INFLUENCE OF NON-PLASTIC FINES ON SHEAR STRENGTH AND COMPRESSIBILITY PARAMETERS OF SAND

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Abstract: In nature, the occurrence and distribution of soil are such that various type of soil can be encountered. As soil is very versatile material it is used as a construction and foundation supporting material. Sand obtain from dredging process is often encountered by some amount of fines (silt/clay). The presence of fines in the sand is generally recognized as a problem in geotechnical engineering because it influences the engineering properties of soil such as strength, permeability, resistance to liquefaction and compressibility. Therefore the question arises "How do fines affect the engineering behaviour of sandy soil?" An Experimental investigation is carried out on different sand (i.e. coarse, medium and fine sand). Reconstituted samples of sand containing different amount of non-plastic fines i.e. 0%, 5%, 10% & 15% were subjected to vibration table for relative density. Then the shear strength and compressibility parameter were obtained by performing the Direct Shear test and Consolidation test. Each sample containing different amount of non-plastic fines were subjected to a Direct Shear test for three Relative Density test i.e. 30%, 60% and 90% at a displacement rate of 0.25 mm/min under two states i.e. Dry & Saturated Condition. Laboratory test results show that as the non-plastic fine content increases the dry density increases and void ratio decreases also the angle of internal friction obtained from the direct shear test is higher in a dry state as compared to the saturated state.

Index Terms **– Sand-silt, Relative density, Direct Shear test, Dry and Saturated condition, Consolidation test.**

I. INTRODUCTION

The soil occurring in nature is composed of different particle sizes in varying percentage. Various constituents of soil i.e. gravel, sand, silt and clay have different physical and engineering properties when they occur alone, in most of the natural soil these constituents exist as a heterogeneous mixture or banded layer based on their formation. The soil is such a versatile material that it can be used as a construction material as well as foundation material. Usually, those construction materials are chosen which best fit the conditions for a given job. Sometimes desired subsurface condition doesn't occur on site then the only alternative remains is to use material from another site. If the character of the soil is unsatisfactory, it may be possible occasionally to improve it by the injection of some substance. It is totally impossible to use some soils as foundation materials. Peat and organic silt are generally so compressible that they are avoided if possible. The ideal foundation materials are sands, gravels, stiff clays, cemented soils and rock. This wide range of soil characteristics holds not only for foundation materials but also for the earth as a material of construction for dams and dykes. No other type of material has a greater range of characteristics than soil has. As per IS 1498 – 1970 (Reaffirmed 2007): Classification and Identification of soil, sand and fines are classified as:-

Coarse Sand: 4.75 mm – 2.00mm IS Sieve
Medium Sand: 2.00 mm – 0.425 mm IS Sieve
Fine Sand: 0.425 mm – 0.075 mm IS Sieve
Silt: 0.075 mm – 0.002 mm IS Sieve
Clay: less than 0.002 mm IS Sieve

During extraction process of sand through an open pit but sometimes dredged from the ocean and river beds or mined from beaches and inland dunes, fines are often encountered. As practically it becomes very difficult to obtain clean and homogeneous sand during the dredging operation. Amount of fines present in the sand has an influence on engineering properties such as strength, permeability, compressibility and resistance to liquefaction.

II. LITERATURE REVIEW

Previously many studies have been conducted to show the effect of fines on different engineering properties of sand. It includes minimum and maximum void ratio of sand (Poul V. Lade, Carl D. Liggio, and Jerry A. Yamamuro, 1998), minimum and maximum void ratio, angle of internal friction and bearing capacity (Rajeev Gupta and Ashutosh Trivedi, 2014), compressional behavior (Keneth

Lupogo, 2013), Compaction characteristic (Prabir K. Kolay, Nurul Wadiah, 2005), effective consolidated drained shear parameters (Toni Glasbergen).

Apurv Kumar Siya (2014) studied the effect of sand gradation on relative density & bearing capacity and also established an empirical relationship between the two. After the establishment of the empirical relationship, it was related to the bearing capacity of the sample with the relative density of its easier application in the field. Relative density, Bearing Capacity and angle of internal friction were found to vary inversely with the mean particle size. Relative Density and Ultimate Bearing Capacity were found to be directly proportional to each other.

