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NUMERICAL CORRELATIONS FOR PREDICTION OF SHEAR STRENGTH PARAMETERS OF COHESIONLESS SOILS FROM BOTH TRIAXIAL AND DIRECT SHEAR TESTS

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Abstract:

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. 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 analysis. 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 behaviour of the soil.

Key Words: *T*riaxial, Direct shear, Cohesionless soils, Correlations, Trendline concept

Introduction

Shear strength of soil is one of the most essential parameter required for analyzing and solving stability problems such as; lateral earth pressure, bearing capacity of foundation, slope stability, and stability of embankment and earth dams. Direct shear tests, Triaxial tests and other tests are usually used to determine shear strength of soil in laboratory. Among other tests, direct shear device is the simplest, inexpensive, and being used successfully for over a century. 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. it is well known that in many cases the field shearing deformations that may eventually lead to failure occur mainly in one plane.

For example most landslide problems, failure of soil beneath a strip footing or a long load, and failure of a retaining wall, are all cases of plane strain, in which the deformations are not well represented by the Direct shear test. The triaxial test is one of the most versatile and widely performed geotechnical laboratory tests, allowing the shear strength and stiffness of soil and rock to be determined for use in geotechnical design. Advantages over simpler procedures, such as the direct shear test, include the ability to control specimen drainage and take measurements of pore water pressures.

Literature Review

Lee Keun Park et.al., (2008) investigated shear strength of juminjin sand having relative density above 40% using plane shear test, triaxial test and direct shear test. This study reported that under plane strain conditions, the plane strain angle of friction exceeds the value obtained from triaxial tests as well as by from 0º to about 9.5º and 5º to about 10º respectively and few empirical correlations were drawn between angle of internal friction and relative density.

Sadanand Ojha and Ashutosh Trivedi (2013) presented a problem associated with the estimation of relative density of the soil containing significant % of plastic and non-plastic silt. From the study, the results indicated that the maximum and minimum void ratio decreases with increase in silt content and critical state angle of internal friction increases with increase in percent silt.

Molnar Iulia (2012) developed correlations between geotechnical parameters that facilitates in the modeling and design of vertical cuts, embankments, retaining walls, foundation systems, tunnelling and dams. As an immediate consequence of structural 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.

S. N. Osano is studied an interpretation is given for the internal angle of friction and its relationship with the strain propagation in both the methods, and a comparison made. Results are presented from both the direct shear box and the ring shear test, and these are compared. Both the tests yield varying internal angle of friction when carried out on the same specimen. Results reveal that the internal angle of friction obtained from a direct shear test is lower than that obtained from the ring shear test. It is established that the ring shear test has an inherent tendency to squeeze out material from the cell due to high stress accumulations at the outer edges. The inner edge is always under stressed.

Materials

Cohesion less soil sample was collected from Cauvery river basin in Tamil Nadu. The sample was taken to the laboratory, cleaned, dried and preserved for further experimental works. Basic soil properties such as specific gravity, particle size distribution and dry densities of collected samples were done as per IS standards and are reported in Table 1.

A poorly graded sand (SP) is used in this study. The sand is classified as SP by IS Soil Classification System. The particle size distribution of the sand is shown in Figure 1.

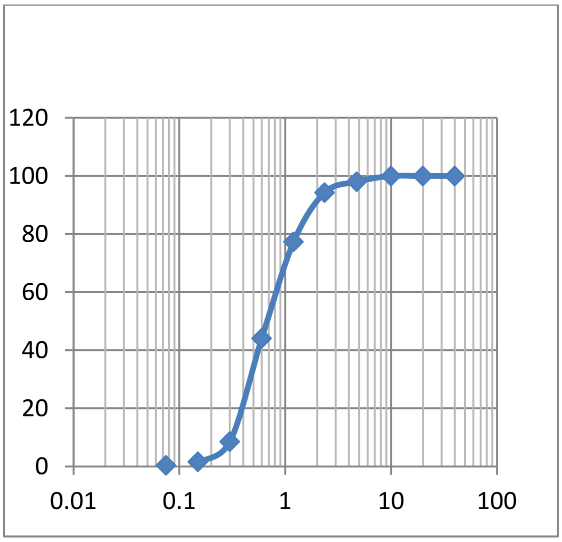

Figure 1. Particle size distribution

Table No 1. Engineering properties of soil used

Soil Properties	Values
Coefficient of uniformity (Cu)	0.58
Coefficient of curvature (Cc)	2.12
Maximum unit weight	1.71g/cc
Minimum unit weight	1.53g/cc
Specific gravity	2.67

