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Influence of Plastic Fines on Compaction and CBR Characteristics of Soil Mixtures

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Abstract--- **In practice, in selection of borrowed earth for construction of highway embankments, pavements, retaining structures, importance is paid to the quality of fines only as if quantity of fines is non-influential. It is necessary to understand the effect of quantity of fines on mechanical behavior of soil mixtures. With this objective, the plastic fines completely exclusive of coarse are added to the coarse fraction/sand completely free from fines in the proportion of 5% to 50% by weight of the sand. The compaction characteristics, the un-soaked and soaked CBR values of mixture in different proportion are determined. The results clearly indicated the fact that, there is a specific Critical Fines Content (CFC) for the mixture, such that the presence of plastic fines up to this critical fines content (CFC) is beneficial in terms of improving the gradation and increase in un-soaked CBR values. The CFC for the soil used in the study was found to be 30%. Hence, this study is useful to the practicing Civil Engineers in predicting the behaviour of soil mixtures based on the plastic fines content. Further, this study suggests the need for inclusion of quantity of plastic fines in addition to their quality in relevant Codes of practice.**

Key words--- plastic fines, soil-mixtures, compaction, CBR, SPSS, regression equations

INTRODUCTION

The occurrence and distribution of soils in nature is such that, the various types of soil can be found together In general, natural sand commonly consists of fines and sand particles with different proportions, and the fines content significantly affects the engineering properties of sandy soil. Several instances are reported wherein soil mass with highly plastic fines but in very low proportion are rejected even though its soaked CBR values are satisfactory. It is therefore necessary to investigate the role of plastic fines possessing objectionable PI value on the design parameter CBR when the fines are in different percentages. Efforts are made in this direction in the present study.

I. OBJECTIVES

The primary objective of this study is,

- To study the influence of plastic fines on the CBR characteristics of the soil mixtures.
- To understand the role of plasticity of fines on CBR characteristics of the soil mixture in soaked conditions.
- Identification of the "Critical Fines Content" for the soils used in this study, above which the plastic fines start influencing the geotechnical behaviour of soil mixtures.
- To explore the possible correlation between the percentage fines and the soaked and un-soaked CBR values.

II. SCOPE

The scope of present study is limited to, investigation of influence of fines on soil mixtures involving one type of sand and plastic fines only. Further, the scope is limited to observe the mechanism at macroscopic level i.e. in terms of CBR.

III. LITERATURE REVIEW

Until recently, few studies have reported on the behavior of granular sandy and/or clayey soil with different fines contents. Georgiannou V.N. (1988), made an investigation on the behavior of clayey sands under monotonic and cyclic loading. Mehmet, M. M. and Gurkan O., (2007), investigated on the compression behavior of clayey sand.
Sreedhar, M.V.S., et al. (2009), investigated on the role of fines content on CBR value of sand-clay mixtures and proposed a Critical Fines Content (CFC). They reported that, fines in excess of CFC transform the load bearing mechanism from cohesion-less behaviour to cohesive behaviour governed by plasticity. Shaker, A., Elkady, T., and Dhowian, A. (2014), investigated the swelling and compressibility characteristics of a sand-natural expansive clay mixture for use as a hydraulic barrier. Vu To-AnhPhan, et al. (2016), investigated on the effects of fines content on cohesion, internal friction angle and critical state in the consolidated undrained shear test of sand-fines mixtures.

IV. METHODOLOGY

The methodology adopted in this study includes:

- Collection and characterisation of materials
- Formulation of Scheme of Experiments
- Conducting Compaction and CBR tests as per scheme of experiments
- Analysis of results and formulation of conclusions.

A. Collection and Characterization of Materials

The materials used in this study are natural sand as coarse fraction and black cotton soil as plastic fines.

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1) Natural Sand: Locally available river sand is used for the present study. The summary of the index and engineering parameters of the tests done in accordance with the respective Indian Standard specifications are shown in the Tables 1 and 2 given below. Based on the tests done, the soil is classified as well graded sand 'SW'.