Rajeev Gupta and Ashutosh Trivedi (2014) experimentally showed the effect of non-plastic fines in the range of 0% to 25% on angle of internal friction, minimum and maximum void ratios and bearing capacity of clean sand through the series of triaxial shear test, relative density test and model plate load test. The result shows that maximum and minimum void ratios of clean sand decreases as fine content increases from 0 to 20% and increases on further addition of fines. It has been also observed that angle of internal friction and bearing capacity decreases on the addition of fines due to the compressibility of fines.

Hence, an attempt has been made to establish a relationship for different sand (i.e. coarse, medium and fine sand) along with the different amount of fines and also to determine the effect of different percentage of non-plastic fines content on strength and compressibility parameters of sand.

III. Experimental Material

3.1 Sand

Sand samples (i.e. coarse, medium, fine sand) have been procured from the locally (i.e. Kathwada) available sand supplier, I-Class Grade & normal silica sand is used. They are fit to be used for various construction purposes & completely free from the cohesive material i.e. purely sandy samples.

3. 2 Non-Plastic Fines

After preliminary examination, soil from Khambhat was finalized for the preparation of the fines which contains the maximum amount of particles passing 75-micron sieve. The obtained soil was washed on 75-micron sieve and collected in the container. After 20 minutes, the settled material was dried in the oven and pulverized. The pulverized material was again sieved through 75-micron sieve. Now, hydrometer analysis was carried out to know the number of clay particles. The number of clay particles was found insignificant; along with the hydrometer analysis, liquid limit & plastic limit was also determined through which sample has been classified as NP soil. Hence the obtained material was finalized as a non-plastic fine (silt). The properties of fines are given in Table 1.

Table 1 Properties of Non-Plastic Fines (Silt)

Sample	Specific Gravity (G_s)	Liquid Limit	Plastic Limit	Plasticity Index
Silt	2.68	21.6	-	NP

IV. Experimental Investigation

4.1 Relative Density Test

To determine maximum & minimum dry density and maximum & minimum void ratio relative density test have been carried out as per the IS: 2720 (part- 14)-1983. In order to determine the effect of fines, the test was conducted with fine contents of 0%, 5%, 10% and 15% by weight. This test was carried out for Coarse (C), Medium (M) and Fine (F) sand on the addition of non-plastic fines.

4.2 Direct Shear Test

To determine the shear strength parameter of the remoulded soil on the addition of non-plastic fines have been carried out as per the IS: 2720 (part-13) - 1986. Each sample containing different amount of non-plastic fines were subjected to direct shear test at three relative densities i.e. 30%, 60% and 90% at a displacement rate of 0.25 mm/min under two states i.e. Dry and Saturated condition.

4.3 Consolidation Test

To determine the compressibility parameter (i.e. Coefficient of volume change-m_v) of the remoulded soil on the addition of non-plastic fines have been carried out as per the IS: 2720 (part-15) - 1986. In addition to a percentage of fines in the remoulded samples, the Coefficient of Volume change (m_v) has been found.

