Geotechnical Safety and Risk V
T. Schweckendiek et al. (Eds.)

doi:10.3233/978-1-61499-580-7-496

Evaluation and Application of Characteristic Values Based on Eurocode 7 Design Methodology

István KÁDÁR, László NAGY
Department of Geotechnics, Budapest University of Technology and Economics, Hungary

Abstract. With the prescence of Eurocode 7 standards the reliability-based design appeared and it is still spreading in geotechnics. In geotechnical design it is essential that we know the physical parameters of the soils as accurately and safely as possible. Therefore experiments and series of experiments are carried out and characteristic values are determined with the tools of statistics. Characteristic parameters are defined as cautious estimates of the soil parameters affecting the limit state. This paper aims to show the basic idea of the determination of characteritic values and describe the different definiton methods for laboratory testing and based on samples collected from larger area. In addition this paper is a contribution to show the application of Eurocode 7 design methodology, based on the limit state design.

Keywords. Eurocode 7, characteristic values, coefficient of variation, reliability based design

1. Introduction

The knowledge of the attributes of soil physics is essential for civil engineer design. Their determination is not possible on a theoretical way just by experimenting. In geotechnics with the appearance of Eurocode 7, it is essential for designing and measurement methods that we know the soil physics attributes with as much accuracy and as minimalized investigation as possible. The reliability of the raw data has a direct influence on the final result. The laboratory testing shows the raw data of designing and the characteristic values with statistical methods. Generally speaking the characteristic values of soil parameters used for designing on the basis of Eurocode 7 is one of the most crucial parts of geotechnical designing.
There are generally accepted methods to describe shear strength and shear strength parameters. The coefficient of variation has a key role in the description of the confidence of different parameters. Based on the performed experiments we can determine the characteristic value with the help of the coefficient of variation ’according to Eurocode 7.

$$X_k = X_m \cdot (1 - k_n \cdot C_v) \tag{1}$$

where X_k is the characteristic value of the soil parameter, X_m is the average of the soil parameter and C_v is the coefficient of variation. The k_n parameter in the formula depends on the number of the samples. The trend of k_n parameters for mean (50%) and 5% fractile values are shown on Figure 1.

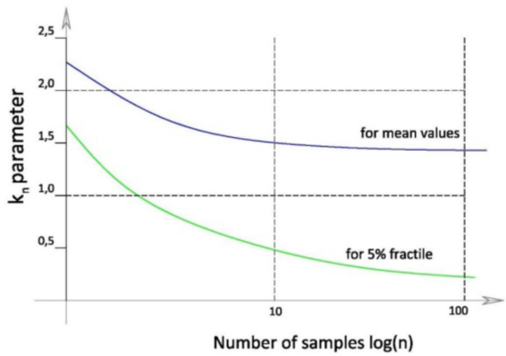

Figure 1. The trend of k_n parameter.

In specific cases there are often not enough data to determine the coefficient of variation. In these cases the followings can be taken into consideration (Szepesházi 2008):

- φ’ effective angle of internal friction: $C_v(φ’) = 0.1$
- c’ effective cohesion: $C_v(c’) = 0.3$
- c_u undrained shear strength: $C_v(c_u) = 0.4$

- E_s Young modulus: $C_v(E_s) = 0.4$

Further methods are available to calculate the characteristic values: pure mean values (Eq. 2), Schneider's equation values (Eq. 3), Ovesen's equation values (Eq. 4), 95% reliable mean values (according to the number of test results and for unknown or known coefficient of variation, referenced as mean) (Eq. 5), 5% fractile values (from a normal probability distribution) (Eq. 6), and 5% fractile values (according to the number of test results and for unknown or known coefficient of variation, referenced as low) (Eq. 7) (Marquez 2011).

$$X_k = X_m \tag{2}$$

$$X_k = X_m - 0.5 \cdot \sigma_x \tag{3}$$

$$X_k = X_m - 1.645 \cdot \sigma_x / \sqrt{n} \tag{4}$$

$$X_k = X_m \cdot (1 - k_{n,mean} C_v) \tag{5}$$

$$X_k = X_m - 1.645 \cdot \sigma_x \tag{6}$$

$$X_k = X_m \cdot (1 - k_{n,low} C_v) \tag{7}$$

2. Examined Soils, Laboratory Work

During present work we focused on two kinds of examinations: a specified laboratory work with 5 different types of soil prepared in large amount for shear box test and the examination of soils of the MAL dams[1] where the samples are collected from the territory of 3 reservoirs.

2.1. 1st Series of Examinations

To determine the coefficient of variation of the shear strength and shear strength parameters of soils we performed series of experiments with 4 different kinds of soils (fine sand, silty sand, sandy silt, high plasticity clay) and fly ash (Figure 2).

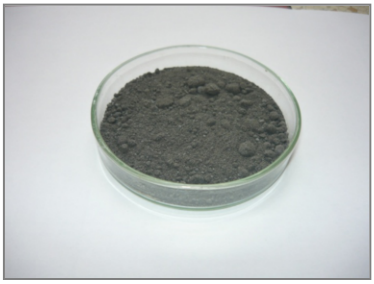

Figure 2. Examined fly ash.

