Proceedings of the XVII ECSMGE-2019
Geotechnical Engineering foundation of the future
ISBN 978-9935-9436-1-3

doi: 17ecsmge-2019-Y-XXXX

The analysis of some cohesive soils engineering characteristics in Croatia

L'analyse de certaines caractéristiques d'ingénierie des sols à grains fins en Croatie

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ABSTRACT: The necessary geotechnical properties of the soil are defined by implementation of the field and laboratory research works. In the case of insufficient relevant data for the individual soil layer, these can be estimated using the appropriate correlations. The results of the previous research indicate a significant dependence between the granulometric composition of the soil, the Atterberg limits of liquid and plasticity, and the shear strength and deformability in the fine grained soils. From more than 50 locations in the Republic of Croatia, undisturbed soil samples were taken, with 230 laboratory tests performed. A total amount of ca. 1100 relevant data were obtained The mentioned data were analyzed by the implementation of standard statistical methods, in order to represent the correlations between the measured values of individual geotechnical parameters. The paper presents the results of the mentioned analyses and compares the obtained results with correlation relations of various authors from the available literature.

RÉSUMÉ Les propriétés géotechniques nécessaires du sol sont définies par la mise en œuvre des travaux de recherche sur le terrain et en laboratoire. En cas de données pertinentes insuffisantes pour la couche de sol individuelle, celles-ci peuvent être estimées à l'aide des corrélations appropriées. Les résultats des recherches précédentes indiquent une dépendance significative entre la composition granulométrique du sol, les limites de liquide et de plasticité d'Atterberg et la résistance au cisaillement et la déformabilité dans les sols à grains fins. En République de Croatie, des échantillons de sol non perturbés ont été prélevés et 230 tests de laboratoire ont été effectués. Un montant total de ca. 1100 données pertinentes ont été obtenues. Les données mentionnées ont été analysées à l'aide de méthodes statistiques standard afin de représenter les corrélations entre les valeurs mesurées de différents paramètres géotechniques. L'article présente les résultats des analyses mentionnées et compare les résultats obtenus avec les relations de corrélation de divers auteurs de la littérature disponible.

Keywords: Cohesive soil, Correlation, Plasticity index, Drained shear strength

1 INTRODUCTION

The laboratory test investigation results of the ground soil on different locations in Croatia were summarized. The main goal of this study was to collect statistically significant number of laboratory test results, with the intention of analyzing relationships between geotechnical parameters, i.e., the correlation between index properties and effective peak shear strength for low and high plasticity clays. In addition, laboratory test results published in the available literature were summarized (Ortolan and Mihalinec 1998, Sorensen and Okkels 2013.) to compare with the results of the study. All geotechnical parameters used in this study are obtained from laboratory tests performed on undisturbed soil samples taken from the field.

The comparison of correlations obtained in this study with correlations from the other authors is made. A general trend in the dependency between certain soil parameters is noticed.

Correlations between soil parameters are a common tool used in everyday engineering practice. They can be implemented in a wide range of geotechnical tasks. Very often, in a certain phase of a project, an engineer encounters a problem of insufficient soil parameters informations. In these cases, it is necessary to conduct an appropriate procedure to estimate values of relevant soil properties. The procedure often includes us-age of empirical correlations derived from experimentally verified and broadly accepted recommendations from available literature.

In this paper, it is shown that for a specific case, correlations between some index properties and an effective shear strength of fine-grained soils, can be used for parameters estimation with an acceptable precision, i.e., they can be applied in everyday engineering practice. Additional favorable fact is that these correlations can be determined by simple, routine laboratory tests, which can be carried out in a short time, without further costs. In such a way, it is possible to acquire the appropriate quantity of data about certain soil layer. This data can be used in an initial geotechnical analysis. At the same time, it can also be used as a benchmark for laboratory test results rectification in the further geotechnical investigation or design phases.

Clays within this study are generally over consolidated, with OCR in range 1 – 3 which has been confirmed with the comparison of data obtained within this study with the data from the available literature.

A number of direct shear tests of undisturbed samples have been performed. The range was from low to high plasticity index values from different types of clays. There is a generally a relatively large scatter results between drained peak angle of shear resistance and plasticity index. Despite that, these two values can be related with reasonable accuracy and applicability.

2 OVERVIEW OF PUBLISHED RESULTS AND DISCUSSION

It has been shown that is possible to obtain relevant soil parameters related on the index correlations with relatively limited resources and laboratory procedures.

Regardless of a clay being normally or over consolidated, for the range of vertical stresses that occur in the most practical cases, the following assumption can be made: at failure, the relationship between vertical normal and shear stresses is linear.

At the landslide's state of failure analyses, i.e., at the predicting the occurrence of undesired state, the detailed investigations of correlation between index properties and effective (peak and residual) angle of internal friction have been carried out. It has been shown that the most significant indicator of coherent soils shear strength is the plasticity index. Generally, when plasticity index increases, the angle of internal friction decreases, regardless of the OCR value and the shear strength type (residual or peak).