TABLE 1. SUMMARY OF INDEX PROPERTIES OF NATURAL SAND

S.No.	Properties	Values
1	*Results of Wet Sieve analysis*	
	Gravel size %	4.60
	Coarse Sand size %	10.90
	Medium Sand size %	49.80
	Fine Sand size %	33.50
	Fines %	1.20
	Coefficient of uniformity of sample Cu	6.92
	Coefficient of Curvature Cc	1.05
2	Specific Gravity (G)	2.67
3	Classification of sand	SW

TABLE 2. SUMMARY OF ENGINEERING PROPERTIES OF NATURAL SAND

S.No.	Properties	Values
1	*IS Heavy Compaction Test*	
	Optimum Moisture Content (OMC) %	13.20
	Maximum Dry Density(MDD) (kN/m3)	19.30
2	*CBR value under a surcharge of 5 kg*	
	Un-soaked (%)	23.00
	Soaked (4 days) (%)	15.40
3	*Shear parameters from Direct Shear Test*	
	At OMC	
	Cohesion 'c' (kN/m2)	0
	Angle of Shearing resistance 'Φ'(degrees)	42.00
	At SMC	
	Cohesion 'c' (kN/m2)	0
	Angle of Shearing resistance 'Φ'(degrees)	38.65

2) Plastic Fines: Black Clay collected from Siddipet area of Karimnagar district crossing Mid Manair R/S Canal at chainage 0.900 km along embankment alignment on Rajiv Rahadari, has been used as plastic fines for the present investigation. The summary of the results of both index and engineering properties are shown in the Tables 3 and 4 below. Based on the soil test results the soil is classified as 'CH'.

TABLE 3. SUMMARY OF CHARACTERISTICS OF PLASTIC FINES

S.No.	Properties	Values
1	*Wet Sieve analysis*	
	Gravel size %	0.20
	Coarse Sand size %	0.60
	Medium Sand size %	5.70
	Fine Sand size %	12.20
	Silt size %	18.50
	Clay size %	62.80
2	Specific Gravity (G)	2.60
3	Atterberg's Limits	
	Liquid Limit (LL) %	52.50
	Plastic Limit (PL) %	21.20
	Shrinkage Limit (SL) %	15.20
	Plasticity Index (PI) %	31.30
4	DFSI %	46.00
5	Classification of soil	CH

TABLE 4. SUMMARY OF ENGINEERING PROPERTIES OF PLASTIC FINES

S.No.	Properties	Values
1	*IS Heavy Compaction Test*	
	Optimum Moisture Content (OMC) %	15.20
	Maximum Dry Density(MDD) (kN/m^3)	18.40
2	*CBR value under a surcharge of 5 kg*	
	Un-soaked (%)	15.40
	Soaked (4 days) (%)	4.80
3	*Shear parameters from Direct Shear Test*	
	At OMC	
	Cohesion 'c' (kN/m^2)	63.0
	Angle of Shearing resistance 'Φ'(degrees)	8.31
	At SMC	
	Cohesion 'c' (kN/m^2)	27.0
	Angle of Shearing resistance 'Φ'(degrees)	3.90

B. Proportioning of Materials

The soil mixtures were obtained by blending clay and sand uniformly of required proportions manually. The natural sand is washed thoroughly out of fines of size minus 75 microns and oven dried. Clean oven dried sand has been mixed with different proportions of black clayey soil (plastic fines) to form different sand-clay soil mixtures. Fines contents of the soil mixtures used as 5, 10, 20, 30 and 50 percent by weight of sand. While proportioning, care was taken to account for the coarser fraction present in clayey soil such that the overall coarse and fines content of the mixture makes up to the designated proportion.

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C. Compaction and CBR tests

The IS Heavy compaction tests were done on mixtures of different fines content as per IS:2720(Part-7)-1980.The corresponding samples for CBR test were prepared at their respective OMC and the tests were conducted under the application of a surcharge of 5kg, as per IS:2720(Part-16)-1987.

