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Effect of Fines on Peak Friction Angle and Critical Friction Angle

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Article Info
Volume 82
Page Number: 6349 - 6361
Publication Issue:
January-February 2020

Abstract

The shear strength of soil is the resistance to deformation by continuous shear displacement of soil particles. The angle of internal friction and cohesion are the shear strength parameters of soil. The effect of fines on peak friction angle and critical friction angle is studied. The sand and silt samples are collected and five samples are prepared with various mix ratios of medium sand and silt. Its index properties such as specific gravity, particle size distribution, maximum dry density and optimum moisture content are determined. Using direct shear test the shear strength parameters are found for every sample. The peak friction angle, critical friction angle and maximum shear stress for each sample are compared and studied. It is found that the shear strength parameter values decreases with the decrease in the particle size of the soil and also it appears that D10 has higher influence on peak friction angle and critical friction angle.

Article History
Article Received: *18 May 2019*
Revised: *14 July 2019*
Accepted: *22 December 2019*
Publication: *30 January 2020*

Keywords: Angle of internal friction, Particle size, Peak friction angle, Shear strength.

1. Introduction

Soil is the most important material in civil engineering, because of which the knowledge on each and every property of soil is important. Soil is a natural material and hence its properties vary considerably from place to place. The behaviour of clay soil depends on its plasticity and stiffness. The behaviour of sandy soils depends on its particle size distribution, angle of internal friction and relative density. Based on the type of soil and nature of the project a detailed test programme is planned. Sand is a naturally occurring granular material composed of finely divided rock and mineral particles. It is defined by size, being finer than gravel and coarser than silt. The most common constituent of sand is silica usually in the form of quartz. It is cohesion less and non-plastic. Silt is a granular material of a size between sand and clay whose mineral origin is quartz and feldspar. The main objective of this study is to determine the effect of fines on peak friction angle and critical friction angle by using direct shear test on different samples of sand, silt and sand silt mixtures.

2. Materials and Methods

2.1 Materials – Sample Collection and Preparation Sand sample is collected from Chengalpattu palar river basin and the silt sample is collected from Sholinganallur, Kanchipuram district, Tamil Nadu. Samples thus

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collected are oven dried, pulverized and used for detailed laboratory investigation. Five samples with different mix ratios are prepared for testing. All the samples are designated as shown in **Table 1. Sample Designation**

Designation	Sample
S1	100% medium sand
S2	75% medium size sand and 25% silt
S3	50% medium size sand and 50% silt
S4	25% medium size sand and 75% silt
S5	100% silt

2 Methods

The detailed laboratory investigations were carried out as presented in the following sections.

2.2.1 Index Properties

Specific gravity tests were conducted using specific gravity bottle as per IS 2720 (part 3/sec 1)-1980. Grain size distribution analysis were performed by mechanical sieve analysis as per IS 2720 (part 4)-1985. Grain size distribution analysis were performed by hydrometer analysis as per IS 2720 (part 4)-1985. Relative density tests were carried out as per IS 2720 (part 3/sec 1)-1980. The results obtained are summarized on Table.2. The grain size distribution curve of S1, S2, S3, S4 and S5 are shown in figure 1. The compaction curves obtained by using Standard Proctor Test results are shown in figure 2.

Sample	D_{10} (mm)	D_{30} (mm)	D_{60} (mm)	Coefficient of curvature, C_c	Coefficient of uniformity, C_u	Specific Gravity	Maximum dry density (kg/cc)	Optimum moisture content (%)
S1	0.45	).48	).55	0.93	1.22	2.6	1.692	6.7
S2	0.08	0.5	).57	5.48	7.13	2.61	1.635	7.1
S3	0.02	).15	0.5	2.25	25	2.57	1.581	7.7
S4	).009	).08	).25	2.84	27.77	2.54	1.525	8.4
S5	).0029	.061	.068	18.86	23.44	2.49	1.473	8.8

