DEVELOPING REGRESSION BASED MODEL TO PREDICT DEGREE OF COMPACTION VALUE OF FINE AGGREGATES SOIL PARAMETERS

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ABSTRACT

Degree of compaction (R %) value is an indicator in strength of earthwork construction. In the design of irrigation earthwork construction, degree of compaction value of compaction characteristics is often used, but laboratory test is time consuming and laborious. Fine aggregate classification and compaction characteristics are routinely determined for in-situ and borrow area (reservation area) soils used in the irrigation earthwork constructions. Developing regression based model to predict degree of compaction value of fine aggregates based on grain size analysis - percentage of Fine (F), Sand (S) and Gravel (G), Plasticity Characteristics Liquid Limit (LL) and Plastics Limit (PL), and Compaction Characteristics Maximum Dry Density (MDD) and Optimum Moisture Content (OMC). In the present study, degree of compaction value of fine aggregates is correlated with index and compaction characteristics. The regression analysis was performed with the result of laboratory test done from a large number of soil sample collected from different irrigation earthwork construction projects in theAmparadistrict (Eastern Province in Sri Lanka). The basic soil properties namely Soil classifications, Liquid Limit (LL), Plastics Limit (PL), Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) are correlated, with the degree of compaction value. Proposed regression model validated from a few independent test data, reported in soil test reports of irrigation department in Ampara region and Eastern Provincial irrigation department in Ampara range, are found to be reasonably accurate.

***Key words*:** Degree of compaction value, Fine Aggregate, Compaction Characteristics, Plasticity Characteristics, Regression, Model.

1. INTRODUCTION

Design of irrigation earthwork construction is a relatively stable crust constructed over natural soil for supporting and distributing hydraulic gradient, wheel loads and providing durable wearing surface. It is constructed layer by layer. The design and the behaviour of earthwork depend on the strength of soil layer, and it is necessary to assess its strength. Compaction of soil is carried out to improve the soil properties. The degree of compaction is often used to indicate percentage of soil density in the constructed earth work. The proctor test (ASTM D 698, Method A) should be considered merely as a guide to compaction on site. The optimum moisture content should not be specified, since climatic condition must be taken into account as well as the difficulties of accurately controlling moisture content on site.

Conventionally, degree of compaction can be determined both in the laboratory as well as in the field. In the laboratory, the test is performed on natural, undisturbed soil sample acquired from the site or remoulded soil prepared at natural or any other moisture content. Degree of Compaction 95 percent is commonly required, but this will depend on the contract and plant used. Usually, the basic properties such as gradation, plasticity and compaction parameters (optimum moisture content, OMC) and the (maximum dry density, MDD) are determined in laboratory. For an irrigation earthwork construction project, a large number of soil samples test is difficult as well as time consuming. This would be delay in the progress of the project, since in most situations the materials for earthwork construction come from highly variable sources. Any delay in construction inevitably leads to rise of project cost. In this research investigation, an attempt has been made for correlating degree of compaction value of fine aggregates with index properties such as grain size analysis (percentage of Fines, Sand and Gravel), Plasticity Characteristics (LL and PL) and Compaction Characteristics; namely OMC and MDD.

The model is established in the form of an equation of degree of compaction value as a function of different soil properties by regression analysis.

2. METHODOLOGY

2.1 Data used for Regression Analysis

The target area was located in Ampara district irrigation tank area (borrow area) in the part of the eastern province in Sri Lanka. Soil properties for developing correlations are percentage of liquid limit, plastic limit, fines, sand, gravel, optimum moisture content and also maximum dry density and the degree of compaction. The soil data is analyzed for the soil classification types (ASTM D 2487) and the range of values of soil properties are given in Table 1.

2.2 Simple Linear Regression Analysis (SLRA)

To develop the model, simple linear regression analysis and multiple linear regression analysis were carried out. Degree of compaction (R%) value is considered as response and Fine (F), Sand (S), Gravel (G), Liquid Limit (LL), Plastic Limit (PL), Optimum Moisture Content (OMC-Laboratory and Field) and Maximum Dry Density (MDD- Laboratory and Field) are considered as the explanatory variables. Simple linear regression analysis has been carried out to develop the correlation between individual soil property and degree of compaction value. SLRA can be carried out using standard statistical software like MINITAB. Estimated parameters of degree of compaction predicted by various SLRA models are presented in Table 2.

2.3 Multiple Linear Regression Analysis (MLRA)

Multiple linear regression analysis has been carried out by considering degree of compaction value as the response variable and the rest of soil properties as explanatory variables. The independent soil properties taken are percentage of finer than 75 μm sieve, F-fine, S-sand, OMC-optimum moisture content and the field dry density FDD. The standard statistical software MINITAB is used in the present case of study.
Independent variable G-gravel is highly correlated with other independent variables. Therefore, G has been removed from the equation and also the PL-plastic limit is not significant ($p < 0.05$). The final equation obtained by performing the analysis is given as:

$$\text{Degree of Compaction (R \%)} = 116 + 0.0775\,(F) - 56.2\,(1/S) + 84.7\,(1/LL) - 60.6\,(1/OMC) - 31.0\,(1/FDD) \quad (1)$$

Where, field maximum dry density is g/cm³ and other properties are in percentage.

