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MODELLING AND PREDICTION OF COMPACTION PARAMETERS BASED ON ATTERBERG LIMITS AND CLAY CONTENT

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ABSTRACT

This study focused on using a modeling technique to determine the soil compaction parameters from Atterberg limits and clay content. Soil samples were collected from various locations in Kano-Nigeria and their compaction and other properties determined. Statistical techniques were employed to relate these properties. The results of the study show that the soils maximum dry density (MDD) and their optimum moisture content (OMC) can be estimated from the soils Atterberg limits and the fine particle contents. The current study has shown an improvement over other existing models by given a better correlation among the parameters modeled.

Keywords: Atterberg limits; Clay content; Compaction; MDD; OMC.

1. INTRODUCTION

The development of land for the construction industries requires considerable quantities of embankment fill of all which must be compacted to an acceptable standard. The present practice involves obtaining the fill materials from randomly selected borrow areas. These materials are used for compaction without prior knowledge of whether or not they can satisfy the specifications for appropriate compaction parameters. Das (2003) defined Compaction of soil as an act of pressing the soil particles tightly together by expelling air from the void spaces. In most cases dry soil can be best compacted if certain amount of water is added to it to act as a lubricant and allows soil particles to be effectively packed together (Liu and Evett, 2004). However, if too much water is added to the soil, it will result in a lesser density. Thus, for a given compaction effort, there is a particular moisture content which gives the greatest dry unit weight; this pair of values are known as optimum moisture content (OMC) and maximum dry density (MDD) respectively. The compaction characteristics are first determined in the laboratory by various compaction tests such as standard proctor test and modified proctor test. The compaction of the soil has three (3) important effects (Gofar and Kassim, 2008); (i) an increase in the shear strength, (ii) a decrease in future settlement of the soil, and (iii) a decrease in the permeability of the soil. Several studies have indicated that there is a relationship between the compaction parameters and Atterberg limits as reported by Faizah (2005). This relationship can be used to estimate the values of MDD and OMC based on Atterberg limits without having to perform the laboratory compaction test.

Various models exist which relate the compaction parameters of soil with Atterberg limits. However, the parameters used in these models were restricted to Atterberg limits only which are not the only parameters that control the density of a soil (Liu and Evett 2004; Das, 2008). Blotz et al. (1998) reports that a linear relationship exists between the maximum dry unit weight and the base 10 logarithm of compaction energy based on the tests conducted on a micaceous silty fine sand. Faizah (2005) reported that there are linear relationships between the compaction parameters (MDD and OMC) and the Atterberg limits (liquid limit (LL), plastic limit (PL) and plasticity index (PI)), which may be expressed in the form:

$MDD=2.132-0.004LL – 0.006 PL$ (1)
($R^2 = 0.588$)

$OMC =4.065+0.125LL+0.180PL$ (2)
($R^2 = 0.517$)

Mohd Ruslan (2005) also investigated the relationship between the compaction parameters and Atterberg limits and reported similar linear relationships between the compaction parameters and Atterberg limits as shown by the following equations:

$OMC=0.079LL+0.24PL+3.577$ (3)
($R^2 = 0.458$)

$MDD=-0.003LL+0.007PL+2.137$ (4) ($R^2 = 0.496$)

However, there are several factors that affect the compaction of soil. Liu and Evett (2004) reported that the factors that affect compaction of soil are moisture content, compaction effort and type of soil. Among the factors, it was reported that the type of soil has a greater effect on compaction. The grain-size distribution of soil, shape, and specific gravity of solids as well as the type and amount of clay minerals present also affect maximum dry unit weight and optimum moisture content for a given compaction effort and method. Hence, this study investigates in to the combine effect of Atterberg limits and the fine particle content of the soil in the determination of the compaction parameters.

Regression analysis is a statistical technique for estimating the relationships among variables. As reported by Natrella (1963), it includes many techniques for modeling and analyzing several variables, when the focus is on the relationship between dependent variables and one or more independent variables. More specifically, regression analysis helps one understand how the typical value of the dependent variables change with a change in the independent variables, while the other independent variables are held fixed. This technique was adopted in the current study.

