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MODELLING OF SHEAR STRENGTH PARAMATERS OF SATURATED CLAYEY SOILS

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ABSTRACT: Shear strength of a soil can be defined as the maximum shear stress that can resist by the internal forces of the soil. Shear strength must be determined to solve the soil stability problems. The shear strength parameters of the soil are cohesion and internal friction angle. These parameters can be determined in the laboratory by the direct shear test, triaxial test and unconfined compression test. However, laboratory tests take time and engineers want to define these parameters easily by using software. The development of the computer technology presents abilities to model the soil behavior in civil engineering applications. In this study, triaxial compression tests are performed on saturated clayey soils under different confining pressures. Unconsolidated-Undrained test is chosen to identify short term behavior. After the experimental procedure, the test is modeled by using the Plaxis program and the results are compared. Relationship between the results are presented.

Keywords: Shear Strength, Clayey Soil, Triaxial Compression Test, Plaxis

1. INTRODUCTION

Defining the soil parameters is the first step of the all designs in geotechnical engineering. Especially, shear strength must be determined for soil stability problems. Shear strength of a soil is the maximum resisting capacity under shear stress. Soils are gain this capacity from the internal forces. Shear strength is related to internal friction for coarse grained soils and cohesion for fine grained soils, respectively. The other factors affecting the clay soil strength can be such as effective stress, plasticity, cementation, moisture content, anisotropy and loading rate.

The soil strength parameters can be found by using triaxial shear tests (consolidated-drained CD, consolidated-undrained CU, and unconsolidated-undrained UU), direct shear test, vane shear test, unconfined compression test in the laboratory and standard penetration test, cone penetration test, pressuremeter test in the site. All of these test require maximum care and time because experimental errors can affect the results significantly. After determining the parameters, soil strength is calculated by using Coulomb theory, derived in 1776 [1]. Equation (1) is given below and shear strength (τ) is accepted just about shear stress on the failure plane [1].

$$\tau_f = c + \sigma'(\tan\phi) \quad (1)$$

where; c is cohesion ϕ is angle of internal friction and σ' is effective stress.

Mohr-Coulomb failure criteria is used to define soil stress concept. Stress conditions at failure in a soil mass is given in Fig. 1.

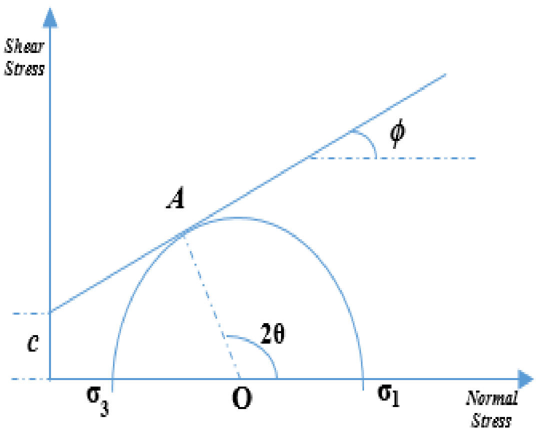

Fig. 1 Mohr's circle and failure envelope

If the failure plane makes an angle θ with the major principal plane, the normal stress and the shear stress on the plane are given in Eq. (2) and (3).

$$\sigma = \frac{\sigma_1 + \sigma_3}{2} + \frac{\sigma_1 - \sigma_3}{2}\cos 2\theta \quad (2)$$

$$\tau_f = \frac{\sigma_1 - \sigma_3}{2}\sin 2\theta \quad (3)$$

Many researchers studied shear strength of the soils in the literature. Some of them determined the parameters by using some laboratory tests and field tests or developed new test methods [2], [3], [4], [5]. Some researchers used numerical and statistical methods for modelling the soil strength [6], [7], [8], [9].

Nowadays, shear strength problems are solved by using software to save time. The soil behavior can be modeled by softwares using finite element or finite differences methods. Thus, soil stability problems such as bearing capacity, slope failure etc. can be easily solved. In this study, triaxial compression tests are performed on saturated clayey soils under different confining pressures. Unconsolidated-Undrained (UU) test is chosen to identify short term behavior of clayey soil. After the experimental procedure, the test is modeled by using the Plaxis program and the results are compared. Relationship between the results are presented.

