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Single Linear Regression Analysis of Geotechnical Parameters of Fine Grained Soils

C Lavanya[1] and Nandyala Darga Kumar[2]

[1] Professor, Department of Civil Engineering, GRIET, Hyderabad-500090
[2] Assistant Professor, Department of Civil Engineering, JNTUH, Telangana -505212

Abstract. Due to huge expenditure is involved in testing of soil by employing heavy machinery and costly equipment; it is necessitated to develop statistical correlations between various geotechnical parameters which can be used mostly in design of foundations and pavement constructions. Many techniques are developed for carrying out regression analysis to establish the relationships between response variable and explanatory variables as per the practice are concerned. Single linear regression analysis (SLRA) and multiple linear regression analysis (MLRA) are the modeling techniques commonly adopted to develop correlations between the required variables. This paper presents the relationships established between geotechnical parameters of fine grained soils using SLRA technique. The geotechnical parameters of fine grained soils such as California Bearing Ratio (CBR), Liquid limit (LL), Plastic limit (PL), Plasticity Index (PI), Optimum Moisture Content (OMC), Maximum Dry Density (MDD) and % fine fraction (FF) are considered from the soil testing carried out on natural soil samples collected at different stretches of a road project in Telangana state. The SLRA showed good fits between the geotechnical parameters of fine grained soils with regression coefficients showing above 0.80.

Keywords: Fine grained soil, CBR, PI, OMC, SLRA.

1 Introduction

The suitability of soil is usually evaluated before start of construction activity on it. Geographical variability in soil conditions from one location to another makes it carry out investigation for its suitability to the intended construction [1]. In geotechnical engineering design, the most essential aspect that requires to be considered involves the soil moisture content, cohesion, friction angle, unit weight, saturation degree, porosity, plasticity index and grain size distribution. These properties are important elements especially in determination of CBR, bearing capacity and slope stability in soil. Soil investigation is laborious, expensive and invasive. Therefore, an alternate quick, non-destructive and environment friendly assessment of soil properties is very crucial. Interpretations of geotechnical data will involve a degree of uncertainty. It is more difficult to acquire a reliable set of representative and undisturbed samples of the various soil strata. Geotechnical investigations are expensive and time consuming activities. Soaked CBR value of a soil sample takes about a week, making CBR test expensive, time consuming and laborious. All these problems may result in delay in the progress of the project and lead to escalation of the project cost. To overcome these difficulties, it is imperative to predict CBR value of subgrade soil with index properties.

In order to cover the site investigation of larger area in a reduced time and cost, both geophysical and geotechnical methods appropriately conducted and the results obtained would be verified for the entire subsurface characterization. There are correlations available with high regression coefficient between P-wave values and engineering parameters of a ground such as the SPT-N values, rock quality, friction angle, velocity index, and density and penetration strength [2, 3]. The design and performance of a flexible pavement depend on the strength of sub-grade material such as California Bearing Ratio [4]. The use of the seismic piezocone test in geotechnical site investigation offers field assessment on stratigraphy and soil behavior and it is more convenient compared to traditional investigation methods [5]. Strength characteristics of the clay were correlated with various index properties [6]. Good agreement was obtained between samples and the CPT data using the new normalized charts [7]. One can use the relationships which were established between normalized shear wave velocity, normalized tip resistance, and mean grain size [8]. Multivariate regression model can be used to predict soil expansion index [9].

Empirical correlations play a key role in geotechnical engineering designs and analysis. By using appropriate empirical correlations, it is possible to derive many design parameters, thus limiting our reliance on these soil tests [10]. The relationship between CBR and water content is commonly presented in analyses [11]. Correlations were well agreed between California bearing ratio and the unconfined compressive strengths of sand- cement samples [12]. Based on the limited tests conducted, the correlations were established between CBR and soil index properties [13].

From the discussion, the correlations available between soil parameters are based on the limited testing in the laboratory and no correlations are established with respect to the % of fines. In this paper, the correlations are developed between % fines and soil index properties and with compaction characteristics. The variations of CBR with PI, OMC and MDD are presented.

2 Experimental Investigation

In order to have enough and reliable data for the target analysis, laboratory tests were conducted on soil samples obtained from different localities of the project site. A total of three hundred disturbed samples were collected within reasonable sampling intervals. Soils were collected from the respective localities at a depth of about 0.5 to 1m from the ground level after removing all the vegetation matter and were subjected to air dry as well pulverization.

2.1 Index Property Tests

In nature soil occurs in a large variety. These simplified tests which are indicative of the engineering properties of soils are called index properties. Index properties of cohesive soils are used to characterize the physical and mechanical behavior of soils by making use of parameters such as moisture content, particle size distribution, Atterberg limits and moisture density relationships. Such parameters are useful to classify cohesive soil sand provide correlations with engineering soil properties.