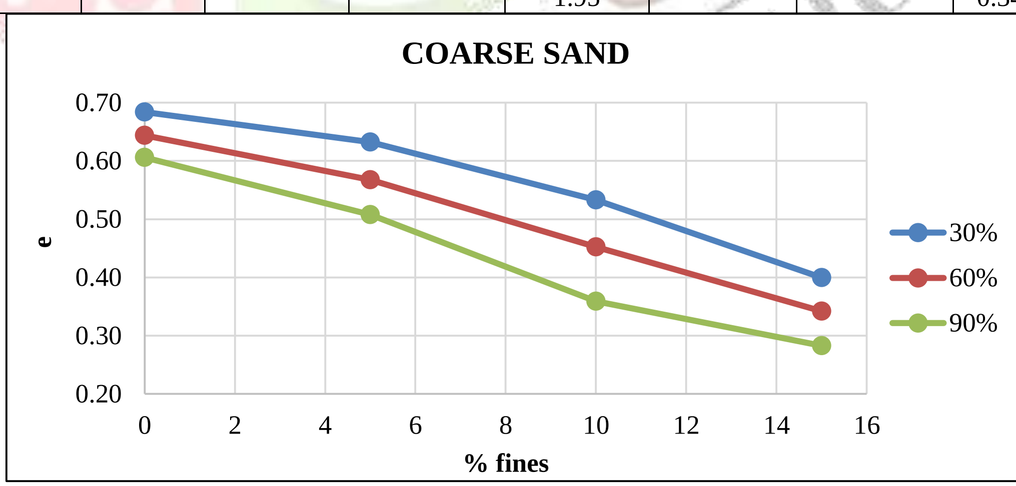
V. Results

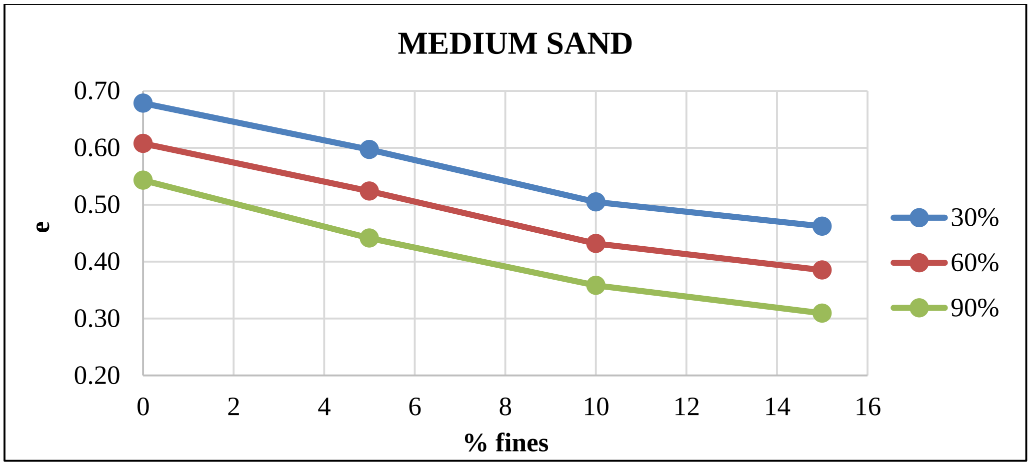
The laboratory results, obtained after performing the tests on each sample are shown here. Details of preliminary properties i.e. maximum and minimum density, maximum and minimum void ratio, shear strength parameters and compressibility parameters are signified through tables and graphs.

Table 2 Properties of Non-Plastic Fines (Silt)

Sample	Silt (%)	Specific gravity	Minimum density (g/cc)	Maximum density (g/cc)	Dry density (g/cc)	Minimum void ratio (e_{min})	Maximum void ratio (e_{max})	Void ratio (e)	R_d (%)
C	0	2.778	1.62	1.74	1.65	0.597	0.715	0.684	30

					1.69			0.644	60
					1.73			0.606	90
	5	2.759	1.63	1.85	1.69	0.491	0.693	0.633	30
					1.76			0.568	60
					1.83			0.508	90
	10	2.759	1.7	2.07	1.80	0.333	0.623	0.533	30
					1.90			0.452	60
					2.03			0.359	90
	15	2.617	1.8	2.07	1.87	0.264	0.454	0.399	30
					1.95			0.342	60
					2.04			0.283	90
M	0	2.685	1.53	1.77	1.60	0.517	0.755	0.678	30
					1.67			0.608	60
					1.74			0.543	90
	5	2.667	1.59	1.88	1.67	0.419	0.677	0.597	30
					1.75			0.524	60
					1.85			0.442	90
	10	2.649	1.68	1.98	1.76	0.338	0.577	0.505	30
					1.85			0.432	60
					1.95			0.358	90
	15	2.632	1.71	2.05	1.80	0.284	0.539	0.462	30
					1.90			0.385	60
					2.01			0.309	90
F	0	2.667	1.5	1.73	1.56	0.542	0.778	0.710	30
					1.63			0.636	60
					1.70			0.569	90
	5	2.667	1.49	1.86	1.58	0.434	0.790	0.688	30
					1.69			0.578	60
					1.81			0.473	90
	10	2.649	1.54	1.95	1.64	0.358	0.720	0.615	30
					1.76			0.505	60
					1.90			0.394	90
	15	2.614	1.56	2.01	1.67	0.300	0.676	0.565	30
					1.80			0.452	60
					1.95			0.341	90





