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Effect of Grain Sizes on the Shear Strength Parameters in Sandy Soils

Harendra Prakash [1], Shahid Noor [2] Siddharth Hedaoo [3], Manish Gupta [4], R Chitra[5]

[1]*Corresponding Author and Scientist 'C', Central Soil and Materials Research Station, New Delhi, India*
Email: harendra.prakash@gmail.com
[2]*Scientist 'D', Central Soil and Materials Research Station, New Delhi, India*
Email: shahidnoor19@gmail.com
[3]*Scientist 'B', Central Soil and Materials Research Station, New Delhi, India*
Email: siddharth_hedaoo@rediffmail.com
[4]*Scientist 'E', Central Soil and Materials Research Station, New Delhi, India*
Email: manish009@gmail.com
[5]*Director, Central Soil and Materials Research Station, New Delhi, India*
Email: chitra009@gmail.com

Abstract*—Soil deposits in nature are often heterogeneous mixtures of particles of different sizes and shapes in different layers forming a non-homogenous configuration. The variability in soil particle sizes and shapes has a great influence on the shear strength behavior especially when the soil contains granular particles. Granular particles play a vital role in the shear strength properties of soil. In general, shear strength of granular soil increases with the increase of soil particle sizes. The shear strength of granular soil depends upon the grading, particle shape and size, density etc. The present paper illustrates the results of the experimental study carried out on the effect of particle size (particles more than 2.00 mm size) on the shear strength of granular soils. The study shows that shear strength increases and the effect is substantial upto certain percentage coarse particle sizes, beyond that the increase in the gravel content does not cause any significant increase in the shear strength of soil.*

Keywords—*Particle size, shear strength, granular material, direct shear test.*

I. INTRODUCTION

Particle size plays an important role on the strength behavior of granular materials. The size of the particles in the granular mass alters the fabric and is responsible for the variation of strength behavior. When granular materials are subjected to loading, coarser particle play an important role in load carrying capacity of soil. The load transformation mechanism of the granular mass depends on the individual soil grains as load transfer occurs particle to particle and the macroscopic response of granular mass is the resultant of the individual response of the particles.

In geotechnical engineering, the shear strength parameters of granular soil/materials are crucial for a safe and economic design of a geotechnical structure. Several factors have been identified which could affect the shear strength of granular materials. The shear strength of granular materials depends on the relative density, gradation, particle strength, particle size and shape and degree of saturation of the specimen etc.

In case of granular soil, shear strength of soil in laboratory is determined by either triaxial test or direct shear test. The direct shear test is a simple and quick test for determining shear strength of the granular soil/materials. The test method is fast and the output data can be relatively easily processed to obtain the necessary shear strength parameters. The direct shear test equipment essentially consists of a shear box which can be split in upper and lower shear box. The soil specimen is packed in the shear box at the desired density and under application of the normal load, the soil is sheared by the relative motion of upper and lower shear box under drained or undrained conditions. Direct shear method is a simple and quick method for determining the granular material shear strength parameters. For the present study, a shear box of 60 mm x 60 mm was used for the testing the granular soil/materials.

Figure 1(a)- Sand Particles passing 2.0 mm IS Sieve

Figure 1(b)-Sand Particles passing 4.75 mm IS Sieve and retained on 2.0 mm IS Sieve

Figure 1(c) Gravel Particles passing 10.0 mm IS Sieve and retained on 4.75 mm IS Sieve

II. METHODOLOGY

A typical direct shear apparatus is shown in Figure-2. The test was conducted according to IS 2720: (Part 13) 1986.

