Prediction of Compaction Characteristics of Soil Using Plastic Limit

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Abstract

Soil properties are unique based on their locality and seasonal variations. Geotechnical researchers always try to correlate one soil property with others based on the specific areas and soil types. Compaction characteristics are important soil properties necessary for building foundations, construction of highway embankments, earth dams, and many other engineering structures. In this study, it has been attempted to correlate compaction characteristics, namely dry density and optimum moisture content, with the Atterberg limit for the soils collected from different locations of the Rajshahi division. Laboratory experiments were performed on ten different soil samples collected from different locations. Optimum moisture content (OMC) and maximum dry density (MDD) were determined from standard proctor test and plastic limit (PL), liquid limit (LL) and plasticity index by Atterberg limit test. Regression models were developed to find the optimum moisture content of the soils using the Atterberg limit. It is found that OMC can be predicted from Plastic limit by the non-linear relationship between OMC and PL having a greater R^2 value. Other correlations can not be predicted having lower R^2 value.

Keywords: *Compaction characteristics, plastic limit, regression model.*

1. Introduction

Compaction of soil is a process of applying mechanical energy for its densification by removing air voids and re-arranging the particles. Few correlations were developed to predict the compaction characteristics of fine-grained soils with the index properties and specific gravity. Sridharan and Nagaraj (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. 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. Thakur et al. (2014) studied the functional correlation between compaction characteristics, undrained shear strength and Atterberg limits. 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. Toms and Philip (2016) conducted a thesis to predict compaction characteristics from Atterberg limits and Specific gravity for Kuttanad Soil. In this study, it was attempted to correlate compaction characteristics of soil with the Atterberg limit.

2. Methodology

Ten soil samples were collected from different districts of Rajshahi Division at a depth of 5 ft below the ground level. Different tests like grain-size analysis, compaction test, specific gravity, Atterberg limit test were performed according to ASTM and AASHTO standard.

2.1 Grain-size Analysis

Grain size analysis was done in the laboratory by sieve analysis and hydrometer analysis. Grain size analysis was done to determine the relative proportions of the different grain sizes that make up a given soil mass. Grain size distribution curves for different samples collected from Bogra, Pabna, Rajshahi-1, Rajshahi-2, and Chapainabgonj-2 symbolized as B, P, R-1, R-2 and C-2 samples respectively are shown in figure 1. Figure 2 represents curves for samples collected from Chapainababgonj-1, Joypurhat, Sirajgonj, Naogaon, Natore symbolizing their names as C-1, J, S, N and NA samples respectively. Rajshahi-1, Rajshahi-2 and Chapainababgonj-1 and Chapainababgonj-2 are the samples designations for collecting samples from different locations of same district.

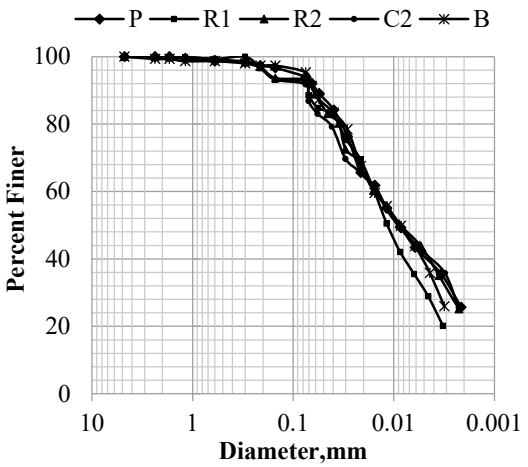

Figure 1. Particle size distribution curve for samples P, R1, R2, C2, B

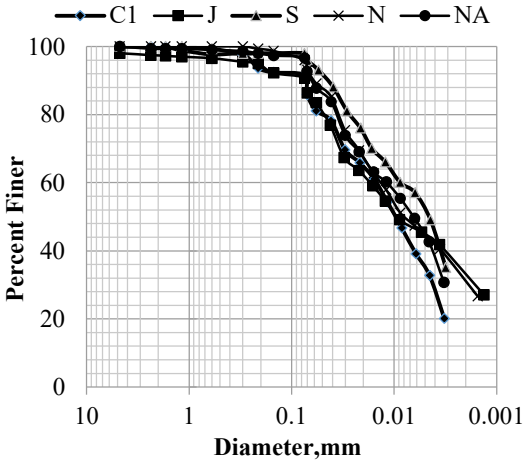

Figure 2. Particle size distribution curve for samples C1, J, S, N, NA

Table 1. Soil type determined from the particle size distribution curve

Location	Sample Designation	**Sand (%)**	**Silt (%)**	**Clay (%)**	**Soil Type**
Naogaon	N	12	43	45	Silty Clay
Bogra	B	14	46	40	Silty Clay
Joypurhat	J	20	35	45	Clay
Chapainababgonj-2	C2	18	40	42	Silty Clay
Sirajgonj	S	8	40	52	Silty Clay
Rajshahi-2	R2	16	42	42	Silty Clay
Rajshahi-1	R1	16	54	31	Silty Clay loam
Pabna	P	12	48	40	Silty Clay
Chapainababgonj-1	C1	20	46	34	Silty Clay Loam
Natore	NA	14	42	44	Silty Clay

USDA soil classification system was adopted and from the USDA textural classification chart the type of soil was determined. Among 10 samples that 7 samples were silty clay, 2 samples were silty clay loam and 1 sample was clay.