Table 2. The index properties of samples

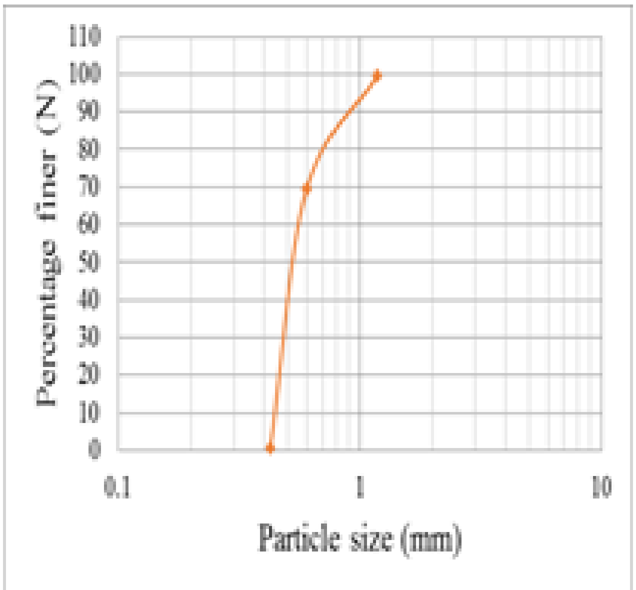

Figure 1.a. Grain Size Distribution Sample 1

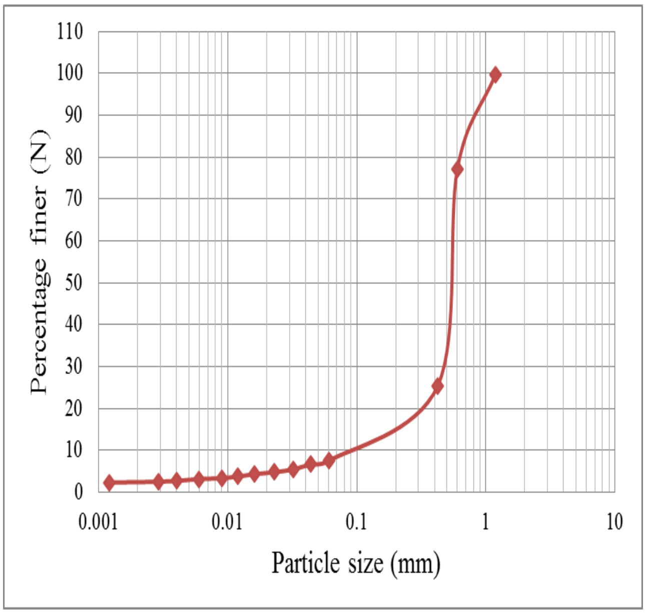

Figure 1.b. Grain Size Distribution Sample 2

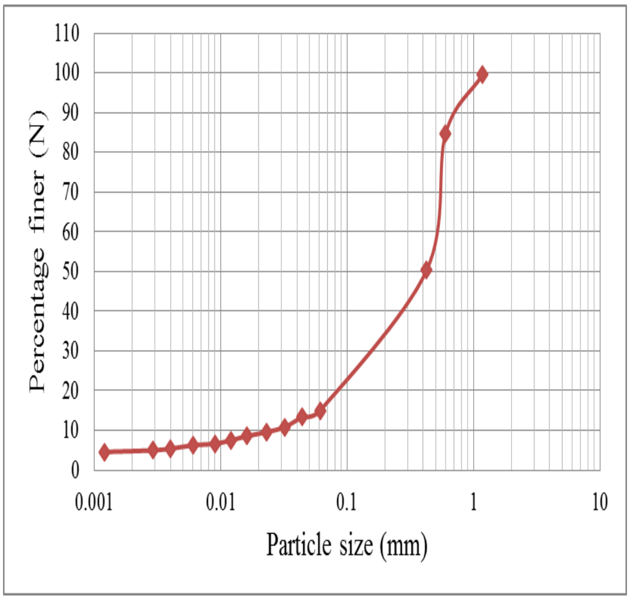

Figure 1.c. Grain Size Distribution Sample 3

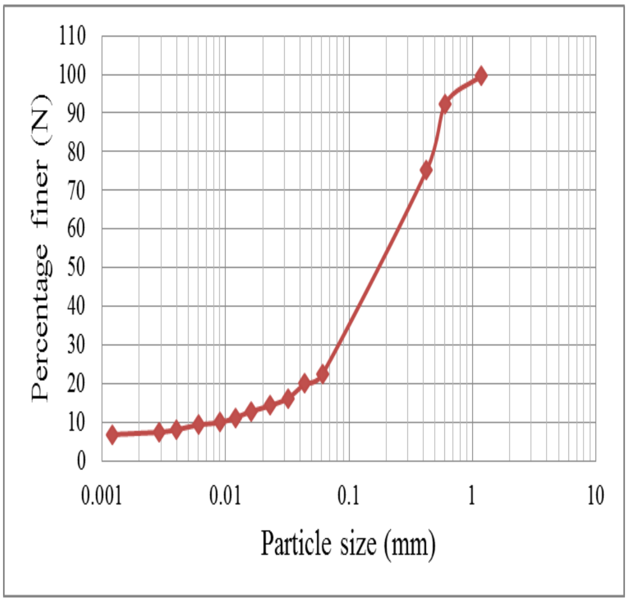

Figure 1.d. Grain Size Distribution Sample 4

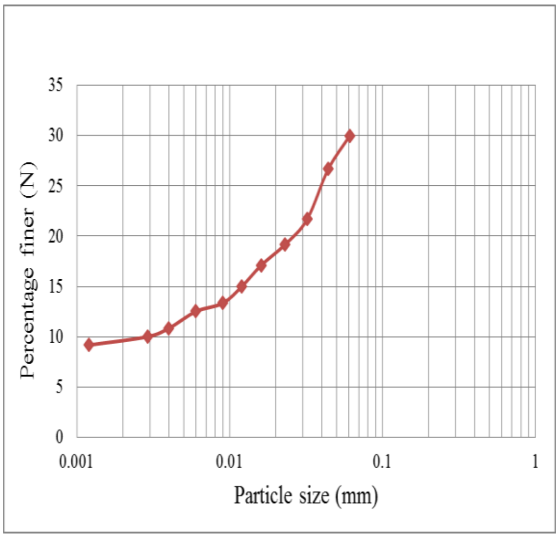

Figure 1.e. Grain Size Distribution Sample 5

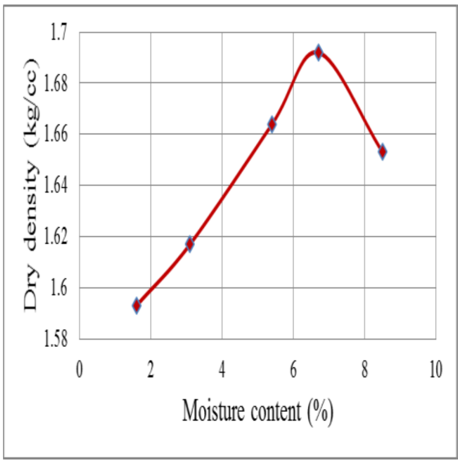

Figure 2.a. Compaction Curve Sample 1

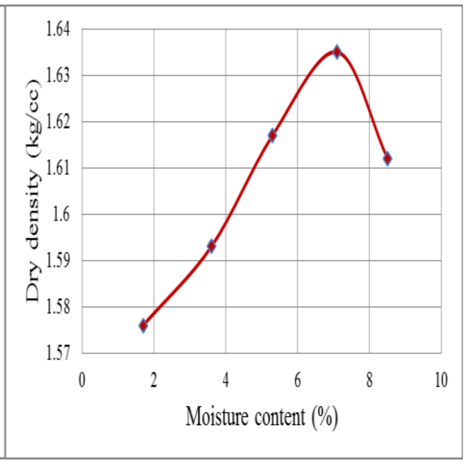

Figure 2.b. Compaction Curve Sample 2

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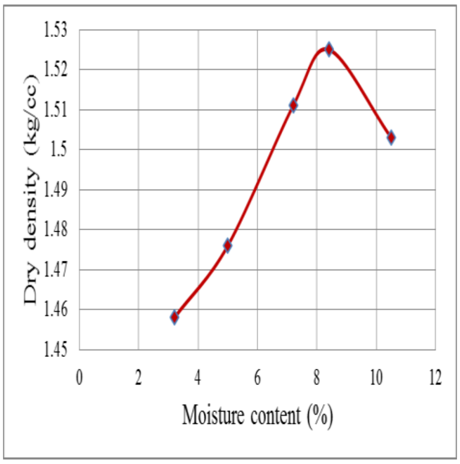

Figure 2.c. Compaction Curve Sample 3

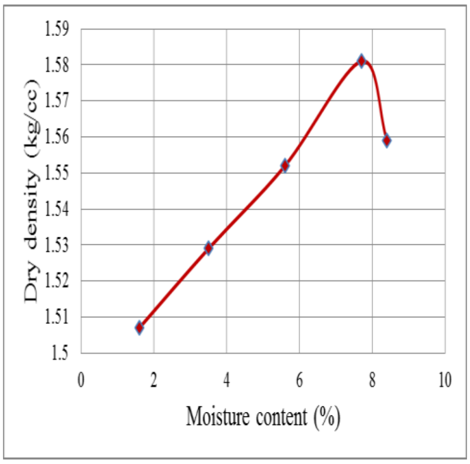

Figure 2.d. Compaction Curve Sample 4

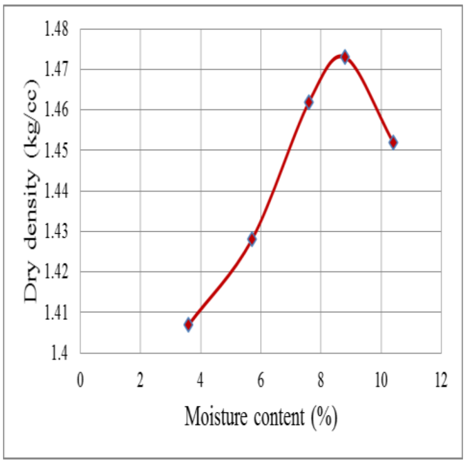

Figure 2.e. Compaction Curve Sample 5

2.2.2 Direct Shear Test

A series of Direct shear tests were conducted on samples of sand, silt and sand silt mixtures for different normal stresses 1kg/sq.cm, 1.5kg/sq.cm, and 2kg/sq.cm. The procedure used during the direct shear testing programme are based on IS 2720 (part 13) – 1986. The direct shear tests conducted on samples S1,S2,S3,S4 and S5, then the test results arrived are used to draw the stress strain curves. These curves are shown in fig 3. Each figure shows the stress strain relationship of the sample for different normal stresses. The maximum shear stress was calculated from these curves are presented in the Table 3. The figure 4 Shows the stress strain relationship of all sample for different Normal stresses. The relationship between Normal stress and shear stress at peak and critical conditions are shown in figure 5. The peak and frictional angles are calculated from the slope of the lines shown in the fig 5 are tabulated in the Table 3