The study for this paper is made based on the results from triaxial compression tests. Triaxial test 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. 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. The triaxial test is performed on a cylindrical sample, having the diameter 76 mm, and the height twice as big as the diameter at a strain rate of 1.25mm/min. Triaxial compression tests are also used as a component in wellbore stability, sand production and subsidence calculations and also for mine and excavation design.

Direct Shear Test

This test is performed to determine the consolidated-undrained shear strength of a cohesionless soil. The shear strength is one of the most important engineering properties of a soil, because it is required whenever a structure is dependent on the soil's shearing resistance. The relative densities are achieved for the six soil samples from 5% to 55%.

Results and Discussions

Based on the values recorded after the failure stage of the triaxial compresion tests the effective stressesσ_3 and σ_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. This model is the most common procedure used for determining the effective shear strength parameters from triaxial laboratory tests. The field of failure is given by the cohesion and internal friction angle. The results obtained from consolidated drained triaxial test on cohesion less soil are presented. The corresponding Mohr's circle plot is shown in figure 2.

The Mohr's circle is drawn for corresponding confining pressure (σ_3) and axial stress (σ_1). The failure envelope is the tangents joining the corresponding Mohr's circles and the angle intercepted of this failure envelope gives the angle of shearing resistance. It is observed from figure 1, for cohesion less soil at 5% relative density and for confining pressures of 100kpa, 200kpa and 300kpa the angle of shearing resistance is calculated as 24.73^0.

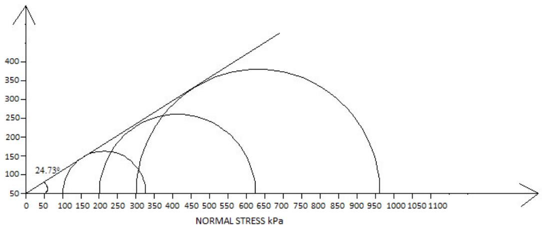

Figure 2. Mohr circle for the sample 5% relative density

The following table shows the summary of triaxial test results

Table 2. Summary of triaxial test results

S.NO.	Relative density	Φ_{tri}
1	5	24.73º
2	15	26.69º
3	25	28.87º
4	35	29.98º
5	45	31.45º
6	55	33.67º

The angle of shearing resistance is found from the graph (figure 3). Table 3 shows the laboratory direct shear calculations for the sample 5% relative density.

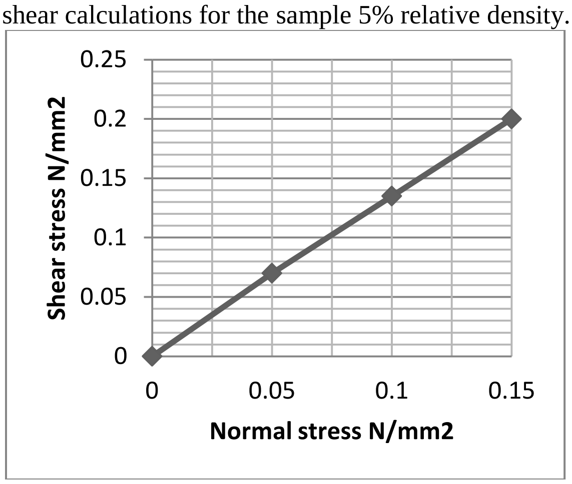

Figure 3. Normal stress Vs Shear stress

The angle of shearing resistance calculated from the above graph is 24.57^0.

The following table shows the summary of direct shear test results

Table 3. Summary of direct shear test

S.NO.	Relative density	Φ_{ds}
1	5	24.57º
2	15	26.12º
3	25	28.07º
4	35	29.18º
5	45	30.99º

Correlation Equations

Since shear tests on course materials are often difficult to conduct, it would be useful for practical purpose relations based on easily measurable parameters. 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 relations.