V. RESULTS AND DISCUSSIONS

The results of different tests performed in this study are presented in this section. The variation of different test parameters is analysed and relevant observations are made.

A. Grain size distribution

The variation in particle size distribution with increase in fines content is shown in Fig.1.

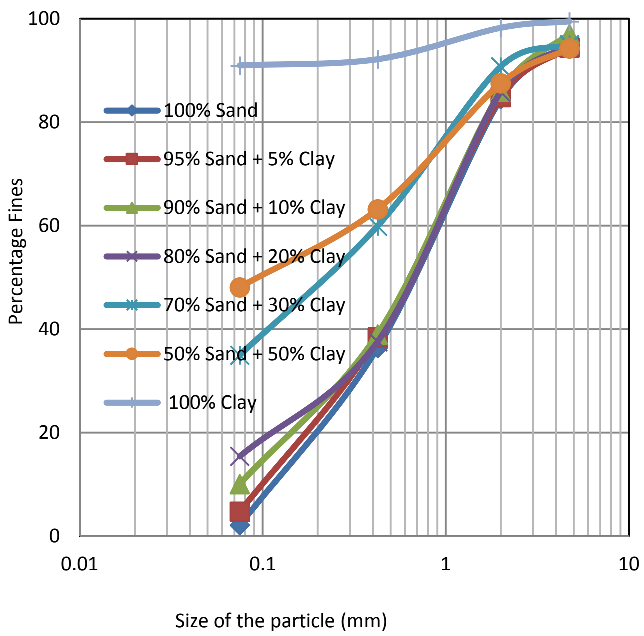

Fig. 1.Variation in Particle size distribution with increase in fines content

B. Plasticity Index

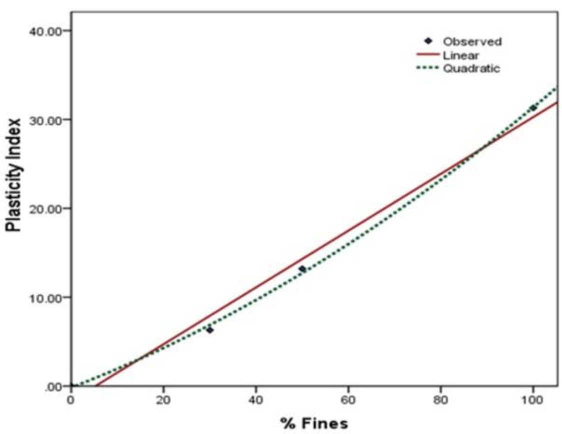

Fig.2.Variation in Plasticity Index with percentage fines

The variation in plasticity index with increase in fines content is presented in Fig. 2. The plasticity index is found to increase proportionately with increase in fines content. It is important to note here that, the plasticity index is essentially a characteristic feature of plastic fines dependent on its mineralogy. Theoretically, if same plastic fines are used in different mixtures, the plasticity index should have been the same. However, as the specimen for determination of consistency limits is recommended as -0.425mm, it is possible that, the fine sand size particles may also become part of the specimen. Hence, the plasticity index is governed by relative proportion of non-plastic and plastic fines within the test specimen.

The correlation between the plasticity index and fines content is presented in equation (1) below.

$$PI = -1.675 + 0.319F \quad (R^2 = 0.986) \tag{1}$$

Where PI = Plasticity Index
F = Percentage of fines content

C. Compaction characteristics

The results of IS Heavy compaction tests performed on different soil mixtures are summarized in Table 5.