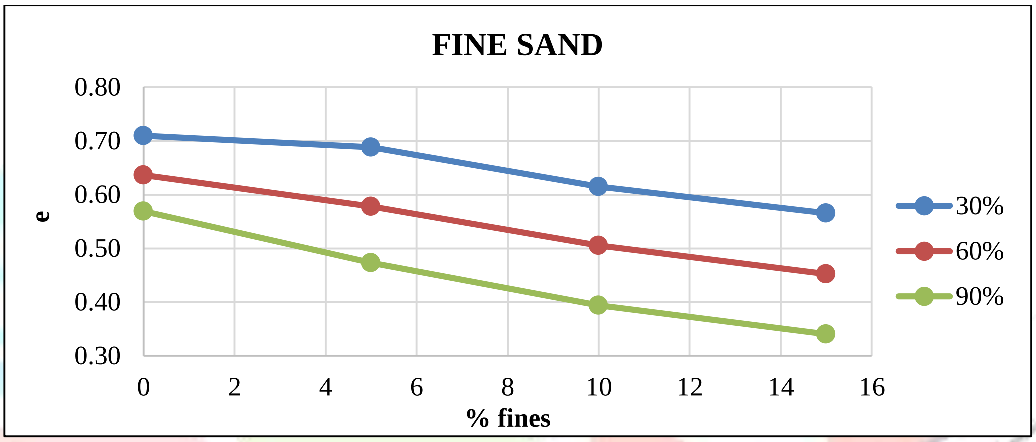


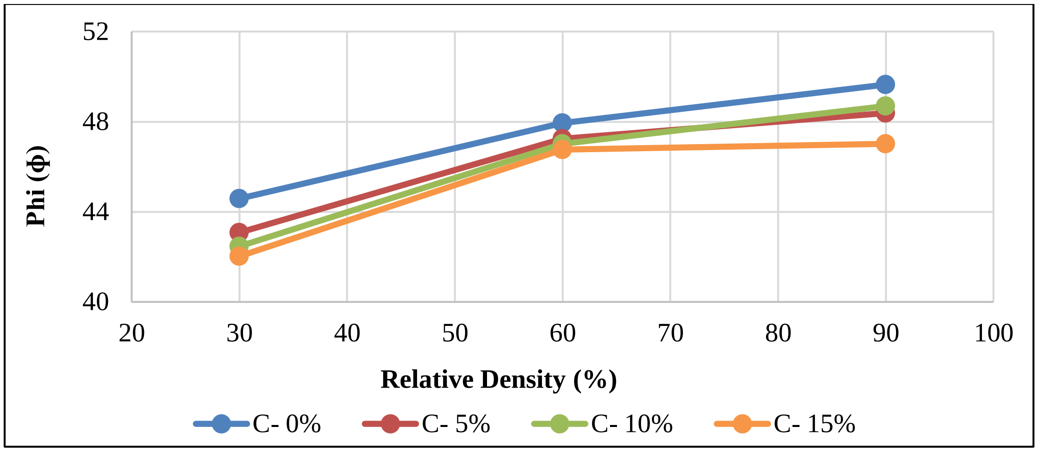
Fig. 1 e v/s % fines correlation for Coarse (C), Medium (M) and Fine (F) sand

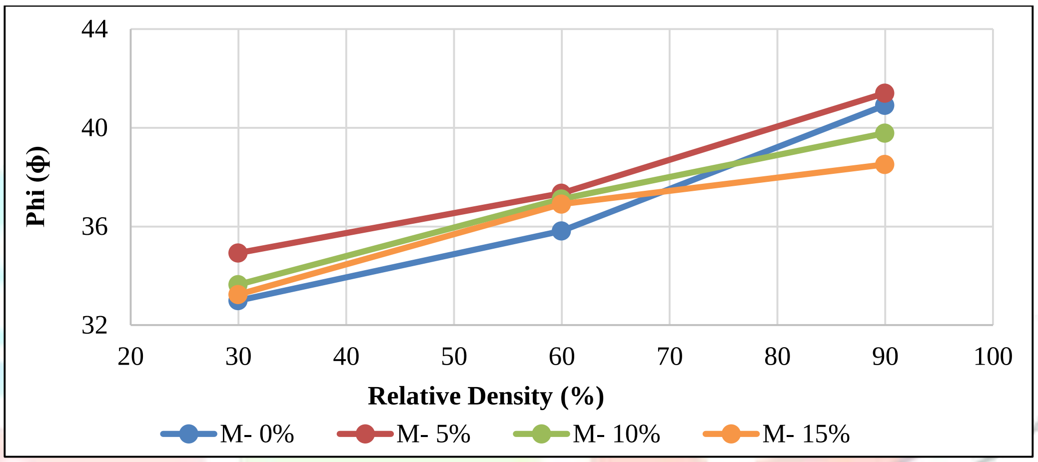
Void ratio is a parameter that affects directly the strength. The density dictates the peak shear strength of the sand. Denser sand has higher peak shear strength and lower void ratio. From the table 2 and fig. 1 it has been observed that void ratio goes on decreasing and the dry density of the sample goes on increasing as the non-plastic fines fill the voids in between the soil particles.