Trend line Concept using MS EXCEL

Straight or curved line in a trend chart that indicates the general pattern or direction of a time series data (information in sequence over time). It may be drawn visually by connecting the actual data points or (more frequently) by using statistical techniques such as exponential smoothing or moving averages.

By Using Trend line approach, the corresponding X,Y values can be under the straight line format. The points are joined in the straight line. Then the Polynomial equation has been derived and R squared value can be determined. Then the strength of the straight line is obtained.

Trend line concept for triaxial results

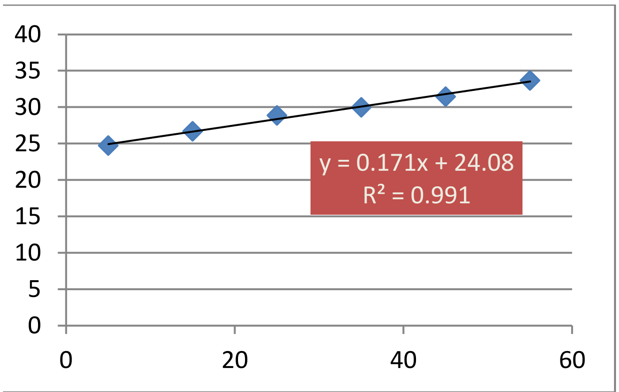

Figure 4. Trend line concept for triaxial results

Trend line concept is the same as the Principle of least squares. The major difference of these two is principle of work. It may be analytical or computer analysis.

From Trendline chart,

R^2 = 0.991

R = 0.994

which implies that, the Correlation coefficient for this fit is 0.991. From this coefficient, the strength of the Linear curve is 99.4894%
from the figure, the correlation is written as

$$\Phi_{tri}=24.08°+0.171I_D \quad [1]$$

Trendline concept for direct shear results

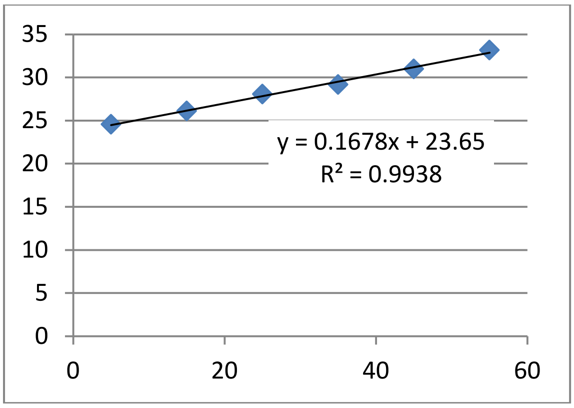

Figure 5. Trend line concept for direct shear results

From Trendline chart,
R^2 = 0.993
R = 0.996
which implies that, the Correlation coefficient for this fit is 0.993. From this coefficient , The strength of the Linear curve is 99.6894% from the figure 5., the correlation is written as

$$\Phi_{ds}=23.65°+0.167I_D \quad [2]$$

Summary of correlation

Table 4. shows summary of two correlation equation and their strength is tabulated below

Table 4. Summary of correlations

Method of correlation	**Observations**	**Correlation equation**	**Strength %**
Trendline Concept	Triaxial test	$\Phi_{tri}=24.08°+0.171I_D$	99.4894 %
	Direct shear test	$\Phi_{ds}=23.65°+0.167I_D$	99.6894 %

The empirical relationships provided above should be used with caution. However, they are useful for initial estimation of the shear strength of cohesion less soils.

Conclusions

1. As a result of present work, angle of Shearing resistance of sand based on relative density is evaluated. Approximate numerical correlations are drawn between angle of shearing resistance and relative density.
2. 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.
3. The triaxial angle of internal friction exceeds the value obtained from direct shear tests. Also the correlation developed from direct shear tests is having higher strength which indicates the goodness of fit.
4. Another direction of the use of correlations between the geotechnical parameters is represented by the study for Numerical simulation of the Direct shear test in a finite difference program which represents the subject of a further study.

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Biography

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