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# APPLICATION OF CORRELATION AND REGRESSION ANALYSIS IN THE PREDICTION OF COMPACTION CHARACTERISTICS USING ATTERBERG LIMIT AS AN INDEPENDENT VARIABLE.

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## ABSTRACT

*The study focuses on the application of correlation and regression analysis in the prediction of compaction characteristic using Atterberg limit as an independent variable. The software used in the analysis is Minitab, from the correlation analysis, the plasticity index has poor correlation with every other parameter and as such was*

## Introduction

Soils are the most used construction materials in the world. Naturally occurring soils to be used as construction material needs their engineering properties determined and as such needs to be compacted for the improvement of their engineering properties. The determination of these properties becomes a very important process for the successful design of any geotechnical structure. Testing the properties of compaction to achieve the optimum moisture content (OMC), and maximum dry density (MDD) of the

*omitted from the regression analysis. Soil samples from twelve (12) borrow pits at dept 1.5m were collected along Ebia river of Ebonyi state Nigeria. The soil was subjected to compaction, the compaction characteristic was carried out using British standard light (BSL) and Atterberg limit was also determined for each sample. The coefficient of correlation between plastic limit versus liquid limit, optimum moisture content versus liquid limit, and optimum moisture content versus plastic limit are 0.937, 0.986, and 0.936 respectively. R-square ($R^2$) value of 97.35% was obtained when regression analysis was conducted with optimum moisture content being dependent on liquid limit, and plastic limit as independent variable. while R-square ($R^2$) value of 72.13% was obtained when regression analysis was conducted with maximum dry density being dependent on optimum moisture content, liquid limit, and plastic limit as independent variable.*

*The equations developed are listed below:*

1. OMC = -15.55 + 0.816 LL + 0.097 PL
2. MDD = -0.696 + 0.1634 LL - 0.0478 PL - 0.1530 OMC

Keywords— Correlation, regression, liquid limit, plastic limit, optimum moisture content, maximum dry density.

soil, requires high amount of time, energy, and work (Hussain & Atalar ,2020). In all kinds of earthwork constructions, the laboratory determination of the compaction characteristics of the soils plays an important role. Soil compaction is defined as the method of increasing the density of the soil by application of mechanical energy. The principal reason for the compaction of the soil is to produce a soil mass which can satisfy the three basic criteria. Firstly, the reduction of subsequent settlement of the soil mass, under working loads. Secondly, for the reduction in permeability which will subsequently avoid built up of large water pressures causing liquefaction problems and is also important for retaining water in case of earth dams. Thirdly, it is used for increasing the

shear strength of the soils. But the determination of compaction characteristics in laboratory is laborious. It requires significant time and effort. Hence, there is a necessity for prediction of compaction characteristics with the help of correlating it with index properties of soil which can be determined easily. The plastic limit of soil can be found effortlessly and it bears a good correlation with compaction characteristic, namely optimum moisture content (Jyothirmayi *et al*, 2015). It is as a result that this study aims to apply correlation and regression analysis in the prediction of compaction characteristics using atterberg limit as an independent variable.

**Literature review**

Yousif. & Mohamed (2022) used Microsoft Office Excel software to conduct regression analysis of compaction parameters and Atterberg limits. Several trials were created to get the relationships between Atterberg limits (LL, PL, and PI) with the compaction parameters (OMC, and MDD). From the regression analysis, they found that OMC and MDD have an excellent relationship with the LL other than the PL and PI. They observed that the (OMC) has an excellent correlation with (MDD) other than the remaining parameters.

Prasanna *et al* (2017) carried out an experimental work to establish the correlation between compaction characteristics (OMC & MDD) of fine-grained soils for varying compaction energy levels with Liquid Limit, Plastic Limit and Shrinkage Limit using MLRA (Multiple Linear Regression Analysis) equations. They observed that a good correlation exists between compaction characteristics of fine-grained soils with index properties of soils with a regression value ranging from 0.993 to 0.997. They concluded that compaction characteristics can be effectively predicted using Atterberg limits of soil.