Shear strength parameter of the prepared samples is obtained for assumed relative density i.e. 30%, 60% and 90% at the strain rate of 0.25 mm/min for dry state and saturated state.

Table 3 Angle of Internal Friction Data of Prepared Samples Having Percentage Fines at 0.25 mm/min in Dry State

SOIL SAMPLES	**ANGLE OF INTERNAL FRICTION (ϕ) FOR DRY STATE**											
% SILT	**0%**			**5%**			**10%**			**15%**		
RELATIVE DENSITY	**30**	**60**	**90**	**30**	**60**	**90**	**30**	**60**	**90**	**30**	**60**	**90**
C	45.46	51.72	54.45	44.95	51.62	53.58	43.45	49.97	51.67	42.92	48.58	49.42
M	36.28	38.82	43.39	39.45	42.27	43.87	38.19	40.3	42.697	36.91	39.02	40.96
F	32.53	35.43	37.26	33.41	35.67	37.48	35.34	37.43	39.46	36.13	37.96	40.29





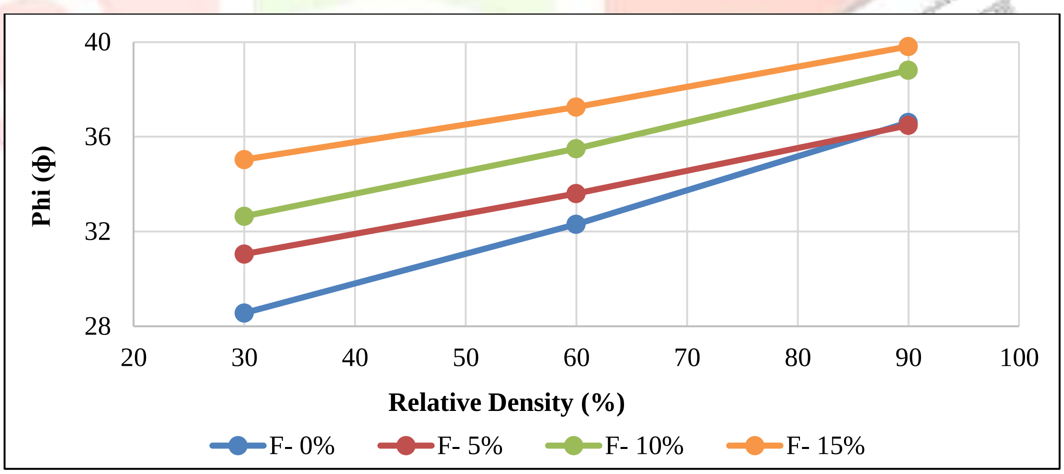
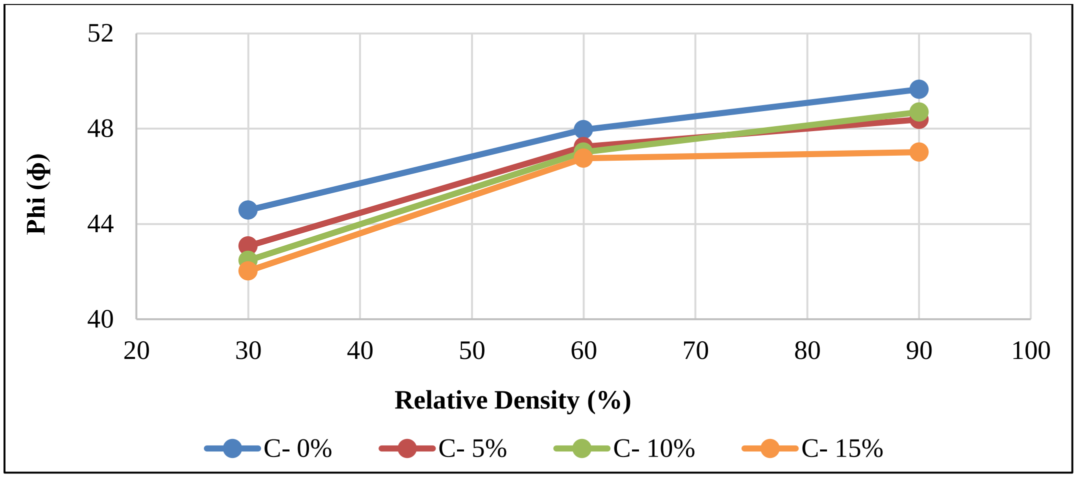


