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Review Article

İnce Toprak İçeriğin Zeminin Kayma Mukavemeti Parametrelerine Etkisi

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Öz

Zeminin kayma mukavemeti, yapının göçmesine neden olan önemli bir faktördür. Zemin üzerine herhangi bir mühendislik yapısı inşa edilmeden önce, yapısal çökme felaketini en aza indirmek için kesme mukavemeti özelliklerinin derinlemesine araştırılması gerekir. Bu çalışma, farklı ince daneli toprak içerik yüzdelerinin zeminin kesme mukavemeti parametreleri üzerindeki etkisini açıklamaktadır. Çalışılan zemin örnekleri esas olarak kumlu ve killi topraktır. Bu araştırma, ince tanelerin kesme mukavemeti parametreleri (sürtünme açısı ve zeminin kohezyonu) üzerindeki etkisini araştırıyordu. Bu çalışmada, literatürde yer alan birçok makale gözden geçirilmiştir. Farklı makalelerden elde edilen sonuçlara dayanarak, zeminde bulunan ince zemin içeriğinin kesme mukavemeti parametrelerini nasıl etkilediğini açıklamak için akış şeması oluşturulmuştur. Kumlu zemin için, kesme mukavemeti parametreleri, karışımın sahip olduğu ince tanelerin yüzdesine ve ince mineralojik bileşimin tipine büyük ölçüde bağlıdır. Killi zeminde ince tane içeriği ve katkı maddesi arttıkça, zemin kesme mukavemeti parametrelerinin her ikisi de önemli ve görünür bir oranda artar. Sonuç olarak, kum ve silt içerikli parçacıkların sürtünme açısı arasında ters bir ilişki vardı. Sürtünme açısı, silt parçacıklarının sayısı arttıkça artar. Değişken parçacıklar (iyi derecelendirilmiş parçacıklar) için sürtünme açısı, düşmeye başlamadan önce ince içerik için %10'dan %20'ye yükselir. Ayrıca ince tane miktarının özellikle %5'in altında olduğu durumlarda sürtünme açısı üzerinde etkisi olmadığı gözlenmektedir.

Anahtar Kelimeler: İçsel sürtünme açısı, kil, kohezyon,, ince zemin içeriği, kum, kesme mukavemeti.

Effect of Fine Content on Shear Strength Parameters of Soil

Abstract

The shear strength of the soil is a crucial factor in the structure's failure. Before any engineering structure is built on the soil, the shear strength characteristics must be thoroughly examined in order to reduce the calamity of structural collapse. The current study investigates the influence of varied percentages of fine material on soil shear strength. The soil sample consists primarily of sandy and clay soil. The study looked into the impact of fines on shear strength metrics (friction angle and soil cohesion). Several journal papers and articles were reviewed for this study. Based on the findings of several papers, the flow chart was created to describe the effect of the percentage of fine content in the soil and how it affects shear strength parameters. The shear strength parameters of sandy soil are significantly dependent on the percentage of fines in the mixture and the type of fine mineralogical composition. Both soil shear strength parameters increase at a substantial and apparent pace as compared to the particle content and additive increases in clay soil. As a result, there was an inverse relationship between the angle of friction of sand and silt-content particles. The angle of friction rises as the number of silt particles does. The angle of friction for variable particles (well-graded particles) rises from 10% to 20% for fine content before starting to decline. Furthermore, the amount of fines, especially when it is less than 5%, has no effect on the angle of friction.

Keywords: Angle of friction, Clay, Cohesion, Fines content, Sand, Shear strength

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1. Introduction

The study of fines' effects on soil shear strength and shear strength parameters is a very wide field of study. The soil is the main natural platform that directly imposed to carry and transfer load systems from the superstructure and substructure surrounding it. Since the numerous soil components (clay, silt, sand, and gravel) have various physical and engineering properties when they are pure, these components exist as an inhomogeneous mixture in most natural soils or as banded layers because of the nature of their formation. Even at some points, it is very difficult to identify the soil as sand or clay in a sand and clay combination as it has both sand and clay properties. It was developed by Al-Shayea (2001) that clay minerals, even if they are only present as small fractions of the soil, have a dominant effect on the behavior of the whole soil mass. Also, in assessing its geotechnical characteristics such as strength and compressibility, the amount of clay fraction in a soil is important.

