The characteristic deformation for the Haarajoki Test Embankment

La déformation caractéristique du remblai d'essai de Haarajoki

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ABSTRACT: The election of the characteristic values in the limit state design is the fundamental design task, but it is specified unfortunately impracticably in design guidelines as Eurocodes. The Haarajoki Test Embankment was executed north of Helsinki in 1997. The comprehensive soil investigations with a large number of laboratory tests were carried out for soft clay samples. Their amounts offer possibility to study the scatter of various parameters and determination of characteristic values by means of a simple statistical approach. The PLAXIS-program has been applied for the comparative settlement analyses.

RÉSUMÉ: La sélection des valeurs caractéristiques de design état limite c`est la tache fondamentale. Malheureusement on l`a spécifié pas pratiquement dans les directives comme les Eurocodes. Le remblai d`essai de Haarajoki était exécuté au nord de Helsinki en 1997. Les investigations compréhensives de sol avec un grand nombre de recherches en laboratoire étaient réalisé pour des échantillons d`argile douce. Leur quantité offrent la possibilité de investiguer la dispersion d`une variété de paramètres et de déterminer les valeurs caractéristiques seulement en utilisant une approche statistique simple. Le programme Plaxis a été utilisé pour les études de tassement comparatives.

1 INTRODUCTION

The Eurocode 7 applies the limit state design concept also to the geotechnical design. The code rules the partial factors that determine the design values from the corresponding characteristic values. The rather complicated design calculation procedures with various design cases easily mislead the designer. Settlement prediction of the road embankment is a part of the serviceability limit state design e.g. the characteristic soil parameters shall be applied to design calculations. The Limit state design points out the meaning of the accurate characteristic values of design parameters beside the reliable calculation models. The election of the characteristic values have been found very challenging, but also inadequately determinate (Simpson 1999, Scheider 1999).

The Haarajoki test embankment was executed near Highway E75 some 40 kilometres north of Helsinki in 1997. The objective of the test embankment is to monitor the accuracy of the settlement predictions and compare the effectiveness of the advanced modelling techniques to the conventional calculation methods. The comprehensive soil investigations with a large number of laboratory tests were carried out. Their amounts offer possibility to study the scatter of various parameters and determination of characteristic values by means of a simplified statistical approach. The derived deformation parameters have been analysed and compared to the performance of the test embankment with PLAXIS-software.

2 CHARACTERISTIC SOIL PROPERTIES

For the design calculations it was necessary to idealise the subsoil by limiting the number of soil layers, whose properties are characterised by means of soil parameters. The applied characteristic soil parameters are supposed to represent the true values of the soils mechanical models parameters. According to design standards and the design guidelines, as Eurocode 7, the characteristic values of the soil parameters shall be conservatively chosen mean values or cautiously selected mean values. The degree of their conservatism is generally not defined or not known. The geotechnical engineers select usually the values of the design parameters basing their judgement on their experience and the available data of the site.

When the degree of conservatism i.e. the degree of uncertainty of the applied parameter's value is not defined, it would be necessary to apply a statistical approach. The quantity of the available data of the soil parameters rarely provides necessity condition for such approach.

Professor H.R. Scheider has presented (Scheider 1999) a simple approach that is derived from fundamental statistic and probability concepts. It offers a rational approach to combine test values, gathered experience and knowledge. The design values for the soil parameters are generally derived from the characteristic values. Based on statistical sampling and estimation theories, the characteristic value x_k can be defined by formula

$$x_k = x_m * \left(1 - \frac{f}{\sqrt{n}} * V_x\right)$$

Where x_m is mean value
f is the statistical coefficient related to the type of distribution
V_x is the coefficient variation
n is the number of test results

The comparative computations have shown that a good approximation for several distributions typical for the soils is achieved with

$$\frac{f}{\sqrt{n}} \cong 0{,}50$$

Scheider presents three cases to apply this practical simple approach:

1. no test values are available
2. test values are available without a priori information
3. combination of test values and priori information

The principle of the combination concept based on Bayes' theorem (Scheider 1999).