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Sample	Normal stress (kg/sqcm)	Maximum Shear force (kg)	Maximum shear stress (kg/sqcm)	Peak friction angle ($\emptyset_P$)	Critical friction angle ($\emptyset_C$)
S1	1	23.58	0.655	33.2°	24.8°
	1.5	36.9	1.025		
	2	47.34	1.315		
S2	1	22.716	0.631	30.32°	23.04°
	1.5	31.5	0.875		
	2	43.92	1.22		
S3	1	20.124	0.559	28.76°	22.14°
	1.5	28.116	0.781		
	2	38.88	1.08		
S4	1	19.728	0.548	26.9°	20.98°
	1.5	27.036	0.751		
	2	36.36	1.01		
S5	1	17.316	0.481	22.83°	18.89°
	1.5	23.832	0.662		
	2	32.472	0.902		

Table 3.Peak and critical friction angle for different sample

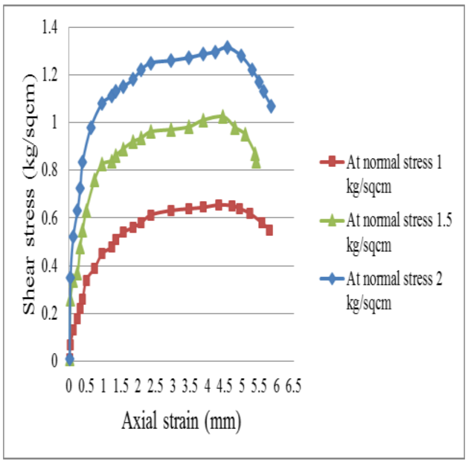

Figure 3.a. Stress strain curve for Sample S1

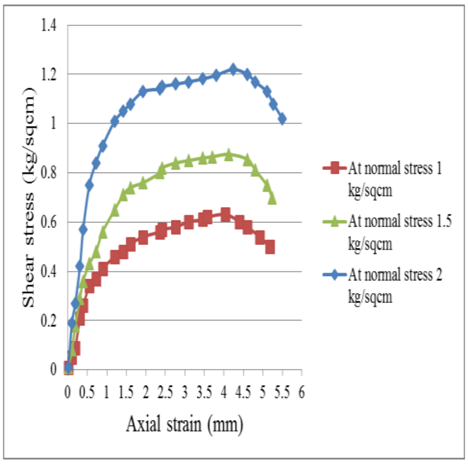

Figure 3.b. Stress strain curve for Sample 2

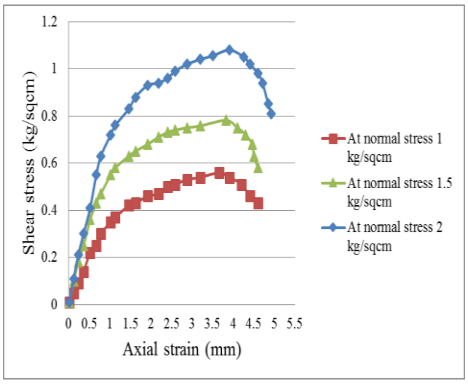

Figure 3.c. Stress strain curve for Sample S3

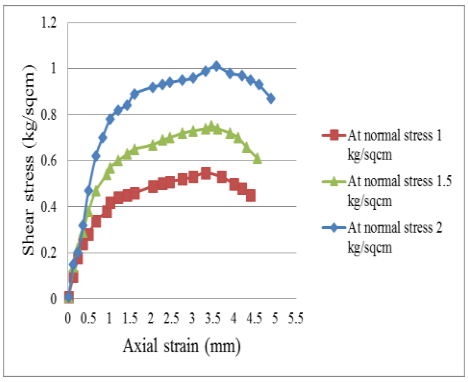

Figure 3.d. Stress strain curve for Sample 4

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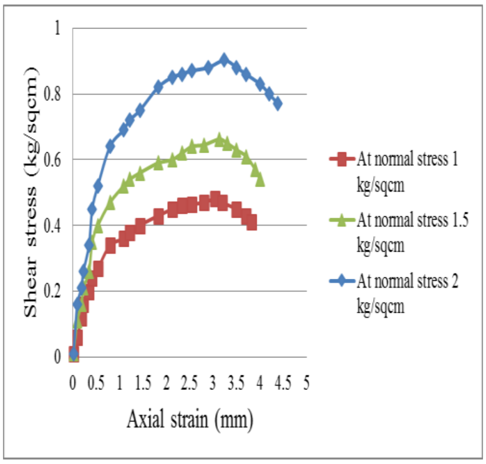