2.2 Tests Conducted

The soil samples which were pulverized using smooth wooden hammers were stored in airtight bags under the controlled temperature in the laboratory. The laboratory tests were conducted on 130 soil samples whose % fines more than 50. All the tests mentioned in the

Table 1 were conducted as per the standard test procedures given in the respective code of practice of concerned test.

Table 1. List of Tests Conducted

Name of the test	Indian Standard Test Code of Practice
Liquid Limit and Plastic Limit Test	IS: 2720 (Part V) – 1985
Heavy Compaction Test	IS: 2720 (Part VIII) – 1983
Shrinkage limit Test	IS: 2720 (Part VI) – 1972
California Bearing Ratio Test	IS: 2720 (Part XVI) – 1987
Free Swell Index Test	IS: 2720 (Part XL) – 1977
Sieve Analysis	IS: 2720 (Part IV) - 1985

3 Results and Discussion

The obtained laboratory results pertinent to index properties, CBR and compaction characteristics such as OMC and MDD were analyzed using statistical analysis such as single linear regression analysis (SLRA). The discussion of results and correlations are presented in the following sections.

3.1 Single Linear Regression Analysis (SLRA)

Fig.1 presents the variation of LL with the % fines. From this figure, it is noticed that as the % fines increases the LL is increasing and for the soil samples of % fines from 80 to 100, the range of liquid limit is 60 to 80%. The correlation between % fines and LL is presented below. It has regression coefficient, $R^2 = 0.822$.

$$LL= 0.465(FF) + 20.12$$

LL and FF are in %.

Fig.2 presents the variation of PI with the % fines. From this figure, it is noticed that as the % fines increases the PI is increasing and for the soil samples of % fines from 80 to 100, the range of PI is 25 to 30%. This indicates that the soil samples whose % fines more than 80% are having PI more than 25 and these can be considered as high plastic clays. The correlation between % fines and PI is presented below. It has regression coefficient, $R^2 = 0.892$.

$$PI = 0.216(FF) + 8.108$$

PI and FF are in %.

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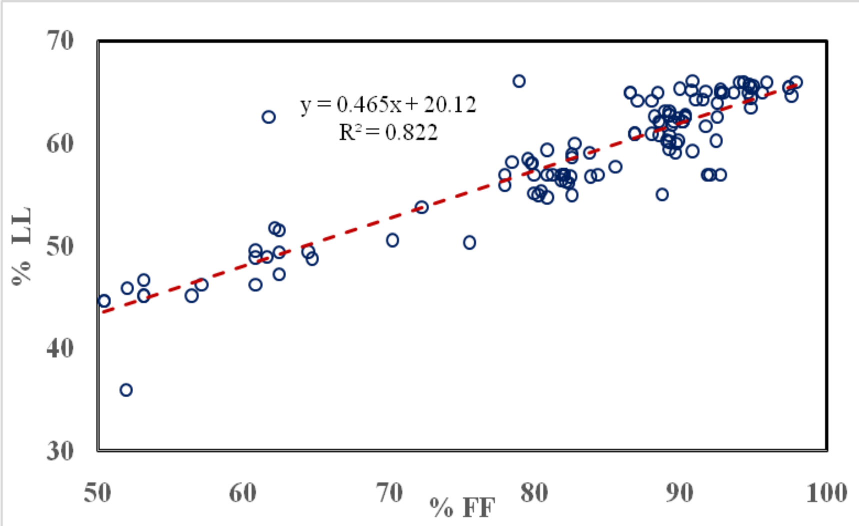

Fig. 1. Variation of LL with % fine fraction (% FF)

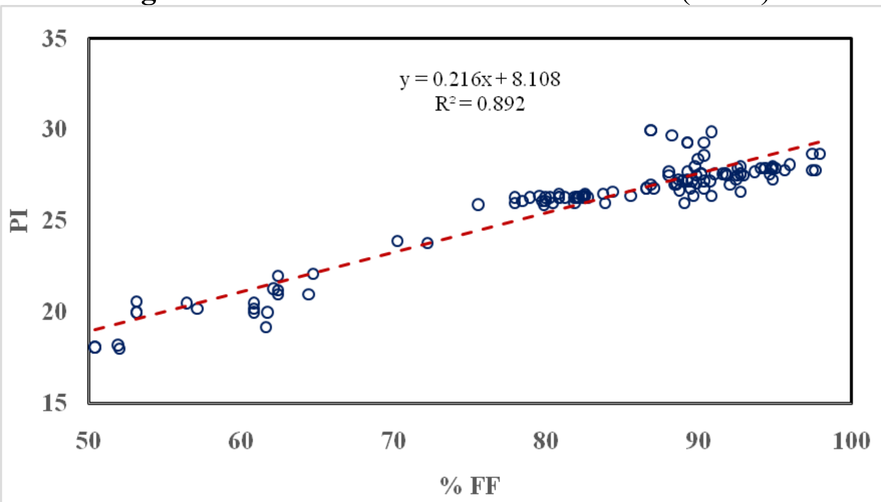

Fig. 2. Variation of PI with % fine fraction (% FF)