The existence of fines in any soil affects the soil's shear strength in a positive or negative way. Some fine material changes the original characteristics of soil mechanics and leads to structural failure. While others improve the soil strength by improving the major parameters of the soil shear strength. To ascertain how fine material affects the shear strength parameter of the soil, the actual behavior of the sample must first be determined. This step assists us in understanding the effect that was brought about by the addition of those fine materials and comparing to what extent the soil parameters were affected, to what extent the effect will continue, and to what maximum point this effect reaches.

One of the important characteristics addressed for granular soil reconnaissance is the internal friction angle. A derivative of soil shear strength is used to compute soil friction angle, which is constantly changing in contrast to pore pressure and cohesion. They are closely examined because fines in coarse soils have an impact on the structure and composition of the soil and affect particular soil properties, including porosity, friction of particles, and cohesiveness.According to Georgiannou et al. (1990), it has also been observed that fines have an impact on liquefaction abilities, compression properties, and stress-strain behavior of the soil. The fine content of soils can have a considerable impact on their dynamic responsiveness. Soil particles are also important in phase conditions such as void and porosity ratios (Wang et al., 2009). Ayodele (2015) explored how fines impact soil's performance as a sub-base material for road building and discovered that as the fines concentration of the soil samples tested increased, the engineering characteristics of the soil samples studied decreased.

A soil mass's shear strength is the internal resistance per unit area that the soil mass may provide to withstand failure and sliding along any plane inside it (Das and Sobhan, 2014).

According to Norsyahariati, N. D. N., and Hui, K. R. (2016), samples with 40% silt have higher shear stress. As the sand's silt content rises and the friction angle falls, the soil becomes more cohesive. The results showed that the decrease in internal friction angle with increasing fineness modulus was significant for fineness modulus up to 1.50, while the angle of internal friction remained nearly constant for fineness modulus greater than 1.70 (Islam et al., 2017). Previous research has shown that raising the silt content in the sand to a certain level reduces shear resistance. However, a portion of the silt that is put on the sand grain contact surfaces contributes to grain separation and slippage during loading. This causes increased soil compressibility and a decrease in the resistance of undrained soil (Bellinaso, 2010).

Soil liquefaction is one of the most important and dynamic processes explored in earthquake geotechnical engineering.The behavior of soils under repeated (mainly earthquake-induced) loading is the central theme of the related studies, and many contentious topics are included in the associated studies. For many years, liquefaction was assumed to be limited to sand. Fine-grained soils, which are generally associated with soil liquefaction, are considered unable to produce high pore pressures. Therefore, much of the previous soil liquefaction research work has concentrated on relatively clean sands. However, a large number of fines are present in many natural sandy soils (passing sieve No. 200, particle size less than 0.074 mm). The influence of fines on the liquefaction resistance of soil mixtures has therefore been integrated into the current requirements for susceptibility to liquefaction.

Avci et al. (2011) demonstrated that cohesiveness rises with increasing clay concentration in a sandy soil. With increased clay concentration in the samples, the friction angle drops." Al-Shayea (2001), Tiwari et al. (2005) reported similar annotations of decreasing friction angle of sandy soils with increasing clay content. Unless the density of the silty sand is particularly high, a silty sand with a fine content greater than roughly 30% may behave similarly to the host fine-grained soil at an analogous void ratio of e_f (Rogers and Glendinning, 1997). The fines achieve more secure arrangements as shearing progresses and gradually increase interlocking, dilatancy, and shear strength (Lu and Huang 2018). The volumetric strain, cohesion, internal friction angle, deviator tension, and shear stress for the consolidated drained shear measure all increased as the fine content increased instantaneously. For specimens with a constant void ratio and constant density, the critical state ratio dropped and appeared steady for same-peak-deviator-stress specimens (Islam et al., 2017).

Scharifi et al. (2019) proved that as the percentage of nano-silica increased, the parameters of soil shear strength mainly increased, then decreased. Assuming the shear strength parameters, the results exhibited that an increment of sand additives on fine-grained soils resulted in a decrease in the cohesion of the soils and an increase in their angle of friction (Al Rawi, Assaf, and Hussein, 2018).

