A new test field in sulphide clay with test embankments for study of compression properties

Un nouveau essai sur le terrain d´argile sulfaté en mettant en place des remblais d´essai pour l'étude des propriétés de compression

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ABSTRACT: In this paper on-going research of compression properties of Swedish fine-grained sulphide soils is presented. In the paper, the establishment of two test embankments founded on sulphide clay at a new test field is described. Some selected results from the project are presented. The characteristics of the particular types of sulphide soils investigated are shortly described. The overall purpose of the research project is to improve the possibilities to predict long term settlements of structures founded on sulphide soils.

RÉSUMÉ : Cet article présente des recherches en cours sur des propriétés de compression des sols à granulométrie fine suédois. L´article décrit l'établissement de deux remblais d'essai fondés sur argile sulfaté, dans un nouveau essai sur le terrain. Quelques résultats choisis du projet sont présentés. Les caractéristiques des types particuliers de sols sulfatés enquêtés sur le terrain sont brièvement décrites. L'objectif général du projet de recherche est d'améliorer les possibilités de prédire des tassements à long terme des structures fondées sur les sols sulfatés.

KEYWORDS: clay, embankments, sulphide, organic, compression, creep, settlements, geotechnical engineering.

1 INTRODUCTION

There is only limited knowledge concerning compression properties of sulphide soils. There is thus a need for improved tools to better predict settlements including creep settlements in sulphide soils. Most often the predicted settlements of an construction founded on sulphide soils deviates significantly from those measured, and normally the predicted settlements are too small.

Sulphide soils, as designated in this paper, are found and common along the coast line of the Gulf of Bothnia, i.e. in north-eastern Sweden over a distance of about 900 km and north-western Finland, figure 1. Sulphide soils in Sweden are not uniform, but properties like grain size distribution, water content, and density vary as for other fine-grained soils with location and often with depth (Westerberg and Andersson 2009). Sulphide soils in Sweden are most often designated as organic silt to organic silty clay and in cases with higher organic contents as silty or clayey gyttja (Larsson et al. 2007). In sulphide soils, the structure is often relatively porous and the voids between the mineral grains and clay particles are filled with pore water, organic material and iron sulphide (Pusch, 1973; Eriksson et al. 2000). The organic matter and iron sulphide are believed to contribute to the open structure, low bulk density and high water content. The sulphide soils are normally coloured black or varved with black bands and the black colour comes from the iron sulphide (FeS). Sulphide soils have normally low undrained shear strength, typically 10-20 kPa, and are in general very compressible and show significant creep behaviour (Westerberg et al. 2005). These properties are accentuated when the temperature is raised from in situ ground temperature to room temperature in the laboratory (Eriksson 1992).

In this paper a few results are presented from an on-going research project at the Swedish Geotechnical Institute (SGI) concerning compression properties and settlement predictions of sulphide soil (Andersson 2012). The results have been obtained in connection with two test embankments founded on sulphide clay in a new test field at Lampen outside the city of Kalix (see figure 1) and next to the new railroad Haparandabanan. The main purpose of the project is to improve the knowledge of compression properties of sulphide soils, with focus on the creep properties. Another aim is to establish extensively instrumented test embankments where settlements and pore pressures can be measured during many decades to come.