TABLE 5. SUMMARY OF COMPACTION TEST RESULTS

S.No.	Sand (%)	Fines (%)	OMC (%)	MDD (kN/m^3)
1	100	0	13.80	19.29
2	95	5	12.00	19.33
3	90	10	11.00	19.90
4	80	20	11.20	21.00
5	70	30	11.80	21.50
6	50	50	13.60	20.80
7	0	100	15.20	18.40

1) Optimum Moisture Content:

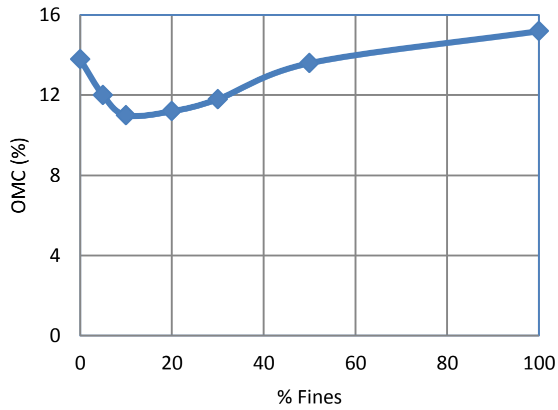

Fig.3.Variation in OMC with fines content

The variation in OMC with increase in fines content is presented in Fig. 3. It may be seen that, the OMC is decreased up to 20% fines content and increased thereon. The higher OMC at no plastic fines stage may be attributed to the typical sand behaviour wherein capillarity shifts the OMC. The drop from 0% to 20% fines may be attributed to the gradual drop in capillarity on one hand and

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improvement in gradation on the other hand. The increase in OMC beyond 20% is due to increased specific surface with increase in fines content.

The percentage change in OMC with increase in fines content is presented in Fig. 4.

The regression equation describing the percentage change in OMC is given in equation (2) as shown below.

$$\Delta OMC = -0.0004F^3 + 0.0562\,F^2 - 1.8302\,F - 3.1888 \quad (R^2 = 0.944) \quad (2)$$

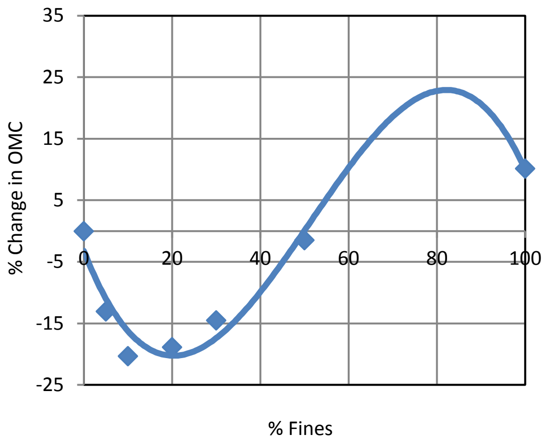

Fig.4.Variation in Percentage change in OMC with fines content

Where ΔOMC = Percentage change in optimum moisture content over that for zero plastic fines
F = Percent plastic fines content.

However, the nature of polynomial infers that, its validity is more appropriate in plastic fines content from 0 to 50% than beyond.

2) Maximum Dry Density: The variation in MDD with increase in plastic fines is presented in Fig. 5.

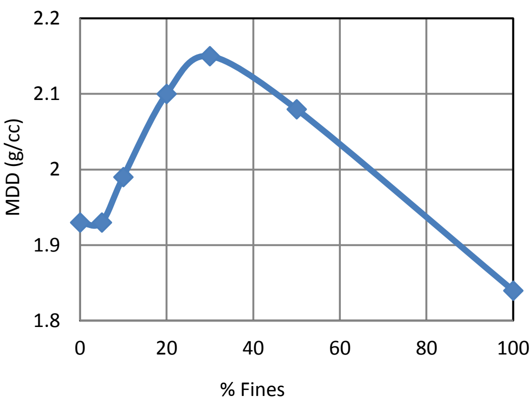

Fig.5. Variation in MDD with plastic fines content

Based on Fig. 5, the following observations can be made.

a) The MDD was least influenced till fines content was up to 5%. This may be for the reason that, these fines are likely to reside in the relatively larger voids with still unfilled empty space.

b) However, the MDD is increasing beyond 5%, showing a peak point at 30% and then decreasing steadily. The increase in MDD is due to the void spaces between the sand particles are occupied by the finer particles. Upto 30% substitution, the fines contributed to improvise the gradation of soil and hence resulted in increased MDD.

c) However, fines in excess of 30% may have contributed to change the gradation to poorly graded and hence causing a reduction in MDD. Further, with higher fines content, the relative ease with which particles can move under compaction effort gets decreased due to cohesion, resulting in a lesser MDD.

