Stress-Strain and Strength Characteristics of Sand-Silt Mixtures

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Abstract- Fine-grained soils comprising silt and clay are the most complicated engineering material. It is of great importance in civil engineering to make realistic predictions of the behaviour of soil under various conditions. Previous researches focused only on clean sand and pure clay. The stress-strain behaviour of pure sand is not as same as that mixed with fines. The quantity of plastic and non plastic fines present in the sand influences the stress-strain behaviour of the sand. The research study deals with the stress-strain behaviour of sand-silt mixtures. The triaxial tests have been conducted on dry sand and sand with various proportions of non-plastic silt and non-plastic silt in loose state. The non-plastic silts were mixed with the sand from 10 to 90% by dry weight of sand. The tests have been conducted with varying confining pressures of 50 to 250kPa with 50kPa increment. The experimental results are revealed that the shear strength value of sand decreasing with increase in the non-plastic silt content. However, the rate of decrement in the angle of internal friction value for 20-30% is significant when compare with the rate of decrement of from 0 to 10% and from 10 to 20% of silt content. The difference in the angle of internal friction of 10-40% of non-plastic silt content the reduction is more when compare to the other proportion of 50-100% of non-plastic silt content.

Keywords – Stress-strain, Confining pressure, Non-plastic silt, Angle of internal friction.

I. INTRODUCTION

Many man-made and natural soil deposits are neither clean sand nor pure clay, but rather a combination of these two materials of silt and gravel in various proportions. In order to find out the shear strength behavior of the sand-silt mixtures and predict the settlement of foundations which will rest on those sand-silt mixture, it's became necessary to investigate the effect of silts on compressibility characteristics and shear strength characteristics of the sand. The stress-strain behavior of pure sand is not as same as that mixed with fines. The quantity of plastic and non plastic fines present in the sand influences the stress-strain behavior of the sand. Where non-plastic silts have characteristics in common with both sand and clay. The non-plastic silts are more compressible for static pressure than sands, and they are more densified by vibration than clays. Most empirical correlations for strength and compressibility have been developed for pure sand and clay. And these correlations have been found not useful for sand and clay when mixed with non-plastic silts.

II. MATERIALS

a. Sand

The virgin sandy soil has been brought from Kumbakonam. A series of laboratory tests have been performed such as specific gravity and grain size distribution analysis tests on the collected virgin sandy soil sample. For better understanding on stress-strain strength behaviour of soils, the triaxial tests have also been performed on sand-silt mixtures. The results obtained from the laboratory test conducted on the virgin sandy soil are listed in Table 1.

Table 1 Summaries of tests conducted on the sand

Properties	Sample
Specific gravity	2.62
Percentage of coarse sand	1.12 %
Percentage of medium sand	95.03 %
Percentage of fine sand	3.85 %
Coefficient of uniformity, Cu	3.57
Coefficient of curvature, Cc	1.201
Soil classification	Poorly graded Sand (SP)
Minimum dry density, $\gamma d,min$	1.47 g/cc

b. Non-Plastic Silt

The silty sand soil has been brought from Sozhinganalur. A wet analysis was carried to know the percentage of particles passing 75 μ sieves on the collected soil samples. The material which passes through 75 μ sieve was collected in a container and allowed to settle. Then a hydrometer analysis was carried out to know the amount of fines particles. The amount of clay particles was found insignificant. After processing, soil was finalized for the preparation of non-plastic silt which has a maximum amount of particles passing 75 μ. Then the passing material is dried in the atmospheric exposure and was again sieved though 75 μ sieve. The non plastic fines which passes through IS 75μ sieve were used. The non-plastic fines were prepared in the laboratory. The specific gravity of non-plastic silt was 2.72. (Gupte, R et al., 2011).

c. Sample Preparation

The collected poorly graded sandy soil samples have been kept at atmospheric exposure for removing the natural moisture content. Then the sand samples were replaced by adding the non-plastic silt content in the ranges from 10 to 50% of the dry weight of soils (Cabalar, A.F et al., 2008; & Della, N et al., 2011). The non-plastic silt added to the soil samples in terms of the percentage by dry weight were thoroughly mixed and make the samples ready for testing. The samples are prepared by mild tamping method to achieve the required density.