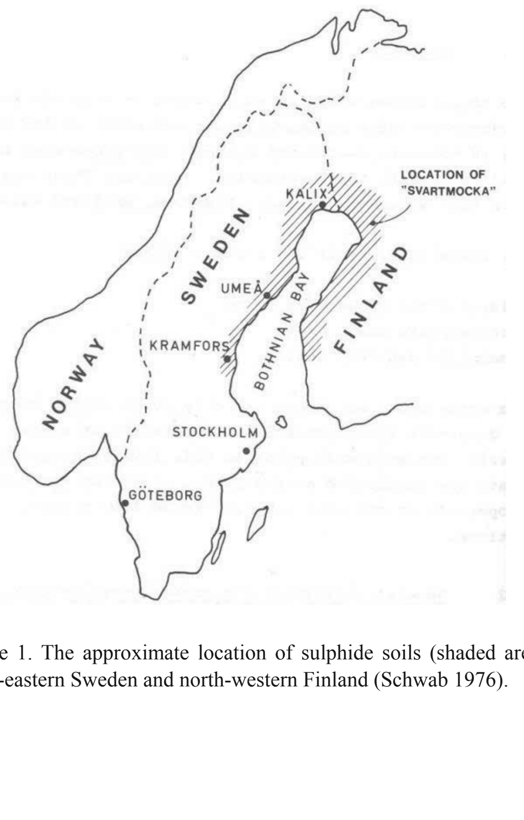

Figure 1. The approximate location of sulphide soils (shaded area) in north-eastern Sweden and north-western Finland (Schwab 1976).

2 FIELD AND LABORATORY INVESTIGATIONS

Field investigations of the properties of the sulphide soil in the test field at Lampen have been performed mainly by cone penetration tests, field vane tests and Swedish piston sampling. An extensive program of laboratory tests, mainly oedometer tests, both by incremental loading and constant rate of strain, creep tests in oedometers, permeability tests and undrained direct simple shear tests, was conducted for the determination of compression and strength properties. In figure 2 bulk density, liquid limit and water content of the sulphide soil in the test field are presented. For the sulphide soil the clay content varies between 25-36 %, the organic content between 2.7-5.1 % of dry weight, the iron content between 2.9-4.3 % of dry weight and the sulphur content between 0.5-1.6 % of dry weight. The soil is designated as organic sulphide clay. Below the test embankments the depth of the sulphide soil is in general about 7-9 m and overlaying a moraine. At the ground surface there is a layer of peat down to about 0.4 m overlaying a layer of about 0.6 m relatively soft dry crust of sulphide soil.

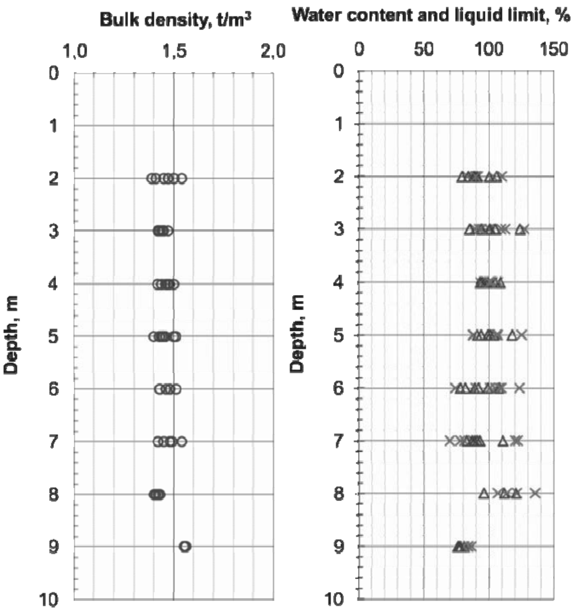

Figure 2 Bulk density, water content (triangle symbol) and liquid limit (cross symbol) with depth in the test field at Lampen.

Evaluated preconsolidation pressures from CRS and incremental oedometer tests conducted at approximately soil temperature and using the evaluation methods from Sällfors (1975) and Casagrande (1936) respectively are presented in figure 3. In the upper part of the soil profile, the two tests give about the same results, and in the lower part the incremental loading tests give higher values of preconsolidation pressure. There is a significant overconsolidation with respect to the current in situ stresses in the whole soil profile, figure 3.

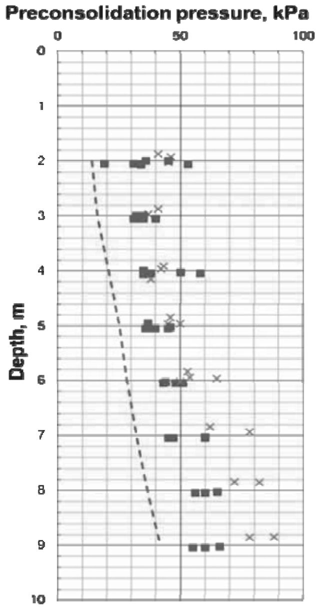

Figure 3 Preconsolidation pressures at the test field at Lampen evaluated from CRS oedometer tests (square symbol) and incremental oedometer tests (cross symbol), and estimated effective vertical in situ stresses (dotted line) with depth.