Tsegaye *et al* (2017) made correlation between compaction characteristics and Atterberg limits of fine-grained soil found in Addis Ababa, they analyzed their recorded data using descriptive and analytical methods, and then found correlation between compaction characteristics and Atterberg limits of fine-grained soil using regression

analysis. Regression analysis conducted was done using EXCEL and SPSS software. They observed that there is a relatively good correlation between OMC and PL and a good correlation between MDD and LL, PL and PI together

Egbe *et al* (2017) applied Multi-Linear Regression Analysis (MLRA) model to predict soil properties in Calabar South. They used Multi Linear Regression Analysis to formulate a model that relates CBR to other soil parameters. The Multi Linear Regression Analysis was done using the Data Analysis tool of Microsoft Excel, they found out that the coefficient of correlation $R^2$= 0.9454 implying that the model can be used to predict CBR at 50.9 % and with ±3.4% error.

## Materials and Methods

### Soil Sample Collection

Twelve (12) soil samples were collected along Ebia river Ebonyi state, Nigeria at a depth of 1.5m below the ground level. The state with coordinate 6° 15'N 8° 05'E and with an area of 5,533km$^2$. It has an estimated population of 3,490,383 based on 2016 population census.

### Laboratory Analysis

Compaction and Atterberg limit tests were performed on each of the 12 samples, the test was in accordance with BS 1377 (1990) and BS 1924 (1990) respectively.

### Regression Analysis Using Minitab

Data were arranged in the work space of the Minitab environment correlation and regression data was specified with the dependent and independent variables clearly defined.

## Result and Discussion

### Compaction

The compaction carried out was based on British standard light (BSL) to determine the optimum moisture content (OMC) and maximum dry density (MDD) of the soil samples.


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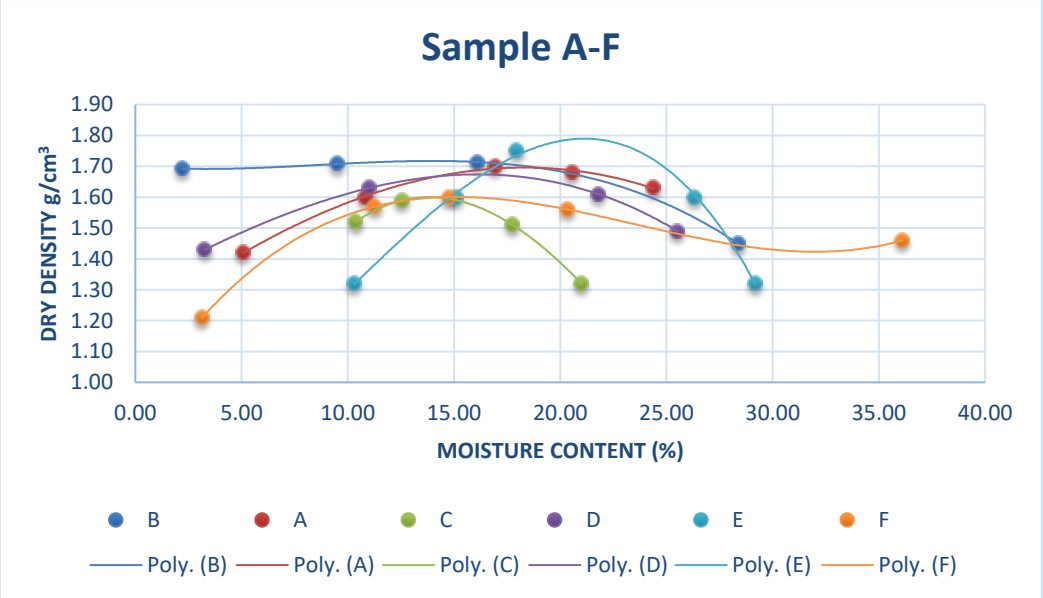


