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Prediction of Compaction Characteristics from Atterberg Limits and Specific Gravity for Kuttanad Soil

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Abstract: ***Compaction of soil is used in majority of Civil Engineering Projects. It is a soil improving method which helps to increase density of the soil by mechanical means. The knowledge of compaction characteristics i.e., maximum dry density, optimum moisture content is very important for soil modification. Regression models were developed to find the optimum moisture content and maximum dry density of fine grained soils using physical and index properties from 30 soil samples collected in Kuttanad region. The liquid limit of the soils analyzed ranged between 70 and 190 %, the plasticity index between 26 and 127 %, and specific gravity between 2.3 and 2.5. The most significant regression variables used were the specific gravity and the index properties. The developed models are accurate and can be used as a simple convenient tool to approximate the maximum dry density and optimum water content of fine-grained soils.***

Keywords: Compaction, Soil modification Regression models, Index properties, Specific gravity

1. Introduction

The construction of structures on fine grained soil is considered as one of the challenging task in geotechnical engineering. For structures to be safe and sound, they are to be built on good soils. Kuttanad region is a unique agricultural land in Kerala. Kuttanad soil is one of the problematic soils in the world. Soil in Kuttanad is fine grained soil. The increase in population and the development of the area has demanded more construction activities in Kuttanad region. But it has got one of the problematic soils in the world. Soil compaction is one of the most important soil improving techniques used in engineering projects such as highways, railway sub-grades, airfield pavements, earth dams, landfill, and foundations. Soil improvement can be carried out by compacting the soil to improve the soil properties. The important parameters obtained from the compaction curve are two important compaction characteristics, i.e., the maximum dry density (MDD) and the optimum moisture content (OMC) that represents the compaction behaviour. It requires relatively more time, effort and money for obtaining these engineering properties of soils. For preliminary assessment of the soil characteristics, predictive models can be useful, especially when index properties are already known. Several relationships to connect OMC and MDD found in the literature for the standard proctor compaction test based on some selected index properties such as liquid limit (LL), plastic limit (PL) and specific gravity (Gs).

Few correlations were developed to predict the compaction characteristics of fine-grained soils with the index properties and specific gravity. The present paper examines the compaction characteristics of Kuttanad soils in Alapuzha district. Data were collected to integrate with a literature database of several fine-grained soil and new best-fit models were developed to predict the compaction properties (OMC and MDD) for the standard proctor compaction test as a function of specific gravity and index properties. H. B. Nagarajet.al (2005) studied the plastic limit and compaction characteristics of fine grained soils. The plastic limit was shown to correlate well with the compaction characteristics, namely optimum moisture content and maximum dry unit weight. Lucio Di Matteo et al (2009) studied the best-fit models to estimate modified proctor properties of compacted soil. Regression models were developed to estimate the optimum moisture content and maximum dry density of fine-grained soils using physical and index properties from 30 soil samples collected in Central Italy. Aswathi Ramabhadran et al (2011) conducted study on Kuttanad clay. K. Hannah Jyothirmayi.et.al, (2015) studied the prediction of compaction characteristics of soil using plastic limit. It was found that the correlation between optimum moisture content and plastic limit was feasible in respect of fine grained soils.

2. Material Properties

Thirty soil samples were collected from Kuttanad region at a depth of 1m beneath the ground level. Figure: 1show the map of Kuttanad region. Basic tests of soil such as specific gravity, particle size distribution, and Atterberg limits were performed according to the IS codes. Geotechnical properties of soil were found by conducting the tests such as permeability test, triaxial compression test, and standard proctor test.

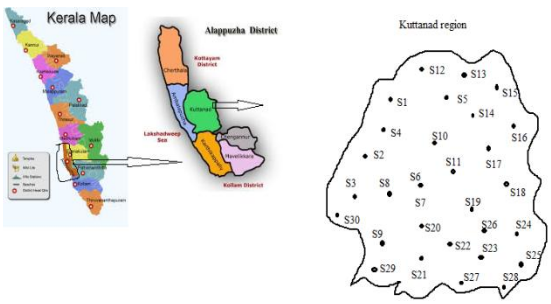

Figure 1: Map showing locations of sample collection

The sample details are shown in Table 1.

Table 1: Sample details

Location	Sample Designation
Kainakary	S1
Pulincunnu	S2
Neelamperoor	S3
Nedumudi	S4
Pallathuruthy	S5
Chempakulam	S6
Mithrakary	S7
Mankombu	S8
Kunnamkary	S9
Vezhapra	S10
Thayankary	S11
Chenamkary	S12
Ramankary	S13
Kumarankary	S14
Puthukkary	S15
Kavalam	S16
Kayalpuram	S17
Veliyanadu	S18
Veeyapuram	S19
Kidangara	S20
Thakazhy	S21
Muttar	S22
Changankary	S23
Thalavadi	S24
Oorukkary	S25
Pullangadi	S26
Vellamkulangara	S27
Valady	S28
Ayaparambu	S29
Kodupunna	S30

3. Analysis and Discussions

Numerous analyses were carried out to meet the objective of the study based on 30 numbers of soil data obtained from Kuttanad region in Alapuzha district. There are many methods that we can use to check the validity of the relationships between two or more variables. In predicting the dependent variable in the regression analysis more than one independent variable may be involved at a time. But in the scatter plot, only one independent variable is involved to predict one dependent variable.

