Additional Geotechnical Investigation Task for Slope Stabilization Project at Regional Road P130 Līgas – Kandava – Veģi, km 14.00 – 14.20, Latvia

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Abstract. Slope stabilization is quite rare geotechnical design task in Latvia. Therefore, no much practical experience is accumulated in geotechnical society hands within this field. The problem solving process is unroutine and shall be based on engineering judgement, made by person responsible for design. The case study of the particular creeping slope stabilization problem contains the history of it's evolution and the planned geotechnical investigation methods which will be implemented for additional geotechnical investigations. In author's opinion the experience described in this article highlights the importance of geotechnical work programme elaboration by the person responsible for the design structural solution, and the necessity of supervision during geotechnical investigation process.

Keywords: geotechnical investigation task, slope stability, soil design parameters, case study.

Conference topic: Transport infrastructure.

Case history and time schedule

The creeping slope at regional road P130 Līgas – Kandava – Veģi, km 14.00 – 14.20, Latvia is situated between the towns of Kandava and Sabile, approximately 9.5 km far away from Kandava town to the Sabile town direction.

This is a man initiated creeping slope that begun actively to creep in 1954, after a new road construction just below the existing (old) road.

Stabilization measures like erection of gravity retaining wall were implemented during the service life of the new road (P130) – first time during its construction in 1954 and afterwards in approx. 1965 when road embankment widening was made.

To the 2013 the creeping mass was almost self stabilized due to favourable geometry changes and its movement was slow enough to make any additional stabilization measures unnecessary. Nevertheless, its front was too close to the road corridor – see Figure 1.

In the beginning of 2013 a new road reconstruction project was elaborated. This project included only solutions for existing road pavement settlements repair and new water drainage ditch excavation along the slope side of the road. The creeping soil mass (sliding body) existence alongside the road was not assumed for drainage ditch solution elaboration. The drainage ditch was designed to be excavated, without any additional creeping slope stabilization measures – see Figure 2.

It took some time to finish public procurement procedure and begin road reconstruction project construction works. In the 2014 autumn the drainage ditch was excavated, creeping soil mass lost its stability and slid down. The construction works were stopped.

Customer decided to elaborate an additional design solution for slope stabilization. A new geotechnical investigation was performed for this purpose within very tight time schedule from the middle of December 2014 to the beginning of January 2015. The new design solution

Fig. 1. Sliding body profile at the autumn 2013

Fig. 2. Excavated sliding soil body geometry

elaborated in the March 2015 was based on the geotechnical report recommendations, but it didn't pass the project verification procedure due to its unfeasibility, and the project was stopped.

Next geotechnical investigation was performed in February – May 2016, but the information gained within this investigation still not enough to solve the particular slope stability problem.

The failure of the last two geotechnical investigation sessions in author's opinion can be explained by the fact, that those were performed without a sound geotechnical investigation task which, in turn, is based on the geotechnical design task. Actually, this is the common problem in the industry. The geotechnical investigation task was not defined precisely enough, work programme wasn't prepared, no supervision by the 3rd party was made.

As the outcome a very little amount of valuable information, than can be used for calculations, is obtained at the moment, no clear geotechnical profiles with the precise borders of soil layers and groundwater pressures can be drawn up to this moment.

It is worth to mention that the information presented in both 2015 and 2016 years' reports in many aspects is

controversial, different soil names and geotechnical terms used for the same soil layers. 2016 year's report contains no soil strata profiles at all – only borehole logs put on the topographical profile. The quality of both reports in the sense of common logic is obviously lower than the quality of the 1962 year's geotechnical investigation report, which still is the main source of information for decision making.

The only parameter that can be defined precisely enough is the soil bulk density of the sliding soil body.

Customer has been spent already twice more money, than it is obviously needed for geotechnical investigations aligned with design task.

An article author was asked to elaborate a slope stabilization project after the last geotechnical investigation field and laboratory work was finished at April 2016.

Problem preliminary analysis and determination of remaining necessary geotechnical data

To prepare an additional geotechnical investigation task, first an already obtained geotechnical data compilation performed. Preliminary calculations are made and feasible solutions are chosen. A brief problem description is shown in Figure 3.

As it can be seen from Figure 3, both the groundwater drainage and structural strengthening solutions are under consideration.

