechanics laboratory, soil samples were prepared for the shear box testing according to LVS EN ISO/TS 17892-10. Soil samples were trimmed out of the sample block to precisely 100x100x45mm and fitted into the shear box. Testing was carried out using the unique back-pressured shear box (BPS) apparatus developed by the University of Durham and constructed by GDS Instruments. The BPS provided the opportunity to carry out direct shear testing on soil samples while controlling the pore water pressure of the specimen.

Figure 2: GDS Instruments Back Pressured Shear Box

The BPS is based on a standard direct shear device, modified to allow the measurement of pore water pressure and control of back pressure. The apparatus can function as both a conventional direct shear and back pressured shear machine (Carey, 2011). The testing was performed in two different set-ups. Firstly, the soil strength properties were tested according to LVS EN ISO/TS 17892-10, but measuring pore water pressure to get effective parameters (saturation, consolidation and shearing). Secondly, the pore water inflation mechanism was tested when desired normal stress and shear stress values were reached (based on the 'safe' side of the Mohr-Coulomb failure plain), they were kept constant. The pore water pressure was raised linearly by 2kPa/hour. The soil sample was therefore under pore pressure inflation and sheared under constant normal stress and shear stress as and when the effective stress reduced enough to allow shearing to occur.

RESULTS

Average physical properties of the soil tested are shown in Table 1

Parameter	Clayey SILT (clSi)
I_P	9.5
I_L	0.39
Natural water content	21.1%
Soil particle distribution:	
0-2µm (CLAY)	22.1%
2-63µm (SILT)	58.4%
63µm-2mm (SAND)	10.1%
>2mm	9.4%
Particle density	27.2kN/m^3
Bulk density	20.7kN/m^3

Table 1. Soil physical parameters

Soil shear strength parameters were determined at three different consolidation pressures (normal stresses), chosen in range between 25kPa and 150kPa, assuming that shearing plane was relatively shallow, about 2m deep at most (Figure 3).

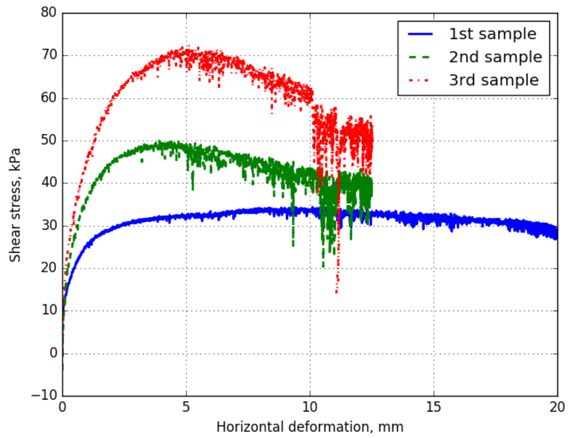

Figure 3. Shear stress (strength) as a function of shear deformations.

Mohr-Coulomb failure criteria was tested on three soil samples for peak and residual parameters, these are shown in Figure 4. The shear strength (peak and residual) of tested soil specimens at particular effective normal stress are as follows:

- For the 1st specimen at normal stress of 39.07 kPa $\tau_1 = 34.38 kPa$, $\tau_{residual\_1} = 20.12 kPa$
- For the 2nd specimen at normal stress of 107.61 kPa $\tau_2 = 50.05 kPa$, $\tau_{residual\_2} = 39.54 kPa$
- For the 3rd specimen at normal stress of 137.27 kPa $\tau_1 = 72.62 kPa$, $\tau_{residual\_3} = 51.08 kPa$

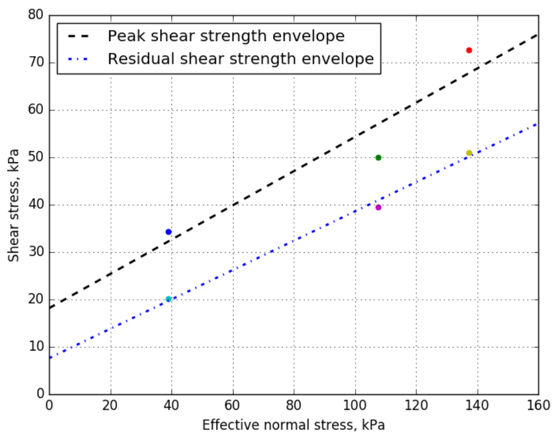

Figure 4. Shear stress (strength) as a function of effective normal stress.

