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CORRELATION BETWEEN OPTIMUM MOISTURE CONTENT (OMC) AND PLASTIC LIMIT (PL) OF FINE GRAINED SOIL

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Abstract: Plastic limit (PL) and optimum moisture content (OMC) laboratory tests are essential for any earthwork construction since they play a significant role in any newly started construction site. But it takes an excessive amount of time to determine OMC. Many of the index properties were found to be related to compaction parameters, optimum moisture content, and maximum dry density. The plasticity indices and the proportion of particles had the most significant connections, with the plastic limit having the highest degree of simple correlation. As a result, using the plastic limit of soil, it is necessary to determine these compaction properties. If compaction properties are correlated to plastic limit, it may be easier to determine OMC. Finally, a simple equation has been generated to obtain the optimum moisture content (OMC) and the plastic limit (PL) of all the fine-grained soil. A **useful equation and many graphical approaches have been used for quickly predicting compaction characteristics from index properties. The accuracy of these equations and graphical approaches has been assessed in this paper and determined to be adequate with most prediction results. This proposed correlation is going to be an easier method for engineers in quickly assessing their suitability for compaction related purposes.**

Keywords: Compaction, optimum moisture content (OMC), plastic limit (PL), earthwork, fine-grained soil.

1. INTRODUCTION

In the geotechnical engineering field, civil engineers have to handle large volumes of soil where the soil is used as a construction material in a construction work [1]. Many large constructions like dams, embankments, airports, canals etc. build on a large amount of soil. Therefore, a compaction test is much needed here to find out the soil's behavior. However, the proctor compaction test is a time-consuming and effortful procedure. It will be easy to compute the compaction value by correlating with the plastic limit properties if the soil's plastic limit is known. The importance of proctor compaction tests in the practical field means achieving the desired strength, compressibility and permeability characteristics [2]-[3]-[4]. As a result, compaction characteristics must be determined at various compaction energies. From a practical standpoint, understanding compaction behavior and features of fine-grained soils at various compaction energy levels is critical [5]. To investigate and solve the problem by the amount of compaction required by the soil and the optimum moisture content (OMC), the compaction tests are conducted on the soil from the laboratory. OMC is determined by the maximum dry density (MDD) analysis curve. On the other hand, the plastic limit (PL) of the soil can be determined by the hand-rolling method [6]. The plastic limit is defined as the gravimetric moisture content where the thread breaks apart at a diameter of 3.2 mm. It is expressed as the percentage of the oven-dried soil at the boundary between the plastic and semisolid states of soil. Other property indexes like liquidity index and shrinkage index are not suitable for correlation with OMC but the plastic limit can be easily correlated with this test [7]. In the earliest research, McRae (1958) experimented on the effect of compaction effort on the maximum dry unit weight. This research experimented on 18 soil samples and took results by standard proctor test. Then Johnson and Sallberg (1962) developed a chart to determine the approximate optimum moisture content (OMC) of soil with the standard Proctor compaction test. They tested 18 soil samples and obtained findings using the conventional proctor test. Nagaraj (2000) experimented by correlating plastic limit, W_p (plastic limit) to OMC and γ_{dmax} (dry density) for standard proctor compaction effort. He also used the standard proctor test to experiment with 10 test results. Later, a few researchers have made attempts to propose a correlation of compaction

characteristics with plastic limits (Gurtug and Sridharan, 2002; Sridharan and Nagaraj, 2005; Nagaraj, 2015) [8]. After all the tests are done in the laboratory the results showed that the correlation is suitable and it was done correctly. The method is based on the linear relationship between γ_{dmax} and the common logarithm of compaction energy. These linear relationships correlate well with the plastic limit [9]. In this work, a relationship is defined and an equation is developed between these two qualities, OMC and PL, which is highly valuable for a wide range of construction projects.