According to design task, to develop economic design solution, both options must be analysed.

Soil parameters for ground water drainage design

Groundwater drainage is assumed to be done either with subhorizontal (inclination $i = 5\div7\%$) and/or coupled vertical and horizontal drain system.

Fig. 3. Problem description:
1) drainage design solution elements; 2) structural design solution elements (retaining structure)

To design it, at least the particle size distribution of drained (sliding body, Devonian strata above dolomite layer) and pounded (Devonian sandstone strata below dolomite layer) soil elements shall be clarified. The suitability check of drain filters available on the market need to be done as soil suffusion and filter colmatation processes may occur in case of unsuitably applied filter material; a drainage system capacity need to be calculated.

Soil parameters for retaining structure design

To design a retaining structure there is a need to define:

- a) design horizontal and vertical force design value acting on it, and
- b) strength parameters of soil strata, in which wall foundation elements (piles) and anchors are embedded.

The design value of acting force depends on sliding plane geometry, ground water level within sliding body, piezometric groundwater pressure on the sliding plane, sliding plane geometry, soil saturated and unsaturated weight, internal friction angle within the sliding plane. To get more stable calculation results it is assumed that cohesion is zero at the sliding plane.

The strength parameters need for the design of both the pile foundation and ground anchor is the cone penetration resistance for non cohesive soil and undrained cohesion values for cohesion soil.

Geotechnical investigation program

To design groundwater drainage system and retaining wall structure, the following additional information is needed:

- sand and silt layers' and interlayers' particle size distribution;
- electrical piezocone cone resistance q_c and measured sleeve friction f_s , normalized excess pore pressure u_2 (for cohesive soil layers) – for soil strata below existing road, within and under sliding body and within soil body under dolomite layer, if sandstone cementation is weak enough;
- groundwater piezometric pressure within the sliding soil body and below the sliding plane – up to 9 m depth maximum;
- weathered strata (clay and sand mix) thickness under the existing road and sliding soil body;
- precise and reliable soil clay and water content log along the borehole down to altitude of +25.0 m (LAS-2000,5).

Restrictions

Dynamic probing of any type according to LVS EN ISO 22476-2 is not allowed.

Soil sampling with an auger type boring equipment is not allowed.

Particle size distribution

At the moment no reliable particle size distribution data are gained because of auger type and dry rotary column

type drilling and sampling equipment was used. As it only meets the requirements of “C” sampling category according to LVS EN ISO 22475-1 Table 2, it can extract remoulded samples of quality class 5, which cannot be used for particle size analysis according to LVS EN 1997-2, Table 3.1.

Analysis of available particle size data from samples extracted from Devonian strata above dolomite layer says that the soil is either silty clay or clayey silt, with very low permeability. In the description or borehole it is mentioned, that Devonian strata above dolomite contain separate sand and silt layers, separated by clayey layers, that means, that samples analysed were remoulded and unsuitable for analysis. The sand and silt layers themselves can exhibit high permeability. Therefore it is assumed, that an additional soil sampling shall be done by at least B – sampling category equipment – double-tube core barrel, according to LVS EN ISO 22475-1 and soil samples at least of quality class 4 shall be extracted to match the LVS EN 1997-2 requirements.

To obtain permeability values of sandstone below dolomite layer, an undisturbed sandstone samples shall be extracted, and permeability shall be measured by the laboratory tests.

The minimum mass of water saturated soil sample for particle size distribution curve determination is 130 g for sand interlayer soil sample and 65 g for silt soil sample, according to LVS CEN ISO/TS 17892-4, Table 1.

Sandy and silty soil samples are to be taken from recovered soil core.

Particle size distribution shall be determined within $<0.002 \div 20.0$ mm range.

Sieve form shall be rectangular. For particles of size $<0.002 \div 0.2$ mm hydrometer method shall be used.

Soil type shall be determined according to LVS EN ISO 14688-2, annex B, but previously a correction shall be made in the classification diagram – see Figure 4.

Fig. 4. Correction in the soil classification diagram

Obtaining of q_c , f_s , u_2 values by piezocone soundings

To obtain q_c , f_s , u_2 parameters, conventional piezocone field tests shall be made by piezocone of $q_{c,max} = 50$ MPa capacity, according to LVS EN ISO 22476-1.

