EFFECT OF SIZE AND GRADATION ON SHEARING RESISTANCE OF SAND

ABSTRACT: Rapid industrialisation is making urban conglomerations imperative. As a consequence lot of structures are being built on less competent soils. Though sand is generally considered as stable material by practicing engineers, its behaviour is mostly dependent on the state of packing of constituent materials, gradation and composition of constituent fractions. Size and arrangement of particle characteristics play vital role on the shear resistance of sands. Quite frequently, effects of these parameters are amalgamated and cannot be easily separated. For example, Well Graded Sand may comprise of different proportions of coarse, medium and fine fractions. What is the effect of each fraction that would constitute to overall behaviour of sand remains to be explored? Further, density of packing plays paramount role in the observed behaviour. It is therefore necessary to understand the behaviour of sand in conjunction with its density and gradation for making useful interpretations while making practical decisions. In the light of the above, a limited experimental work has been carried out using sands with different gradations and grain size distribution. The present investigation considers five different sands with classification ranging from Well Graded Sand (SW) to Poorly Graded Sand (SP). These sands were obtained by scalping specific size fractions from river sand of same origin. They are coarse sand (CS) (particle size 4.75–2 mm), medium sand (MS) (particle size 2–0.425 mm) and fine sand (FS) (particle size0.425–0.075 mm). The Direct Shear Tests have been conducted at void ratios at loosest and densest states and corresponding angles of internal friction has been determined. The experimental investigation indicates useful results in terms of possible boundary values of angles of internal friction.

INTRODUCTION:

It has been found that relative density better indicates the compaction of granular soil, i.e. coarser soil as compared to relative compaction. Also sands are more preferred as a foundation/base material because of its tendency to be less affected by pore water as compared to cohesive soils which can be attributed to its greater void size, which holds more air than water. During cut and fill operations, compaction using sand from different sources may be done, resulting in mixed sand which will have different compaction characteristics than those of the parent sands. Also it is practically impossible to obtain fines-free sand for construction purpose. From the number of studies done, there has not been a proper attempt on establishing the relationship between relative density and gradation of sand, i.e. coarse, medium and fine sand. Hence, an attempt through means of experimental study is being made to find a relation among the two, if possible a mathematical one. Also to make the results more practicable in the field, the effect of different proportions of fines present in the sample would also be considered. As the mathematical formula expresses relative density in terms of the void ratios in the natural, loosest and densest soil states, several lab experiments would be performed for determining the different void ratios for different proportions of sand grades. Prior to it, the tests for the grain size analysis to determine the proportion of fines present in the sample and the proportion of different sand grades to be added in the sample would also be taken up.

EXPERIMENTAL PROGRAMME

3.1 General

The experimental program considers five different sands collected from Swarnamukhi River and Penna river basins. The tests are conducted to determine Grain size distribution, Specific gravity, Relative density and Direct shear test. The tests have been conducted as per the Indian standard code of procedure as listed as given in the following table.

Table No : 3.1 Indian Standard Code of Practice for tests

S.No	Description	IS Specification
1	Sieve analysis	IS 2720 (PARTIV)-1985

2	Specific Gravity	IS 2720 (PART3)-1973
3	Direct shear test	IS 2720 (PART13)-1986
4	Relative Density of soil in a Graduated Cylinder	IS 2720 (PART14)-1983

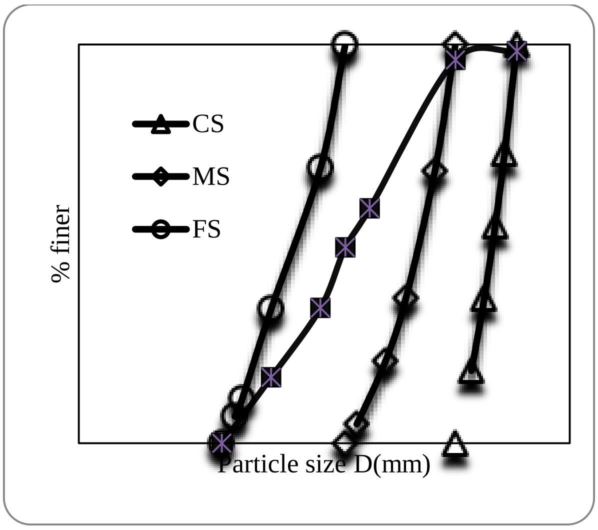
3.2 Methodology:The basic index properties of the sand shown in table 3.2