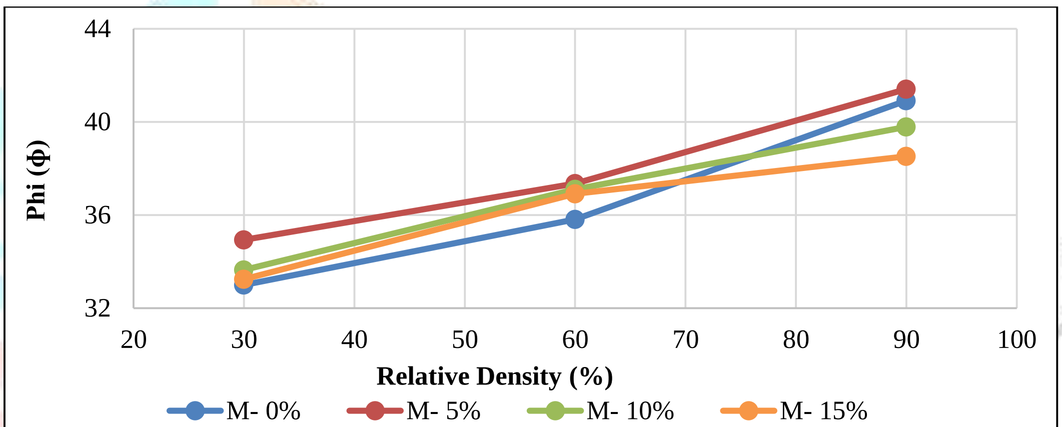
Fig. 2 Relative Density v/s ϕ of saturated state at 0.25 mm/min for Coarse (C), Medium (M) and Fine (F) sand for dry state

Table 4 Angle of Internal Friction Data of Prepared Samples Having Percentage Fines at 0.25 mm/min in Saturated State

SOIL SAMPLES	**ANGLE OF INTERNAL FRICTION (ϕ) FOR SATURATED STATE**											
% SILT	**0%**			**5%**			**10%**			**15%**		
RELATIVE DENSITY	**30**	**60**	**90**	**30**	**60**	**90**	**30**	**60**	**90**	**30**	**60**	**90**
C	44.58	47.95	49.65	43.07	47.24	48.38	42.47	47.02	48.70	42.02	46.76	47.02
M	33.00	35.82	40.91	34.93	37.35	41.40	33.64	37.11	39.78	33.24	36.91	38.52