Figure 1. Dry density vs moisture content graph for samples A, B, C, D, E, F

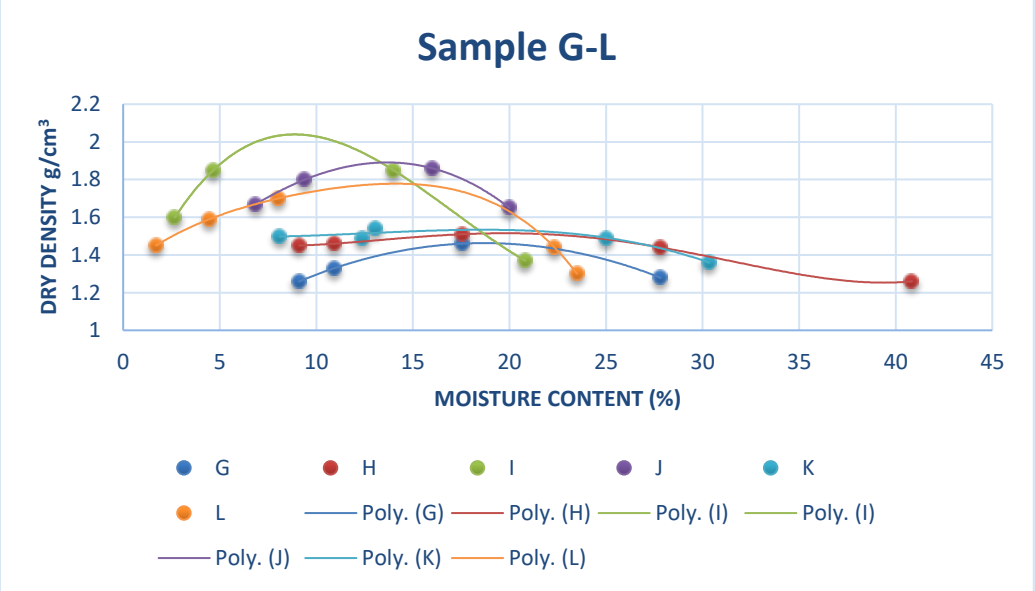


Figure 2. Dry density vs moisture content graph for samples G, H, I, J, K, L

With the experimental data, a graph of dry density vs moisture content is plotted for sample A, B, C, D, E, F in figure 1 and for samples G, H, I, J, K, L in Figure 2. Table 2 shows the values of the OMC and MDD of the various samples.

Table 2: OMC and MDD for 12 (A-L) samples

| Sample | Optimum moisture content (OMC) % | Maximum dry density ($g/cm^3$) |
|---|---|---|
| **A** | 18 | 1.79 |
| **B** | 16 | 1.70 |
| **C** | 13 | 1.60 |
| **D** | 15 | 1.67 |
| **E** | 23 | 1.80 |
| **F** | 14 | 1.60 |
| **G** | 19 | 1.46 |
| **H** | 22 | 1.50 |
| **I** | 10 | 2.09 |
| **J** | 13 | 1.88 |
| **K** | 17 | 1.57 |
| **L** | 12 | 1.78 |

The value obtained from compaction shows that the optimum moisture content and maximum dry density is consistent with the respective type of soil. The OMC ranges from 12%-23% while MDD ranges from 1.46 $g/cm^3$-2.09 $g/cm^3$.

**Atterberg Limit**

From the test conducted, the values of Liquid limit (LL), Plastic limit (PL) and Plasticity index (PI) are shown in Table 3.

Table 3: LL, PL, PI for 12 (A-L) samples

| Sample | LL (%) | PL (%) | PI (%) |
|---|---|---|---|
| **A** | 38 | 20 | 18 |
| **B** | 36 | 22 | 14 |
| **C** | 33 | 20 | 13 |
| **D** | 34 | 21 | 13 |
| **E** | 45 | 30 | 15 |
| **F** | 33 | 21 | 12 |
| **G** | 39 | 25 | 14 |


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| | | | |
|---|---|---|---|
| **H** | 42 | 28 | 14 |
| **I** | 30 | 15 | 15 |
| **J** | 34 | 20 | 14 |
| **K** | 37 | 22 | 15 |
| **L** | 32 | 19 | 13 |

**Correlation analysis**

With the laboratory test carried out on the 12 soil samples collected from different chainage of Ebia river at dept 1.5m, a correlation relationship was made with the various test properties which was analyzed using Minitab software. Figure 3 shows the relationship of the test properties between LL, PL, PI, OMC and MDD.