	Sample 1	Sample2	Sample 3	Sample 4	Sample5
D_{10}	0.13	0.1	0.15	0.045	0.15
D_{30}	0.25	0.23	0.2	0.27	0.35
D_{60}	0.6	0.5	0.5	0.6	0.9
C_U	4.61	6	4	13.333	6
C_C	0.801	0.881	0.44	2.7	0.907
Classification	Sp	Sp	SP	Sw	SP
Specific gravity G	2.61	2.56	2.57	2.59	2.57
%sand	98.64	93.66	97	90.95	92.42
%coarser sand	2.48	3.76	0.2	1.15	16.32
%medium sand	47.01	37.76	42.96	40.72	44.49
%finer sand	49.15	52.14	53.84	49.08	31.61
Φ	29	28	28	28	29

In order to assess the effect of the density, grain size, Relative density on shear resistance of the sands the following procedure is adopted. The Direct shear test for over all sample is conducted at a density by imparting tamping compaction in layers after transferring the sample to the Direct shear box. Further the sand samples are factored into Coarse, Medium and Fine fractions. The test results of gradation of the fractions are presented in figure 3.3

S.NO	SAMPLE	Angle of Internal Friction (Φ)
1	1	29
2	2	28
3	3	28
4	4	28
5	5	29

3.3 Gradations of Different Samples:



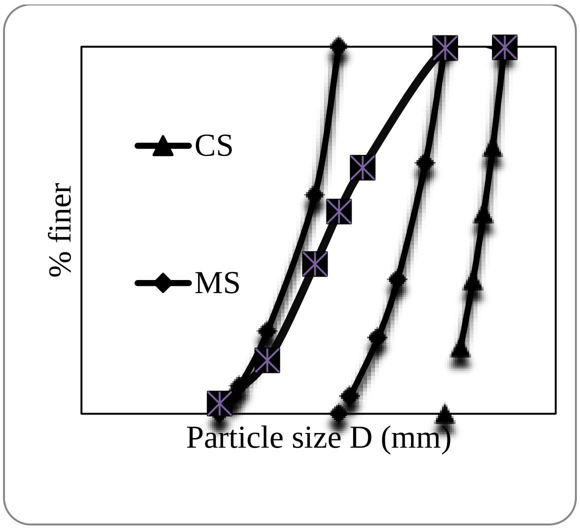
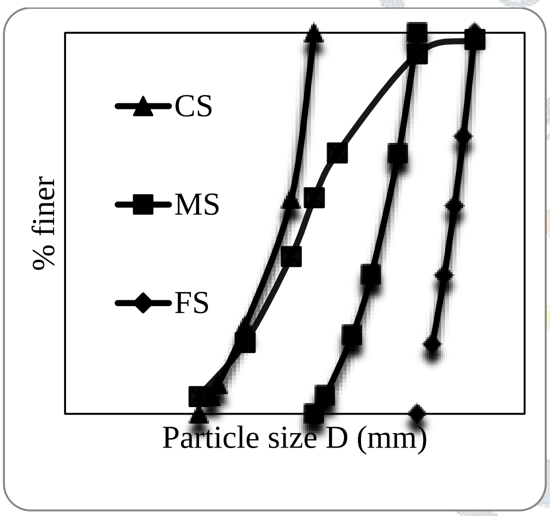


Figure 3.3(a) – Natural Gradation for the Chandragiri sand Figure 3.3(b) – Natural Gradation for the Gollapalli sand



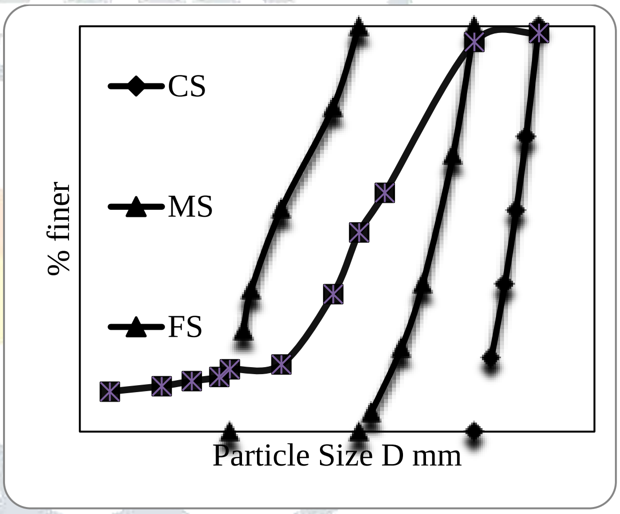


Figure 3.3(c) – Natural Gradation for the Srikalahasti sand Figure 3.3(d) – Natural Gradation for the Nellore sand