Shear strength tests are defined below shortly:

1.1 Direct Shear Test

A soil sample is evaluated in a square cross-section of a confined metal box in this test. The box is divided into two halves horizontally, with a little gap between them. Figure 1 depicts a direct shear test arrangement. The upper half of the box is fixed, and the lower half is pushed or pulled horizontally in relation to the fixed half. A shear is thus used in the soil sample. Throughout the operation, the sample is subjected to a constant normal force (vertical). Before the breakdown occurs, horizontal force, or shearing is applied. Shearing is usually done at a steady strain rate. The sum of the shear load is calculated using a proving ring. The vertical and horizontal deformations are measured using dial gauges. The method is repeated for several common pressures (four to five normal stresses). The failure shear pressure is displayed against various normal stresses (as shown in Figure 2). The shear strength parameters are calculated using the best-fit straight line that passes through the test locations. The test is appropriate for sandy soils. Porous stones are put below and on top of the sample to facilitate free drainage, whether the sample is partially or entirely saturated (Liu et al. 2014).

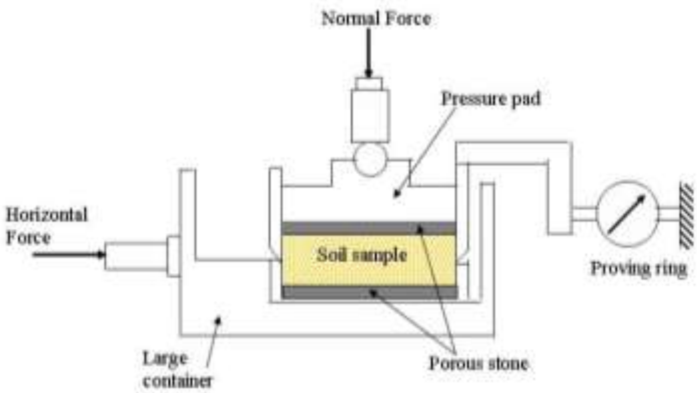

Figure 1. Direct shear test

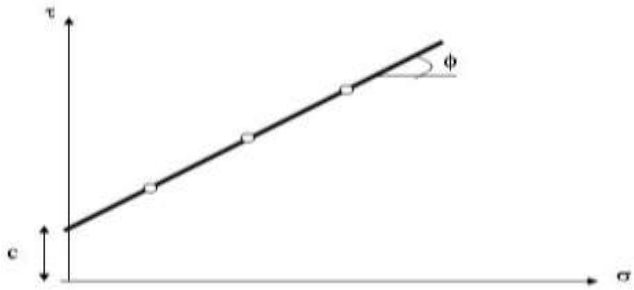

Figure 2. Shear stress-normal stress plot

1.2 Unconfined Compression Test

The test is appropriate for saturated clay (Øu =0). Under zero cell strain, the test is performed. Pending failure, a cylindrical specimen is subjected to axial tension. The Mohr circle for unconfined test compression is shown in Figure 3. The subscript u is used for strictly artificial soil, Øu =0, since the test is undrained. The key stress (σ1) is equivalent to the soil's unregulated compressive power (qu) (Chae et al. 2010).

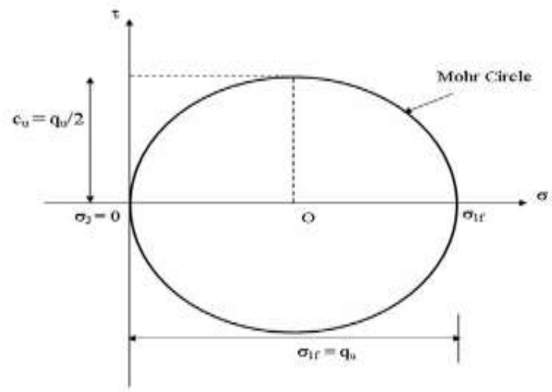

Figure 3. Mohr-Coulomb plot for a saturated clay unconfined compression test

The undrained cohesion can be determined as:

$$C_u = \frac{q_u}{2}$$

The complete cross-section of the given soil sample at failure load (A_f) is calculated in the calculation procedure of unconfined compressive strength of the soil (q_u) (the direct applied load at failure point across the total cross-sectional area of the given sample).