2. METHODOLOGY

Samples are collected from nine different districts in Bangladesh. Most of the soil was found in medium and low plasticity soil and some of the soil is found in low plasticity silt. Dhaka soil was collected from the old airport of the Dhaka cantonment. Low plasticity clay (CL) soil was collected from this location. Savar is in the Dhaka district. Savar soil was collected from the main town of Savar, which lies near the new market area of Savar. Low plasticity clay (CL) soil was collected from this location. Sylhet soil was collected from the city of Sylhet. This location produced low plasticity silt (ML) soil. Rangpur soil was gathered from the city of Rangpur. This area produced low plasticity silt (ML). Rangpur Division's Kurigram district is located. Kurigram soil was taken from Jorgas, a village in Chilmari upazila. Low plasticity silt was found in the soil (ML). The district of Gaibandha is part of the Rangpur division. Gaibandha soil was collected in the Gaibandha district's Saghatta Upazila. Low plasticity silt (ML) was found in this location. Bogura is a district in the Rajshahi Division. The soil was collected in Bogura district's Sonatola Upazila. This location produced low plasticity silt (ML) soil. Bhola is a district of the Barisal Division. Soil from Bhola city was collected, and it was found low plasticity silt (ML) soil. Cox's Bazar is located in the Chattogram division. Soil from Cox's Bazar was collected and identified as low plasticity silt (ML) soil. To begin, all of the soil was placed in the oven to dry. After that, #4 ASTM standard sieve was used for the OMC test and #40 ASTM standard sieve was used for the plastic limit test. All the soil was characterized for physical properties namely, grain size analysis test, atterberg limit test, maximum dry density and optimum moisture content. Grain size analysis is performed to determine the soil sample which is fine-grained or coarse-grained which are examined by sieve analysis. In this laboratory experiment there are some ASTM standard sieve which are #4 , #16 , #30 , #40 , #50 , #100 , #200 and a pan. This test is required ASTM standard. For optimum moisture content, standard proctor compaction machinery was employed, optimum moisture content (OMC) and maximum dry density (MDD) of soil can be determined by standard proctor compaction test. The compactive effort is the amount of mechanical energy that is applied to the soil mass. Soil samples must be taken extra weight than the test apparatus. ASTM D 698 - Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbs/ft^3 (600 kN-m/m^3), and the most often used method for plastic limit testing was the hand-rolling method, in which wet clay was rolled into threads about 3.2mm in diameter. The results of the compaction are then analyzed using graphical analysis. The maximum dry density (MDD) curve peak point in the graph was used to calculate the optimum moisture content. These are all methods that have been used for determining the values of OMC and PL. Aside from these tests, the laboratory also performs liquid limit testing and grain size analysis tests. The ASTM standard Casagrande apparatus was used to test the liquid limit, and all ASTM standard sieves were used to test sieve analysis. All the tests are followed by American Society for Testing and Materials (ASTM) standards.

Fig.1: Sample Collection Area

3. RESULTS AND DISCUSSION

Fig. 2, shows the results of grain size analysis for nine different soils of Bangladesh. The curve from all of the soil samples is shown below.

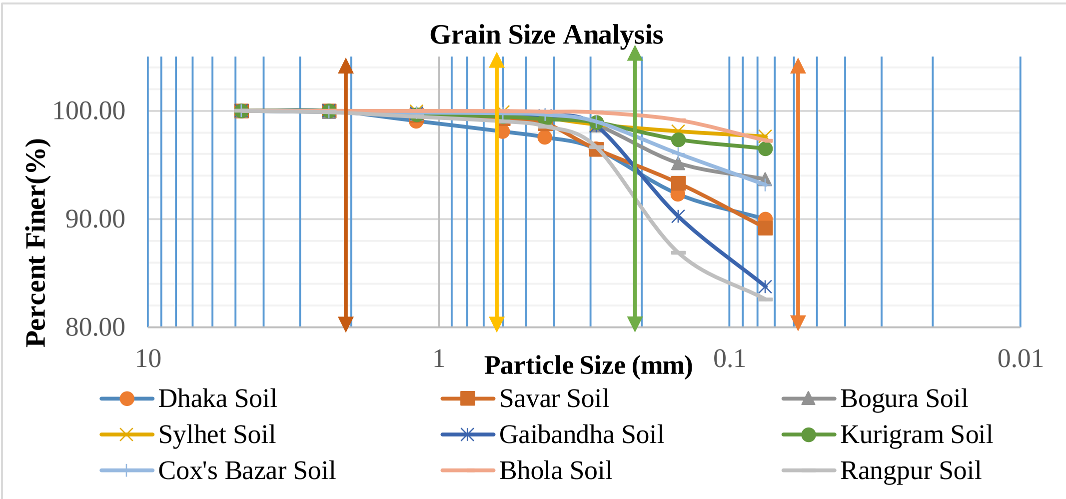

Fig. 2: Grain size analysis for all soil samples.