The statistical performance indicators are namely regression determination of coefficient (R^2) and standard error. Equation (1) is found to be 0.507 and 0.9217. Hence, the developed correlation and above prediction of degree of compaction of fine aggregates soil can be regarded as given above equation. The statistical parameters indicate that the performance can be obtained from multiple linear regression analysis rather than simple linear regression analysis by showing the highest R^2 value of 0.507 and R value 0.7120. Hence the above model may be proposed for estimating degree of compaction value. In order to confirm the significance of regression, analysis of variance (ANOVA) was employed. This test follows an F-distribution with degree of freedom = 5 and 83 for the degree of compaction, so that the critical region will consist of value exceeding 2.33. In this test, a 95% level of confidence was chosen. If the calculated F value is greater than the tabulated F value, the null hypothesis is rejected and there exist relationship between response and independent variables. Since the calculated F value = 17.05 is greater than the tabulated F value = 2.33, the null hypothesis is rejected. Therefore, it is concluded that the model is appropriate.

3. RESULTS

The statistical parameters indicate that the model developed by Simple Linear Regression Analysis for correlating degree of compaction value. And also that can be obtained from the model developed using Multiple Linear Regression Analysis by showing the R value of 0.7120 and R^2 value of 0.507 and the error of 0.9217. It was observed that the use of index properties such as Grain Size Analysis (percentage of Fine, percentage of Sand and percentage of Gravel), Plasticity Characteristics (Liquid Limits and Plastic Limits) and Compaction Characteristics (Laboratory and

Field Moisture Content and Maximum Dry Density) appears the estimation of Degree of Compaction value of Fine Aggregates.

Table 1. Range of values of Soil Classification and Compaction Characteristics used in Developing Correlation

Soil	No. of	Range of Values of Soil Parameters										
Type	Samples	Fine %	Sand %	Gravel %	LL %	PL %	PI %	OMC %	MDD (g/cm³)	FMC %	FDD (g/cm³)	Degree of Compaction %
CL	8	75-79	16-20	3 - 8	38-48	18-21	19-27	12.60-13.50	1.721-1.812	12.6-14.0	1.687-1.788	98.0-99.1
SC	73	25-38	51-64	5 - 19	26-49	13-23	9 - 29	6.30-17.00	1.722-1.886	7.10-15.20	1.640-1.899	95.0-99.8
GC	8	19-30	27-36	39-48	30-36	16-19	14-18	12.00-12.60	1.727-1.930	10.1-13.0	1.640-1.900	95.0-99.5

CL-Sandy Clays, Medium Plasticity SC-Clayey Sand GC-Clayey Gravel

Table 2. Models Developed from Simple Linear Regression Analysis (SLRA)

Type of	Model		Statistical Parameters		
RA	No.	Model	R^2	Adjusted R^2	Standard Error
SLRA	1	R% = 97.2 + 0.0170 F	0.035	0.023	1.259
SLRA	2	R% = 97.9 - 0.00222 S	0.001	0	1.281
SLRA	3	R% = 98.1 - 0.0228 G	0.040	0.029	1.256
SLRA	4	R% = 97.5 + 0.0091 LL	0.002	0	1.281
SLRA	5	R% = 98.4 - 0.0327 PL	0.003	0	1.280
SLRA	6	R% = 94.0 + 0.294 OMC	0.206	0.196	1.142
SLRA	7	R% = 108 - 5.43 MDD	0.087	0.076	1.225
SLRA	8	R% = 92.3 + 0.431 FMC	0.261	0.253	1.102
SLRA	9	R% = 95.8 + 1.14 FDD	0.003	0	1.280

Table 3. Analysis of Variance (ANOVA) for Testing Significance of Regression

Source of Variation	Degree of Freedom (df)	Sum of Squares (SS)	Mean Square (MS)	$F = MS_R / MS_E$
Regression	5	72.423	$MS_R = (72.423/5) = 14.485$	
Error or Rasidual	83	70.518	$MS_E = (70.518/83) = 0.850$	(14.485/0.850)= 17.05
Total	88	142.940		

4. CONCLUSION

The conventional method of determining the degree of compaction of the Fine Aggregates, soil is tested by laboratory. The test requires careful preparation of soil samples for the 4.75 mm sieve. And also test for Plasticity Characteristics for the above soil samples sieve 425 μm. The equation developed in the present work relates prediction of degree of compaction value, the soil classification and compaction characteristics. It has regression coefficient R^2 and could judiciously be used for estimating degree of compaction of fine aggregates. It is simple and gives estimate of degree of compaction without actually performing the test.

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