$$A_f = \frac{A_0}{1 - \varepsilon}$$

1.3 Triaxial Shear Test

Solid cylinders of soil are used as test specimens for triaxial shear. Typically, "the height of the test specimen is about twice its diameter." It has a diameter of around 25 mm. Alternatively, or (33 mm to 100 mm) for specimens that are more common. In a conventional triaxial cell, the soil specimen is held in place by the triaxial cell's base pedestal and top cap and is laterally limited by a narrow, impermeable rubber barrier. The membrane uses silicone grease and rubber O-rings to seal the top cap and base pedestal, as illustrated in Figure 4 (Wu, Li, and Niu, 2014).

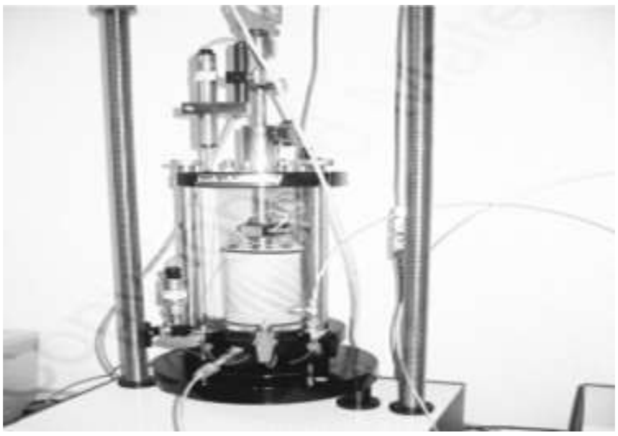

Figure 4. Photograph of a triaxial cell.

Based on the combination of flow conditions under which confining loads are applied and when shear is induced, there are three different types of triaxial analyses that are conceivable. Consolidated-drained, consolidated undrained, and unconsolidated-undrained are the three ways of conducting research. It is accompanied by brief explanations of these kinds of triaxial tests.

2. Material and Method

The previous studies of different journal papers and the most cited articles recommended by geotechnical researchers on the effects of fines content on shear strength parameters were reviewed for this study.

2.1. Shear Strength Parameters

2.1.1. Angle of Friction, φ

A significant parameter in the static and dynamic stability studies of hydraulic fill is friction angle. In underground mines, traditional penetration or cone penetration test rigs are frequently impractical; hence, direct shear or triaxial testing on reconstituted hydraulic samples in the laboratory to replicate in-situ densities is the most usual approach. Cyclic triaxial tests are advised for testing dynamic loading caused by blasting, liquefaction potential, and other factors.

The tests should be performed on reconstituted fills that replicate the in-situ grain packing in the stope, which can range from 45 to 80% relative density. Cohesion is zero since there is no clay percentage. "The hydraulic fill friction angles calculated by direct shear testing are significantly higher than those determined for common granular soils" (Rankine et al., 2006). This could be because the waste rock crushing produces very angular grains, which interlock more than less angular, ordinary granular soils. Table 1 shows the friction angle and relative density of soil packing, and Table 2 demonstrates the friction angle of sandy soil.

Table 1. Friction angle and Relative density

Soil packing	**Relative Density [%]**	**Friction angle [°]**
Very loose	< 20	< 30
Loose	20-40	30-35
Compact	40-60	35-40
Dense	60-80	40-45
Very Dense	> 80	> 45

Table 2. Friction angle of sandy soil

Type of sand	**USCS**	**Friction angle [°]**
Sand	SW, SP	37-38
Loose sand	(SW, SP)	29-30
Medium sand	(SW, SP)	30-36
Dense sand	(SW, SP)	36-41
Silty sand	SM	32-35

3. Results and Discussion

3.1. The Influence of Fines Content on Sandy Soil Shear Strength

Shear stress is greater in the sample containing 40% silt (Norsyahariati et al., 2016). As the sand's silt concentration increases, so does soil cohesiveness, while the angle of friction drops. This is attributed to soil particle shape and the grading of soil samples. The gradation will be compared because the shape of the soil particles in all samples is the same. The 20% silt content sample contained enough fines to assist the sand particles and keep them from slipping and rolling. However, silt particles have a greater influence on stress behaviors, accounting for 40% of the total. At this moment, the friction angle is lower. Table 3 demonstrates that the 20% silt content sample's cohesiveness is considerably lower than that of the 40% silt content sample. Obviously, this is due to the presence of more tiny particles with a larger surface area.