The grain size analysis component of all soil is shown in this figure. It denotes the finer proportion of soil and also identifies the percentages of clay, silt, and sand in the soil. According to the plasticity index, maximum soil samples have been classified as low plasticity silt (ML) and the rest of the soil is low plasticity clay. Low plasticity clay (CL) soil is found in Dhaka and Savar.

Fig. 3, shows the results of liquid limit analysis for nine different soils of Bangladesh.

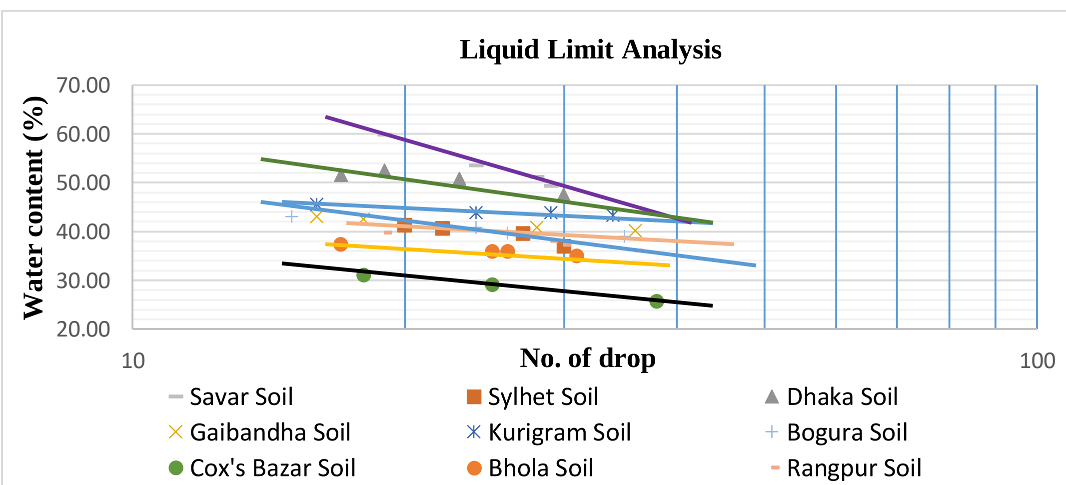

Fig. 3: Liquid limit analysis for all soil samples.

The highest liquid limit result for 25 drops obtained in Dhaka and Savar soil is shown in the liquid limit analysis graph. Their respective liquid limit values are 49 percent and 53 percent.

Fig. 4, shows the results of standard proctor test analysis for nine different soils of Bangladesh. The curve from all soil samples is shown below.

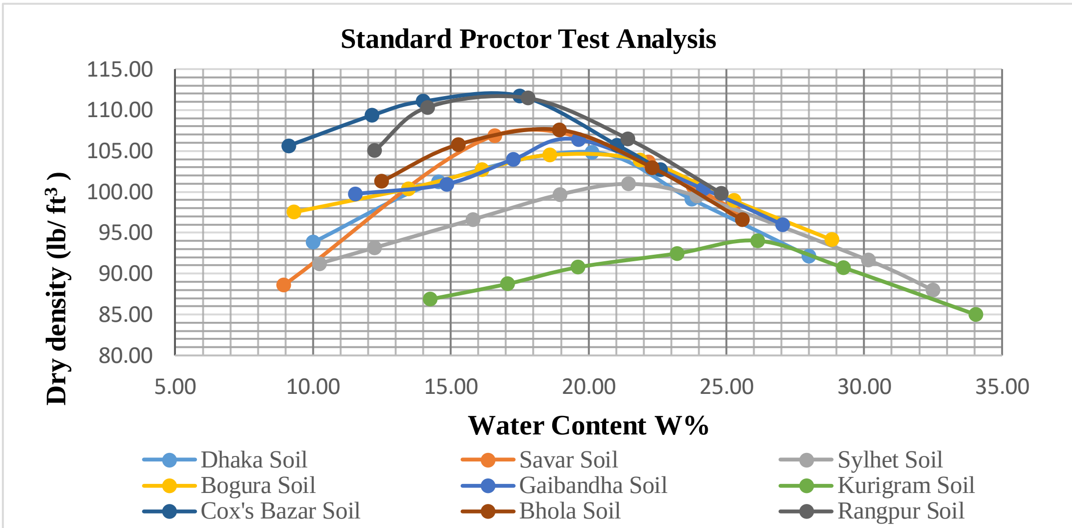

Fig. 4: Standard proctor test analysis for all soil samples**.**

OMC value is determined from the MDD peak point. Here 'y' axis is denoted as MDD and 'x' axis is denoted as OMC. From the analysis curve highest OMC value gained from Kurigram 26% and the lowest from Cox's Bazar 16%.