2.2 Specific Gravity

Specific gravity for different samples was determined in the laboratory by following ASTM D 854 and AASHTO T 100 procedures. Results of specific gravity are shown in Table 2.

Table 2. Specific gravity for different samples

Location	Sample Designation	Specific gravity ,G
Naogaon	N	2.72
Bogra	B	2.71
Chapainababgonj-1	J	2.68
Chapainababgonj-2	C2	2.73
Sirajgonj	S	2.77
Rajshahi-1	R2	2.69
Rajshahi-2	R1	2.76
Pabna	P	2.70
Joypurhat	C1	2.74
Natore	NA	2.77

This value satisfies the type of soil that we determined because the standard range is 2.67-2.90 for clay and silty clay. So our obtained result is consistent with standard results for the respective soil type.

3. Test Results

3.1 Optimum Moisture Content

Following ASTM D 698 and AASHTO T-99 codes standard proctor tests were performed to determine optimum moisture content (OMC) and maximum dry density for different samples.

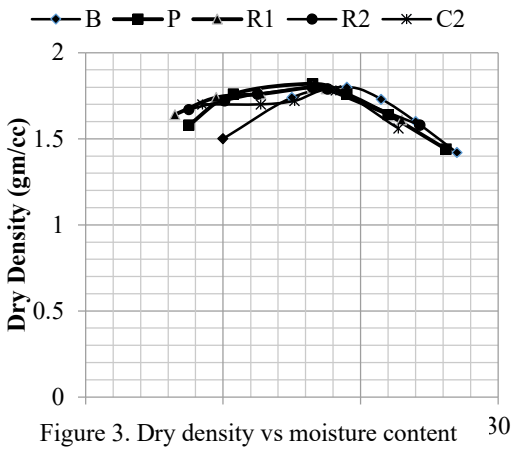

Figure 3. Dry density vs moisture content graph for samples B, P, R1, R2, C2

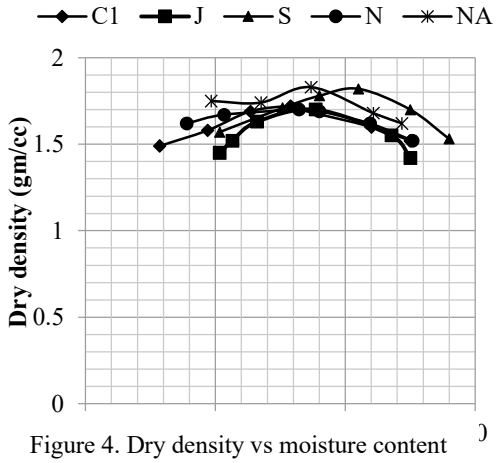

Figure 4. Dry density vs moisture content graph for samples C1, J, S, N, NA

With the experimental data graph is plotted for sample B, P, R1, R2, C) in figure 3 and for samples C1, J, S, N, NA in Figure 4.

Table 3. OMC and MDD for ten samples

Location	Sample Designation	Optimum moisture content (w%)	Maximum Dry Density(gm/cc)
Naogaon	N	18.00	1.69
Bogra	B	19.00	1.81
Joypurhat	J	17.72	1.61
Chapainababgonj-2	C2	18.00	1.75
Sirajgonj	S	25.00	1.80
Rajshahi-2	R2	17.00	1.81
Rajshahi-1	R1	17.00	1.69
Pabna	P	18.00	1.81
Chapainababgonj-1	C1	16.00	1.65
Natore	NA	17.36	1.81

The obtained value of optimum moisture content (%) and maximum dry density (gm/cc) is consistent with the respective type of soil that we determined by grain size analysis.

3.2 Atterberg Limit

The test results are obtained by ASTM D-4318 and AASHTO T89 and T90 procedures in the laboratory. Liquid limit (LL), Plastic limit (PL) and Plasticity index (PI) are shown in Table 3. Our obtained result is approximately consistent with the standard value of Liquid Limit (%) and Plastic Limit (%) for the respective soil type that we determined by grain size analysis.

Table 4. Liquid limit, plastic limit and plasticity index of different samples

Location	**Sample Designation**	**Liquid limit, LL(%)**	**Plastic limit, PL(%)**	**Plasticity index PI= LL-PL**
Naogaon	N	32	20.05	11.95
Bogra	B	26.5	18.6	7.9
Joypurhat	J	33	18.12	11.88
Chapainababgonj-2	C2	34.5	23.23	11.27
Sirajgonj	S	41	26.72	15.14
Rajshahi-2	R2	35.4	22.59	12.81
Rajshahi-1	R1	26.5	20.1	6.4
Pabna	P	29.3	22.55	6.75
Chapainababgonj-1	C1	26	19.23	6.77
Natore	NA	34	23.9	10.1

4. Analysis and Discussions

Different tests were carried out in the laboratory on the 10 samples collected from various locations of Rajshahi Division. To find the correlation for the compaction parameters OMC, we use only the results of the standard proctor test and Atterberg limit.

