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Influence of Density and Degree of Saturation on the Shear Strength Characteristics of Marine Sands

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Abstract. The shear strength of soil is not an intrinsic property of soil but varies over a considerable change under varying conditions. The shearing strength of soil depends on density, moisture content, grain size, particle shape and gradation. An attempt has been made in this project to study the shear strength characteristics of marine sand deposits along the Eastern coast of Tamilnadu such as Pichavaram, Pazhayar, Nagapattinam and Samiyarpettai. Bore hole sand at different depths were collected by conducting SPT. The soil samples were tested in loose dry, loose saturated, dense dry and dense saturated condition by direct shear test. Soil samples were collected at two different depths at each site. The different shear tests havebeen carried out at a constant strain rate of 0.25 mm per minute for all the 32 tests. The variation of the friction angle under different conditions has been discussed and presented in this work.
Angle of internal friction for the above soils has been determined for peak shear strength and shear strength corresponding to a constant volume. There is considerable difference in the observed friction angles from the above two conditions. This difference is more for the saturated soils. Higher values of friction angles were observed for the sand collected from Nagapattinam and Samiyarpettai regions than that of the samples collected from Pichavaram and Pazhayar regions. This is due to the more angularity of the soil particles in the Nagapattinam and Samiyarpettai regions.

Keywords: Shear Strength; Density; Degree of Saturation; Friction angle.

1 Introduction

The desk of civil engineers is not merely designing structures from the aesthetic point of view but has to design and built it keeping in mind economy and safety of the structures. To have a stable structure to be placed on sound foundation, a civil engineer ought to have a good idea of the properties of the foundation soil that is confronted with. For a sound foundation design, a thorough investigation of strength and stability characteristics of soil is necessary [1].
Slopes of all kinds including embankments, hills, mountains and manmade cuts and fills. Stay firmly in place because of the shearing strength possessed by the soil or rock of which they are composed of the importance of soil strength analysis was keenly felt during the investigation of the great landslides in the Panama Canal and

the failure of fort peck dam [2].Stability analysis includes checking the structures against required and available shear strength to safe guard it against any possible failure. Thus it is clear that with all boils down to the necessity for a clear understanding of the strength characteristics of soils [3].

The shear strength of soil is not an intrinsic property of soil but varies over a considerable range under varying conditions. The shearing strength both in the laboratory specimen and the soil in the natural state are dependent on density, moisture content, state of compaction, grain size, its distribution and particles shape and gradation [4].

Since World War II, fundamental research on shearing strength phenomena has led to the improved understanding of the various phases of the subject, but even to-day it cannot be claimed that all the factors affecting it have been fully understood [6]. The estimation of shear strength of soil, which exists under natural conditions, from laboratory test data is highly complex in nature because it is difficult to simulate actual conditions existing in site in the laboratory test [5]. Further difficulties arise from non-homogeneity of the representative samples.

An attempt has been made in this work to study the shear strength characteristics of marine sand deposits along the Coromandel Coastal areas of Pichavaram, Pazhayar, Nagapattinam and Samiyarpettai. Bore hole sand at different depths were collected by conducting the SPT. The soil samples were tested in loose dry, loose saturated dense dry and dense saturated condition by direct shear test. The variation of the friction angle under different condition has been discussed and presented in this work.

2 Experimental Programme

In general, there are two types of direct shear apparatus one the stress controlled type in which provision is made to increase the shearing force gradually until failure and the other strain controlled type, where in shearing displacement is increased and the force required to produce the increase is measured [9].