Figure 3.e. Stress strain curve for Sample S5

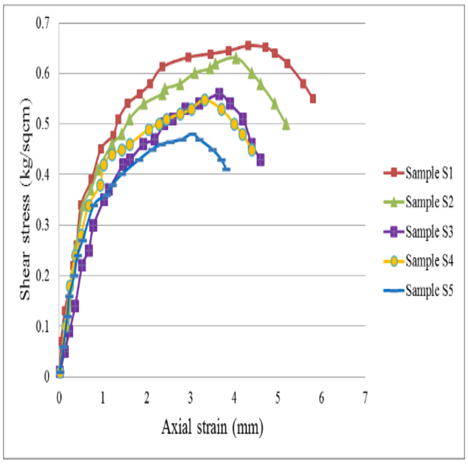

Figure 4.a. Stress strain curve at Normal Stress of 1 kg/sq.cm

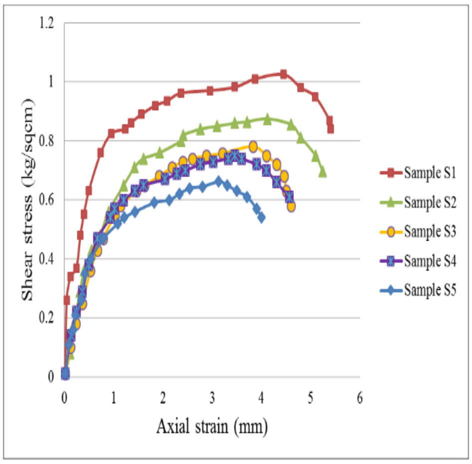

Figure 4.b. Stress strain curve at Normal Stress of 1.5 kg/sq.cm

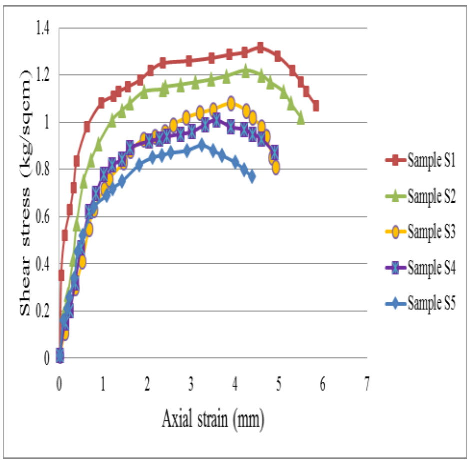

Figure 4.c. Stress strain curve at Normal Stress of 2 kg/sq.cm

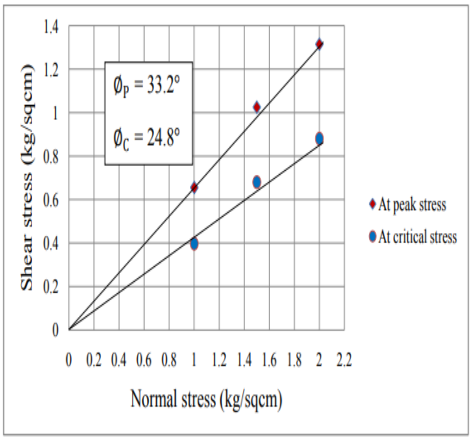

Figure 5.a. Variation of Shear Stress With Normal Stress for Sample S1

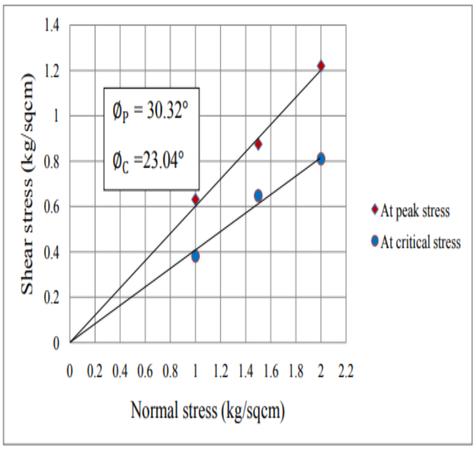

Figure 5.b. Variation of Shear Stress with Normal Stress for Sample S2

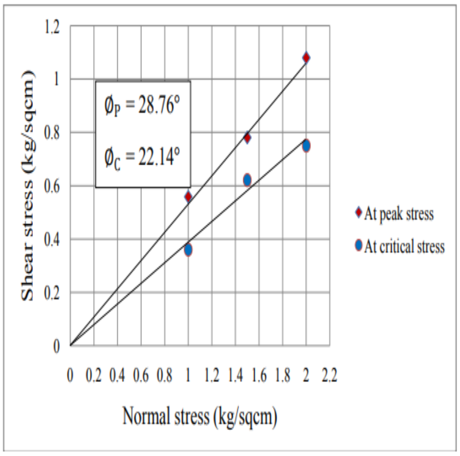

Figure 5.c. Variation of Shear Stress with Normal Stress for Sample S3

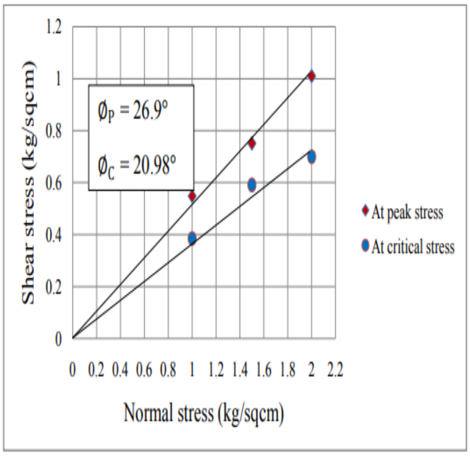

Figure 5.d. Variation of Shear Stress with Normal Stress for Sample S4

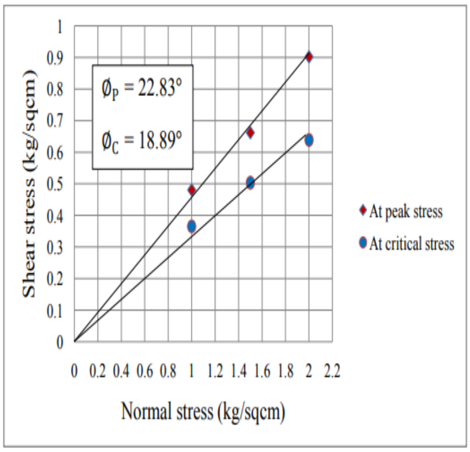

Figure 5.e. Variation of Shear Stress with Normal Stress for Sample S5

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2. Results and Discussions

All the test results are presented in the Table 4. The figure 6 shows the variation of critical and peak angle of friction for all five samples. The critical friction angles are comparatively lesser than the peak friction angle for all the samples.The variation of peak and critical friction angles for sand, silt and sand silt mixtures are shown in figure 7 and 8. The peak and critical friction angles are higher for sand than the silt. Both the angle of friction are decreases