3 HAARAJOKI TEST EMBANKMENT

The Haarajoki test embankment was built and instrumented some 40 kilometres north of Helsinki in 1997. The soil conditions, the instrumentation and the calculation competition organised by Finnish National Road Administration are described in various papers (Aalto et al. 1998, Näätänen et al.1997, Smura et.al. 2000). The embankment is located on a soft clay deposit with a thickness of about 20 metres. CPTU soundings indicate homogeneous soil conditions.

The total number of the tested soil samples from the subsoil is 176. Oedometer tests were made for nineteen samples. When the testing is compared to a conventional design task, an exceptionally large number of soil samples were bored and tested for a relatively homogenous subsoil profile. On the other hand when one divides the number of tests by the geotechnical soil layers, one gets only one to nine oedometer test results per layer. This does not provide a sufficient population to apply a pure statistical approach.

The well-known relation of soil compressibility and soil porosity, or water content in saturated conditions, offers additional information of the compressibility variation in every geotechnical soil layer. The locally defined relation of the water content and the compressibility can offer a reliable tool to determine the variation of the compressibility in every layer (Vepsäläinen et al 1999, Vepsäläinen et al 2000).

Below the dry crust of two meters in thickness the subsoil is slightly over consolidated in the natural state. The vertical stress increase due the weight of the three metres high embankment is larger than the preconsolidation stress, but only slightly. The consolidation stage is discussed in detail by Aalto et al. (Aalto et al. 1998)

The characteristic soil parameters were defined applying the method described by Scheider (Scheider 1999):

(1) The compressibility properties derived from the water content as an "estimated priori value"

(2) The oedometer results were applied as "test values"

(3) The combination of (1) and (2) as a "combined posterior information".

When the number of test values was too low to provide a reliable figure of the variation, the coefficient of variation was elected from the data publicised in the reference literature (Lee et al. 1983, Poon et al. 1999),

The characteristic (C_{cki}) and mean (C_{cmi}) values of the compressibility index above the preconsolidation stress, the coefficient of variation (V_i) and the number of test results are presented in table 1and in figure 2a. The figure 2b presents the characteristic and the mean values the compressibility index below the preconsolidation stress (C_{rmi}).

4 SETTLEMENT ESTIMATION WITH PLAXIS-SOFTWARE

The Finite Element Program PLAXIS (version 7.2) was applied for time-settlement estimation. The embankment and the dry crust of the clay were modelled as Mohair Coulomb material and the clay layers under the dry crust as Soft Soil (PLAXIS 1999). The full width of the embankment cross section was included the plain strain model of 15-noded triangu-