The effective peak strength parameters are φ'=19.86^0 ; c'=18.15kPa and the effective residual strength parameters are $\varphi'_{residual}$=17.20^o ; $c'_{residual}$=7.61kPa.

Pore water pressure inflation mechanism was tested. Four separate tests were conducted assuming point at the "safe" side of the Mohr-Coulomb failure plain and raising pore water pressure at constant rate until shearing. Three samples were tested at the same constant shear stress of 30kPa and one sample at 25kPa as shown on the Figure 5.

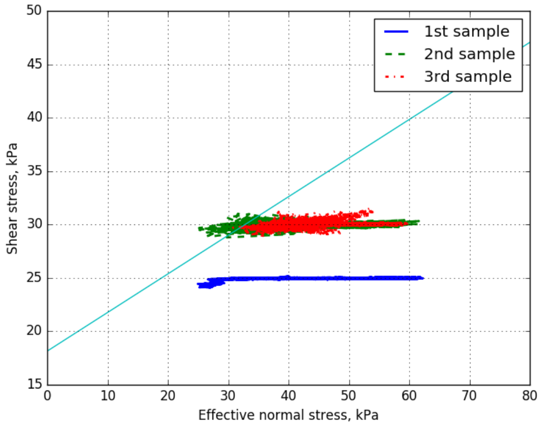

Figure 5. Shear stress as a function of effective normal stress; pore pressure inflation testing.

This set-up acts as a physical model of real condition, where in slopes pore water pressure is rising due to water infiltration or exfiltration. These initial tests have proved that soil will shear close to the peak shear strength envelope, as expected (Fig. 5).

CONCLUSION

1. The shear strength of soil is highly dependent on pore water pressure changes. The effective stress analysis is the most appropriate design approach in natural slopes where the upper soil layer is colluvium and there is no additional load applied.
2. The GDS back Pressure Shearbox (BPS) allows the effective shear strength peak and residual parameters by measuring pore water pressure to be determined.
3. Pore water inflation testing allows the application of the stress path (Fig. 5), which pretends real case situation of pore water triggered landslide.
4. Pore water inflation testing has shown that soil will shear close to the peak shear strength envelope, it is possible to evaluate shear strength parameters by testing different stress path starting from the “safe” side of envelope, and by changing the effective normal stress by pore water pressure control.
5. BPS test data can be used for further analytical and/or numerical design of slope stability in the Abava river valley.

TESTIMONIAL

“Riga Technical University have worked in close collaboration with GDS Instruments since 2014. GDS have always delivered us with high quality test equipment, whether it be standard or bespoke. Their valuable advice and guidance has been key in ensuring that the test equipment and procedures we receive meet with our research requirements and project specifications.”

“We chose GDS Instruments as the sole apparatus supplier because of their track record of supplying advanced testing systems, as well as the fast, efficient and friendly technical support that I have received dealing with GDS.” Peteris Skels, Researcher, Riga Technical University.

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LVS EN ISO 17892-1:2015 Geotechnical investigation and testing - Laboratory testing of soil - Part 1: Determination of water content.

LVS EN ISO 17892-2:2015 Geotechnical investigation and testing - Laboratory testing of soil - Part 2: Determination of bulk density.

LVS CEN ISO/TS 17892-3:2005 Geotechnical investigation and testing - Laboratory testing of soil - Part 3: Determination of particle density - Pycnometer method.

LVS CEN ISO/TS 17892-4:2005 Geotechnical investigation and testing - Laboratory testing of soil - Part 4: Determination of particle size distribution.

LVS CEN ISO/TS 17892-10:2005 Geotechnical investigation and testing - Laboratory testing of soil - Part 10: Direct shear tests.

LVS CEN ISO/TS 17892-12:2013 L Geotechnical investigation and testing - Laboratory testing of soil - Part 12: Determination of Atterberg limits.