The percentage change in MDD with fines content is presented in Fig. 6. A maximum percentage increase of 11.77% was observed at 30% fines due to improvement in gradation of the mixture.

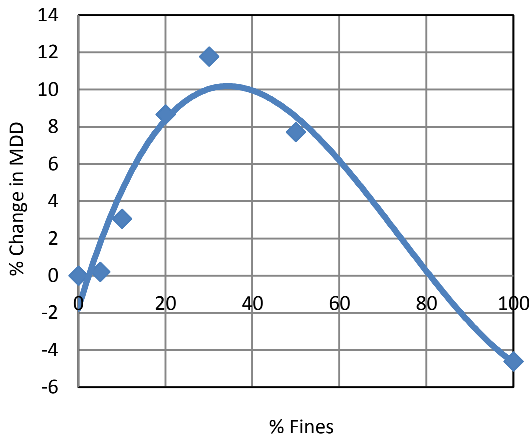

Fig.6.Variation in Percentage change in MDD with plastic fines content

The regression equation for percentage change in MDD is as given in equation (3) below.

$$\Delta M = 0.00007F^3 - 0.0147F^2 + 0.7736F - 1.7693 \quad (R^2=0.942) \quad (3)$$

Where ΔM = Percentage change in MDD over that for zero plastic fines.

D. California Bearing Ratio

The CBR tests were performed on the specimen of different soil mixtures prepared at OMC corresponding to IS Heavy Compaction test under the application of surcharge of 5kg. The results are summarised in Table 6 as shown below.

TABLE 6. SUMMARY OF CBR TEST RESULTS

S.No.	Sand (%)	Clay (%)	CBR Values	
			Un-soaked	*Soaked (4 days)*
1	100	0	22.90	15.40
2	95	5	22.60	14.00
3	90	10	23.40	12.70
4	80	20	27.80	10.40
5	70	30	35.90	9.50
6	50	50	25.10	7.70
7	0	100	19.30	4.80

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1) Un-soaked CBR: The variation in un-soaked CBR values with increase in plastic fines content is presented in Fig. 7.

Based on Fig. 7, the following observations are made.

a) The Un-soaked CBR values were almost same upto 10% of fines. From 10% to 30%, there was an increase and from 30% on wards, there was a steady decrease.

b) From 10% to 30%, the fines continued to occupy the voids thereby contributing to densification. The increase in un-soaked CBR at 30% is due to the fact that, at this proportion, the mixture was having maximum of MDDs, as the gradation was more well graded.

c) However, as the fines content increased beyond 30%, the fines were in excess, making the sand particle now get embedded in the clay matrix. Accordingly, in load bearing mechanism, the Sand to Sand contact is replaced by fines to fines contact. Hence the Un-soaked CBR values are lowered. This phenomenon has continued till 100% fines without much deviation.

The percentage change in Un-soaked CBR value with increase in fines content is presented in Fig. 8, below. As it can be seen, a maximum percentage increase of about 56.40% was seen at 30% plastic fines. The drop beyond 30% signifies that, there is a threshold value of fines content known as Critical Fines Content (CFC), up to which they are beneficial in improving the un-soaked CBR value, which in the present case is around 30%.