The result of basic tests gives the liquid limit of the soils analyzed ranged between 70 and 190 %, plastic limit varies from 39 to 81%, the plasticity index between 26 and 127 %, and specific gravity between 2.3 and 2.5.

3.1 Linear Regression Analysis

In statistics, linear regression attempts to model the relationship between two variables by fitting a linear equation to observed data. One variable is considered to be an explanatory variable and other is considered to be a dependent variable.

3.1.1 Relation between maximum dry Density (MDD) and Specific gravity (G) observations

Linear regression is done between MDD and specific gravity and the result is represented by equation (1) and the graphical representation is given in figure: 2. Figure: 3 show the comparison graph and figure: 4 show the residual plot.

MDD = 0.339*G+0.488............... (1)

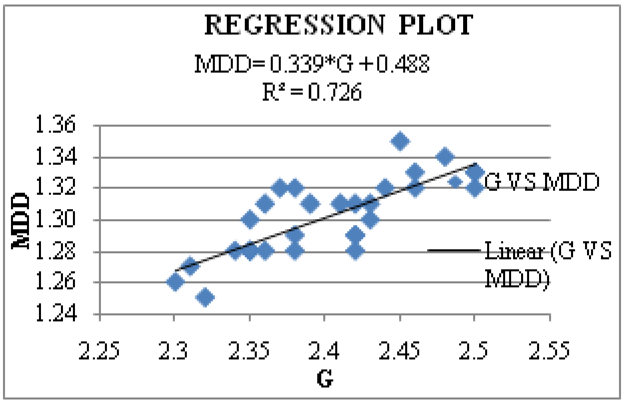

Figure 2: Effect of Specific gravity on Maximum dry density

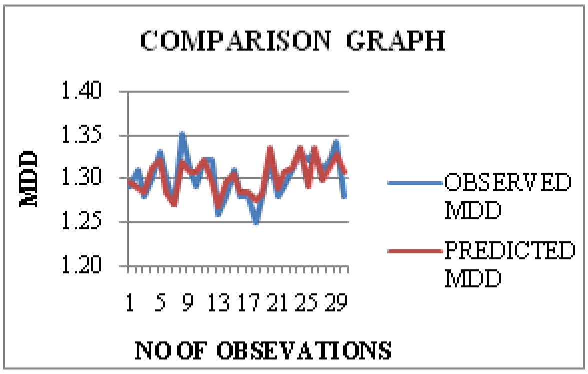

Figure 3: Comparison between observed MDD values from MDD obtained from equation 1

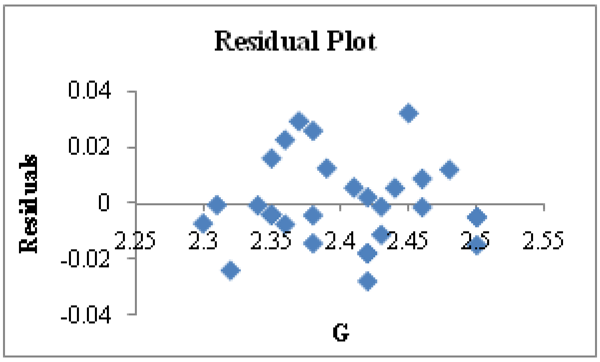

Figure 4: Residual plot

3.1.2 Relation between Optimum Moisture Content (OMC) and Plastic Limit (PL) observations

A relation between OMC and PL is formulated as shown in equation (2) and the graphical representation is given in figure: 5. Figure: 6 show the comparison graph and figure: 7 show the residual plot.

OMC = 0.186*PL+16.55............. (2)