All series of experiments contained at least 30 direct shear tests. Based on these tests we determined the values and statistical parameters of shear strength, angles of internal friction and cohesion.

The different kinds of soils were properly prepared before the experiments. It was an essential question how we can guarantee the same circumstances like density and moisture content during the measuring. Moisture content is mainly important in the case of high plasticity soils because it influences considerably the shear strength of soils.

2.2. Soil Investigation of MAL dams (2nd series)

In case of MAL dams the experimental results of the Geotechnical Laboratory of the department were used. In the area of MAL dams 3 significantly different soils can be found. These are clayey silty sand, gravel and high plasticity clay. The experiments were carried out also with shear box.

- clayey silty sand [clsiSa]: fine, medium and coarse sand with gravel some places, silty elsewhere, but generally has steep grain size distribution curve (C_u <7), moderately dense and well-draining.
- gravel [Gr]: compacted sandy, clayey gravel in good condition (2-5 m thick)
- high plasticity clay [Cl]: the upper part of the clay layer is softer, in the deeper region it is in tough condition. Partly it is calcareous, contains limestone rubbles, gravel collocations. Considered as watertight in terms of vertical seepage.

The material of the dams is fly ash. The fly ash is not a soil, but due to its properties it is similar. It is confirmed by the the grain size distribution

[1] Place of Ajka alumina plant accident, 2010

curve which can be determined, and used for similar purpose in structures as earthworks. Typically it is a residue of coal-fired power stations. Stacked in layers, compacted or after chemical handling is used as a building material.

The key question of stability analysis is usually not the correctness of the theoretical method, but the reliability of the shear strength parameters used in the calculation. Therefore during the dam stability analysis the determination of the worst shear strength has fundamental importance. Based on past experience the seepage in the material of the dam has no significant effect on the shear strength of the fly ash.

3. Statistical Analysis and Results

The determination of shear strength and shear strength parameters and their statistical analysis have a great importance because these attributes are the starting elements of every stability calculations. The following data have been determined for each group of soil samples:

- data that don't fit in the set of the experimental results,
- the most important statistical parameters,
- the type of the best distribution for the measured values,
- the number of the minimally required experiment for every sample.

The statistical parameters of shear strength values and of the determined shear strength parameters can be calculated on the results of the measurements. The most important statistical parameters are mean, standard deviation, coefficient of variation, coefficients of skewness and kurtosis. The value of the coefficient of variation must be pointed out because it has a great importance among the statistical parameters as we can determine more precisely the reliability of the determination of a type of soil with its value.

The evaluation of the statistical results started with the filtering of the wrong data. There are several ways to handle the extreme values: ignoring them; correction based on statistical methods; new experiments instead of them; handling the remaining values like a 'disfigured' group of samples. During the analysis the wrong data were filtered out with Grubbs' (1969) method. Only two value had to be filtered out from the series of experiment so it can be said that the results were reliably homogeneous. It is probably due to the fact that proper experiments were made which could also mean that the coefficients of variation were underrated in all series (see Table 1).

Table 1. Values of coefficient of variations (C_v) for 1st series

Soil	τ_{100kN}	τ_{200kN}	φ	c
Sand	0.046	0.037	0.069	0.154
Silty sand	0.030	0.031	0.072	0.257
Sandy silt	0.036	0.033	0.106	0.205
Clay	0.120	0.105	0.309	0.521
Fly ash	0.078	0.066	0.119	(1.864)

Table 2. Values of coefficient of variations (C_v) for MAL dams

Soil	φ	c
Fly ash	0.42	0.79
Clayey silty Sand	0.43	1.06
Gravel	0.08	(3.46)
High plasticity clay	0.72	0.57

Taking these results into account the following statements can be made:

- The coefficient of variations calculated for the soil layers of MAL dams are relatively high except the gravel's values by angle of friction. The reason is that the soil samples were taken from a big area (under the VIII., IX. and X. tailings). The significantly different soils can be separated on such a big area but there are slight features and differences locally.
- According to the first statement it is hardly recommended to make experiments more densely for stability analysis.
- All types of soils cannot be characterized with one coefficient of variation neither for the angle of internal friction nor for cohesion.
- The value of the coefficient of variation grows towards cohesive soil in both cases of shear strength statistical parameters.
- The gravel layer's coefficient of variation by angle of friction shows that the reliability of the determination of this parameter is very high.
- It is important to notice, that the coefficient of variation at the cohesion and angles of internal friction is higher than the coefficient of variation at the shear strength. So the

unreliability of the shear strength parameters does not arise only from the unreliability of the experimental results.

The coefficients of variation, determined to the different types of soils, can be evaluated in themselves (independently) but there is a new result if the coefficients of variation are represented with the types of soils, containing finer and finer grains (Figure 3 and Figure 4).