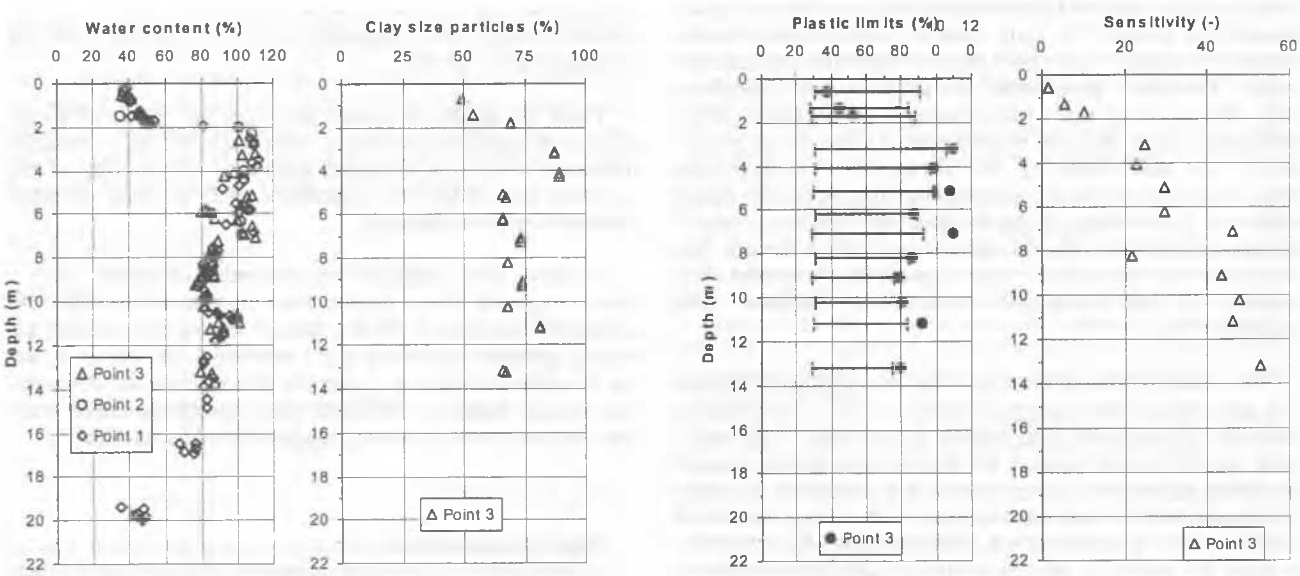

Figure 1. The classification properties of Haarajoki subsoil

Table 1. The characteristic mean values the compressibility index in geotechnical of Haarajoki

		Compressibility index, C_c									
Layer	depth	Priori			Test value				Combined		
		C_{cm1}	V_1	C_{ck1}	C_{cm2}	V_2	N	C_{ck2}	C_{cm3}	V_3	C_{ck3}
1	0…1 m	0,14	0,10	0,14	0,23	0,30*	1	0,26	0,14	0,09	**0,15**
2	1…2 m	0,34	0,29	0,39	0,28	0,30*	2	0,32	0,29	0,17	**0,32**
3	2…7 m	2,25	0,17	2,43	2,69	0,20	9	2,95	2,61	0,06	**2,69**
4	7…10 m	1,55	0,20	1,71	1,52	0,11	5	1,61	1,52	0,05	**1,56**
5	10…12m	1,65	0,10	1,73	2,83	0,30*	1	3,25	1,70	0,10	**1,78**
6	12…15m	1,19	0,14	1,28	2,31	0,30*	1	2,66	1,26	0,13	**1,33**
7	15…19m	0,78	0,09	0,82	-	-	-	-	-	-	-
8	19…22m	0,15	0,26	0,17	-	-	-	-	-	-	-