Strain controlled apparatus manufactured by Messrs. Associated Instrument Manufacturers India Private Limited, was used for this series of 32 tests. The essential feature of the apparatus is a rectangular box 6 cm x 6 cm consisting of two separate parts called the upper frame and lower frame [10]. The box is provided with a detachable base plate, one top and another bottom porous plates, one bottom perforated grill plate and another top grill plate. The vertical load is transmitted through a sturdy top cover with ball bearing. The vertical load is applied by means of a loading frame through a lever arm of magnification ratio 1.5. For each test of the series different normal loads 10 kgs, 20 kgs, 30kgs, 40kgs, 50kgs respectively were applied [7]. To multify the effect of the weights of tie bar leaver and load hanger, counter weight is provided. By means of the capstan, the height of the leaver fulcrum is adjusted until the leaver is level and the loading yoke just rests on the loading ball.

The shear failure through the soil at the plane of separation between the two frames is caused by the relative movement between the top and bottom frames. The whole box is placed with in a metallic container which is mounted on ball races on a tract over the base plate of the apparatus [7].

The movement of the bottom frame is produced by means of a loading screw worked by a small electric motor through a pulley block. Nine different speeds are possible by suitable combination of pulleys and gears0.002mmsensitivity for measuring the shearing stresses. The values of one division of proving ring is 0.2325 kg. The change in thickness is recorded by a gauge. The relative movement of the box is also recorded by a similar gauge [8].
The minimum and maximum density of soil sample were found out for the soils from four different places at Pichavaram, Pazhayar, Nagapattinam and Samiyarpettai. The minimum density is found out through loose filling of soil in the mould. The maximum density is found out by filling the soil in several layers in through mould a compacting each layer through vibrator. The minimum and maximum densities are shown in table 1.

Table1. Grain size Distribution & Densities of soil at different depths

S.No	Soil Collected	Depth of Soil Occurrence (m)	Minimum Density(g/cm^3)	Maximum Density(g/cm^3)
1.	Pichavaram	3 5	1.39	1.67
2.	Pazhayar	3 5	1.51	1.78
3.	Nagapattinam	3 5	1.48	1.72
4.	Samiyarpettai	3 5	1.72	1.81

Fig. 1 shows the grain size distribution of soil and the results are presented in a graph shown in below with percent passing versus the sieve size. On the graph the sieve size scale is logarithmic.

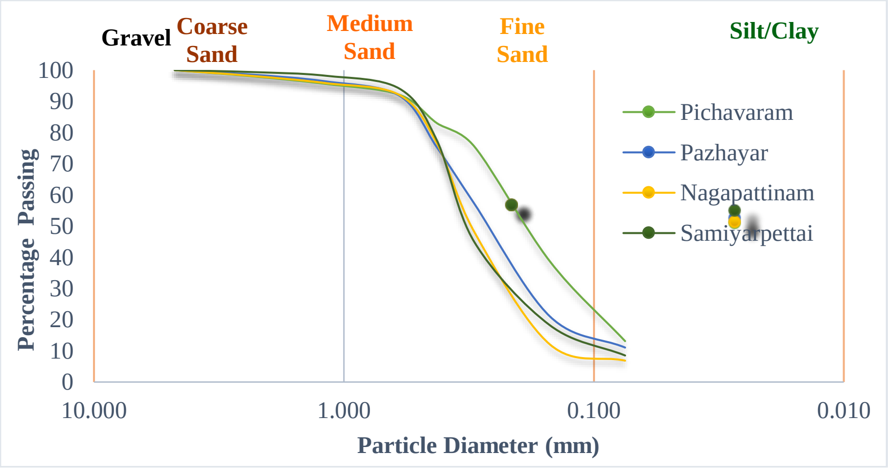

Fig.1. Grain size distribution curve of different soils used in the study.

3 Results & Discussions

In this study, Soil samples were collected from three locations. i.e., Pichavaram, Pazhayar, Nagapattinam and Samiyarpettai. Soil samples were collected at two different depths at each site. The soil samples were tested in loose dry, loose saturated, dense dry and dense saturated condition by direct shear test. The different shear tests have been carried out at a constant strain rate of 0.25 mm per minute for all the 32 tests. The variation of the friction angle under different conditions at pichavaramlocation has been discussed and presented in table 2.