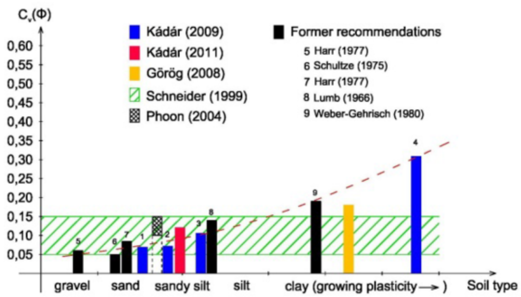

Figure 3. Values of coefficient of variation for angle of friction.

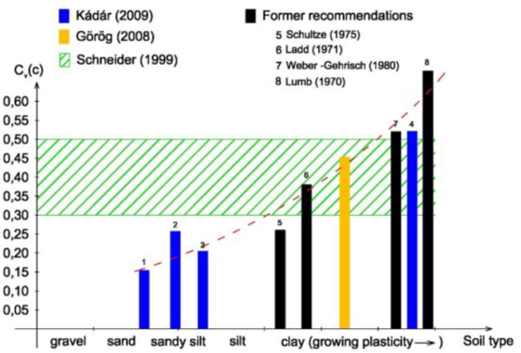

Figure 4. Values of coefficient of variation for cohesion.

Even before these series of experimentations the practising soil mechanical engineer had have the suspicion that the reliability of the shear strength and the shear strength parameters of the granular soils is better than the reliability of soils with high plasticity. It was also presumable that the reliability of the cohesive value is lower than the reliability of the angles of internal friction.

The characteristic values for angles of friction were determined for the soils of 1st series based on Eq. 2-7. (Figure 5).

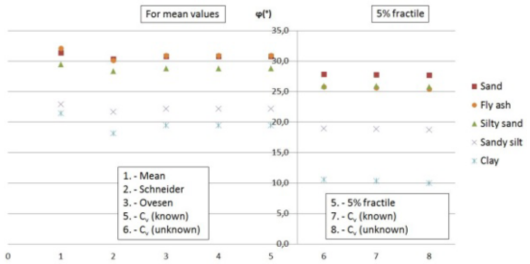

Figure 5. Characteristic values for angles of friction.

4. Summary

Based on the results of the measurements and the data found in the literature, the following important facts can be stated in connection with the reliability of shear strength parameters:

- The results of the measurements fit into the tendency of the results determined in international literature that is the determined coefficient of variation does not differ from the data in the literature.
- All types of soils cannot be characterized with one coefficient of variation neither for the angle of internal friction nor for cohesion.
- The value of the coefficient of variation grows towards cohesive soil in both cases of shear strength statistical parameters.
- Living up to the expectations the coefficients of variation of angles of internal friction is less than that of cohesion which has wider ranges (see Figure 3, 4).
- It is important to notice, that the coefficient of variation at the cohesion and angles of internal friction is higher than the coefficient of variation at the shear strength. So the unreliability of the shear strength parameters does not arise from the unreliability of the experimental results.
- With the introduction of Eurocode 7 we can use $C_v(\varphi)$ = 0.04-0.07 for coefficients of variation of angles of friction of granular soils and $C_v(c)$ = 0.5-0.6 for coefficients of variation of cohesion of cohesive soils without hesitation.

It is important to handle the coefficients of variation of shear strength parameters separately to meet the contradictory requirements of safety and thrift (Takács 2012). The results of the laboratory testing suggest that using the recommended $C_v(\varphi) = 0.1$ and $C_v(c) = 0.4$ values by Schneider (1999) in Eurocode 7 (for every type of soil) cannot be done without critical overview.

References

Duncan J. M. (2000). *Factors of Safety and Reliability in Geotechnical Engineering*. Journal of Geotechnical and Geoenvironmental Engineering, Vol.126 N.4, 307–316., 2000

Grubbs, F. E. (196). *Procedures for Detecting Outlying Observations in Samples*. Technometrics, No. 1.

Orr, T. L. L. (2000). *Selection of characteristic values and partial factors in geotechnical designs to Eurocode 7. Computers and Geotechnics*, Vol. 26, Issues 3–4, pp. 263–279.

Marquez S. H., A. Topa Gomes, A. Abel Henriques (2011). *Reliability Assessment of Eurocode 7 Retaining Structures Design Methodology*, ISGSR 3rd International Symposium on Geotechnical Safety and Risk, 455-462., Munich, Germany.

Rétháti, L. (1985). *Valószínűségelméleti megoldások a geotechnikában*. Akadémiai Kiadó, Budapest. (in Hungarian).

Schneider, H.R. (1999). *Definition and determination of characteristic soil properties*. Proceedings of the fourteenth international conference on soil mechanics and foundation engineering, Hamburg. pp. 2271-2278.

Szepesházi R. (2008). *Geotechnikai tervezés, Tervezés az EUROCODE 7 és a kapcsolódó európai geotechnikai szabványok alapján*. Business Media Magyarország Kft., (in Hungarian).

Takács A. (2012). *Karakterisztikus értékek meghatározásának új módszere nem független talajjellemzők esetén*, ÉPKO2012, Nemzetközi Építéstudományi Konferencia, Csíksomlyó, Romania. (in Hungarian).