III. EXPERIMENTAL RESULTS

A.Triaxial Test Results

To find the stress-strain characteristics of sand and sand-silt mixtures, the triaxial test is a reliable one. So a series of triaxial tests have been performed on sand and sand-silt mixtures in dry state with the confining pressure of 50 kPa to 250 kPa at a strain rate of 0.12mm/min. The density at which test conducted is 1.47g/cc. Some of the test results are shown in below figures.

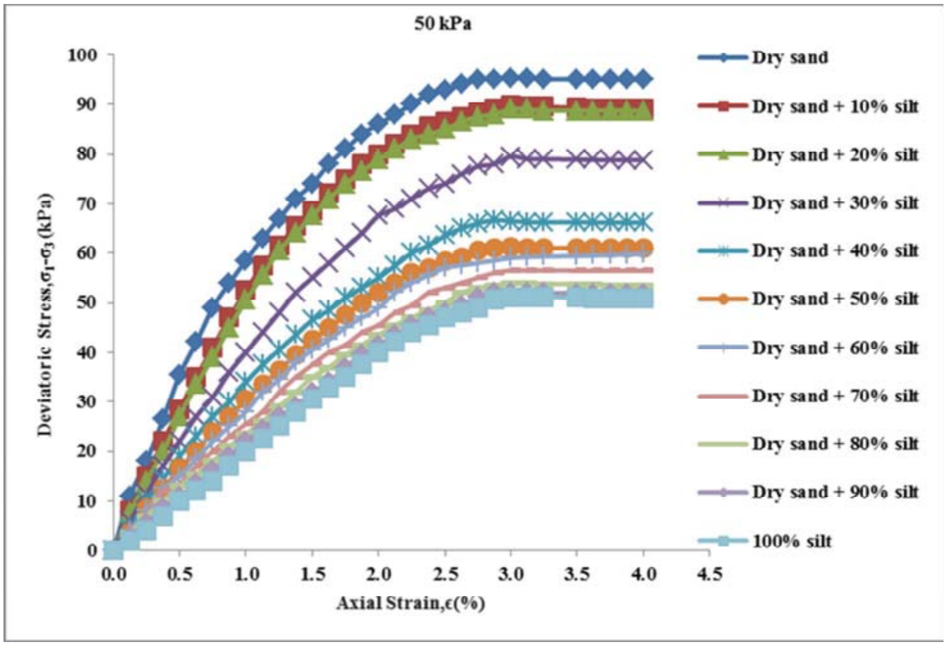

Figure. 1 Stress-strain curves of sand-silt mixtures for confining pressure of 50kPa