Table 3. Silty sand sample, shear strength parameters

Silt Content	Cohesion, c′ (kPa)	Friction angle, φ'	Shear strength, τf (kPa)		Normal stress, σf (kPa)	
			100	300	100	300
20%	38.407	31.479	150	350	180	500
40%	60.235	27.686	180	380	210	530

Source: Norsyahariati et al. (2016)

The effects of non-plastic silt, intergranular void ratio, and initial confining stress on undrained shear strength were studied, and considering the findings of (Thevanayagam), sand-silt having more than 30% silt exhibited the same behavior as silt. Thian and Lee (2011) found that as the clay content rose, the undrained shear strength, soil modulus, and pore pressure all dropped. Kim et al. (2005) conducted a series of triaxial compression tests on soil mixed with varying silt concentrations, and the findings revealed that as the amount of fine aggregate material increased, the critical state friction dropped. Maleki et al. (2011) found that "an equivalent void ratio which takes into account the non-plastic fine participation ratio in the soil-bearing skeleton can be used to describe the undrained conductivity of sand mixed with different non-plastic silt contents."

Belkhatir et al. (2013) examined the relationship between undrained shear strength, permeability of sand-silt mixes, and soil void ratio. According to other studies, the steady-state strength at the same void ratio was initially reduced as the silt content rose, then increased in shear strength as the silt content rose further to values greater than 30%. According to recent research, the fines effect of a soil varies depending on the type and amount of fines present in the soil's mixture. So, using the aforementioned information as row data and correlating the data with the unified soil classification system, the flow chart for sandy soil and the effect of fines on shear strength parameters, as shown in Figure 6, were established.

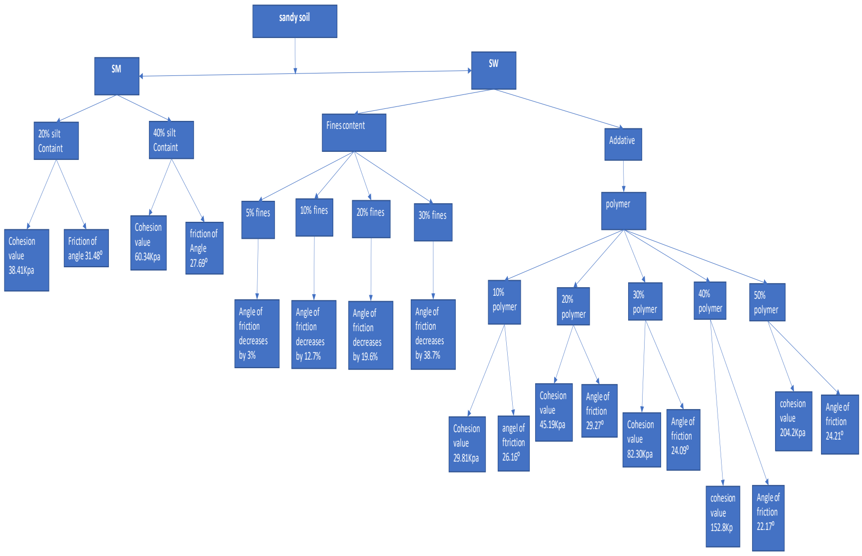

Figure 6. Flowchart showing fines content effect on sandy soil shear strength

3.2. The Influence of Fines Content on Clay Soil Shear Strength

Using nanosilica particles to enhance the mechanical and resistance qualities of soft clay was researched by Changizi and Haddad (2017). Characteristics including the Atterberg limit, ideal moisture content, maximum dry weight, and compressive strength have all been measured in the presence of nanosilica. The ratio of nanosilica to soil was 0.5, 0.7, and 0.1%. With an increase in nanosilica content, the constraint has improved. A decrease in the plasticity index and an increase in contraction limitation were caused by increasing ratios (Phan et al., 2016).