Ortolan has suggested so-called RNK method (Ortholan, 1996) for the definition of consistent Engineering Geology model, from which is possible to determine zones with minimal residual shear strength parameters, with respect to their thickness and distribution along the investigated soil profile.

Figure 1 shows the correlation between effective peak angle of internal friction and plasticity index for overconsolidated clays. Presented values are obtained from the available literature (Ortolan and Mihalinec 1998) and from this study.

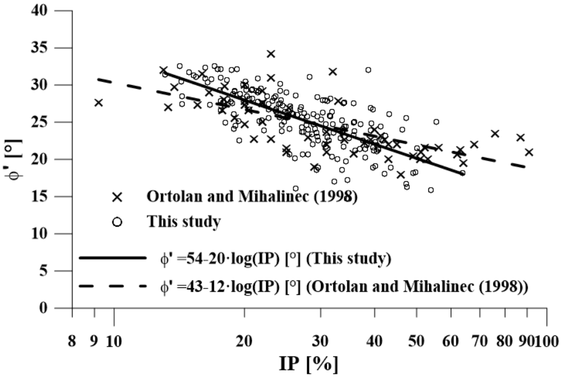

Figure 1. φ'_{oc} vs IP for overconsolidated undisturbed clays after Ortolan and Mihalinec 1998 (included Gibson 1953, Nonveiller 1988, Skempton 1964, Skempton and La Rochele 1965, Skempton and Petley 1967) and for this study.

Figure 2 shows the relationship between the plastic limit over liquid limit ratio and the cosine of peak angle of internal friction. Presented values are also obtained from the available literature (Ortolan and Mihalinec 1998) and from this study.

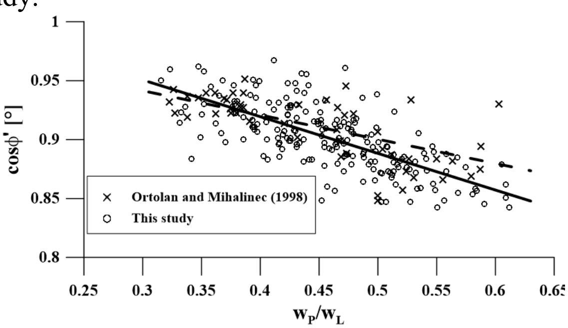

Figure 2. W_P/W_L vs $\cos\varphi'$ for overconsolidated undisturbed clays after Ortolan and Mihalinec 1998 (included Gibson 1953, Nonveiller 1988, Skempton 1964, Skempton and La Rochele 1965, Skempton and Petley 1967) and for this study.

Figure 3 shows the relationship between the plasticity index over liquid limit ratio and the cosine of peak angle of internal friction. Presented values are obtained from (Ortolan and Mihalinec 1998) and from this study.

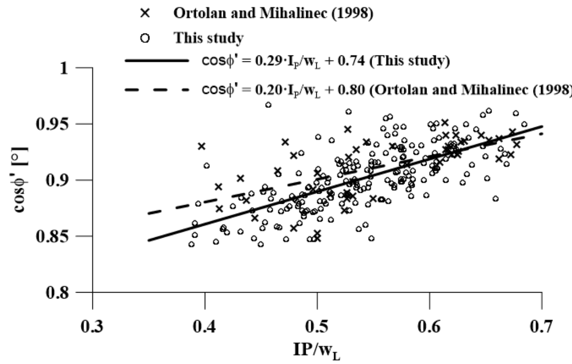

Figure 3. IP/W_l vs $\cos\varphi'_{oc}$ for overconsolidated undisturbed clays after Ortolan and Mihalinec 1998 (included Gibson 1953, Nonveiller 1988, Skempton 1964, Skempton and La Rochele 1965, Skempton and Petley 1967) and for this study.

Figure 4 shows the relationship between the clay fraction and the peak angle of internal friction. Presented values are also obtained from the (Ortolan and Mihalinec 1998) and from this study.

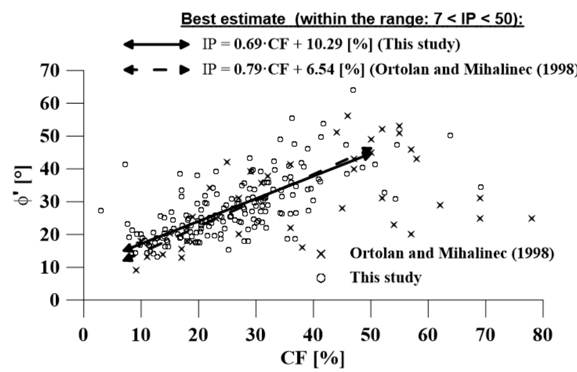

Figure 4. CF[%] vs φ'_{oc} for overconsolidated undisturbed clays after Ortolan and Mihalinec 1998 (included Gibson 1953, Nonveiller 1988, Skempton 1964, Skempton and La Rochele 1965, Skempton and Petley 1967) and for this study.

Figure 5 shows summarized correlations between the plasticity index and the peak angle of internal friction, obtained from various authors.