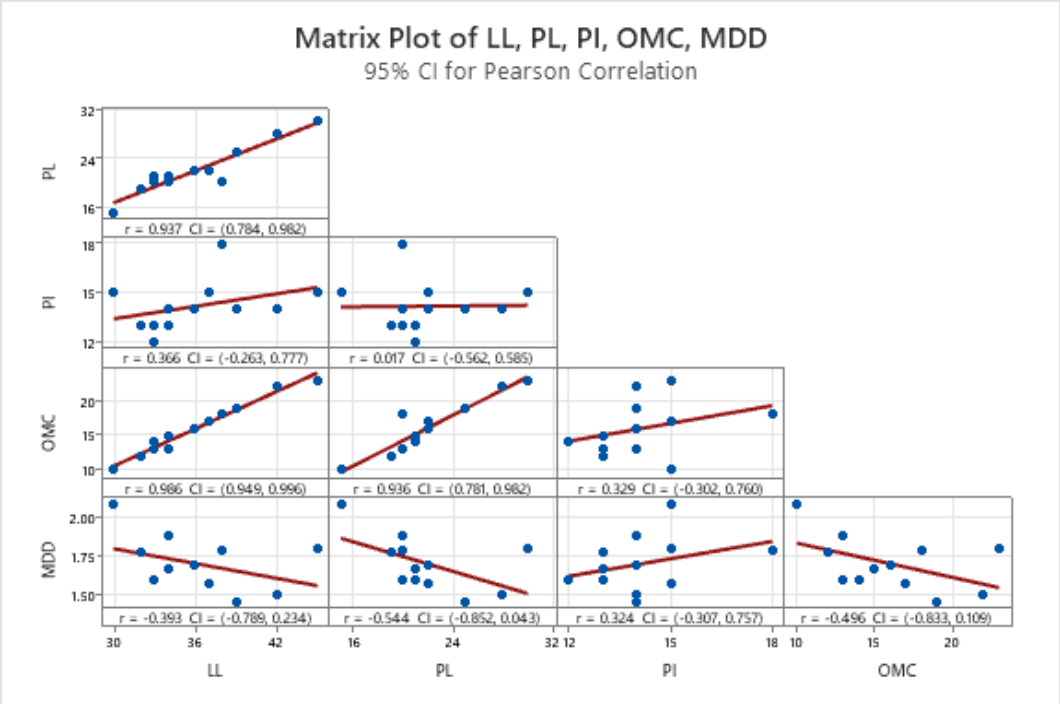


Figure 3. Correlation: LL, PL, PI, OMC, MDD

From table 4 below and figure 3, it can be seen that there is a high correlation between PL vs LL of 0.937, and also a high correlation strength between OMC vs LL of 0.986. Another test result showing high correlation strength is OMC vs PL of 0.936. so, we can say from the above plotted graphs in figure 3, that there is a strong linear relationship


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between PL vs LL, OMC vs LL and OMC vs PL. Every other correlation except MDD vs PL which shows a negative linear relationship of -0.544, displayed a correlation value less than 0.5. it can clearly be seen from figure 3 that PI has a very poor relationship with OMC, MDD, PL and LL. So as a result, in our regression analysis the PI will be omitted.

Table 4: Correlations between PL, PI, OMC and MDD

| | LL | PL | PI | OMC |
|---|---|---|---|---|
| **PL** | 0.937 | | | |
| **PI** | 0.366 | 0.017 | | |
| **OMC** | 0.986 | 0.936 | 0.329 | |
| **MDD** | -0.393 | -0.544 | 0.324 | -0.496 |

**Regression Analysis: OMC versus LL, PL**

For the regression analysis, the OMC is analyzed first with it being the dependent variable while liquid and plastic limit are the independent variables since they show a strong linear relationship in their respective correlation phase. It can be seen from the table 6, that the R-square ($R^2$) value is 97.35% which indicates a strong predictive strength of the generated equation as shown in equation 1. With the equation generated predictions of the OMC can be made with respect to LL and PL values respectively.

**Regression Equation**

$$OMC = -15.55 + 0.816\ LL + 0.097\ PL \quad \text{equation 1}$$

Therefore, equation (1) represents the regression equation that relates OMC to LL and PL. The value of OMC as coefficient was derived from Table 5.

Table 5: Coefficients OMC versus LL, PL

| Term | Coef | SE Coef | T-Value | P-Value | VIF |
|---|---|---|---|---|---|
| **Constant** | -15.55 | 2.31 | -6.73 | 0.000 | |


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| | | | | | |
|---|---|---|---|---|---|
| **LL** | 0.816 | 0.141 | 5.77 | 0.000 | 8.14 |
| **PL** | 0.097 | 0.152 | 0.64 | 0.541 | 8.14 |

Table 6: Model Summary OMC versus LL, PL

| S | R-sq | R-sq(adj) | R-sq(pred) |
|---|---|---|---|
| **0.716092** | 97.35% | 96.76% | 92.88% |

**Regression Analysis: MDD versus LL, PL, PI, OMC**

The second dependent variable to be analyzed is MMD, with OMC, LL, and PL being the independent variables. From table 8, it can be seen that the R-square ($R^2$) value is 72.13%, the low percentage value gotten is associated with the low correlation between the independent variables from the phase of correlation, where all the independent variable showed a correlation value less than 0.8. the generated equation from the regression analysis is shown in equation 2.