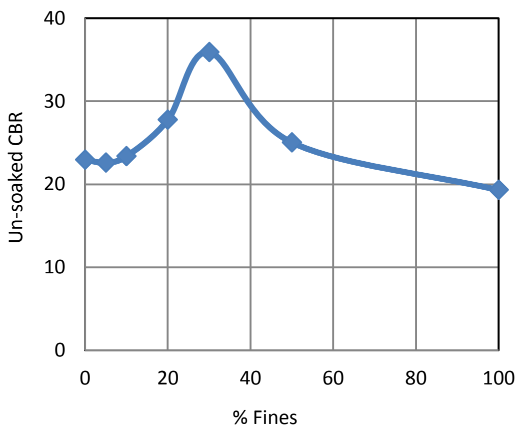

Fig.7. Variation of un-soaked CBR value with fines content

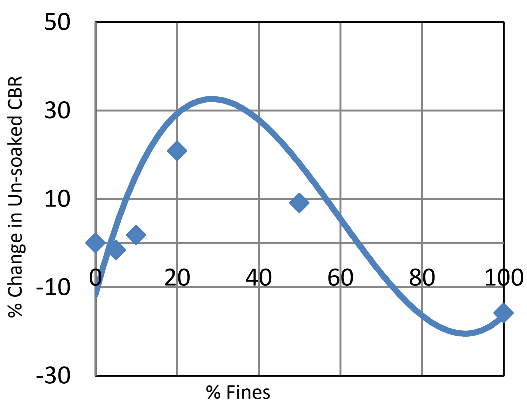

Fig.8.Variation of percentage change in Un-soaked CBR value with fines content

The regression equation describing the change in un-soaked CBR value is given in equation (4) below.

$$\Delta U\text{-}CBR = -\,0.08F^2 + 3.460F - 11.64 \qquad (R^2=0.67) \qquad (4)$$

Where ΔU-CBR = Percentage change in Un-soaked CBR value over that for zero fines.

2) Soaked CBR: The variation in soaked CBR value with fines content is presented in Fig. 9 below.

Based on Fig. 9, the following observations are made.

a) There is a definite drop in soaked CBR values with the increase in plastic fines content. This significant decrease may be attributed to plasticity the fines that are brought in due to soaking. Greater the fines content greater will be the effect of plasticity and hence lower will be the soaked CBR value.

b) The large value of PI of 31.30 emphasizes the high plasticity of clay and hence the steep drop in CBR value. Accordingly, this may be essentially due to shift in the interaction from sand-sand to sand-fines.

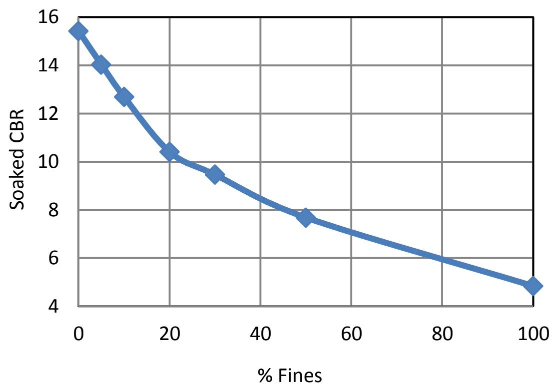

Fig. 9. Variation of Soaked CBR value with fines content

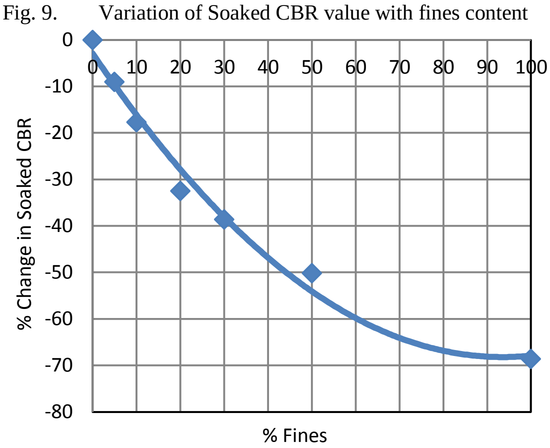

Fig.10.Variation of percentage change in Soaked CBR values with fines content

For the clay used in the present study, there was an overall drop of 68.60 % in the CBR value when it was soaked for four days. The regression equation that describes the variation in soaked CBR value is given in equation (5) below.

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$$\Delta S\text{-}CBR = 0075F^2 - 1.3963F - 2.9172 \quad (R^2 = 0.986) \quad (5)$$

Where ΔS-CBR = Percentage change in 4-day soaked CBR value over that for zero fines.