*) Coefficient of variation according to Lee et al. 1983

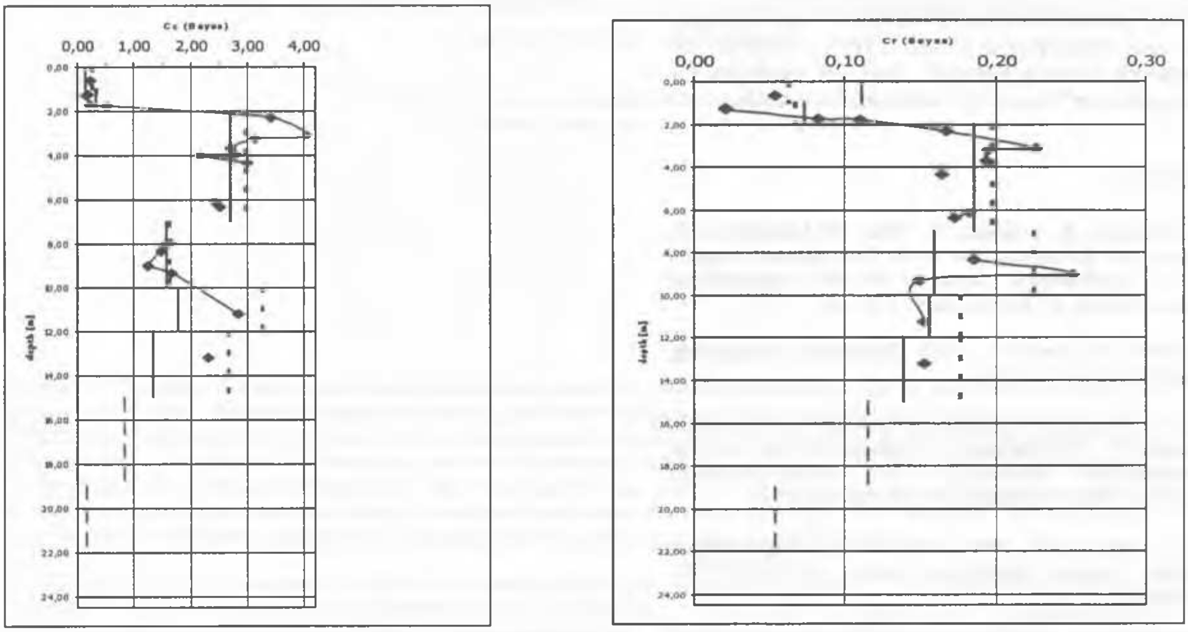

Figure 2a and 2b. The characteristic mean values of the compressibility index above (C_{cmi}) and below (C_{cmi}) the preconsolidation stress. The vertical solid lines and the long dash lines present the defined characteristic values. The short dash line shows the characteristic values based on the oedometer results only.

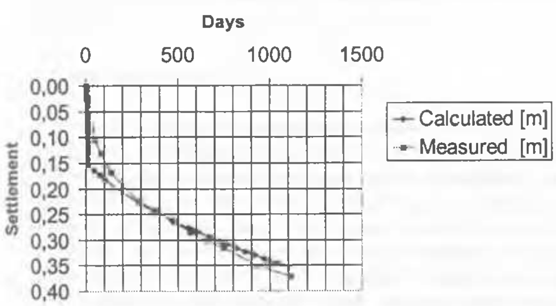

Figure 3 Comparison of the calculated settlement Uy to the measured settlement.

lar elements. The construction of the embankment was calculated with the staged construction procedure and the consolidation of construction phases and three years after it with the consolidation procedure of the PLAXIS.

The material parameters are presented in table 1 and the results of the calculation including their comparison to the observed settlements in figure 4.

5 DISCUSSION

The Haarajoki Test Embankment was chosen as a trial case for the characteristic soil parameter study, because an exceptionally large number of test results are available. The international calculation competition organised by the Finnish National Road Administration showed how challenging the soil conditions at Haarajoki are (see website: www.tielaitos.fi/pailas/pailas.htm).

The variation of the soil properties were found to be smaller than the typical values of variation published in literature (Lee I.K. 1983,Phoon K-K., Kulhawy, F.H. 1999) as a result of splitting the subsoil in to rather thin geotechnical soil layers for the calculations.

There is a good local relation between the water content of saturated soil and the compressibility when the data includes all clay layers (figure 4)

When the data is sorted for every geotechnical layer, the scatter appears. The compressibility parameters derived from the water content indicate a much lower settlement below the depth of 10 meters than the single oedometer test results do. This finding reflects the overall difficulty to define an accurate model of the soil layers compressibility.

The calculation results, when the applied parameters were defined as described above, did not lead to a very reliable time-settlement estimations so far. The sensitivity of the clay is very high and the vertical strains above the preconsolidation stress are very large and strongly non-linear in the oedometer tests. These properties have some influence on the calculation results. Further studies should be focused on the permeability of the clay, the one key parameter of time-settlement predictions. In this case soil permeability was interpreted from the oedometer tests only.

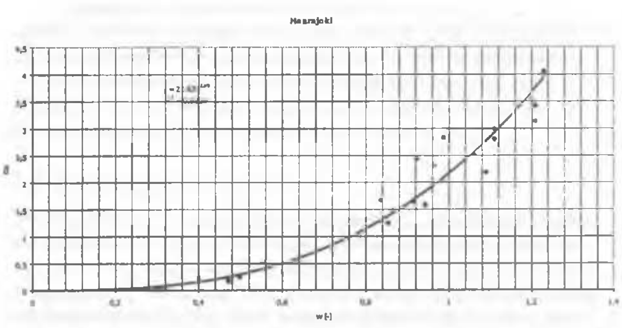

Figure 4. Correlation of water content and compressibility index at Haarajoki

6 ACKNOWLEDGEMENTS

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