2. MODELLING AND METHODS

In this study; Plaxis 2D performed to determine soil behavior. Plaxis is a commercially available program which is using finite element method and commonly used in civil engineering applications [10]. Example screen of the Plaxis menu is given in Fig. 2.

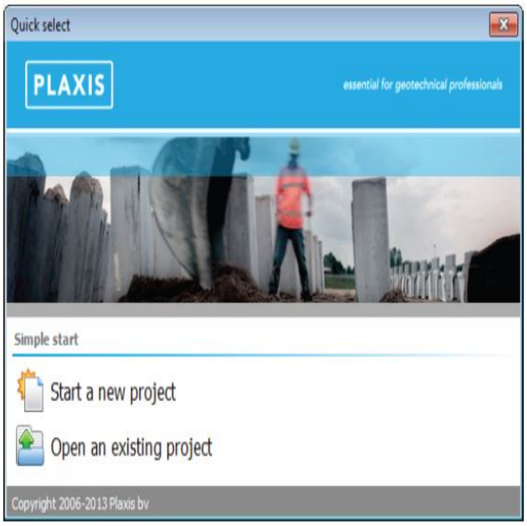

Fig. 2 Example screen of the Plaxis menu

Plaxis 2D consist of three steps; input, calculation, and output. Geometry, is created and materials data is identified in the input step. After meshing procedure, loads are marked in the calculation step. At the end of the calculation step, deformations and force graphs can be seen in the output segment.

Areas and surfaces are formed by 6-node or 15-node triangular elements in Plaxis 2D [10]. In this study, 15-node analysis were chosen due to considering sensitivity. The finite element mesh is generated when the geometry model is complete. The mesh generation records whole position of points and lines in the model [10].

2.1 Experimental Procedure

Test soil is taken from a construction site in the city of Eskisehir, Turkey. After boring, soil index properties determined such as moisture content, atterberg limits, specific gravity, sieve analysis, and hydrometer. Standard proctor tests are also performed on the samples. Basic characteristics of the soil are given in Table 1.

Table 1 Basic characteristics of test soil

USCS	MH-OH
ω_n (%)	30,20
ω_L (%)	85,00
ω_P (%)	20,00
ω_{opt} (%)	49,00
Gs	2,52
Gravel (%)	0,32
Sand (%)	12,50
Silt (%)	64,18
Clay (%)	23,00

The reconstituted samples have 70 mm in diameter and 140 mm in length. In this study samples were prepared by compacting with optimum moisture content. Unconsolidated-Undrained triaxial test is performed on the compacted samples. The test procedures were designed according to the ASTM D2850. A test sample is given in Fig. 3.

Fig. 3 A test sample

The confining pressures are chosen 10, 20 and 30 psi and the deviator stress are applied to the failure. Shear stress parameters are found by drawing the Mohr's circles. Detailed information is given in Table 2. Mohr's circles are also given in Fig. 4.

Table 2 Test Details

Sample	A	B	C
Confining Stress	10,0 psi	20,0 psi	30,0 psi
Deviator Stress	20,4 psi	28,7 psi	35,7 psi
Principal Stress	30,4 psi	48,7 psi	65,7 psi
Max. Strain	6,0 %	8,0 %	9,0 %
Cohesion	4,99 psi	4,99 psi	4,99 psi
Friction angle	16^0	16^0	16^0