2. MATERIALS AND METHODS

Disturbed soil samples were collected at a depth of 1.5 m from existing borrow pits at different locations in Kano; including Sharada, BUK new campus, Janguza and Zaria road. Small portions were collected in small polythene bags for the determination of natural moisture content, while the bulk portions were collected in sacks for easy transportation to the testing laboratory. Samples and specimens were prepared in accordance with BS 1377 (1990). Prior to specimens' preparation, the samples were air dried and carefully crushed to smaller fragments without reducing the size of the individual particles. The basic properties of the samples such as the particle size and size distribution, and Atterberg limits were determined for each sample. The soil samples were then compacted at various moisture contents using the standard proctor compaction method and the corresponding dry densities at these moisture contents were determined. Plots of dry density versus moisture content were made and from these plots, the maximum dry density (MDD) for each sample was obtained as the peak value of the graph and the corresponding moisture content from each graph was taken as the optimum moisture content (OMC). Regression analysis tool was then employed where various combinations of the basic properties were taken as independent variables, and the MDD and OMC as dependent variables. The applicability of the existing models that relate index properties of the soil to its maximum dry density and optimum moisture content was verified using the parameters gotten from the laboratory test conducted on the different soil samples. One hundred (100) sets of data from Idris and Abdulfatah (2013) were then used; 70 sets in testing the regression model and 30 sets for validation.

3. RESULTS AND DISCUSSIONS

The results obtained for the preliminary tests show that the soil is silty with fine contents ranging from 22.89% (in one sample) to 70% (in another sample). The Atterberg limits also varied from 18% to 33% for LL and 7% to 21% for PL. Also from the compaction test, the maximum dry density ranges from 1.88 Mg/m^3 to 2.05 Mg/m^3 while the optimum moisture content ranges between 9.36% and 15.15%. The results of the regression analysis indicates that the fine particle content of the soil have a significant influence in the model for MDD and OMC determination.

Based on the good regression obtained, the following equations were developed:

$$\rho_{dmax}=-2.035W_L+2.034W_P+2.033PI-.004F+2.142 \quad (R^2 = 0.9604)$$

$$W_{opt}=-92.092W_L+92.521W_P+92.189PI+0.179F-4.74 \quad (R^2 = 0.8628)$$

Where: ρ_{dmax} = Maximum dry density of the soil (g/cm^3); W_{opt} = Optimum moisture content of the soil (%); W_L = Liquid limit (%); W_p = Plastic limit (%); PI = Plasticity index (%); F = Fine aggregates contents (%).

The current model together with the models developed by Faizah (2005) and Mohd (2005) were tested using the data in Idris and Abdulfatah (2013). Figure 1 shows that an R-square of 0.8190, 0.443 and 0.209 were obtained for the current study, Faizah (2005) and Mohd (2005) respectively when the three models were tested for the estimated and measured MDD. The results from the three models in estimating the OMC also show R-square values of 0.919, 0.715 and 0.939 for the current study, Faizah (2005) and Mohd (2005) respectively as shown in

Figure 2.