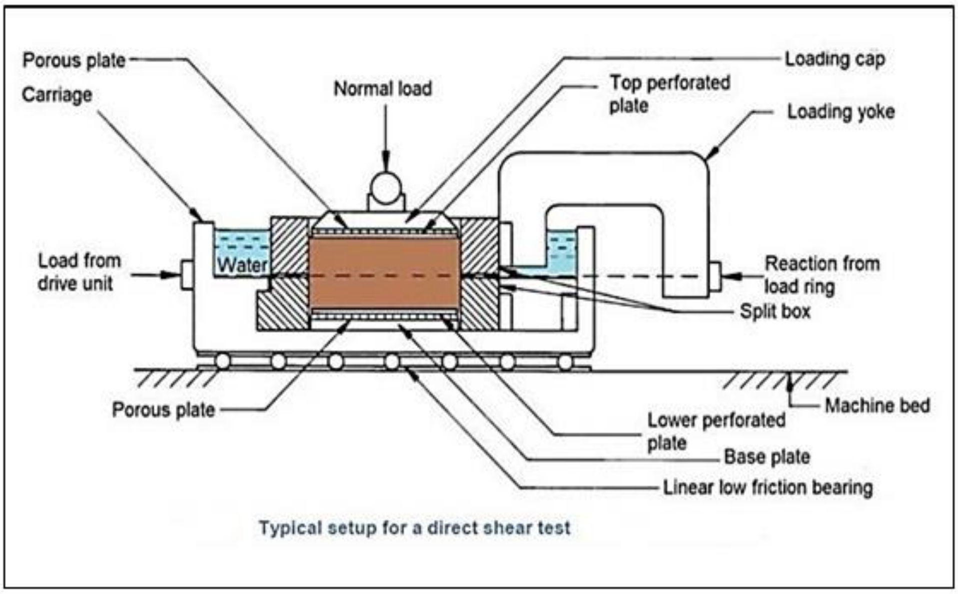


Figure -2: Typical setup Shear Box in a Direct Shear test

The size of shear box was 60 mm x 60 mm. The tests were conducted in saturated condition of the soil specimen under undrained conditions. The specimens were prepared after mixing the soil particles of three different groups, particles passing IS sieve 2.0 mm size, particles passing IS sieve 2.0 mm size and retained on IS Sieve 4.75 mm and particles passing IS sieve 4.75 mm size and retained on IS Sieve 10.0 mm and shown in Figure 1(a), 1(b) and 1(c). The soil particles of three group are mixed in different proportions and 4 specimens were prepared as presented in Table-1 and typical picture is shown in Figure 3(a), 3(b), 3(c) and 3(d). All the soil samples were packed in shear box at the density of 1.85 g/cc and sheared under the normal load of 1.0, 2.0 and 3.0 kg/cm^2. The grain size curves of the four soil specimens are presented in Figure 4.

Table-1: Different proportions of specimens

Specimen	Soil particles passing 2.0 mm in %	Soil particles 2.0 mm - 4.75 mm in %	Soil particles 4.75 mm-10.0 mm in %	Soil Classification
Sample-1	100	0	0	SM
Sample-2	90	5	5	SM
Sample-3	80	10	10	SM
Sample-4	70	15	15	SM

Figure-3(a): Sample-1

Figure- 3(b): Sample-2

Figure- 3(c): Sample-3

Figure-3(d): Sample-4

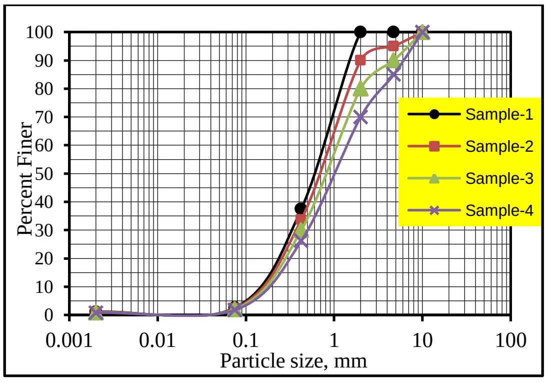


Figure-4: Grain Size Curves

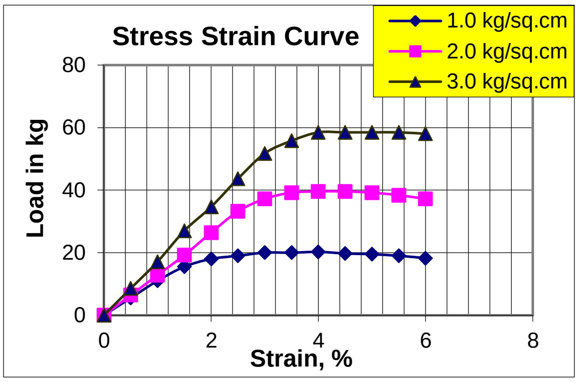
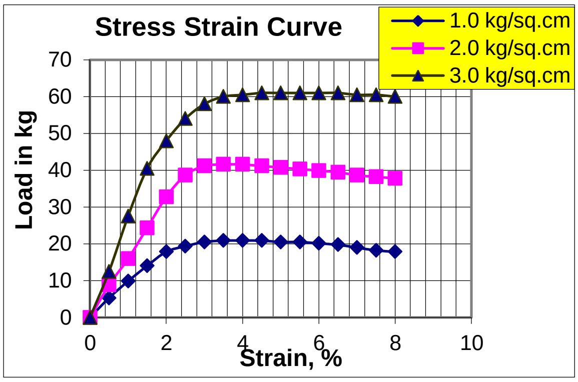


