CORRELATIONS BETWEEN GEOTECHNICAL PARAMETERS OF TRANSILVANIAN COHESIONLESS SOILS BASED ON TRIAXIAL LABORATORY TESTS RESULTS

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ABSTRACT
The current rhythm for construction works and their complexity raise various geotechnical problems. One of the key issues in both the execution and design stage is to ensure stability while building especially when unfavorable soil conditions are present. Accurate information regarding geotechnical parameters represents an important subject in solving various problems using computer programs used worldwide. Most times the number and complexity of parameters needed as input to specialized computer programs is very high and requires advanced knowledge of soil mechanics science. Because of this, very often complete data for such analysis are not included in geotechnical studies. As an immediate consequence of this problem, determining correlations between geotechnical parameters both mechanical and physical in order to facilitate the input process for computer analysis represents an actual necessity. The paper presents ways of processing parameters determined based on laboratory triaxial test and correlations between them. The study was conducted on a cohesionless soil from Transylvania Region near Baia Mare City.

Keywords: geotechnical parameters, triaxial laboratory tests, cohesionless soil, correlations between parameters

INTRODUCTION
The purpose for field and laboratory tests is to provide the needed data for optimal design process of soil constructions, foundation systems calculation, bearing capacity calculation, tunneling and slope stability analysis. A complete characterization detailing the intricate and complex response of soils remains a challenging task that can only be realized through careful drilling and sampling program coupled with detailed laboratory testing [1]. However, the situation when complete data for computer analysis is not included in the geotechnical studies is very often encountered. The determination of different correlations between the geotechnical parameters will simplify the input process for computer analysis and will also facilitate the process of selection for the correct parameters needed for the analyze [2]. The main purpose of this study is about to determine the required parameters from the geotechnical parameters that can easily be determined from laboratory tests. However relations between the geotechnical parameters need to be accurately calculated in order to precisely represent the true behavior of the soil.

MATERIALS AND METHODS
The study for this paper is made based on the results from triaxial compression tests. Triaxial tests is the most complex test procedure that can be performed in geotechnical laboratories. It implies a complex procedure that requires advanced knowledge of soil mechanics, laboratory testing procedures and sample preparation.

1. Triaxial compression laboratory test principles
The triaxial test is the laboratory test that provides the most accurate results because of its complexity and also because it manages to simulate the best the situation on the site by creating the same stress state for the tested samples. [3]. The triaxial test is performed on a cylindrical sample, usually having the diameter 100 mm, and the height twice as big as the diameter.
Triaxial apparatus is a complex system made of several components so that during the test sample can be subjected to various triaxial controlled tensions. Also throughout the test data regarding: the value of pore water pressure, volume deformations, vertical displacement and axial stress are provided (fig.1) [4]. Triaxial shear testing can be performed in several ways depending on the situation in the field [5]:

- The UU (unconsolidated-undrained)test. This type of test is usually performed when the speed of execution for the construction is faster than the consolidation speed for cohesive soils.
- The CU (Consolidated-undrained)test. This type of test is usually performed when, after the consolidation of the foundation soil under the existing construction new loads appear and there is no water drainage possibility.
- The CD (Consolidated-drained)test. This test is usually done when there is water draining conditions as consolidation pressure increases.

Thus the complexity of data obtained from the triaxial tests allows different and various possibilities for processing [6]. Due to extensive areas that triaxial tests are used it is very important that data provided to be accurate. Possible errors should be anticipated and a careful analysis must be made on the values of correction factors and how to apply them [7]. Triaxial compression tests are also used as a component in wellbore stability, sand production and subsidence calculations and also for mine and excavation design.

![Triaxial apparatus](image)

**Fig.1. Triaxial apparatus**

2. **Triaxial compression tests performed on cohesionless soil extracted from Baia-Mare Area**

Triaxial shear tests on cohesionless soil present certain particularities especially in preparation of samples. Before their construction, in order to ensure accurate test results, pore indexes describing the maximum and minimum density were determined ($e_{\text{max}}$ and $e_{\text{min}}$). With the pore indexes values the density index $I_D$ of the samples subjected to the triaxial compression test were calculated [8]. If field conditions allow the initial density index should also be determined. In this case the sample subjected to triaxial compression can be created at the same density index as that cohesionless soil had in the field before extraction. The triaxial tests discussed in this paper were executed on a cohesionless soil extracted from a site near Baia-Mare City from Transylvania Region.

Regarding the geomorphological aspect of the tested soil the location where samples were extracted belongs to the Somes Depression from the right side of the river Somes. The area is characterized by alluvial material with chaotic bedding. The formations are composed of quaternary deposits represented by clays and gravels and sands. Based on the granulometric analysis the material tested in the laboratory is a medium sand with round particles and it was extracted from a
depth of about 4m [9]. During the laboratory testing, nine triaxial tests were conducted in consolidated-drained system (table 1). The tested samples were constructed at three different density indexes. The samples with the same density index were tested at three different confining pressures.