Table No: 3.6 The angle of internal friction obtained for the fractions of all the five samples

S. No	Designation	Samples	Angle of Internal Friction (Φ)
1	**Sample1**		
	Coarse Sand	CS	31
	Medium Sand	MS	29
	Fine Sand	FS	27
2	**Sample2**		
	Coarse Sand	CS	32
	Medium Sand	MS	28
	Fine Sand	FS	25
3	**Sample3**		
	Coarse Sand	CS	32

	Medium Sand	MS	28
	Fine Sand	FS	26
4	**Sample4**		
	Coarse Sand	CS	29
	Medium Sand	MS	28
	Fine Sand	FS	27
5	**Sample5**		
	Coarse Sand	CS	31
	Medium Sand	MS	28
	Fine Sand	FS	25

The void ratios corresponding to maximum and minimum possible densities have been conducted by using standard procedures. These values are computed to determine relative density and the values of maximum and minimum void ratios presented in

Table No:3.7 Obtained Void Ratios for the fractions of all the five samples

S. No	Designation	Samples	e_{Max}	e_{Min}
1	**Sample1**		**0.63**	**0.43**
	Coarse Sand	CS	0.84	0.41
	Medium Sand	MS	0.63	0.31
	Fine Sand	FS	0.56	0.29
2	**Sample2**		**0.56**	**0.38**
	Coarse Sand	CS	0.80	0.34
	Medium Sand	MS	0.63	0.29
	Fine Sand	FS	0.56	0.28
3	**Sample3**		**0.55**	**0.35**
	Coarse Sand	CS	0.77	0.43
	Medium Sand	MS	0.59	0.29
	Fine Sand	FS	0.55	0.27
4	**Sample4**		**0.50**	**0.29**
	Coarse Sand	CS	0.70	0.43
	Medium Sand	MS	0.58	0.32
	Fine Sand	FS	0.60	0.24
5	**Sample5**		**0.57**	**0.34**
	Coarse Sand	CS	0.7	0.37
	Medium Sand	MS	0.55	0.27
	Fine Sand	FS	0.54	0.25

ANALYSIS OF TEST RESULTS

4.1 Analysis of Result:

An Examination of test results has been carried out to find out relative effect of size, relative density, Void ratio and coefficient of curvature on angle of internal friction .A comprehensive test results is presented in Table 4.1

Table NO : 4.1 Analysis of test results

Sample		Φ	e_{Max}	e_{Min}	e	D_{10}	ϒ	Cc	RD	D_{50}
I	1	29	0.63	0.43	0.53	0.13	1.710	0.8012	0.50	0.45
	CS	31	0.84	0.41	0.58	2.1	1.66	0.06	0.60	3.20

	MS	29	0.63	0.31	0.47	0.6	1.78	0.96	0.50	1.20
	FS	27	0.56	0.29	0.45	0.1	1.81	0.9	0.40	0.21
II	2	28	0.56	0.38	0.48	0.1	1.760	1.25	0.45	0.38
	CS	32	0.80	0.34	0.52	2.2	1.72	0.93	0.61	3.50
	MS	28	0.63	0.29	0.48	0.6	1.76	0.74	0.44	1.20
	FS	25	0.56	0.28	0.479	0.12	1.75	0.87	0.30	0.19
III	3	28	0.55	0.35	0.46	0.15	1.79	0.768	0.46	0.39
	CS	32	0.77	0.43	0.56	2.2	1.68	0.002	0.62	3.20
	MS	28	0.59	0.29	0.46	0.6	1.749	0.96	0.43	1.20
	FS	26	0.55	0.27	0.45	0.09	1.8	0.89	0.35	0.22
IV	4	28	0.50	0.29	0.4	0.045	1.870	0.474	0.47	0.20
	CS	29	0.70	0.43	0.56	2.2	1.68	0.93	0.51	2.80
	MS	28	0.58	0.32	0.47	0.6	1.78	0.93	0.42	1.25
	FS	27	0.60	0.24	0.45	0.08	1.81	0.12	0.41	0.15
V	5	29	0.57	0.34	0.45	0.15	1.815	1.069	0.52	0.65
	CS	31	0.70	0.37	0.51	2.2	1.75	0.42	0.57	3.20
	MS	28	0.55	0.27	0.44	0.6	1.825	0.9	0.40	1.30
	FS	25	0.54	0.25	0.45	0.09	1.815	1.25	0.30	0.18