Table 2. Angle of internal friction for different soil conditions @ different depths at Pichavaram location

S.No	Test Condition	Angle of internal friction for 3 m depth	Angle of internal friction for 5 m depth
1.	Loose Dry	$\varphi = 36^0$	$\varphi = 39^0$
2.	Loose Saturated	$\varphi = 33^0$	$\varphi = 34^0$
3.	Densest Dry	$\varphi = 47^0$ $\varphi_{cv} = 36^0$	$\varphi = 49^0$ $\varphi_{cv} = 38^0$
4.	Dense Saturated	$\varphi = 44^0$ $\varphi_{cv} = 41^0$	$\varphi = 46^0$ $\varphi_{cv} = 39^0$

Fig. 2 shows the shear stress and normal stress variation for loose dry and loose saturated conditions at 3 m and 5 m depths located in pichavaram. From the Fig.2,it is observed that angle of internal friction is high for loose soil in dry condition at 5 m depth as compared to the angle of internal friction obtained in soil saturated condition.

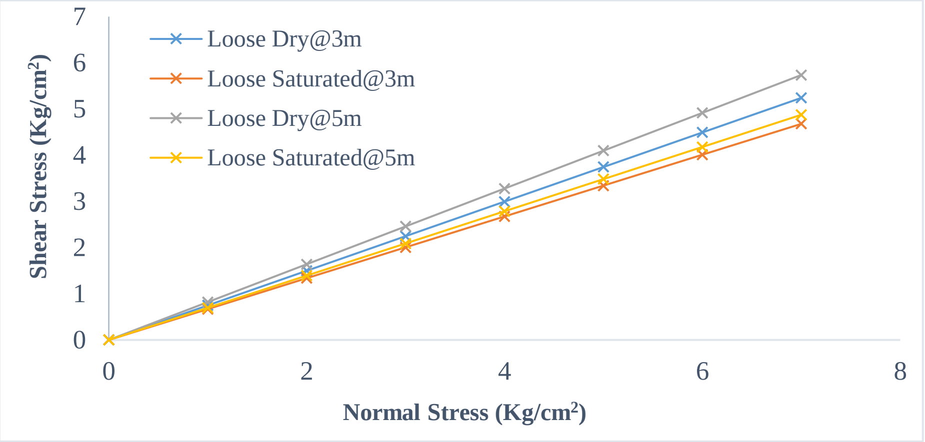

Fig.2. Shear stress and normal stress variation of loose soil at 3 m and 5 m depths located in pichavaram.

Fig. 3 shows the shear stress and normal stress variation for loose and dense dry conditions at 3 m depth located in pichavaram. From Fig.3,it is clearly observed that at 3m depth of pichavaram location the angle of internal friction is more for dense dry soil as compared to loose soil condition.

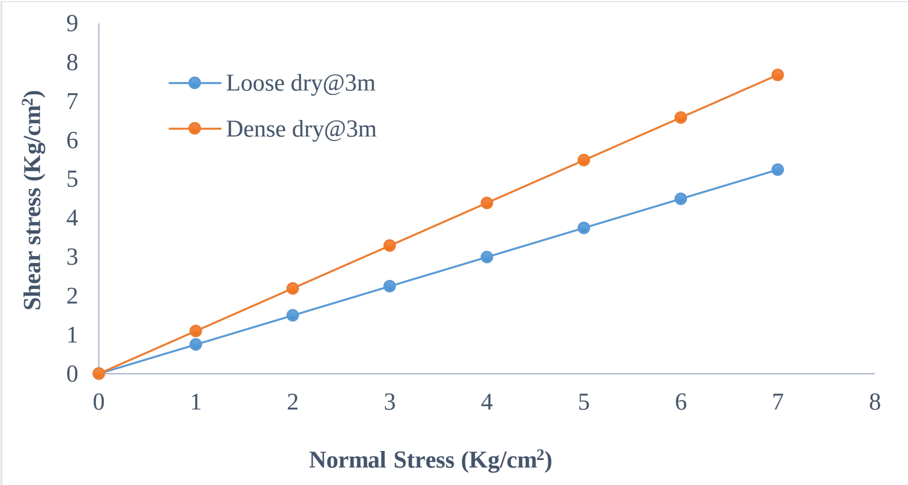

Fig.3. Shear stress and normal stress variation of loose & dense dry soil conditions at 3m depth located in pichavaram.