<table>
<thead>
<tr>
<th>Sample Number</th>
<th>Pore Index $e_{initial}$</th>
<th>Density Index $I_D$</th>
<th>Confining pressure [kPa]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>0.50</td>
<td>0.95</td>
<td>100 kPa</td>
</tr>
<tr>
<td>1.2</td>
<td>0.50</td>
<td>0.95</td>
<td>200 kPa</td>
</tr>
<tr>
<td>1.3</td>
<td>0.50</td>
<td>0.95</td>
<td>400 kPa</td>
</tr>
<tr>
<td>2.1</td>
<td>0.67</td>
<td>0.15</td>
<td>100 kPa</td>
</tr>
<tr>
<td>2.2</td>
<td>0.67</td>
<td>0.15</td>
<td>200 kPa</td>
</tr>
<tr>
<td>2.3</td>
<td>0.67</td>
<td>0.15</td>
<td>400 kPa</td>
</tr>
<tr>
<td>3.1</td>
<td>0.55</td>
<td>0.71</td>
<td>100 kPa</td>
</tr>
<tr>
<td>3.2</td>
<td>0.55</td>
<td>0.71</td>
<td>200 kPa</td>
</tr>
<tr>
<td>3.3</td>
<td>0.55</td>
<td>0.71</td>
<td>400 kPa</td>
</tr>
</tbody>
</table>

RESULTS

Based on the values recorded after the failure stage of the triaxial compression tests the effective stresses $\sigma_3'$ and $\sigma_1'$ were calculated. Based on the calculated values of the effective stresses the effective shear strength parameters were determined by using the Mohr-Coulomb Model (fig.2), (fig.3), (fig.4).

This model is the most common procedure used for determining the effective shear strength parameters from triaxial laboratory tests. Mohr-Coulomb model relies on a line defined by the Coulomb failure stress and the stress circles of Mohr. The field of failure is given by the cohesion and internal friction angle [10].

![Fig.2. Determination of effective shear strength parameters using Mohr-Coulomb model for the samples 1.1., 1.2, and 1.3](image-url)
DISCUSSIONS

For a certain type of soil the purpose is to establish relations between the geotechnical parameters both mechanical and physical in order to facilitate the input process for computer analysis. Based on the initial density index of the samples and on the processed data from the triaxial tests a linear relation between the initial density index and effective shear parameters was established. The frictional angle for the tested sand can be calculated with the following relation (fig.5):

\[
\phi' = 3.2587 I_D + 35.784
\]  

\( \phi' \) is the effective frictional angle and \( I_D \) is the initial density index.
If the density index directly influences the effective frictional angle than it will also influence its residual value. Similar with the previous determination, the relation between the residual frictional angle and the density index was expressed in the following way (fig. 6):

\[ \varphi' = 2.8022D + 34.656 \]  

(2)

Fig. 6. The influence of the density index on the residual value of frictional angle

In the case of sands with maximal densification and minimal porosity, the particles slip tending to the state of maximal loosening. In this way, the soil is loosed by shearing. The loosening phenomenon of dense sands by shearing is named dilatancy.

The effective frictional angle value is afferent to the maxim value of the shear strength. After the maximum value for the shear strength is reached it starts to decrease until it reaches the residual value that is afferent to the residual frictional angle. The difference between the effective frictional angle and the residual value of the frictional angle represents the dilatancy angle. The dilatancy angle is a very used parameter in geotechnical engineering problems especially as an input parameter for computer analysis. Based on the sample principle a relation between the density index and the dilatancy angle was determined (fig. 7):

\[ \psi = 0.4565D + 1.1279 \]  

(3)

Fig. 7. The influence of the density index on the dilatancy angle

CONCLUSIONS

A complex analyze of the behaviour of a cohesioless soil and also the analyze of its geotechnical parameters represents a challenge task and it requires advance knowledge of soil
mechanics. Also accurate results must be ensured by a careful analyze of each step of the geotechnical parameters determination process. Determination of correlations between geotechnical parameters that represent the true behavior of a certain type of soil studied is an important task that will facilitate the next steps of modeling and design of various structures. Also in terms of modeling, the use of correlations between the geotechnical parameters subject may be carried out further in order to evaluate different computational models used in geotechnical engineering in order to highlight the advantages and disadvantages of the used model for a particular type of soil. Another directions of the use of correlations between the geotechnical parameters is represented by the study for simulation the triaxial compression test in a finite element program which represents the subject of a further study.

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