Piezocone sounding tests shall be made also in the (possibly) weakly cemented sandstone strata under dolomite layer, therefore, predrilling through dolomite layer need to be performed.

Predrilling also may be necessary when cone penetration in sand layer exceeds $30 \div 40$ MPa. The proposed predrilling sequence is shown in Figure 5.

Fig. 5. Predrilling procedure during CPT sounding

Groundwater piezometric pressure measurements

Measurements of piezometric groundwater pressure u_2 are to be made by CPTU piezocone u_2 water pressure sensor – see Figure 6.

Fig. 6. Locations of pore pressure filters and sensors

Measurements within sliding soil body are to be made to obtain the ground water level altitude.

Measurements below sliding soil body slip plane are to be made to obtain the ground water excess static pressure, which is acting on the slip plane and reducing

effective pressures between soil particles, thus directly affecting shear bearing capacity of the slip plane.

Measurements are to be done with a vertical interval of ≤ 1.0 m.

At groundwater piezometric pressure u_2 measurement point cone penetration must be stopped and “full” excess positive or negative pore pressure dissipation must take place.

Excess pore pressure dissipation time is not prescribed, as it may be considerably differ in different types of soils or soil macroinclusions.

Process quality control criteria is defined as pore water pressure changes per time: dissipation process may stop and u_2 pore water pressure may be documented, if changes of pore water pressure do not exceed 0.5 kPa per 5 min observational period.

Weathered strata (clay and sand mix) thickness determination

Weathered strata thickness determination is to be done by electrical resistivity tomography method.

Electrical resistivity tomography shall be made in 4 slope perpendicular sections. Electrodes shall be pinned in the soil with 2.0 m distance. Profile length is approx. 200 m and therefore scanning depth is about 15 m along the whole length of considered profile (road structure and sliding soil body).

After the field works an interpretation of data shall be done by the company, who performs the data acquisition. Borehole logging data shall also be taken into account. An example of electrical tomography profile is shown in Figure 7.

Fig. 7. Electrical resistivity tomography profile example

It can be seen from Figure 7 that some evidences of slip planes can be also defined on the electric resistivity tomography profile.

Nevertheless, the most valuable information to be gained from electrical tomography survey is dolomite strata vertical border.

Borehole logging

To obtain precise and reliable soil clay and water saturation log along the borehole in Devonian strata, a borehole logging after soil sample extraction shall be done:

- natural gamma ray logging for sandy and clayey layer distinguishing;
- self-potential logging for clay content degree and water mineralization determination;
- resistivity logging for water saturation and clay relative content determination.

Borehole logging is performed by lowering the probe in an open borehole, which is filled with the stabilizing mud.

Borehole logging shall be done immediately (during first 2 hours) after the sampling works are finished and borehole filled with stabilizing mud of adequate consistency.

An example of clay and sand layer soil profile is shown in Figure 8.

Fig. 8. Borehole logging result soil profile. Yellow – sandy layers, black – clay layers

An example of water saturation soil profile is shown in Figure 9.

Fig. 9. Borehole logging result soil profile. Blue – layers with high water content, red – layers with low water content

It should be noted, that borehole logging collects an information on soil properties at the radius of 2 m around the borehole.

In geotechnical section all layers of thickness more than 10 cm shall be shown.

Geodetic survey program

Previously described types of measurements and soil sampling are to be done in accordance with elaborated investigation point and profile layout.

All logging profiles and survey points shall be fixed on terrain just before the beginning of geotechnical investigation works. After geotechnical investigation works the actual investigation point and logging profile plan positions and altitudes shall be measured once more and geodetic survey report shall be submitted to the customer.

Temporary roads for geotechnical equipment shall be constructed before geotechnical investigations and completely dismantled when those are finished.

Conclusions

The case study and geotechnical investigation task described above demonstrate the basic principle of geotechnical investigation – the person responsible for design must either elaborate or at least participate in geotechnical investigation program elaboration.

The problem of geotechnical supervision is only slightly touched in this article, but nevertheless it is very important topic for unroutine design problems.

A direct supervision of geotechnical investigation both field and laboratory works preferably shall be made by designer personally, as this allows to make correction to the geotechnical investigation program during geotechnical investigation process.

The conclusions mentioned above lie in line with the Eurocode 7 general rules.

References

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