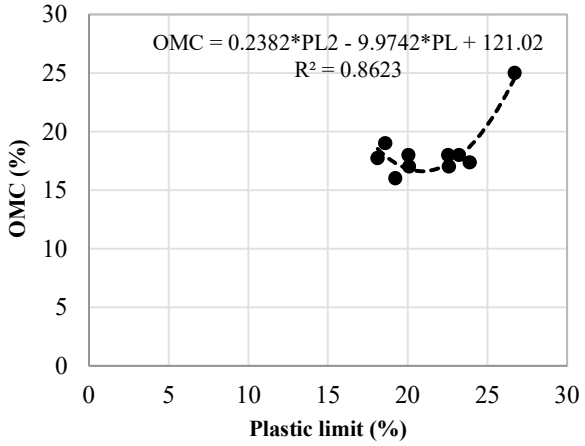

Figure 5. Effect of plastic limit on optimum moisture content (Non-linear relationship)

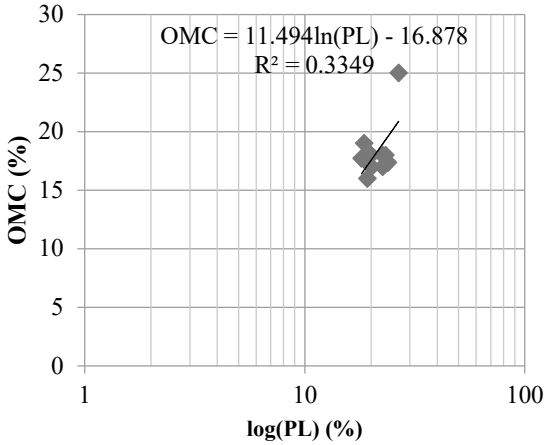

Figure 6. Effect of plastic limit on optimum moisture content (Linear relationship)

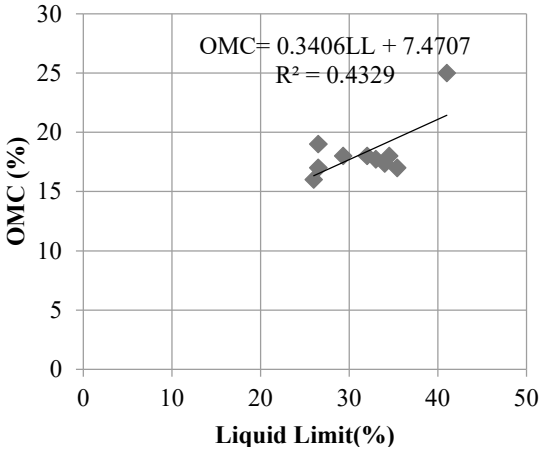

Figure 7. Effect of liquid limit on optimum moisture content

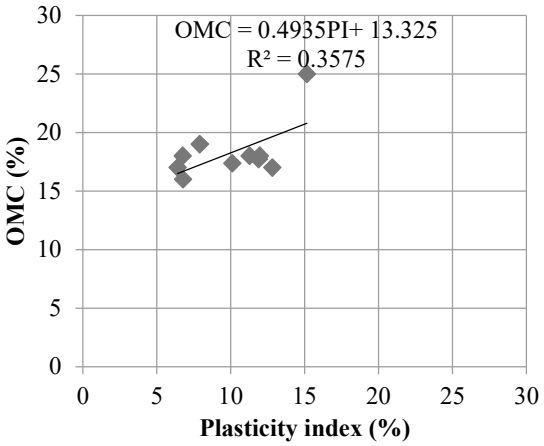

Figure 8. Effect of plasticity index on optimum moisture content

Regression analysis were done to form a relationship between two variables by fitting a polynomial equation to observed data. One variable is an explanatory variable and other is considered to be a dependent variable.

Relation between OMC vs PL, OMC vs LL and OMC vs PI are given below.

$$OMC = 0.2382 * PL2 - 9.9742 * PL + 121.02;\ R^2 = 0.8623 \quad (1)$$

$$OMC = 11.494ln(PL) - 16.878;\ R^2 = 0.3349 \quad (2)$$

$$OMC = 0.3406LL + 7.4707;\ R^2 = 0.4329 \quad (3)$$

$$OMC = 0.4935PI + 13.325;\ R^2 = 0.3575 \quad (4)$$

The value of R^2 of these three plots was very low so they did not show good relationship.

5. Conclusions

Laboratory investigations were conducted to correlate compaction characteristics with Atterberg limit of soil samples collected from different location of Rajshahi. It can be concluded from this study that laboratory test results were consistent within the standard range. There is no good relation of optimum moisture content with log (PL) , LL and PI. So extended research work is necessary with a large number of samples in this case. Optimum moisture content showed a good correlation with plastic limit. This relationship arises one question about linearity or non-linearity as various researchers have variability in their opinion about the type of relation.

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