Fig. 5(a) Load v/s Strain Curve for Sample-1



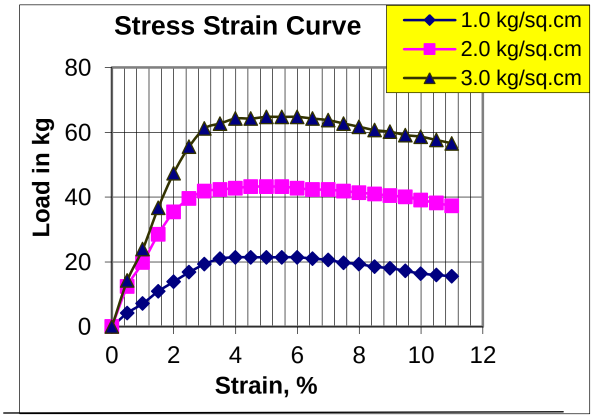


Fig. 5(c) Load v/s Strain Curve for Sample-3

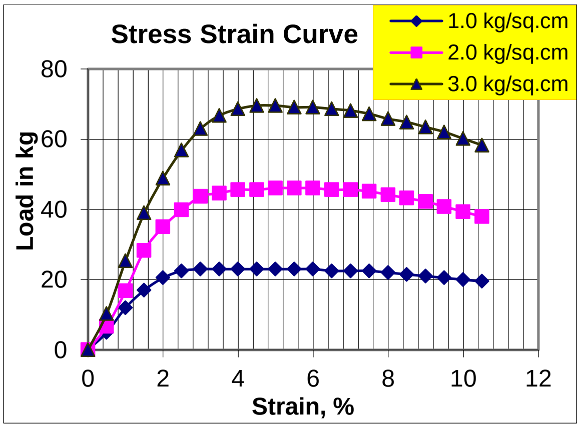


Fig. 5(d) Load v/s Strain Curve for Sample-4

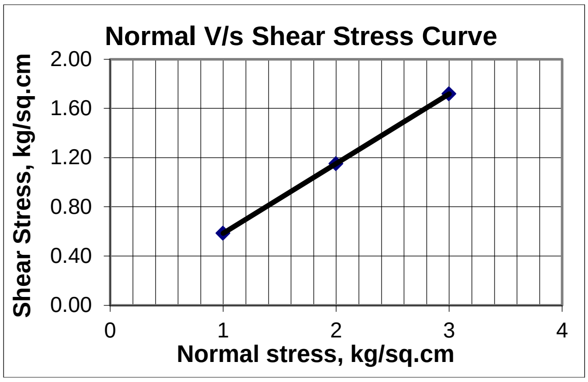


Fig. 6 (a) Stress v/s Strain Curve for Sample -1

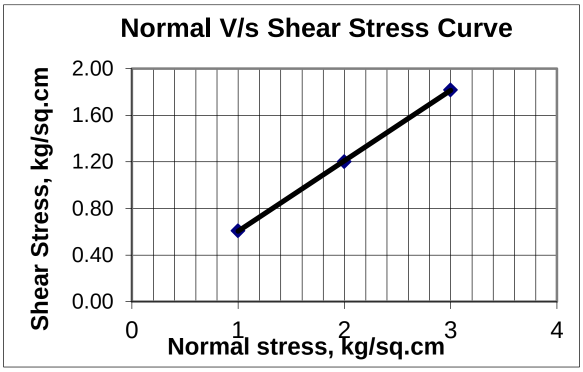


Fig. 6 (b) Stress v/s Strain Curve for Sample-2

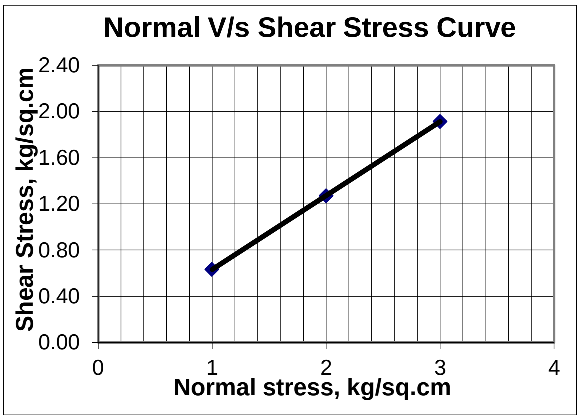


Fig. 6 (c) Stress v/s Strain Curve for Sample-3

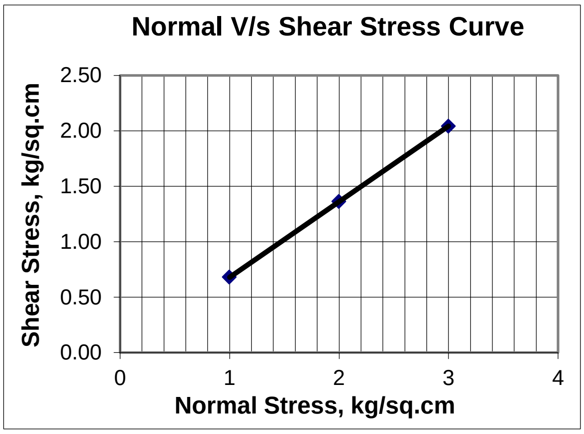


Fig. 6 (d) Stress v/s Strain Curve for Sample-4

III. RESULTS AND DISCUSSIONS

The stress-strain curves of four different specimens, i.e. sample 1, 2 3 & 4 under the normal stress of 1.0, 2.0 and 3.0 are presented in Figure 5(a), 5(b), 5(c) and 5(d). It is clear from the stress-strain curves, as the particle size increases, the shear stress also increases. The shear stress vs. normal stress curves for the four different samples 1, 2 3 & 4 are presented in Figures 6(a), 6(b), 6(c) and 6(d). The direct shear test results on four different specimens are presented in Table-2. The test results show that the value of Angle of Internal Friction (ϕ) for the different soil samples containing the coarse material 0%, 10%, 20 % and 30% increases as the percentage of coarse material increases from 0% to 30%.

Table-2: Angle of Internal Friction

Parameters	Direct Shear Test			
	Sample-1	Sample-2	Sample-3	Sample-4
Cohesion (kg/cm^2)	0.0	0.0	0.0	0.0
Angle of Internal Friction (ϕ)	30.1°	31.3°	32.8°	35.2°