The natural soil that remains at the site of the structures is not always appropriate for proper support. Clay minerals can cause a variety of issues in various projects due to their high water absorption and retention, as well as their fine-grained nature. In other words, most of the problematic soils are made up of clay minerals, except for liquefiable soils, so they need to be reclaimed. In this report, clay soils with a low plasticity index (CL) were investigated. One of the strategies for soil alteration is the use of additives. Figure 7 represents the flowchart of fines' effect on clay soil shear strength material.

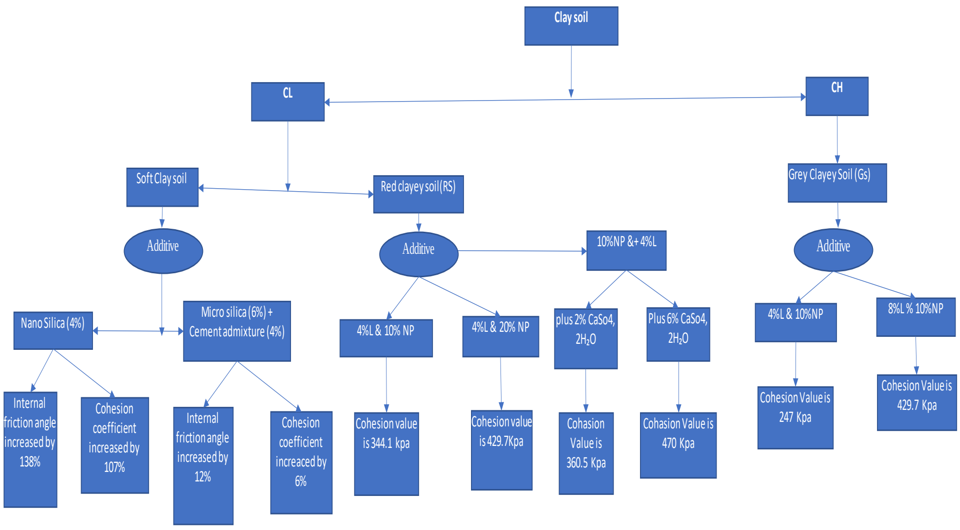

Figure 7. Flowchart showing fines content effect on clay soil shear strength

4. Conclusions and Recommendations

When assessing any engineering structure, primarily focus is on soil engineering properties. All design plans and funds are dependent on the approval of soil strength and compatibility for resistance to liquefaction potential.

The phenomenon of "liquefaction" takes place when quick loading from an earthquake or another source lessens the intensity and rigidity of the ground. Liquefaction and related phenomena have caused significant quantities of damage in past earthquakes all around the world. Liquefaction happens in saturated soils, or soils where water entirely fills the area between separate particles. This water presses down on the soil's particles, changing how tightly they are packed together. Prior to the earthquake, the water pressure was not particularly high. On the other hand, water pressure might increase as a result of an earthquake's shaking, allowing soil particles to move freely in relation to one another.

However, shear strength parameters such as cohesion and angle of internal friction are highly influenced by the percentage of fines that exist inside a given soil mixture. Depending on the percentage of fines in the soil, the value of cohesion and angle of internal friction vary accordingly.

Based on a review of reliable materials, an attempt was made to estimate the impact of fine content on soil shear strength. In the case of sandy soil shear strength characteristics, the particles changed the direction of the soil's angle of friction and cohesion. This is determined by the fines percentage in the mixture and the type of fine mineralogical composition. The angle of friction of sand with silt-content particles was thus inversely proportionate to each other. As the amount of silt particles increases, so does the angle of friction. For varied particles (well graded particles), the angle of friction increases from 10% to 20% for fine content and then begins to fall. Furthermore, fine content, especially less than 5%, has little effect on the angle of friction. In most cases, it is negligible. The mineralogical composition and fines of clay soil have great importance and play an important role in the stabilization and shear strength of the soil. In clay soil, both soil shear strength parameters increase at a rapid and visible rate.

5. Limitation

The importance of this study is to explain how fine content affects shear strength, how to increase soil strength by using different fines content, and whether or not the current fines content reduces shear strength by controlling the parameters that govern shear strength. These findings provide guidelines for soil improvement.

The impact of fine content on sandy and clay soils is the subject of considerable investigation. They concentrated on the cohesiveness and angle of friction of the two soils as well. Give an explanation of how fines content affects both natural combinations and additives.

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