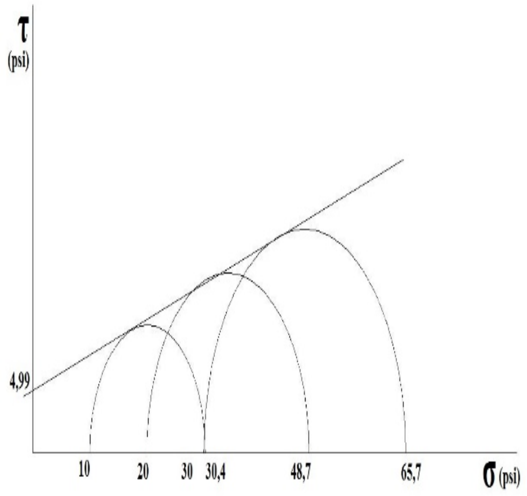

Fig. 4 Mohr's circles of the test samples

2.2 Modelling Procedure

Plaxis is using different soil models to define soil behavior such as Mohr-Coulomb Model, Hardening Soil Model, Soft Soil Model, Soft Soil Creep Model, Jointed Rock Model and Modified Cam-Clay Model. Mohr-Coulomb Model is chosen for this study. Because it is commonly used and not required extra soil parameters. The behavior is linearly elastic and perfectly plastic in this model that needs Young's Modulus, Poissons Ratio, and cohesion, internal friction angle and angle of dilatancy [10].

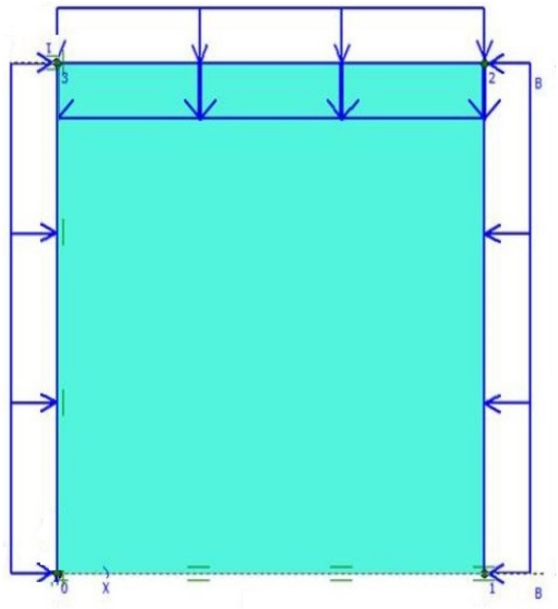

Fig. 5 Model screen

Plaxis modelling is prepared with considering boundary conditions, loading and soil properties. Modulus of elasticity is calculated from the initial part of stress-strain graphs of the samples. Confining pressures are applied as the triaxial test at top and two sides. Three dimensional effect is ignored because of the 2D analysis. Deviator stress are applied at the top and the deformations are determined. Model details are given in Table 3.

Table 3 Model Details

Sample	A	B	C
Soil Model	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Cohesion	4,99 psi	4,99 psi	4,99 psi
Friction angle	16^0	16^0	16^0
Young Modulus	2875 kN/m^2	2875 kN/m^2	2875 kN/m^2
Dilatancy angle	0	0	0
Poissons Ratio	0,3	0,3	0,3

3. RESULTS

Plaxis models are performed and strains are calculated. Maximum strains are compared with the triaxial test results. The comparisons of the maximum strains are given in Table 4.

Table 4 Strain Values

Sample	A	B	C
Max. Strain (Triaxial Test)	6,0 %	8,0 %	9,0 %
Max. Strain (Plaxis Model)	5,9 %	8,1 %	9,1 %

The results shows approximately similar values despite the lack of two dimensional analyses. Mohr-Coulomb model is known as conservative model and gives safe results. In this study Mohr-Coulomb model simulate the results safely. Strain value in the Plaxis is a bit less in the first model but it is negligible.

4. CONCLUSION

In this paper, the comparison between the laboratory tests and computer modelling are presented. Unconsolidated-Undrained triaxial test is performed in the experimental analyses and Plaxis 2D is performed to simulate these test results. The strain results under the loading and modelling are presented. Based on the results, the following conclusions can be drawn:

- The study shows similar results as the literature.
- Mohr-Coulomb model shows approximately similar values as laboratory tests, and gives safe results. For sample A, 6,0 % strain is obtained from the test and 5,9 % strain is obtained from the Plaxis. For sample B, 8,0 % strain is obtained from the test and 8,1 % strain is obtained from the Plaxis. For sample C, 9,0 % strain is obtained from the test and 9,1 % strain is obtained from the Plaxis.
- If more sensitive results are desired 3D analysis should be done with considering the third dimensional confining effect.
- Presented values can be used in geotechnical applications.

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