**Regression Equation**

MDD = -0.696 + 0.1634 LL - 0.0478 PL - 0.1530 OMC

equation 2

Equation (2) represents the regression equation that relates MDD to OMC, LL and PL. The value of MDD as coefficient was derived from Table 7.

Table 7: Coefficients MDD versus LL, PL, OMC

| Term | Coef | SE Coef | T-Value | P-Value | VIF |
|---|---|---|---|---|---|
| **Constant** | -0.696 | 0.868 | -0.80 | 0.445 | |
| **LL** | 0.1634 | 0.0469 | 3.49 | 0.008 | 38.26 |
| **PL** | -0.0478 | 0.0237 | -2.01 | 0.079 | 8.51 |
| **OMC** | -0.1530 | 0.0510 | -3.00 | 0.017 | 37.70 |

**Table 8: Model Summary MDD versus LL, PL, PI, OMC**

| S | R-sq | R-sq(adj) | R-sq(pred) |
|---|---|---|---|
| **0.109519** | 72.13% | 61.68% | 20.96% |



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**Actual and Predicts**

Table 9 shows the actual and predicted values of the optimum moisture content and that of the maximum dry density. While Figures 4 shows the graphical comparison of the actual values and predict of OMC vs LL and PL, and figure 5 shows the graphical comparison of MDD vs LL, PL, and OMC.

Table 9: Actual and predict of OMC and MDD

| | OMC | | MDD | |
|---|---|---|---|---|
| **Sample** | Actual | Predict | Actual | Predict |
| **A** | 18 | 17.3782 | 1.79 | 1.80227 |
| **B** | 16 | 15.9401 | 1.7 | 1.68573 |
| **C** | 13 | 13.2998 | 1.6 | 1.75013 |
| **D** | 15 | 14.2121 | 1.67 | 1.55975 |
| **E** | 23 | 24.0541 | 1.8 | 1.70277 |
| **F** | 14 | 13.3964 | 1.6 | 1.54932 |
| **G** | 19 | 18.6769 | 1.46 | 1.57348 |
| **H** | 22 | 21.4138 | 1.5 | 1.46124 |
| **I** | 10 | 10.3697 | 2.09 | 1.95807 |
| **J** | 13 | 14.1155 | 1.88 | 1.91353 |
| **K** | 17 | 16.7558 | 1.57 | 1.69616 |
| **L** | 12 | 12.3875 | 1.78 | 1.78755 |

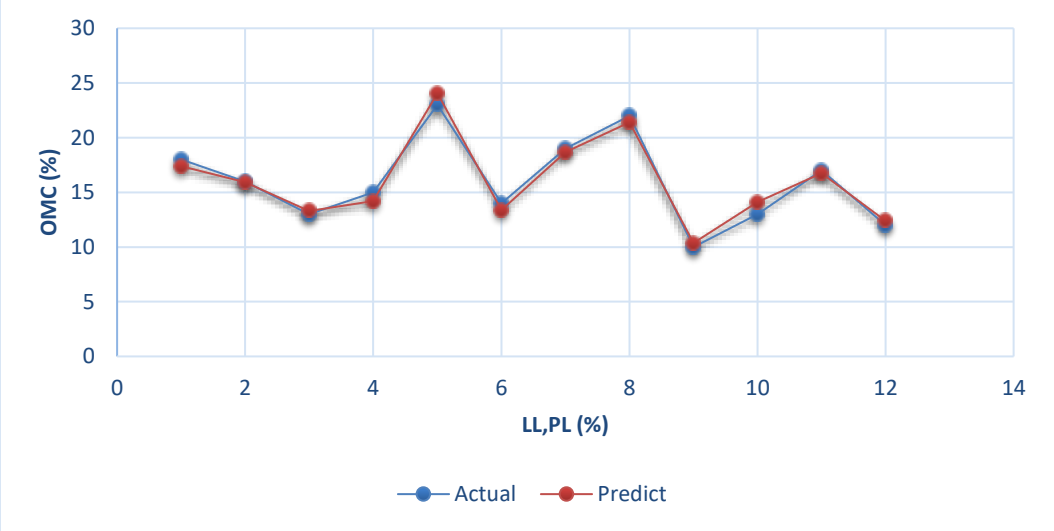


Figure 4: Comparison between actual values and predict values of OMC vs LL and PL for MC and MDD