3 TEST EMBANKMENTS AND INSTRUMENTATION

Two test embankments with square bases of 30x30m^2, one with the final height 2.0 m (embankment 1), and the other with 1.5 m height (embankment 2) have been constructed the year 2010 up to 1.5 m, and raised 2011 to 2.0 m (embankment 1), figures 4-6. A fine-grained moraine, with an average compacted bulk density of 2.0 t/m^3, was used as construction material for the embankments, leading to pressures of about 40 kPa and 30 kPa from the two embankments respectively.

Figure 4 Cautious construction of embankment around the measuring equipment.

Figure 5 Construction up to height 1.5 m for embankment 1.

Figure 6 Finished construction of embankment 2 (1.5 m height). Photograph taken about two years after finished the construction.

Equipment for measuring movements (deformations), pore pressures and soil temperatures have been installed below and beside the two embankments, see figure 7 for embankment 2. For measuring horizontal movements inclinometer tubes of PVC with a square cross-section were used. This equipment has been designed for measurements in soft clays but had never before been tested in sulphide soils, figure 8.

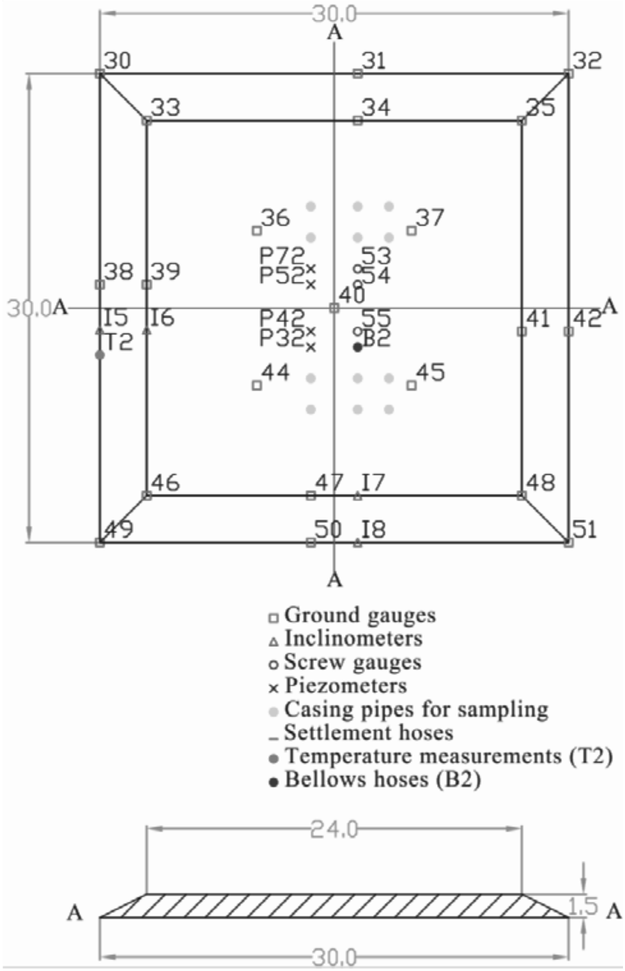

Figure 7 Plan of measuring equipment and cross-section of embankment 2 (in meters).

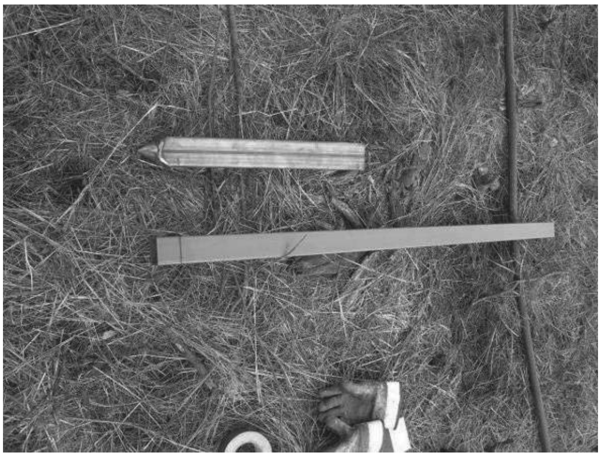

Figure 8 Inclinometer tube of PVC with square cross-section with steel point at the end.