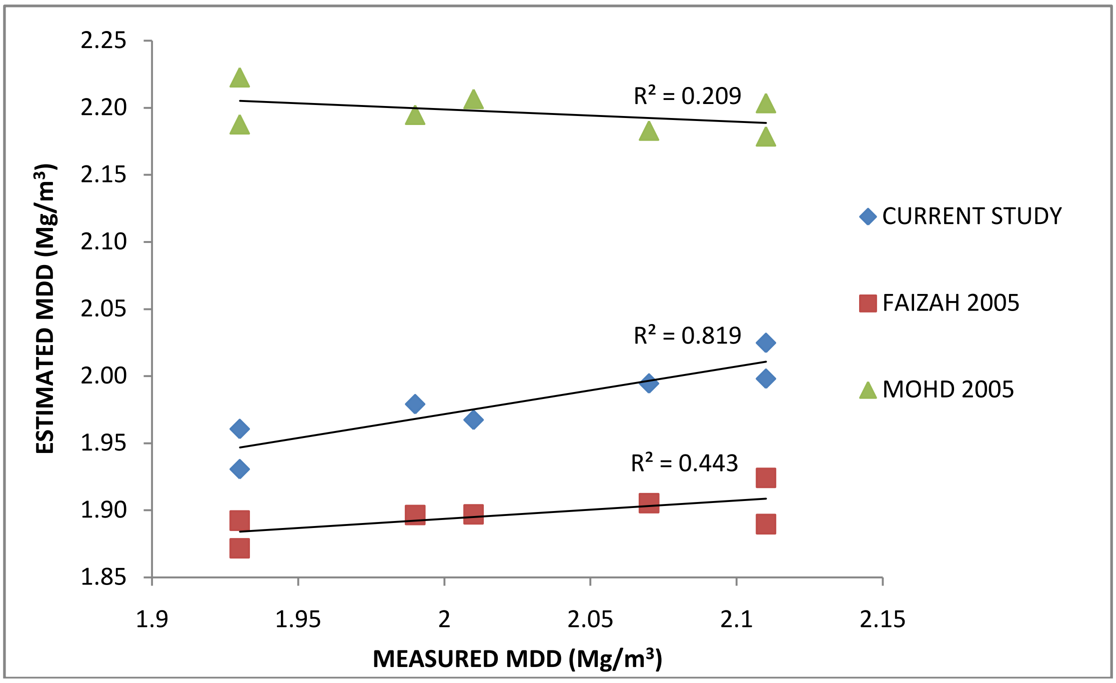

Figure 1: Plots of Measured MDD Versus Estimated MDD for the Three Models

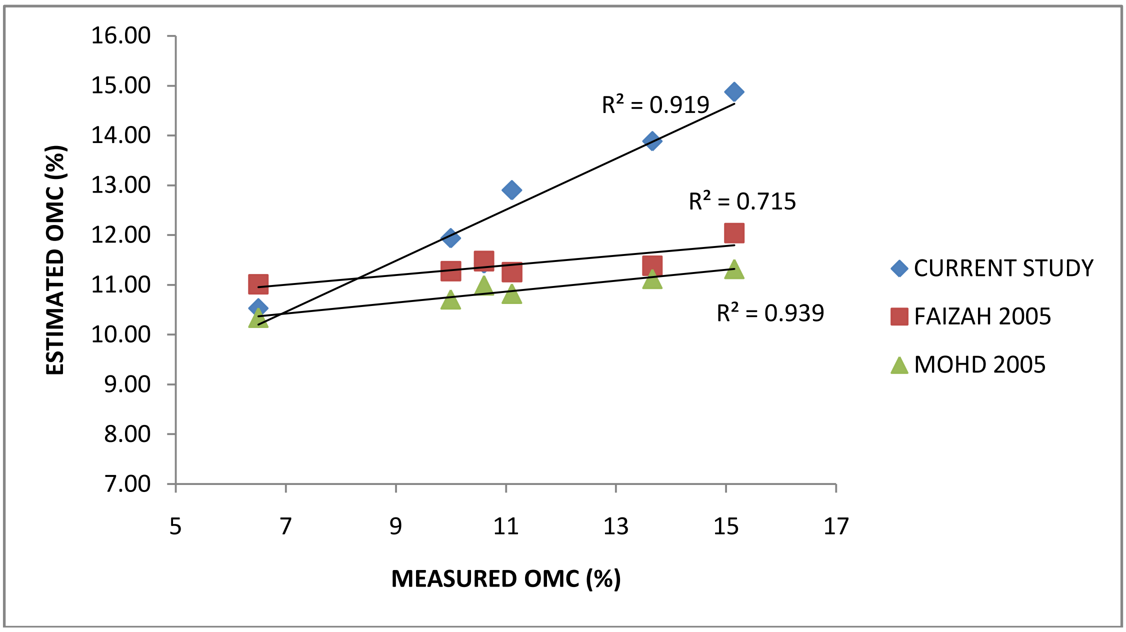

Figure 2: Plots of Measured OMC Versus Estimated OMC for the Three Models

4. CONCLUSIONS

From the results obtained in this study, it was observed that the fine particle content of a soil has significant effect in the determination of the soils MDD. This is shown in the model developed where the model shows an improvements over the existing models that did not consider the fine particle content. However, for the OMC, even though the model developed in this study shows a better R-square value, the test results have indicated an almost equal capability to estimate the OMC by each of the three models, hence the fine particle content has little or no influence in the determination of the OMC.

REFERENCE

Blotz, L.R.; Benson, C.H.; and Boutwell, G.P. (1998). Estimating Optimum Water Content and Maximum Dry Unit Weight for Compacted Clay" *Journal of Geotechnical and Geoenvironmental Engineering.* Vol. 124, No. 9, pp:907-912.

Das, B.M (2008). Advanced Soil Mechanics. *Taylor and Francis Publishers,* London, United kingdom.

Das B.M (2003). Principles of foundation Engineering. Fifth edition, Thompson brooks/Cole, 743pp.

Faizah K (2005). Estimation of Compaction Parameters Based on Atterberg Limits. M.Eng Thesis, Universiti Teknologi Malaysia, Skudai, Johor, Malaysia.

Gofar, N. and Kassim, K.A. (2008). Ground improvement and stabilisation. *Univision Press*, Selangor, Malaysia.

Idris, A. and Abdulfatah, A.Y. (2013). Predicting Shear Strength Parameters from Compaction Parameters of Soil Using Artificial Neural Network. Proceedings of The Third International Conference on Soft Computing Technology in Civil, Structural and Environmental Engineering, Cagliari, Sardinia, Italy, 3-6 September 2013.

Liu, C. and Evett, J. B. (2004). Soils and Foundations. SI Edition, Prentice Hall, Singapore.

Mohd, R. and Che, G. (2005). Correlation regression between Soil Compaction Parameters and Atterberg Limits. B.Eng. Thesis, Faculty of Civil Engineering, Universiti Teknologi Malaysia, Skudai, Johor, Malaysia.

Natrella, M.G. (1963). Experimental Statistics. National Bureau of Standards, Washington DC.