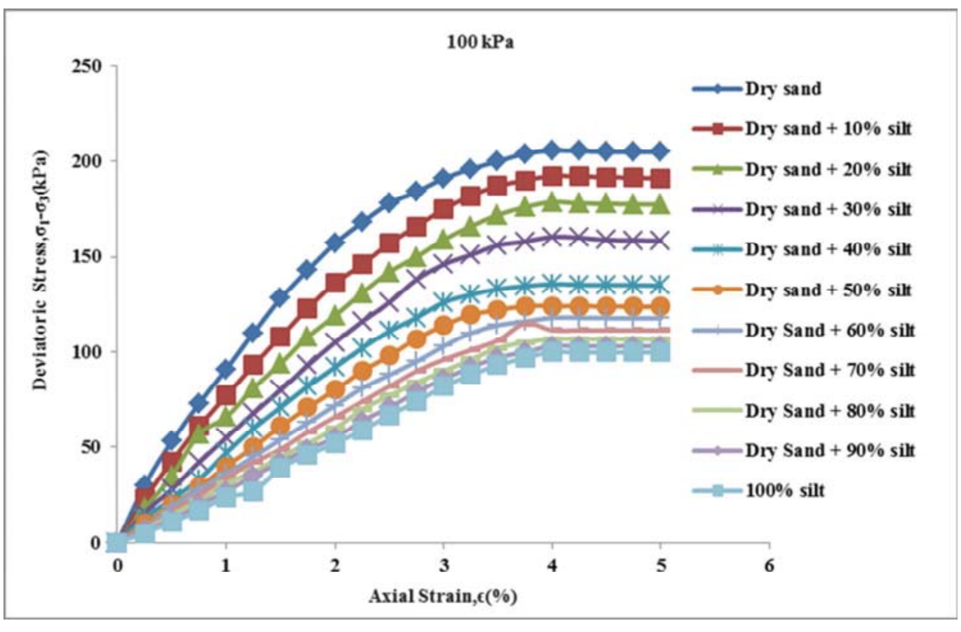

Figure.2 Stress-strain curves of sand-silt mixtures for confining pressure of 100kPa

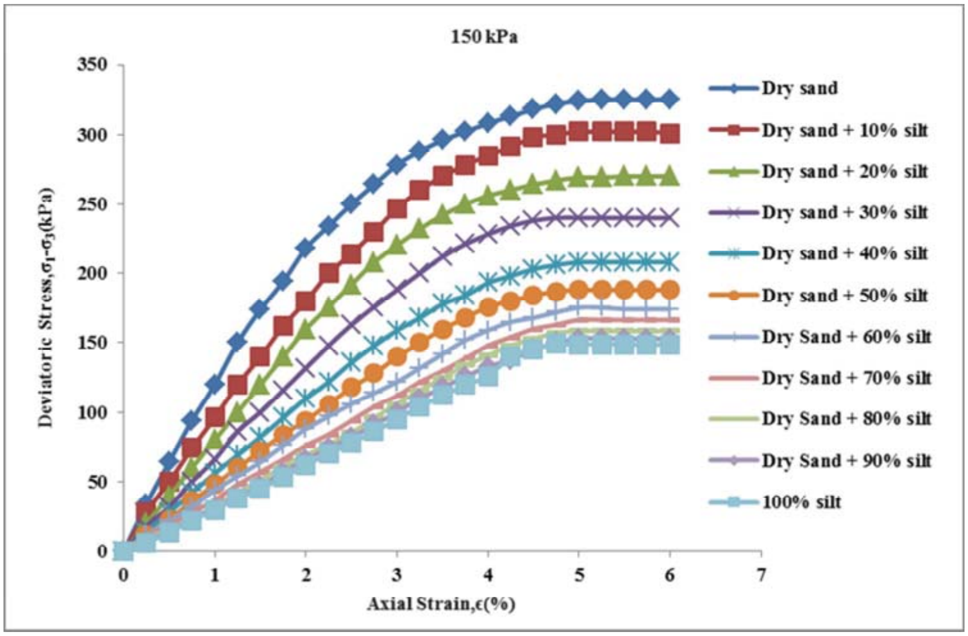

Figure. 3 Stress-strain curves of sand-silt mixtures for confining pressure of 150kPa