with the increase in the percentage of silt content as in figure 8. The angle of friction increases when the percentage of sand particles increases in the sand silt mixtures as in figure 7. The shear stress values are increases when the normal stress increases as shown in figure 3. The shear stress decreases as the percentage of silt content increases. The shear stress for sand is higher than the value of silt. These was shown in figures 9 and 10.The values of D10, D30 and D60 are decrease with the increase in silt content and these values for silt are lesser than the sand. These variations are shown in figure 11 and 12. The semi log plots are drawn for understanding the inference of D10 and D60 values in the critical and peak friction angle. The equation of the straight line found from the plots are used to estimate the critical and peak frictionangle for any particle size influenced by D10, D30 and D60. These variations are shown in figure 13. These equations are shown in the Table 5.

Sample	D_{10} (mm)	D_{30} (mm)	D_{60} (mm)	Coefficient of curvature, C_c	Coefficient of uniformity, C_u	Max dry density (kg/cc)	Optimum moisture content (%)	Peak friction angle ($\emptyset_P$)	Critical friction angle ($\emptyset_C$)
S1	0.45	0.48	0.55	0.93	1.22	1.692	6.7	33.2°	24.8°
S2	0.08	0.5	0.57	5.48	7.13	1.635	7.1	30.32°	23.04°
S3	0.02	0.15	0.5	2.25	25	1.581	7.7	28.76°	22.14°
S4	0.009	0.08	0.25	2.84	27.77	1.525	8.4	26.9°	20.98°
S5	0.002	0.061	0.068	18.86	23.44	1.473	8.8	22.83°	18.89°