Fig. 4 shows the shear stress and normal stress variation for loose and dense dry conditions at 5 m depth located in pichavaram. From Fig.4,it is clearly observed that at 5m depth of Pichavaram location the angle of internal friction is more for dense dry soil as compared to loose soil condition.

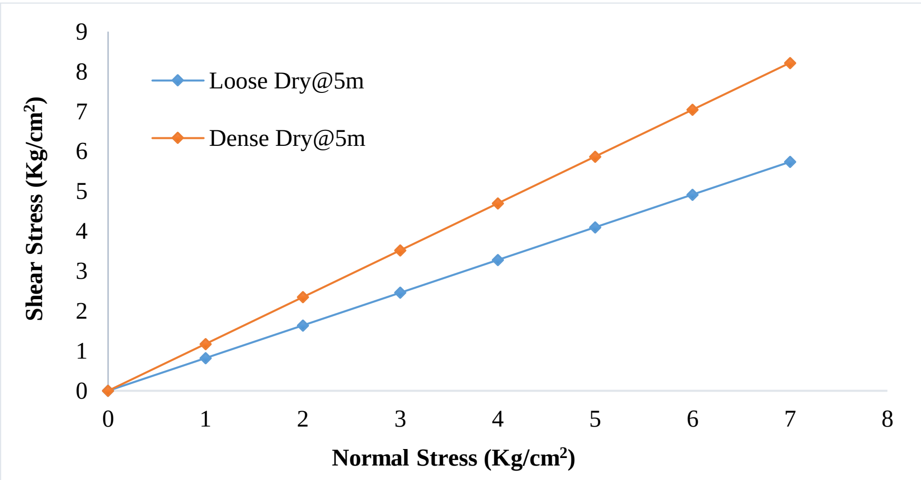

Fig.4. Shear stress and normal stress variation of loose& dense dry soil conditions at 5 m depth located in pichavaram.

Fig. 5 shows the shear stress and normal stress variation for dense dry and dense saturated conditions at 3 m and 5 m depths located in pichavaram.From Fig.5,it is observed that angle of internal friction is high for dense soil in dry condition at 5 m depth as compared to the angle of internal friction obtained in soil saturated condition.

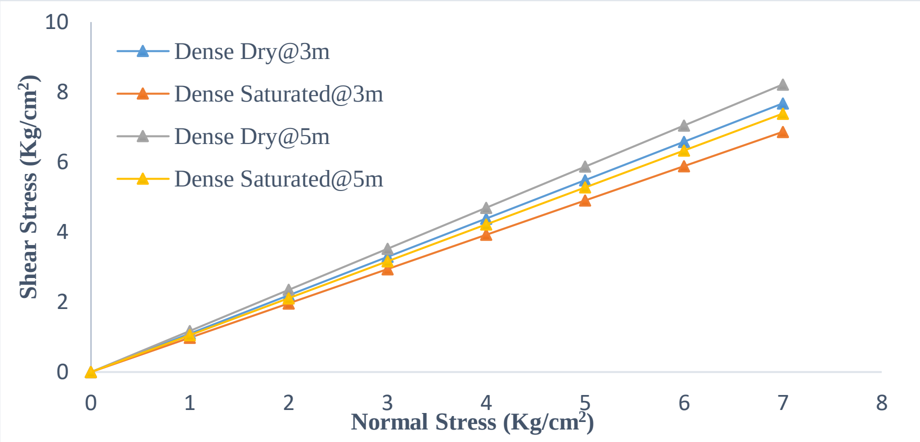

Fig.5. Shear stress and normal stress variation for dense dry and dense saturated conditions at 3 m and 5 m depths located in pichavaram.