Fig.3 presents the variation of MDD with the % fines. From this figure, it is noticed that as the % fines increases the MDD is decreasing and for the soil samples of % fines from 80 to 100, the range of MDD is 15 to 12 kN/m^3. The correlation between % fines and MDD is presented below. It has regression coefficient, R^2 = 0.802.

$$MDD = -0.18(FF) + 29.77$$

MDD in kN/m^3 and FF in %.

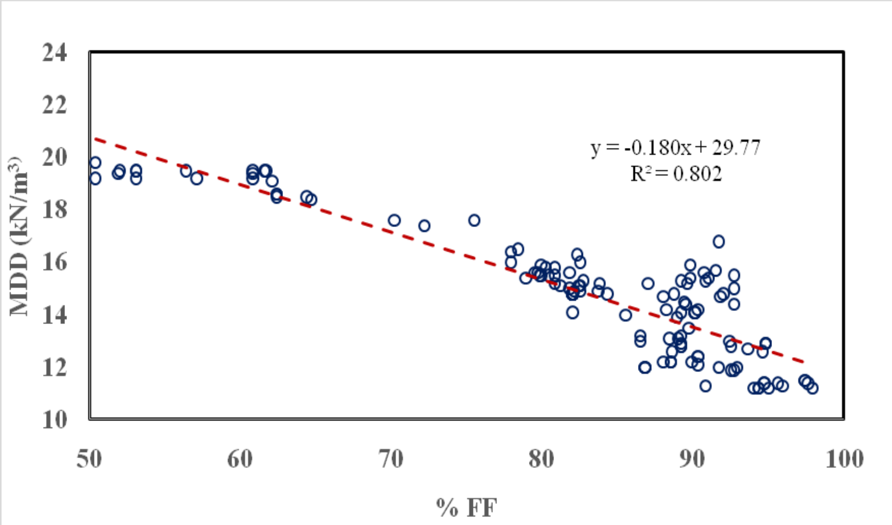

Fig. 3. Variation of MDD with % fine fraction (% FF)

Fig.4 presents the variation of OMC with the % fines. From this figure, it is noticed that as the % fines increases the OMC is increasing and for the soil samples of % fines from 80 to 100, the range of OMC is 20 to 26%. The correlation between % fines and OMC is presented below. It has regression coefficient, $R^2 = 0.846$.

$$OMC = 0.262(FF) - 1.620$$

OMC and FF are in %.

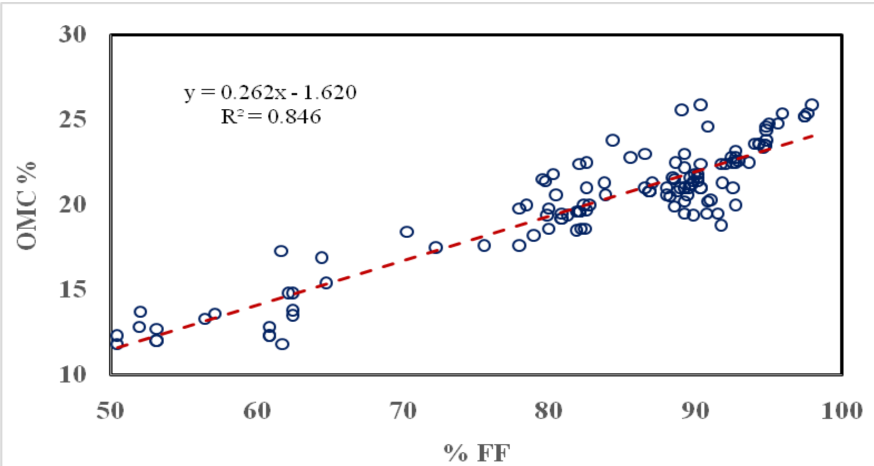

Fig. 4. Variation of OMC with % fine fraction (% FF)

Fig.5 presents the variation of CBR with the OMC. From this figure, it is noticed that as the OMC increases the CBR is decreasing and for the soil samples of OMC from 20 to 26, the range of CBR is 3 to 1%. The correlation between % CBR and OMC is presented in equation below. It has regression coefficient, $R^2 = 0.736$.

$$CBR = - 0.465(OMC) + 12.57$$

CBR and OMC are in %.