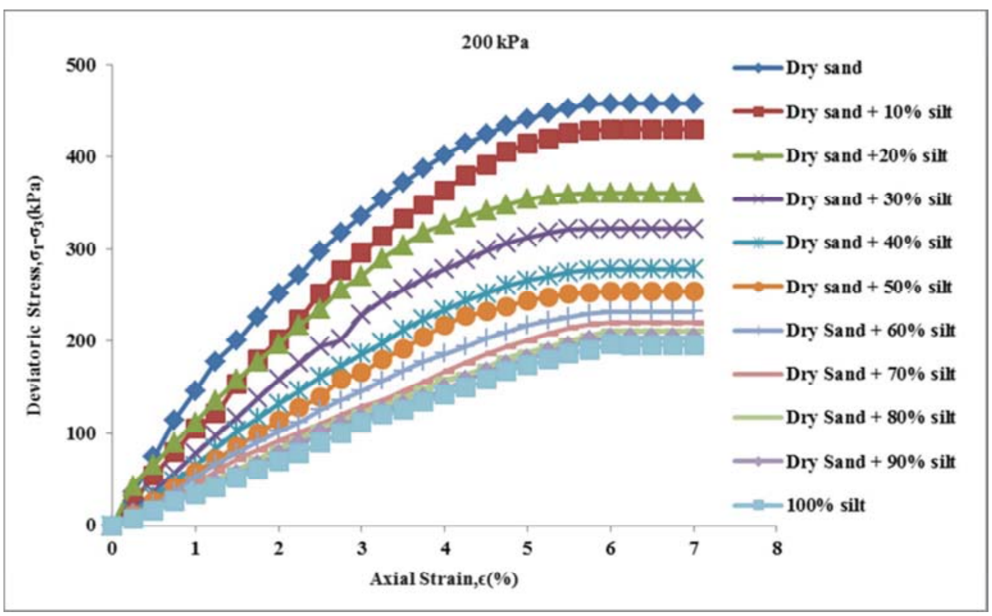

Figure .4 Stress-strain curves of sand-silt mixtures for confining pressure of 200kPa

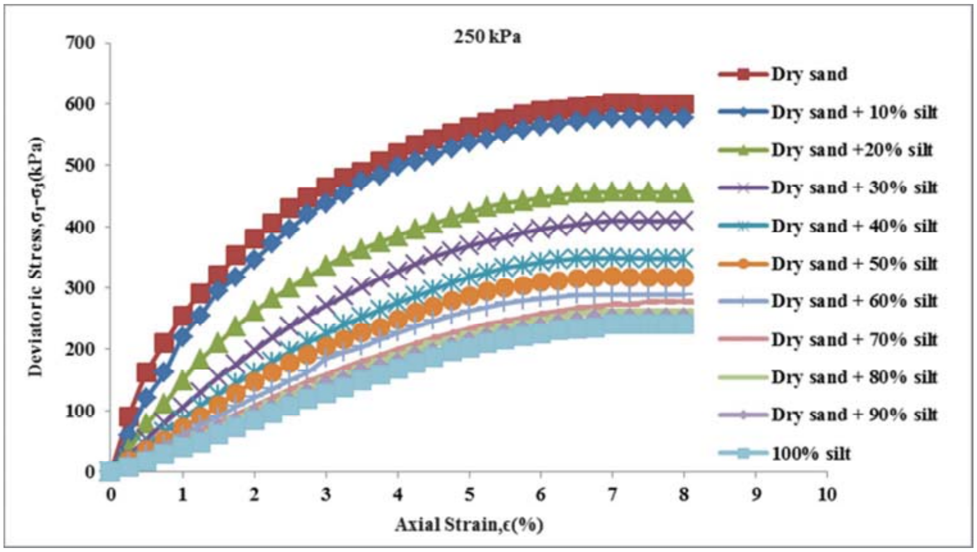

Figure 5.Stress-strain curves of sand-silt mixtures for confining pressure of 250kPa

Figure 1 to 5 shows the typical stress-strain curves of sand-silt mixtures. The observations made from the figures are irrespective of grain size (i.e., for sand, sand-silt mixtures and non-plastic silt) increases in confining pressure increased the failure deviatoric stress and failure axial strain and increasing in the silt content, decreases the failure deviatoric stress for all the confining pressures.

For each proportion of sand-silt mixtures the values of failure deviatoric stress with respect to different confining pressure are taken and Mohr circles have been plotted. From the Mohr's circle the angle of internal friction for each proportion of sand-silt mixtures have been taken and the values also presented in Table 3.

Table 2 Angle of internal friction for sand-silt mixtures

Proportions	Angle of internal friction ,ϕ
Dry Sand	31°04′
Dry Sand+10% silt	30°15′
Dry Sand+20% silt	28°18′
Dry Sand+30% silt	26°32′
Dry Sand+40% silt	23°52′
Dry Sand+50% silt	22°40′
Dry Sand+60% silt	21°42′
Dry Sand+70% silt	20°56′
Dry Sand+80% silt	20°19′
Dry Sand+90% silt	19°48′
100% silt	19°22′

The relation between non-plastic silt content and angle of internal friction is shown in Figure 6.