F	28.56	32.30	36.60	31.05	33.61	36.49	32.64	35.50	38.81	35.04	37.26	39.81





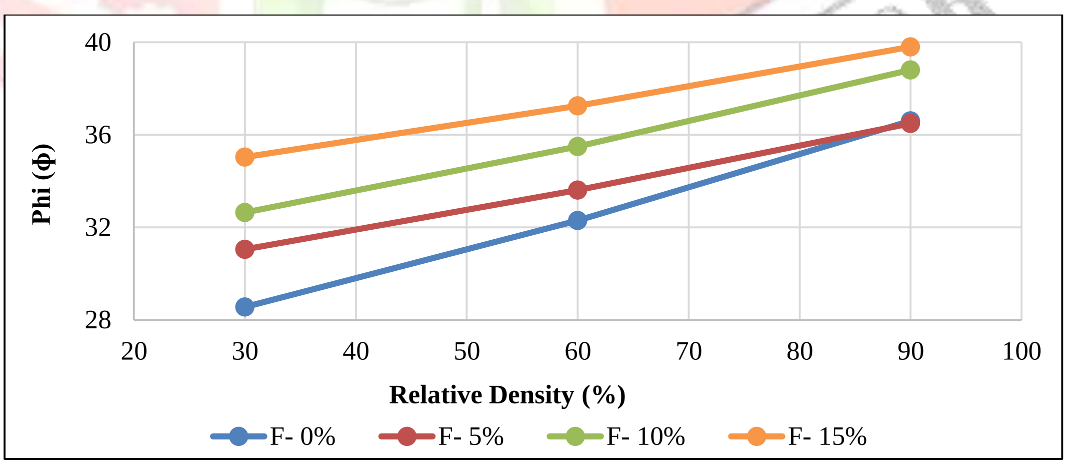
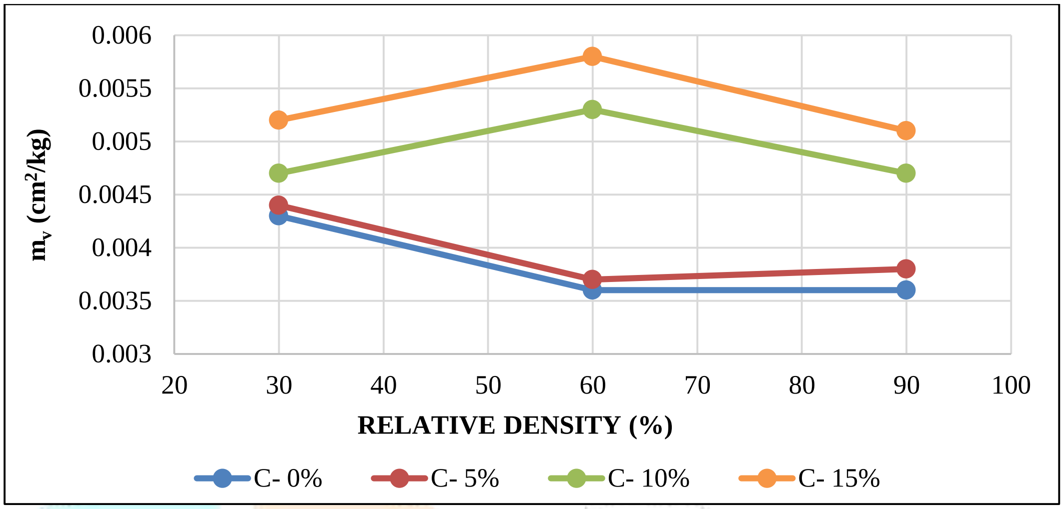


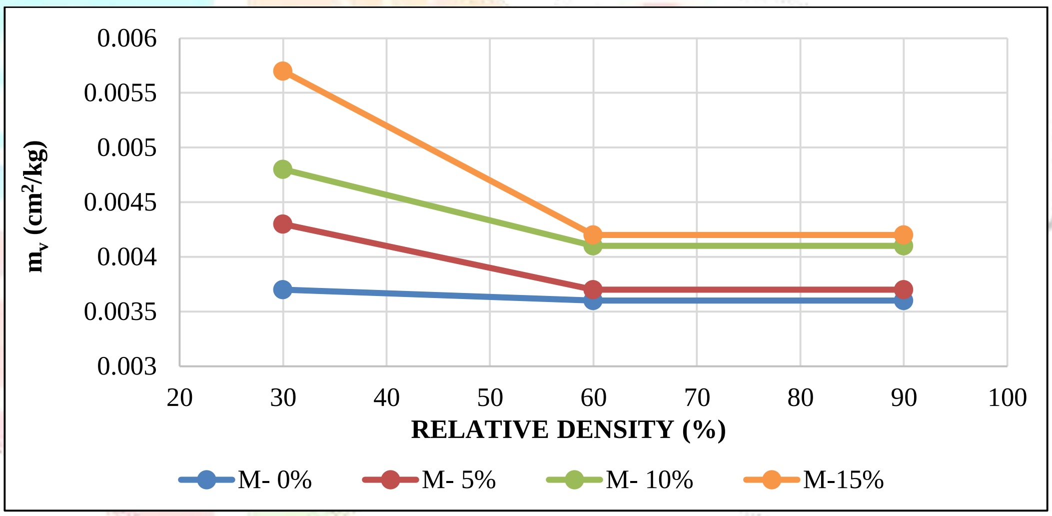
Fig. 3 Relative Density v/s ϕ of saturated state at 0.25 mm/min for Coarse (C), Medium (M) and Fine (F) sand for saturated state