Fig.6 presents the variation of CBR with the MDD. From this figure, it is noticed that as the MDD increases the CBR is increasing and for the soil samples of MDD from 11 to 14 kN/m^3, the range of CBR is 1 to 3%. The correlation between % CBR and MDD is presented in . It has regression coefficient, $R^2 = 0.806$.

$$CBR = 0.688(MDD) - 6.985$$

CBR in % and MDD in kN/m^3.

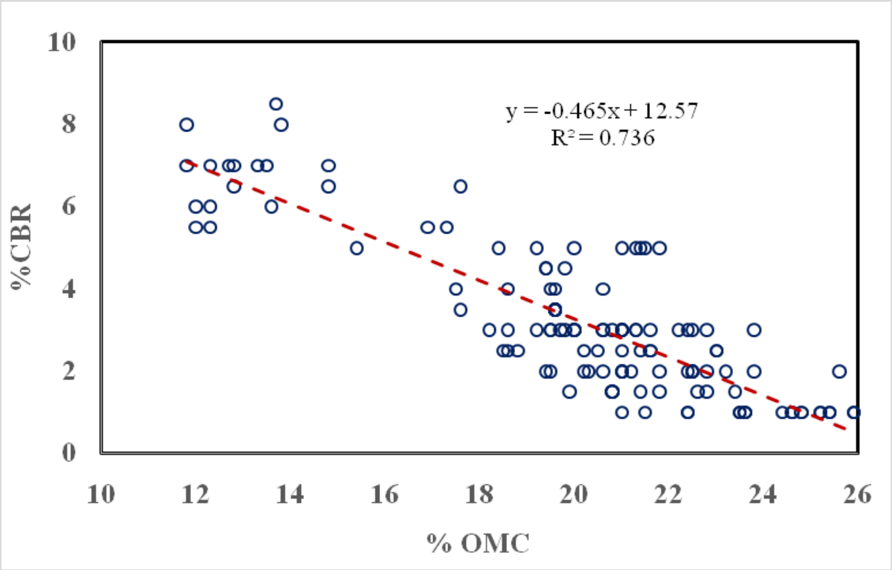

Fig. 5. Variation of CBR with OMC

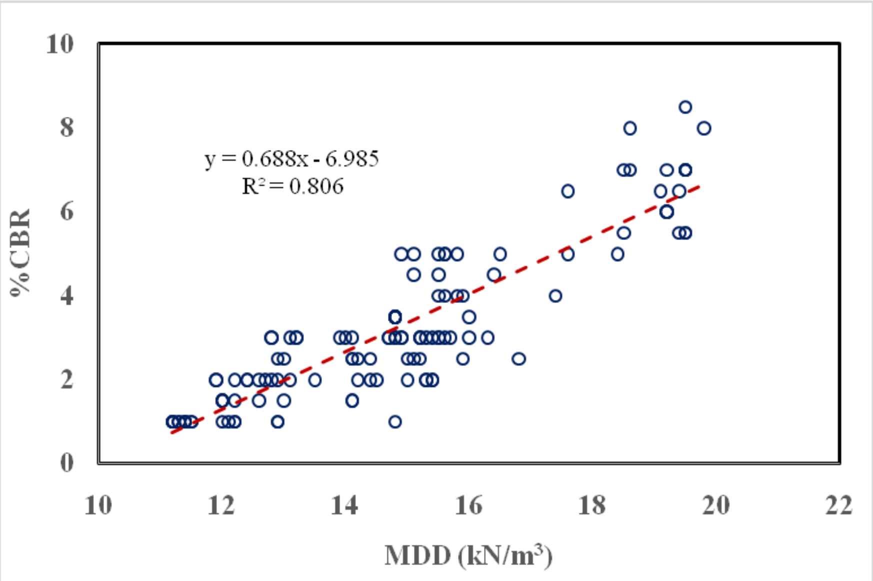

Fig. 6. Variation of CBR with MDD

4 Conclusions

Single linear regression analysis carried out between the index properties, compaction characteristics and CBR showed good correlations. The regression coefficient, R^2 values for most of the cases is found to be above 0.8. The % fines (FF) obtained from the grain size analysis can be well utilized to ascertain the LL, PI and also MDD and OMC of fine grained soils, whose % fines more than 50%. The statistical correlations as established above from the SLR analysis can be utilized to obtain CBR for fine grained soil sub grades.

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