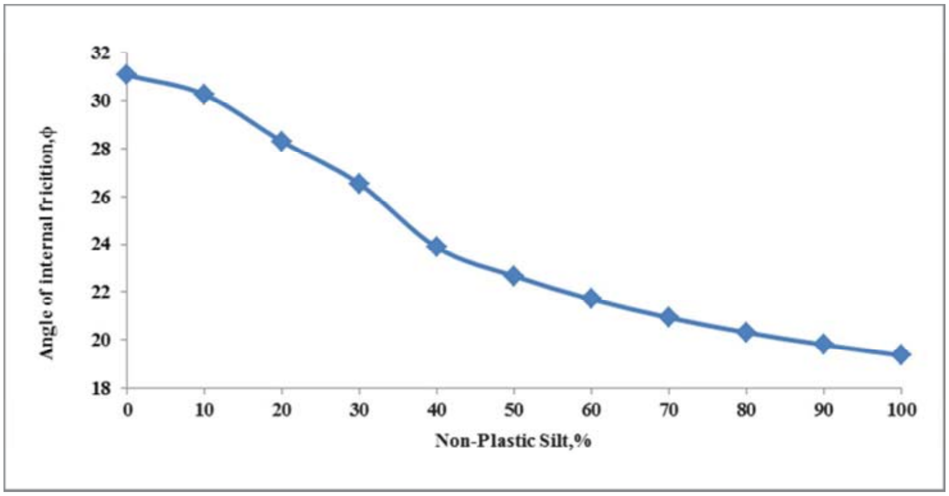

Figure. 6 Effect of non-plastic silt content in angle of internal friction of sand

From the Figure 6 it is observed that the angle of internal friction decreases with increases in the silt content from 10 to 100% to the sand. The difference in the angle of internal friction of 10-40% of non-plastic silt content the reduction is more when compare to the other proportion of 50-100% of non-plastic silt content.

B.*Intergranular Void Ratio Of Sand-Silt Mixtures,* e_s

When granular soil contains fines, the global void ratio (e) of the soil can no longer be used to describe the behaviour of the soil. In this aim, the use of intergranular void ratio has been suggested by Kenny, 1977; Kuerbis et al., 1988; Mitchell, 1993, Mitchell 1993, and Thevanayagam & Mohan (2000).

The concept of the intergranular void ratio suggests that the fines fill the voids formed between the sand grains and thus the behaviour of sand with a moderate amount of fines should be governed by the intergranular void ratio instead of the natural void ratio. However, when the intergranular void ratio exceeds the maximum void ratio of the clean sand, there are sufficient fines to prevent grain-to-grain contact of the sand particles. In this case, the fines constitute the dominant structure and carry the shear forces while the coarse grains may act as reinforcing elements (Thevanayagam and Mohan, 2000). The below equation gives the intergranular void ratio defined by Thevanayagam (1998),

$$e_s=[e+(F_c/100)]/[1-(F_c/100)] \quad \textbf{(1)}$$

Where e is the overall void ratio of soil and F_C is the fine content in percentage.

By using the equation 1 intergranular void ratios are computed and graph is plotted to show the variations between the non-plastic content and intergranular void ratio and it is shown in Figure 7.