Fig. 6 shows the shear stress and horizontal displacement variation for loose dry and loose saturated conditions at 3 m and 5 m depths located in pichavaram. From Fig.6, it is observed that with increase in the degree of saturation of soil, the horizontal deformation increases for a given shear stress value. This is due to decrease in density as saturation increases. As the depth of soil location increases, the shear stress of the soil increases for a given horizontal deformation.

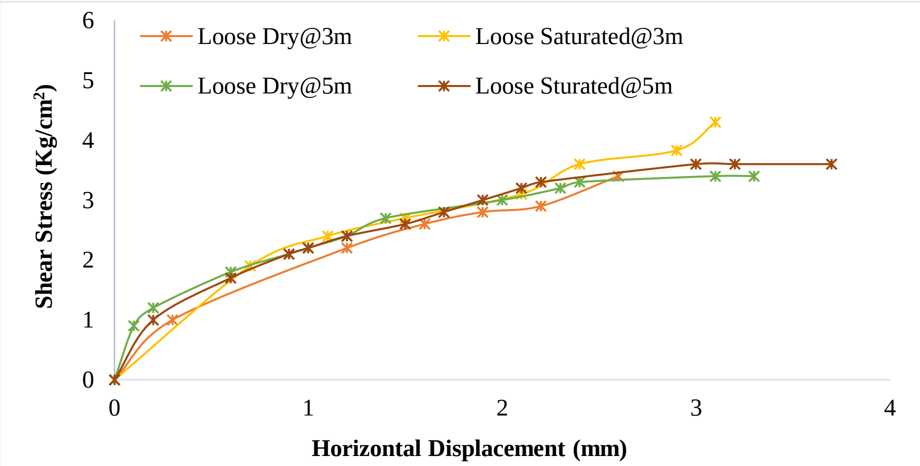

Fig.6. Shear stress and horizontal displacement variation for loose dry and loose saturated conditions at 3 m and 5 m depths located in pichavaram

Fig. 7 shows the shear stress and horizontal displacement variation for loose dry and dense dry conditions at 3 m depth located in pichavaram. From Fig.7, it is observed that with increase in the degree of saturation of soil, the horizontal deformation increases for a given shear stress value at same depth. This is due to decrease in density as saturation increases.

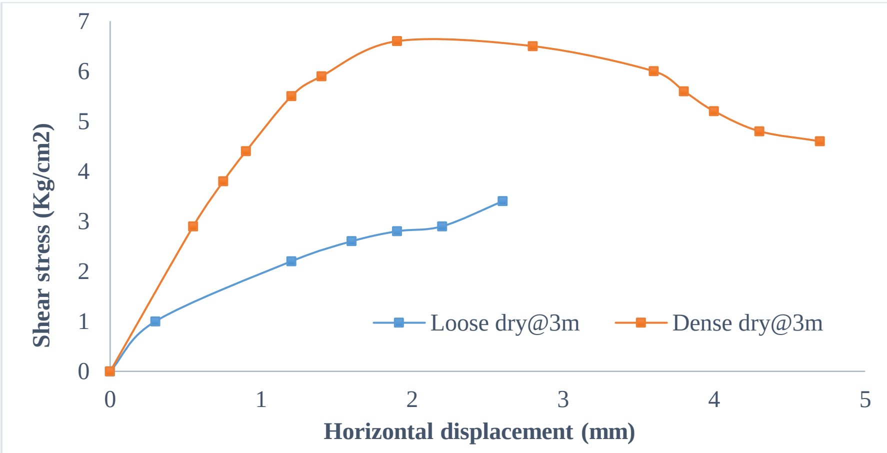

Fig.7. Shear stress and horizontal displacement variation for loose dry and dense dry conditions at 3 m depth located in pichavaram.