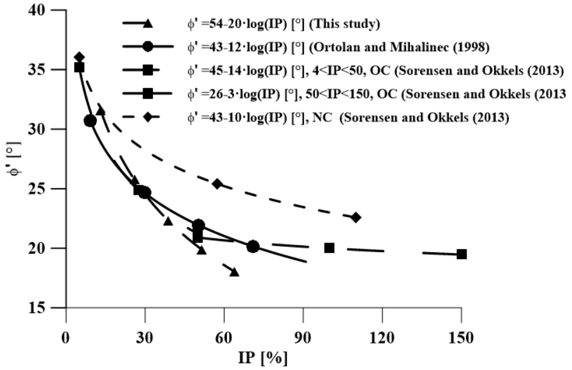

Figure 5. IP[%] vs φ'$_{oc}$ for overconsolidated undisturbed clays after Ortolan and Mihalinec 1998 (included Gibson 1953, Nonveiller 1988, Skempton 1964, Skempton and La Rochele 1965, Skempton and Petley 1967, Sorensen and Okkels 2013) and for this study.

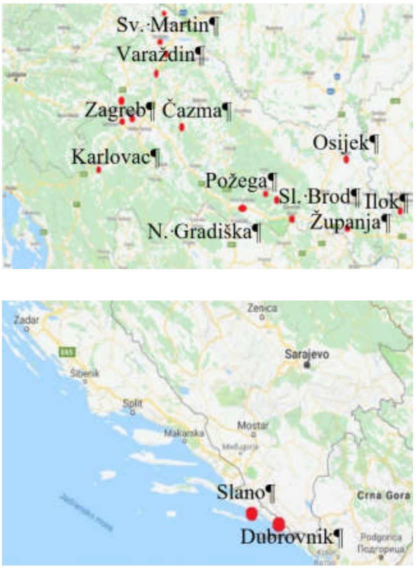

Figure 6. Locations from which the soil was sampled (the northern part of Croatia and Dubrovnik area)

3 LOCATIONS OF THE PERFORMED FIELD INVESTIGATIONS

Parameters values used in this study are obtained from laboratory tests performed on 230 soil samples taken from multiple locations across the Republic of Croatia. Tests on soil samples were performed by the geotechnical laboratory at Faculty of Geotechnical Engineering, University of Zagreb, between the January 2007 and June 2010. All tests were performed in strain-controlled direct shear test apparatus. Generally, all samples come from low and high plasticity clays, some samples sporadically contained a certain amount of sand.

Figure 6 shows the locations from which samples were taken in the continental part of the Republic of Croatia. The largest part of the samples tested belongs to this area. These are the locations in the wider Zagreb area. Other locations include locality of Karlovac, Čazma, Nova Gradiška, Požega, Slavonski Brod, Osijek, Županja and Ilok.

Slightly a smaller number of samples were taken from wider area around city of Dubrovnik.

4 GAINED RESULTS AND DISCUSSION

The numerical values, together with correlation in the logarithmic scale of the ratio of the plasticity Index and the friction angles obtained on the basis of the tests presented in this paper were given in Figure 1. It can be noticed that relatively higher deviation occurs at lower and higher values of the plasticity index. For a range of IP 20 -40 linear correlations in the logarithmic metric gives a relatively narrow value range or a negligible deviation.

In Figure 2, similar to Figure 1. a relatively good correlation between the results of the study and the data from the available literature may be noticed. In this case, the relation of the relative values of the plasticity limit and liquid limit on the abscissa and cosine of the friction angle on the ordinate in a linear scale is given. Here, only a relatively higher value of relative dispersion comes from the relative relation of the abscissa.

In Figure 3, a significant deviation only for values of the relative relation of the plasticity index and the liquid limt of less than 0.5 can be found.

The slightest deviation, meaning the best correlation between the measured values and the results from the literature used, is seen by the percentage of clay fraction and the internal friction angle for the values of plasticity index in the range of IP = 10-50, as can be seen in Figure 4. However, the relationship between the two parameters generally has not been found to be correct correlation.

Figure 5 shows a correct correlation between the results obtained from this study and the available literature. This is especially true for the value of the plasticity index of less than 40. A somewhat greater deviation is generated compared to the results given by (Sorensen and Okkels 2013). The reason for mentioned deviation can be found in different values of pre-consolidation stress.

5 CONCLUSIONS

The plasticity index is an nondirect indicator of the shear strength of the coherent materials. Mutual dependence of the peak values of the internal friction and the plasticity index was demonstrated for the examined clay (cohesive soil) samples. Diagrams and correlations from the paper show acceptable complience level with the results from available literature.

The observed deviations are because of the impossibility of taking ideally undisturbed samples and due to the different composition of fine clayly materials, ie deviation in the mineralogical composition of clay and heterogenity with respect to the different geological compositions of the test sites.

No significant pattern was observed, ie correlation ratio for low and high plasticity with mixed with some amount of sand.

Established correlations and connections allow for the determination of initial, estimated peak values of the soil drained friction angle. They can be used as initial approximations of relevant values, or may be an integral part of the preliminary geotechnical design. The mentioned dependencies can serve as a measure of determining the characteristic of the observed continuum. At the same time, established correlation relationships will serve as the basis for that segment of further research that is necessary in everyday engineering practice.

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