Table 4. Peak and critical friction angle for all samples

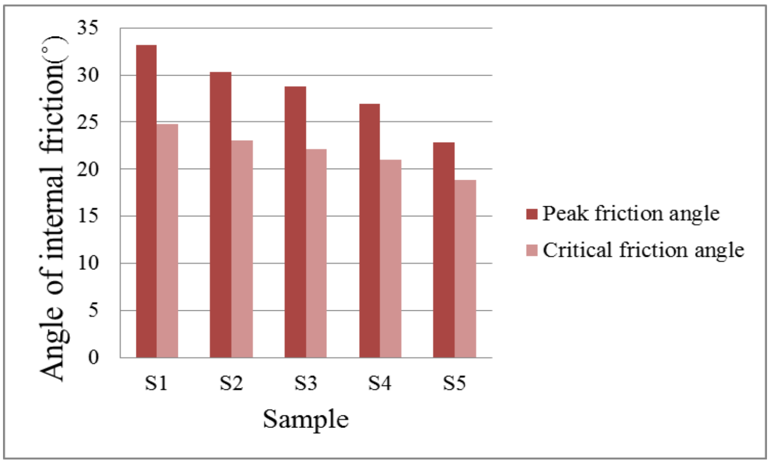

Figure 6. Comparison of angle of internal friction for different samples

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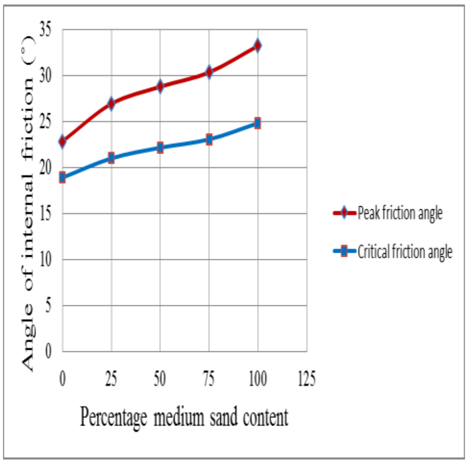

Figure 7. Variation of Angle of Internal Friction for Different Percentage of sand content

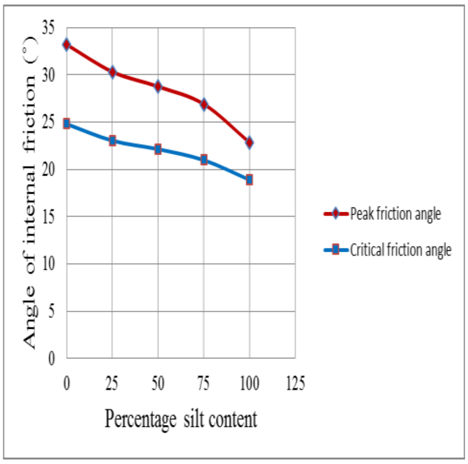

Figure 8. Variation of angle of Internal Friction for Different Percentage of Silt Content

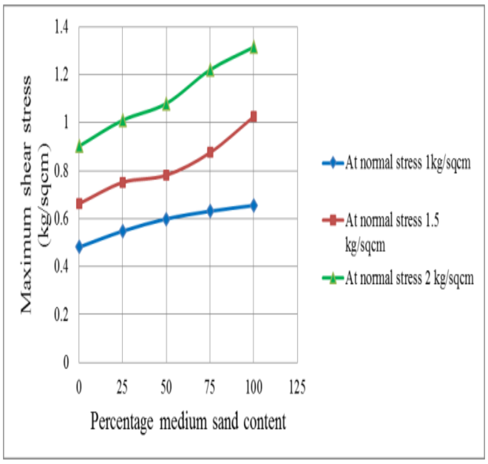

Figure 9. Variation of Maximum Shear Stress for Different Percentage of Sand Content

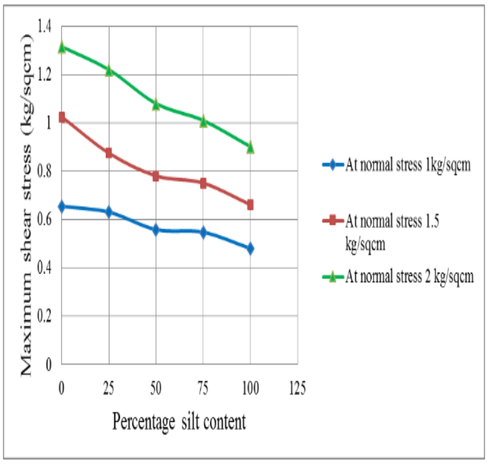

Figure 10. Variation of Maximum Shear Stress for Different Percentage of Silt Content