Fig. 8 shows the shear stress and horizontal displacement variation for loose dry and dense dry conditions at 5 m depth located in pichavaram.From Fig.8, it is observed that with increase in the degree of saturation of soil, the horizontal deformation increases for a given shear stress value at same depth. This is due to decrease in density as saturation increases.

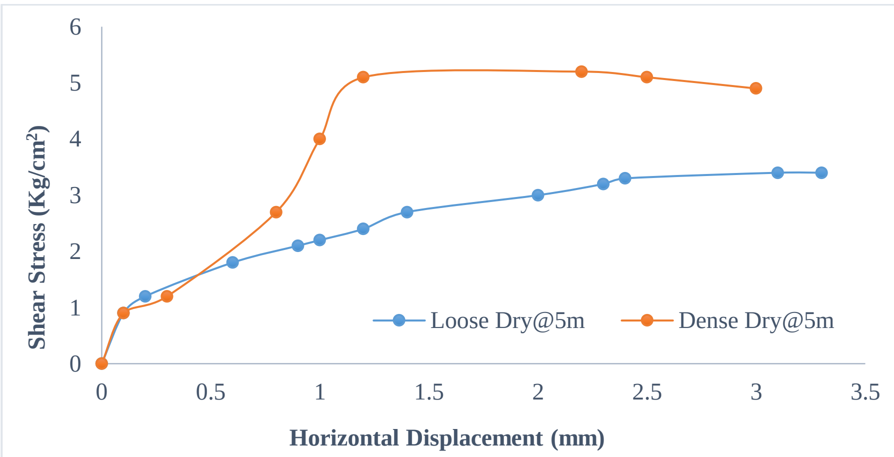

Fig.8. Shear stress and horizontal displacement variation for loose dry and dense dry conditions at 5 m depth located in pichavaram.

Fig. 9 shows the shear stress and horizontal displacement variation for dense dry and dense saturated conditions at 3 m and 5 m depths located in pichavaram. From Fig.9, it is observed that with increase in the degree of saturation of soil, the horizontal deformation increases for a given shear stress value. This is due to decrease in density as saturation increases. As the depth of soil location increases, the shear stress of the soil decreases for a given horizontal deformation.

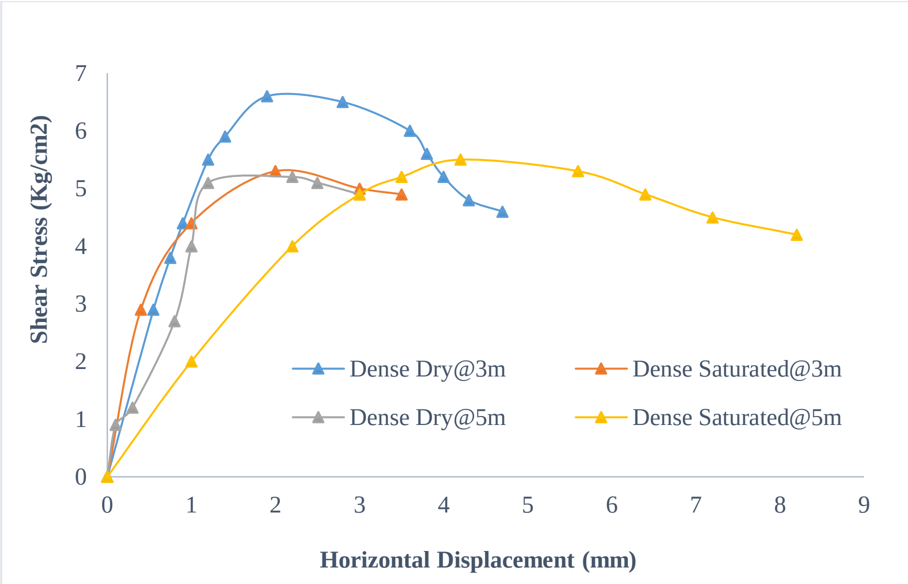

Fig.9. Shear stress and horizontal displacement variation for dense dry and dense saturated conditions at 3 m and 5 m depths located in pichavaram.