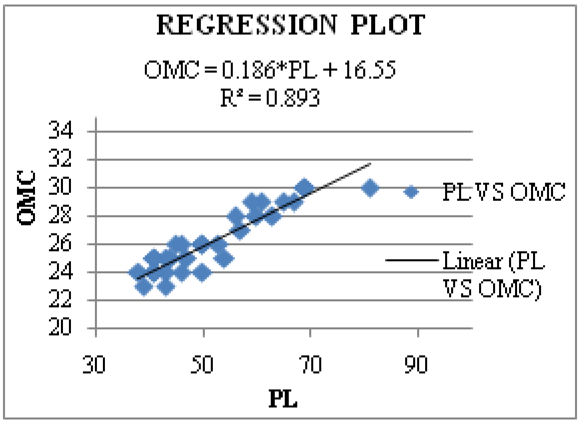

Figure 5: Effect of plastic limit on Optimum dry density

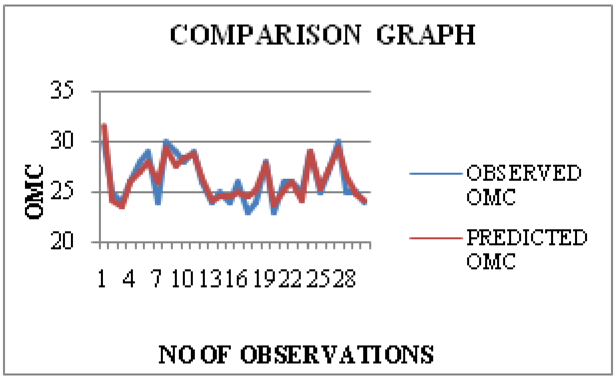

Figure 6: Comparison between observed OMC values from OMC obtained from equation 2

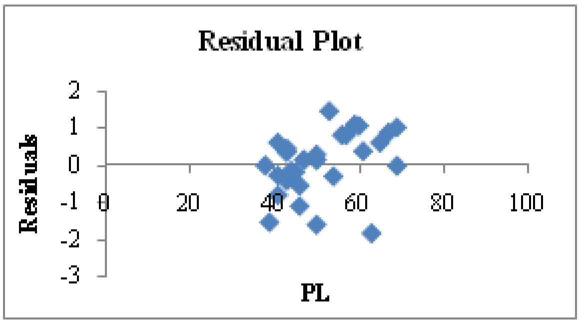

Figure 7: Residual plot

3.2 Multiple variable regression analysis

Linear regression models with more than one independent variable are referred to as multiple linear models. Here OMC model is predicted by two input parameters. These input parameters are Specific gravity (G) and Plastic limit (PL) and the correlation is shown by equations (3). Fig: 8 show the comparison graph. The analysis output is given in table 2 and 3.

OMC = 11.531+2.147*G+0.183*PL............ (3)

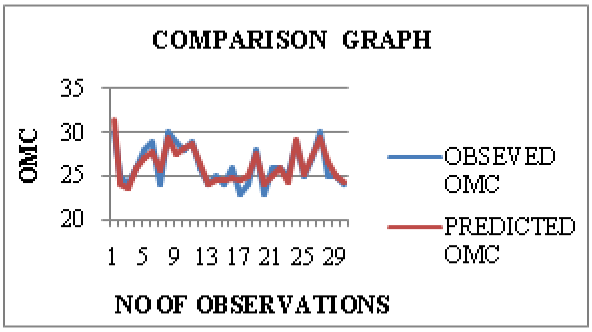

Figure: 8 Comparison between observed OMC values from OMC obtained from equation 3

Table 2: Model summary

Regression Statistics	
Multiple R	0.950052045
R Square	0.902598891
Standard Error	0.015134684
Observations	30

Table 3: ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	121	60.5	73.038	1.28E-11
Residual	27	22.365	0.8283		
Total	29	143.36			

The first part of the analysis model summary and is shown in table (2). It shows three things. First shows the value of Pearlson's coefficient (R) between the variables is 0.950 which shows there exist a strong positive relation between the soil parameters. Second, the value of coefficient determination (R^2), which is a measure of how much of the variability in the outcome is accounted for by the predictor, is 0.903. Third, value and standard error of estimate (estimate of standard deviation) is 0.015. The second part is ANOVA (Analysis of Variance), which is used to test for the significance of regression and displayed in table (3). This approach uses the variance of the observed data. The observed variance is partitioned into components that are then used in the test for significance of regression. After analysing the output it is clears that, model (3) has greater R^2 value compared to other models.

3.3 Regression validation

In statistics, regression validation is the process of deciding whether the numerical results quantifying hypothesized relationships between variables, obtained from regression analysis, are acceptable as descriptions of the data. For regression model, it may be important to confirm the goodness of fit of the model and the statistical significance of the estimated parameters. A well fitting regression model results in predicted values close to the observed values shown in figures 3, 6, 8. Commonly used checks of goodness of fit include R^2 value, F- test, t-test and residual plot.

For simple linear regression models:
p- value < 0.05

For multiple variable regression models:
Significance F < 0.05

4. Conclusions and Recommendations

Based on the analysis of data obtained from laboratory soil testing, correlation between compaction characteristics with index properties and specific gravity for Kuttanad soil is developed. The following are the conclusions from the study:

1) The present study was undertaken to develop regression based models to estimate the compaction characteristics.
2) The best predictive model is represented by equation (3), which includes two input parameters: specific gravity and Plastic limit.
3) Analysis of the experimental results demonstrates that a direct linear relationship exists between compaction characteristics and the soil properties such as Atterberg limits and specific gravity.
4) A good agreement was observed between the actual and the predicted values of compaction characteristics.
5) Residual plots are plotted for the data, it appears randomly suggest that model fits the data well.

It is recommended that more number of samples may be collected from the other parts of Kuttanad region and this work can farther be extended to correlate the Atterberg limits & specific gravity with different compaction energies such as Modified Proctor test.

5. Acknowledgements

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