VI. REGRESSION MODELS

In Civil Engineering practice, in certain circumstances, there may not be adequate time or resources to get the engineering properties determined through laboratory or field tests. In such circumstances, prediction of such properties based on the easy to determine properties through correlations will be helpful. In view of this, efforts have been made in this study to constitute regression models using SPSS Software version 24.0 as presented below.

Linear Regression Analysis

Model 1: Correlation between Group Index (GI) and Maximum Dry Density (MDD)

For qualitative evaluation of the desirability of a soil as a highway subgrade material, a number referred to as the *group index* as determined in equation (6) is widely considered. Higher the value of the group index for a given soil, weaker will be the soil's performance as a subgrade.

$$GI = (F-35)[0.2+0.005(L-40)] + 0.01(F-15)(PI-10) \quad (6)$$

Where GI = Group Index
F = Percentage of Fines/ Fines content
L = Liquid Limit
PI = Plasticity Index

The variation of percentage change in MDD with Group Index is shown in Fig. 11 below.

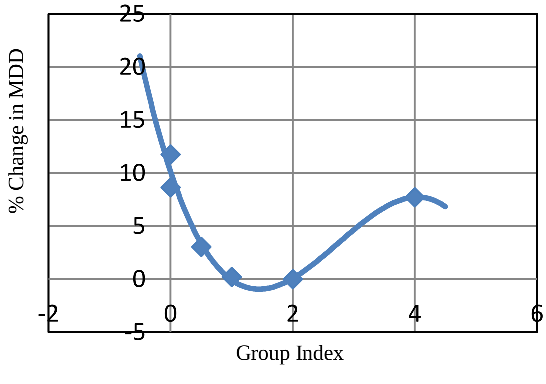

Fig.11.Variation of Percentage change in MDD with GI

The regression model that describes the correlation between GI and MDD is as given in equation (7) below:

$$\Delta M = -0.9895*GI^3 + 8.1548*GI^2 - 17.397*GI + 10.16 \quad (R^2=0.957) \quad (7)$$

The details of the statistical out-put indicates that the relationship developed between MDD and GI is significant (α<0.01) i.e. at 1% level of significance and also a strong relationship exists between the correlation variables.

Model 2: Correlation between Un-soaked CBR and Maximum Dry Density (MDD)

Efforts have been made to develop a correlation between the Un-soaked CBR value and the MDD. The percentage change in Un-soaked CBR value with MDD is as shown in Fig.12 and the regression equation describing the correlation is given in equation (8).

$$\Delta U\text{-}CBR = 0.0574*\Delta M^3 - 0.3219*\Delta M^2 + 0.6699*\Delta M - 0.3842 \quad (R^2=0.99) \quad (8)$$

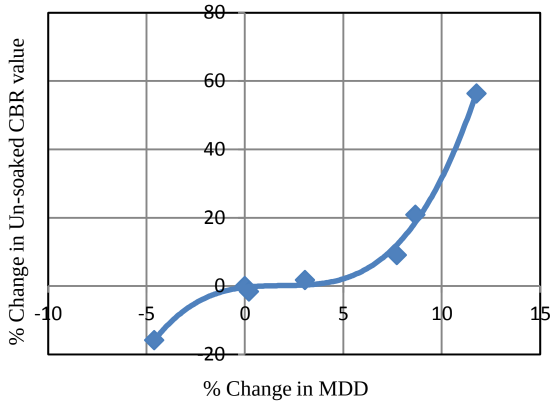

Fig.12. Variation of percentage change in unsoaked CBR with percentage change in MDD

The details of the statistical out-put indicates that the relationship developed between MDD and CBR is significant (α<0.01) i.e. at 1% level of significance and also a strong relationship exists between the correlation variables.