Angle of internal friction of different soil conditions for different depths at Pazhayar, Nagapattinam and Samiyarpettai locations are given in tables 3, 4 & 5 respectively
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Table 3. Angle of internal friction for different soil conditions @ different depths at Pazhayar location

S.No	Test Condition	Angle of internal friction for 3 m depth	Angle of internal friction for 5 m depth
1.	Loose Dry	$\varphi = 35^0$	$\varphi = 37^0$
2.	Loose Saturated	$\varphi = 32^0$	$\varphi = 34^0$
3.	Densest Dry	$\varphi = 45^0$ $\varphi_{cv} = 41^0$	$\varphi = 47^0$ $\varphi_{cv} = 43^0$
4.	Dense Saturated	$\varphi = 42^0$ $\varphi_{cv} = 39^0$	$\varphi = 45^0$ $\varphi_{cv} = 43^0$

Table 4. Angle of internal friction for different soil conditions at different depths at Nagapattinam location

S.No	Test Condition	Angle of internal friction for 3 m depth	Angle of internal friction for 5 m depth
1.	Loose Dry	$\varphi = 33^0$	$\varphi = 36^0$
2.	Loose Saturated	$\varphi = 30^0$	$\varphi = 34^0$
3.	Densest Dry	$\varphi = 49^0$ $\varphi_{cv} = 36^0$	$\varphi = 49^0$ $\varphi_{cv} = 34^0$
4.	Dense Saturated	$\varphi = 46^0$ $\varphi_{cv} = 36^0$	$\varphi = 51^0$ $\varphi_{cv} = 42^0$

Table 5. Angle of internal friction for different soil conditions at different depths at Samiyarpettai location

S.No	Test Condition	Angle of internal friction for 3 m depth	Angle of internal friction for 5 m depth
1.	Loose Dry	$\varphi = 35^0$	$\varphi = 41^0$
2.	Loose Saturated	$\varphi = 36^0$	$\varphi = 39^0$
3.	Densest Dry	$\varphi = 53^0$ $\varphi_{cv} = 44^0$	$\varphi = 47^0$ $\varphi_{cv} = 43^0$
4.	Dense Saturated	$\varphi = 46^0$ $\varphi_{cv} = 38^0$	$\varphi = 45^0$ $\varphi_{cv} = 42^0$

At Pazhayar location, the Normal stress, Shear stress and Horizontal displacement values are decreasing by 1% as compared to results obtained at Pichavaram location and increasing by 2% than the Nagapattinam location and also observed 1.2% decreasing values than the Samiyarpettai location.
Similarly, At Nagapattinam location, the Normal stress, Shear stress and Horizontal displacement values are increasing by 1.7% as compared to results obtained at Pichavaram location and increased by 2.4% than the Pazhayarlocation and also observed 1.6% decreasing values than the Samiyarpettai location.
Similarly, At Samiyarpettai location, the Normal stress, Shear stress and Horizontal displacement values are decreased by 0.8% as compared to results obtained at Pichavaram location and increased by 3% than the Nagapattinam location and also observed 1.8% increasing values than the Pazhayar location.

4 Conclusions

From the results obtained from direct shear test conducted on the soil samples, the following important conclusions may be drawn.

1. There is considerable difference between friction angle using peak shear strength and shear strength corresponding to constant volume.
2. The difference between φ and φ_{cv}appears to be least for the soils at dry condition as compared to the values when the soils are tested in saturated condition.
3. The difference between φ and φ_{cv} is more in dense condition for a soil tested than in loosest state.
4. In the case of soil tested in loose condition, it is generally observed that the value obtained from saturated condition is lower than that of the obtained values for the loose sand.
5. The higher difference between the values of φobtained for loose and dense condition indicates better interlocking of soil grains, due to the angularities of the soil grains.

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