TABLE I: Soil type and consistency limit. Here all summary results are shown in the table.

Sample No.	Soil type	Atterberg Limits			Standard proctor Test	
		Liquid Limit %	Plastic limit %	Plasticity Index %	Maximum Dry Unit W_t lb/ ft^3	OMC %
Dhaka	CL	49	22.15	26.85	104	20
Savar	CL	53	21.31	31.69	107.5	18
Sylhet	ML	40.2	24.73	15.47	100	21.5
Bogura	ML	40.8	23.96	16.84	104.98	20
Gaibandha	ML	41.49	23.61	17.88	106.5	19.2
Kurigram	ML	44.21	30.57	13.64	94	26
Cox's Bazar	ML	29	21.07	7.93	112	16
Bhola	ML	36	21.36	10.64	108	18
Rangpur	ML	38	19.14	20.86	112	17

Table I shows the classification of soil as well as the results of laboratory tests such as the atterberg limit test and the standard proctor test. Following the classification of all soil samples, the majority of them were classed as low plasticity silt and low plasticity clay. According to laboratory test results, the plastic limit is from 19.14 to 30.57 percent, and the optimum moisture content level ranges from 16 percent to 26 percent. Also in Fig. 5 an equation is plotted through a linear graph which is shown in below

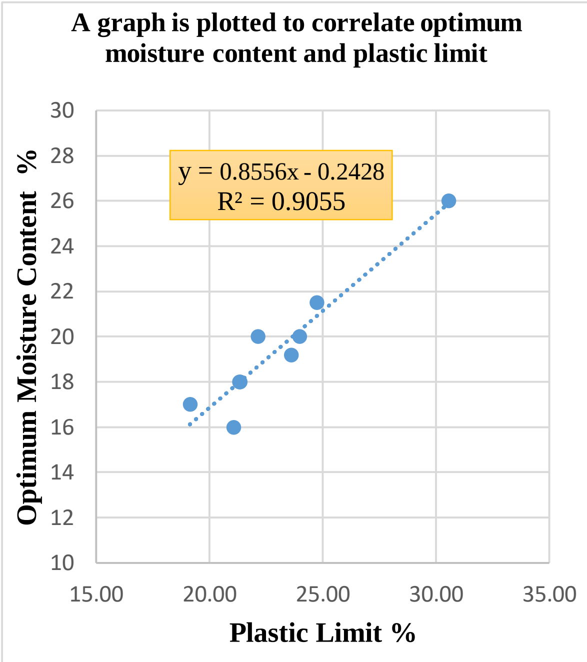

Fig. 5: OMC vs. Plastic limit.

The linear equation graph is shown in figure 5, where 'y' is denoted as OMC and 'x' is denoted as PL. The correlation coefficient is denoted by the letter 'R'. When the plastic limit value is put into this equation, the new results of OMC are visible. It is well known that R-value near 1 indicates a strong correlation. For this research the result of y = 0.8556x - 0.2428 and R^2 = 0.9055 in this case.

TABLE II: Compaction characteristics of soil found with proctor test and proposed

OMC % By proctor test	OMC % By proposed equation	Difference %
16	17.8	1.8
18	18.0	0.0
19.2	20.0	0.8
20	18.7	1.3
20	20.3	0.3
21.5	20.9	0.6
26	25.9	0.1
18	18.0	0.0
17	16.1	0.9

Table II shows the OMC value produced by the proposed equation, and the difference between them is very little. The OMC ranges from 16.1 percent to 25.9 percent after using the proposed equation to obtain OMC findings, here the biggest difference is 1.8 percent and the lowest is 0.0 percent, which is not a significant difference.