Model 3: Correlation of Soaked CBR with MDD and PI

The variation of percentage change in PI, MDD and 4-day soaked CBR value with fines content is shown in Fig. 13. The multiple regression equation for correlation of these parameters is presented hereunder in equation (9).

$$\Delta S\text{-}CBR = 0.42 - 2.038*\Delta M - 2.506*PI \quad (R^2 = 0.999) \quad (9)$$

Using SPSS software version 24.0, the significant level of correlation coefficients was checked and found that the soaked CBR is statistically significant at 5% (α<0.05) level of significance with PI and MDD.

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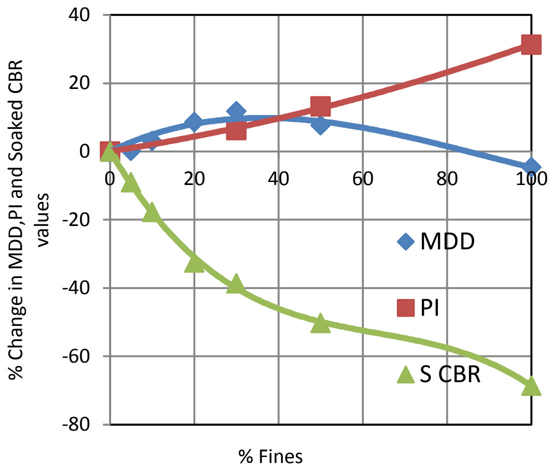

Fig.13. Variation of Percentage change in soaked CBR, MDD and PI values with fines content

For the developed models, the derived regression coefficients R^2 are neither zero nor less than the standard error. Variance inflation factor (VIF) for the input variables are lower than 10 indicating that there is no multi-collinearity. All the regression coefficients of predictors are also statistically significant. Therefore, the regression coefficients in the equations for prediction of CBR values are validated.

VII. CONCLUSIONS

Based on the experimental results found in this project, the following conclusions are made.

1. In general, it is found that, apart from the quality, quantity of the plastic fines also has a definite influence on the compaction and CBR characteristics of the soil mixtures.
2. As the fines content increases up to a critical value known as "Critical Fines Content (CFC)" the MDD and Un-soaked CBR values increases considerably and gradually decreases as fines content increases beyond CFC.
3. For the materials used in this study, the CFC was 30% and the increase in MDD and Un-soaked CBR values was up to 11.77% and 56.40% respectively.
4. The effect of plasticity was more pronounced in saturation state. As the fines content increases the Plasticity Index increases and the soaked CBR values continuously decreases owing to the increase in plasticity of the soil mixture. For the materials used in this study, the maximum drop was up to 68.60%.
5. To facilitate the blending of soils, correlations are developed to predict the effect of fines content on compaction and CBR characteristics. The fines content is accounted in easy to determine Group Index (GI). With GI as input, a model (Eq.7) is developed for prediction of percentage change in MDD (viz., ΔM). In turn, the percentage change in Unsoaked CBR value can be predicted based on ΔM using Eq.8. The percentage change in 4-day Soaked CBR can be predicted as a function of MDD and PI using Eq.9.

On the whole, this study provided an insight in to the effect of fines on compaction and CBR characteristics and provides correlations to predict the effect. This study is useful in blending of similar soils.

REFERENCES

[1] Georgiannou V.N. (1988), "The behavior of clayey sands under monotonic and cyclic loading," PhD thesis, University of London.
[2] Mehmet, M. M. and Gurkan O., (2007), "Compression behavior of clayey sand and transition fines content'', Engineering Geology, Elsevier, Volume 89, Issues 3–4, 2007, pp 195-205.
[3] Sreedhar, M.V.S., et al., (2009), "Investigations on the role of fine content on CBR value of sand-clay mixtures", Indian Geotechnical Conference, 2009.
[4] Shaker, A., Elkady, T., and Dhowian, A. (2014), "Swell and Compressibility of Sand-Expansive Clay Mixtures", Soil Behavior and Geomechanics, 2014, pp 15-24.
[5] Vu To-AnhPhan, et al. (2016), "Effects of Fines Contents on Engineering Properties of Sand-Fines Mixtures", Proceeding of Sustainable Development of Civil, Urban and Transportation Engineering, Volume 142, 2016, pp 213-220.

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