The test results show that angle of internal friction increases from 30.0 to 35.2 as the percentage of coarse material increases from 0% to 30% which is in good agreement of earlier researchers.

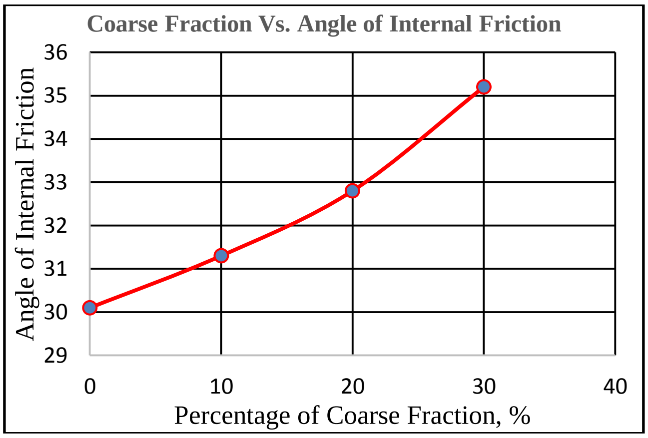


Figure-7: Coarse Materials (Gravel) Vs. Angle of Internal Friction (ϕ)

Effects of Particle Size on Shear Strength

The test results show that with the increase of particle sizes, the angle of internal friction increases thereby leading to increase in the shear strength of soil. The increase in the angle of internal friction with the increase of particle size may be attributed to the fact that as the particles size increase, the interlocking among the soil particles and the surface area under friction also increases. Figure-7 presents the effect of percentage of coarse fraction on the angle of internal friction.

IV. CONCLUSION

Based upon the study, it is concluded that as the percentage of coarse particles increases in the sandy soil, the value of angle of internal friction (ϕ) also increases that results increase in the shear strength of sandy soils. The increase in the angle of internal friction with the increase of particle size is attributed to the fact as the particles size increase, the interlocking among the soil particles and the surface area under friction also increases. In the present study, the effect of coarser particles up to a percentage of 30 % is studied, which indicate that, a lower content of coarser material, the effect on shear strength is nominal and at higher percentage of coarser particles, the effect is substantial.

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