Fig.6, shows the comparison between the present study and from the literature which is shown below

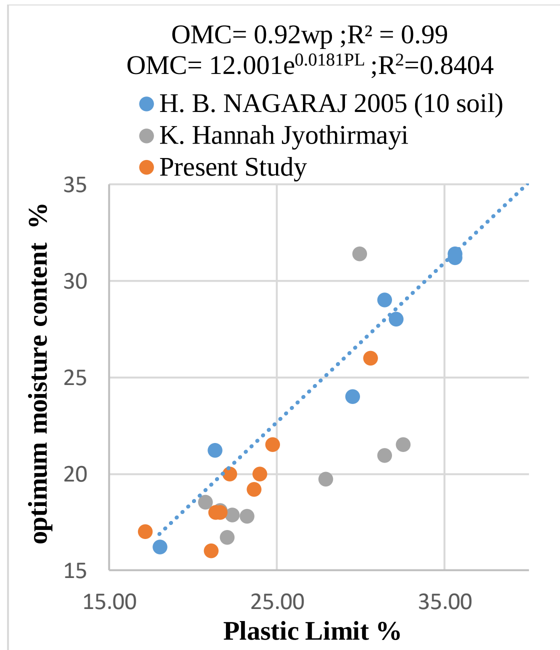

Fig.6: Plot of optimum moisture content vs plastic limit of soil from the present study as well from literature (Sridharan, Nagaraj, 2005 and K.H. Jyothirmayi, T. Gnanananda & K. Suresh, 2015.)

This research result differs slightly from theirs in this area which is shown in fig. 6. Nagaraj 2005 obtained a value of R^2 of 0.99 and from K.H. Jyothirmayi 2015 obtained value of R^2 is 0.84 and respectively OMC 0.92wp and $12.001e^{0.0181PL}$, while this study obtained a value of R^2 of 0.90 and an OMC of 0.8556x - 0.2428, which is close to them.

4. CONCLUSION

This research result has been made from the correlation of optimum moisture content (OMC) and plastic limit (PL) of the soil samples. The correlation between optimum moisture content and plastic limit of fine-grained soils is found to be

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practicable based on the experimental findings. This study's investigation provided the following correlation below:

$$\mathbf{y = 0.8556x - 0.2428}$$

$$\text{and } \boldsymbol{R^2} \mathbf{= 0.9055}.$$

OMC can be easily found out by this equation with the help of the plastic limit of soil. So if only knowing the plastic limit result it can easily calculate the OMC value by using the plastic limit value in the equation. For more sophisticated analysis, it is not necessary to determine OMC again by the proctor compaction apparatus where the approximate results have been taken by the equation already. The proposed correlation equations between natural soil compaction properties and their plastic limit will be a useful tool for geotechnical engineers in swiftly analyzing natural soil suitability for compaction-related uses.

5. REFERENCES

[1] Prof. Emer Tucay Qezon, P.Eng, (2019) "Parametric Modelling on the Relationships Between Atterberg Limits and Compaction Characteristics of Fine-Grained Soils Worku Firomsa". Vol. 8 | No. 7, *International Journal of Advanced Research in Engineering and Applied Sciences.*

[2] H.B. Nagaraj, B. Reesha, M.V. Sravan, & M.R. Suresh, (2015). "Correlation of Compaction Characteristics of Natural Soils with Modified Plastic Limit". Transportation Geotechnics, 2, 65-77.https://doi.org/10.1016/j.trgeo.2014.09.002

[3] A Sridharan, &H.B. Nagaraj, (2005). "Plastic Limit and Compaction Characteristics of Fine-Grained Soils", Ground Improvement 9, No. 1, 17–22.

[4] N. S. Pandian, T. S. Nagaraj and M. Manoj ,(1997) "Re-examination of Compaction Characteristics of Fine-Grained Soils" Geotechnique 47, No. 2, 363±366

[5] K. Hannah Jyothirmayi, T. Gnanananda, & K. Suresh, (2015). "Prediction of Compaction Charecteristics of Soil Using Plastic Limit". In IJRET: International Journal of Research in Engineering and Technology. https://www.researchgate.net/publication/327719939.

[6] B. M. Das, Khaled Sobhan, (2018). "Geotechnical Engineering". www.cengagebrain.com.

[7] Ksenija Dokovic, Dragoslav Rakic, Milenko Ljubojev (2013). "Estimation of Soil Compaction Parameters Based on the Atterberg Limits". Mining and Metallurgy Engineering Bor, 4, 1–16. https://doi.org/10.5937/mmeb1304001d

[8] Y. Gurtuoi, & A. Sridharan, (2004). "Compaction Behaviour and Prediction of Its Characteristics of Fine-Grained Soils with Particular Reference to Compaction Energy" (Vol. 44, Issue 5). Japanese Geotechnical Society.

[9] M. Jesmani, A. N. Manesh, & S.M.R. Hoseini, (2008). "Optimum Water Content and Maximum Dry Unit Weight of Clayey Gravels at Different Compactive Efforts". EJGE (Vol 13).