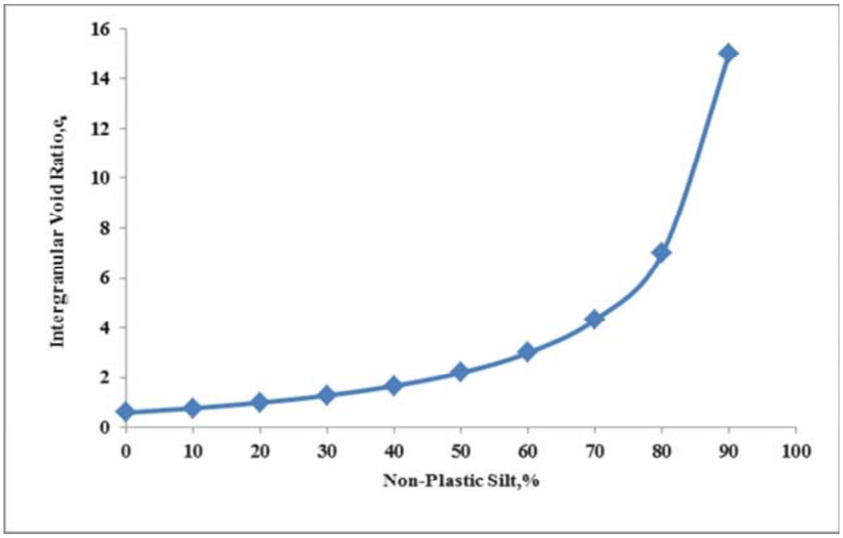

Figure 7 Effect of Non-Plastic Fines Content on Intergranular Void Ratio

From the Figure 7 it is observed that intergranular void ratio (e_s) increases with the increase in the non-plastic silt content. And it has been seen that intergranular void ratio is greater than maximum void ratio of clean sand when the non-plastic fines content is increasing beyond 10%. It means that the sand particles are on average, not in contact and mechanical behaviour is no longer controlled by the sand matrix. Figure 8shows the intergranular void ratio versus angle of internal friction for the non-plastic fine content ranging from 0 to 90%.

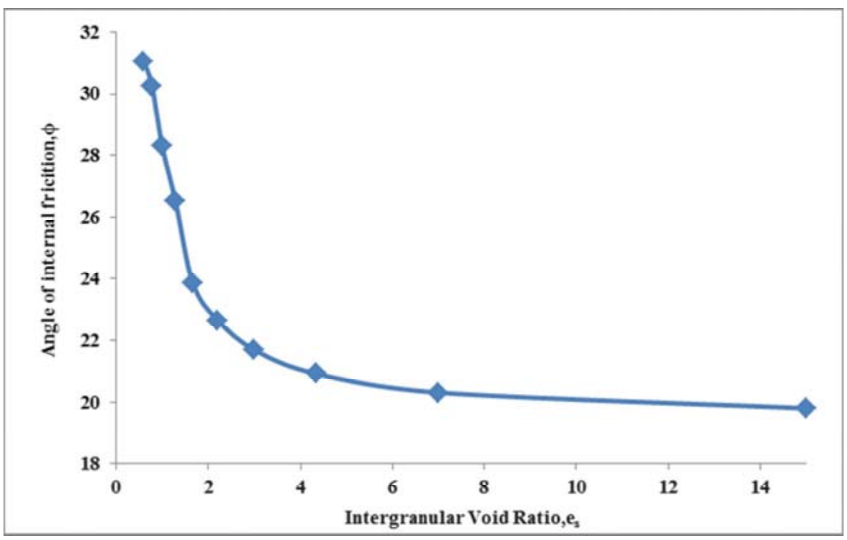

Figure 8 Intergranular void ratio versus Angle of Internal Friction

From the Figure 8 it is clear from this that the angle of internal friction decreases as the intergranular void ratio increases. It means that when increasing in the fines contents the angle of internal friction decreases.

IV.CONCLUSIONS

Based on the laboratory investigation of the sand-silt mixtures, the following conclusions are made

1. Irrespective of grain size (i.e., for sand, sand-silt mixtures and non-plastic silt) increases in confining pressure increased the failure deviatoric stress and failure axial strain. And increasing in the silt content decreases the failure deviatoric stress for all the confining pressures.
2. The angle of internal friction decreases with increases in the silt content from 10 to 100% to the sand. The difference in the angle of internal friction of 10-40% of non-plastic silt content the reduction is more when compare to the other proportion of 50-100% of non-plastic silt content.
3. The intergranular void ratio (e_s) increases with the increase of the non-plastic fines content. And it has been seen that intergranular void ratio is greater than maximum void ratio of clean sand when the non-plastic fines content is increasing beyond 10%. It means that the sand particles are on average, not in contact and mechanical behaviour is no longer controlled by the sand matrix. The angle of internal friction decreases as the intergranular void ratio increases. It means that when increasing in the fines contents the angle of internal friction decreases.

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