Table 5 Coefficient of volume change (m_v) data of prepared samples having percentage fines at 2 kg/cm^2 to 4 kg/cm^2 stress

SOIL SAMPLES	m_v (cm^2/kg)											
% SILT	0%			5%			10%			15%		
RELATIVE DENSITY	30	60	90	30	60	90	30	60	90	30	60	90

C	0.0043	0.0036	0.0036	0.0044	0.0037	0.0038	0.0047	0.0053	0.0047	0.0052	0.0058	0.0051
M	0.0037	0.0036	0.0036	0.0043	0.0037	0.0037	0.0048	0.0041	0.0041	0.0057	0.0042	0.0042
F	0.0049	0.0036	0.0036	0.0050	0.0043	0.0042	0.0051	0.0044	0.0045	0.0060	0.0039	0.0033





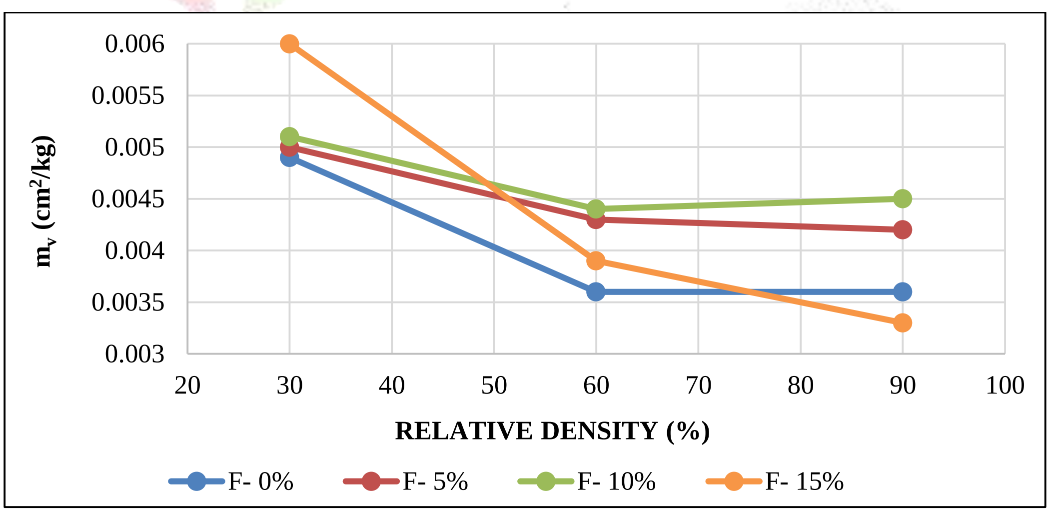


Figure 4.22 – Relative Density v/s Coefficient of volume change (m_v) for Coarse, Medium and Fine sand

VI. CONCLUSION

From the above observations following conclusion can be made:

- Dry density of sample goes on increasing as the particle size and percentage of fines increases.
- The void ratio obtained indirectly from dry density goes on decreasing on the addition of fines content at 30%, 60% and 90% relative density for each sample.
- The angle of internal friction obtained from Direct Shear Test increases directly with the increase in particle size and relative density.
- The angle of internal friction is higher in Dry State as compared to Saturated Sate.
- The angle of internal friction for Coarse Sand goes on decreasing while in case of Fine Sand it goes on increasing, the addition of non-plastic fines in Dry State as well as Saturated State.
- In case of the Medium Sand angle of internal friction increases up to the addition of 5% fines but on further addition of non-plastic fines it goes on decreasing in both Dry and Saturated State.
- The coefficient of Volume Change (m_v) obtained from Oedometer goes on increasing for each sample on the addition of fines ranging from 0% to 15%.
- In case of Fine sand, m_v decreases on the addition of 15% non-plastic fines and in well-graded Medium + Fine sand mv decreases on the addition of 10% and 15% of non-plastic fines.
- This shows that on the addition of non-plastic fines the compressibility of soil sample increases by 30%, 60% and 90% relative density.

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