4 FIELD MEASUREMENTS

In figure 9 is presented one example of measured vertical movements from settlement hoses and settlement gauges, embankment 2 about 1.2 years after construction. The settlements are similar when comparing the two measuring methods.

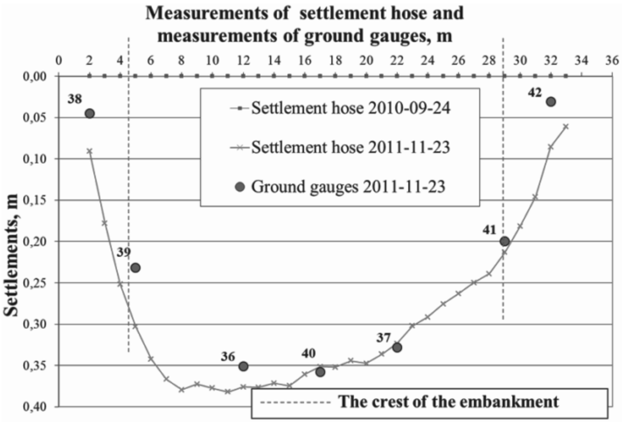

Figure 9 Measured settlements by settlement hose and ground gauges, embankment 2 about 1.2 years after construction.

5 CONCLUSIONS

Two test embankments, one with the height 1.5 m and the other with 2.0 m, have been constructed on sulphide clay at a new test field. Extensive measuring equipment has been installed to measure movements and pore pressures in the underlying sulphide clay. The construction of embankments and installation of equipment has been successful and the measured deformations obtained from the different equipments are in general agreement.

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7 REFERENCES

Andersson M. 2012. Kompressionsegenskaper hos sulfidjordar, En fält- och laboratoriestudie av provbankar. Licentiate thesis, Division of Mining and Geotechnical Engineering, Luleå University of Technology, Luleå. (in Swedish)

Casagrande A. 1936. The determination of the Preconsolidation Load and its Practical Significance. 1st International conference on Soil Mechanics and Foundation Engineering, Cambridge, Massachusetts, Vol. 3, p. 60.

Eriksson L. G. 1992. Sulfidjordars kompressionsegenskaper, Inverkan av tid och temperatur. Licentiate thesis, 1992:08L, Division of Soil Mechanics and Foundation Engineering, Luleå University of Technology, Luleå. (in Swedish)

Eriksson L. G., Mácsik J., Pousette K. and Jacobsson, A. 2000. Sulfidjord – en problemjord längs Norrlandskusten. Bygg & Teknik, Vol. 92, No. 1. (in Swedish)

Larsson R., Westerberg B., Albing D., Knutsson S. and Carlsson E. 2007. Sulfidjord – geoteknisk klassificering och odränerad skjuvhållfasthet. (Sulphide soil – geotechnical classification and undrained shear strength). Research report, 2007:15, Luleå University of Technology, Luleå / Swedish Geotechnical Institute, Report No. 69, Linköping. (in Swedish)

Pusch R. 1973. Influence of organic matter on the geotechnical properties of clay. National Swedish Building Research, Document 11:1973, Stockholm.

Schwab E. 1976. Bearing capacity, strength and deformation behaviour of soft organic sulphide soils. Ph.D. Thesis, Department of Soil and Rock Mechanics, Royal Institute of Technology, Stockholm.

Sällfors 1975. Preconsolidation pressure of soft high plastic clays. Ph.D. Thesis, Department of Geotechnical Engineering, Chalmers University of Technology, Gothenburg.

Westerberg B., Albing D. and Larsson R. 2005. Research on strength and deformation properties of Swedish fine-grained sulphide soils. Osaka: Proceedings, International conference on soil mechanics and geotechnical engineering, 16, vol 2, pp 623-626.

Westerberg B. and Andersson M. 2009. Undrained shear strength and compression properties of Swedish fine-grained sulphide soils. Alexandria: Proceedings, International conference on soil mechanics and geotechnical engineering, 17, vol 1, pp 72-75.