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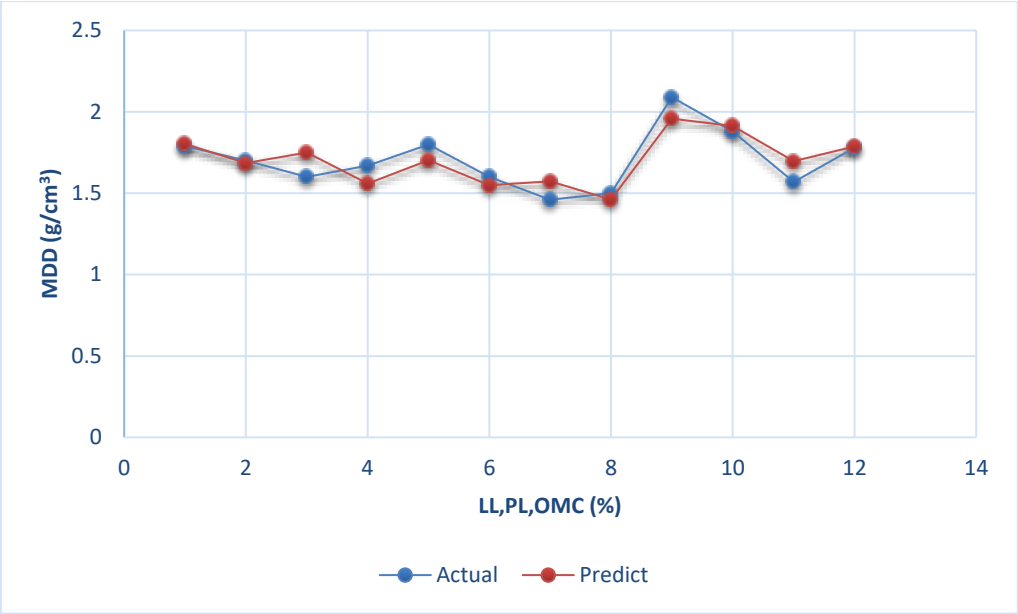


Figure 5: Comparison between actual values and predict values of MDD vs LL, PL and OMC

**Conclusion**

From the results of the study, it can be said that there is a strong positive linear correlation between optimum moisture content (OMC) versus liquid limit (LL), plastic limit (PL) versus optimum moisture content (OMC), and plastic limit (PL) versus liquid limit (LL) with R-values of 0.937, 0.986 and 0.936 respectively. A poor correlation relationship of plasticity index (PI) versus other parameter with R-values ranging from 0.017 to 0.366. As for the correlation relationship of maximum dry density (MDD) versus liquid limit (LL), maximum dry density (MDD) versus plastic limit (PL) and maximum dry density (MDD) versus optimum moisture content (OMC), there is a negative linear relationship with R- values -0.393, -0.544, and -0.496 respectively.

From the regression analysis, the $R^2$ value was found to be 97.35% for optimum moisture content (OMC) as the dependent variable while liquid limit (LL) and plastic limit (PL) where the independent variables. The $R^2$ value gotten indicates a strong predicting characteristic of the developed equation. Similarly, the $R^2$ value was found to be 72.13% for maximum dry density (MDD) as dependent variable while liquid limit (LL), plastic limit (PL) and optimum moisture content (OMC) where the

independent variables. The $R^2$ value once again shows a predicting characteristic of the developed equation. The regression equation developed can predict Compaction characteristics of the experimental actual values as can be seen in figures 4 and 5, using Atterberg limits of the soils, thus saving money, time and materials.

Generally, from the regression analysis the following equations were found satisfactory.

1. OMC = -15.55 + 0.816 LL + 0.097 PL
2. MDD = -0.696 + 0.1634 LL - 0.0478 PL - 0.1530 OMC

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