It may be observed that the Angle of internal friction for the overall sample is found to be higher for coarse fraction compared to overall sample, medium sand, fine sand. It may be due to the fact that the coarser fraction may offer greater shear resistance owing to inter locking effect. The same trends are observed for all the 5 samples. I t may by further noticed that the densities obtained for the different fractions vary marginally for the same compactive effort. This may be due to the fact that the grain size characteristics' slightly vary depending on the size and packing for each fraction attains for same compactive effort. The analysis of test results for individual samples have been carried out by following linear regression analysis for the different properties as shown

Linear Regression Results:

The combined regression analysis for all the samples considered are presented in Table 4.2

Table No: 4.2: Linear Regression Analysis Results

Parameters	R^2
Φ vs I_D ,D_{50}	0.976
Φ vs I_D	0.962
Φ vs D_{50}	0.976
Φ vs e_{max}	0.678
Φ vs e_{min}	0.496
Φ vs D_{10}	0.652
Φ vs e	0.431
Φ vs Υ	0.350
Φ vs Cc	0.215

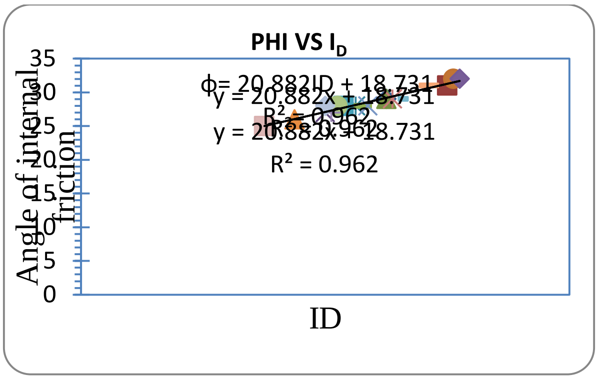


Fig no: 4.7(a) Relationship between Relative Density and Angle of Internal Friction

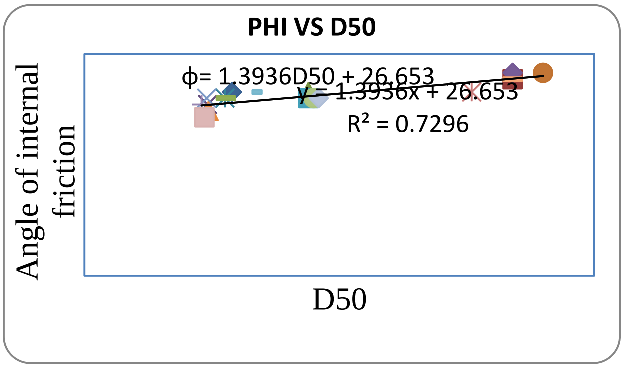


Fig no: 4.7(b) Φ vs. D50curve for combined samples

SUMMARY AND CONCLUDING REMARKS

Previous studies on sand have been quite elaborate and varying considerations were made to explain the observed response of sands under applied loads. However, effect of each fraction such as coarse, medium and fine remains to be understood in much greater detail. The present work considers five different sands with varying grain size distribution. The shear resistance of these sands at constant density has been found out apart from evaluating shear resistance at respective maximum and minimum void ratios. These sands are further factored into various fractions and shear resistance is evaluated at respective maximum and minimum void ratios. The analysis of test results indicate the following concluding remarks

- The maximum and minimum void ratios are found to depend on grain size characteristics.
- The shear strength as represented by angle of internal friction is found to vary over a range of 6^0 to 7^0 from lowest density to possible highest density.
- The above observations indicate that the coarse grained soils are characterized by relatively lower magnitude of strength variation but the deformations these soils undergo are cause for concern.
- As the coefficient of curvature decreases the angle of shearing resistance decreases.
- The coarse fraction has higher angle of shearing resistance compared to fine sand.
- The angle of internal friction is affected by grain size. Greater the grain size greater will be the angle of internal friction.
- The angle of internal friction seems to have direct bearing on relative density of the soil. As relative density increases, angle of internal friction increase.
- The effective size seems to have less significant effect on angle of internal friction.
- The maximum void ratio which is sometimes related to angularity number is likely to have marginal effect on angle of internal friction.

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