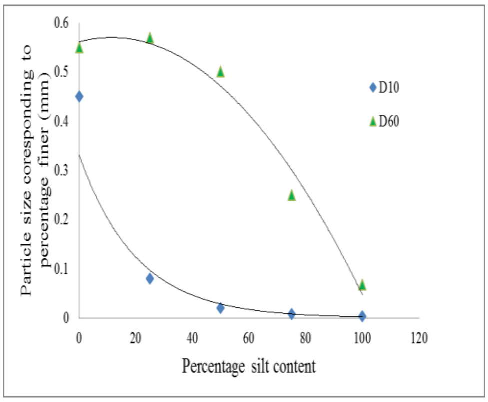

Figure 11. Variation of D_{10} and D_{60} With Different Percentage of Silt

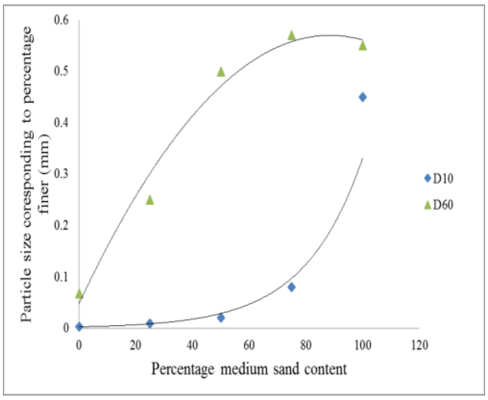

Figure 12. Variation of D_{10} and D_{60} With Different Percentage of Sand

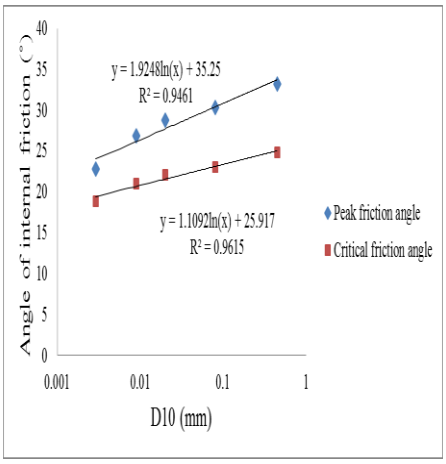

Figure 13. Variation of Frictional Angle with D_{10}

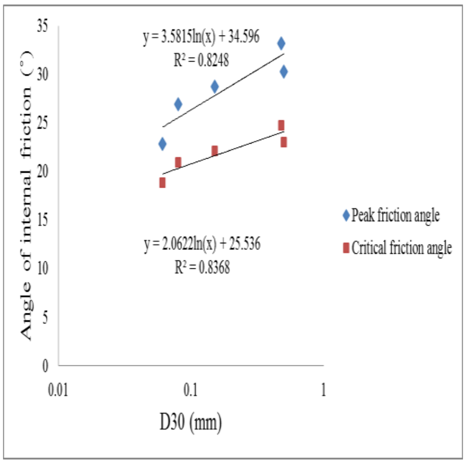

Figure 14. Variation of Frictional Angle with D_{30}

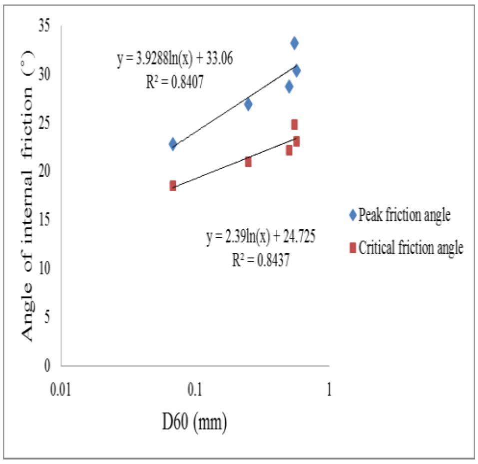

Figure 15. Variation of Frictional Angle with D_{60}

Table 5. Peak and critical friction angle equations

Particle size corresponding to percentage finer (x)	Peak friction angle equation (y)	Critical friction angle equation (z)
D_{10}	y = 1.924ln(x) + 35.25	z = 1.109ln(x) + 25.91
D_{30}	y = 3.581ln(x) + 34.59	z = 2.062ln(x) + 25.53
D_{60}	y = 3.928ln(x) + 33.06	z = 2.39ln(x) + 24.72

4. Conclusion

The effect of fines on the essential properties of non cohesive material was studied through direct shear test and following are the conclusions based on this study,

- It was found that the percentage of particles less than 0.075 mm have higher influence on the peak friction angle than the critical friction angle.
- It was found that as the fine content increases, the peak friction angle varied steeply. The percentage of variation is tending to become non – linear when percentage varied from 30% to

100%. However in the case of critical friction angle, the rate of change in the critical friction angle is much smaller. When percentage varied from 50% to 100% the variation was found to be more linear unlike peak friction angle.

- Percentage of medium sand content have a much higher influence on the shear stress. At higher normal stress the rate of increase of maximum shear stress was found to be much higher. It is seen that at lower normal stress, percentage of medium sand grains has much lesser influence. In case of silt, similar but decreasing trend is seen.
- Medium sand grains have a much higher influence on D_{60} and D_{10}. It is seen that D_{60} and D_{10} showed a non – linear increase. In case of silt, similar but decreasing trend is seen.
- Similarly, the effect of D_{10}, D_{30} and D_{60} is studied on the influence of peak friction angle and critical friction angle. As can be seen that the trend is identical for D_{30} and D_{60} indicating that the values of D_{30} and D_{60} has very little influence on peak friction angle and critical friction angle.
- This conclusion is drawn mainly because variation of slope intercept values are very small between D_{30} and D_{60} but variation between D_{30} and D_{10}& D_{60} and D_{10} is much higher.
- Therefore it is concluded that the grain size has considerable influence on the friction angle. From the study it appears that D_{10} has higher influence on peak friction angle and critical friction angle.

Acknowledgments

We are highly thankful to our secretary Dr.K.S.Babai, and our Principal, Dr.P.K.Suresh for their valuable support, encouragement and appreciation to our project. We also thankful to Miss S.Revathy for writing this paper.

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January - February 2020
ISSN: 0193 - 4120 Page No. 6349 - 6361

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