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Research article

DEVELOPMENT OF COMPARATIVE MODELS TO PREDICT THE RATE OF BULK DENSITIES OF DELTAIC CLAYAND FINE SAND IN COASTAL AREA OF PORT HARCOURT

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Abstract

Development of comparative models to predict the rate of bulk densities of deltaic clay has been expressed, the model to compared different predictive model that has developed to monitor different predictive model of bulk densities in clay formation, the variation of bulk densities has different impact on porosity and permeability of the soil base on the stratification of the formation, the established model were generated from express mathematical model equation from different location for bulk densities, the models were compared for validation, both parameters expressed a faviourable fits, the developed model and its theoretical values shows that both generated model can be applied to monitor the rate of bulk densities for any soil engineering design that can produced good results in the study location.

Keywords; comparative models, bulk densities and deltaic clay

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Introduction

High bulk density is an indicator of low soil porosity and soil compaction. It may cause restrictions to root growth, and poor movement of air and water through the soil Compaction can result in shallow plant rooting and poor plant growth, influencing crop yield and reducing vegetative cover available to protect soil from erosion. By reducing water infiltration into the soil, compaction can lead to increased runoff and erosion from sloping land or waterlogged soils in flatter areas. In general, some soil compaction to restrict water movement through the soil profile is beneficial under arid conditions, but under humid conditions compaction decreases yields. Bulk density reflects the soil's ability to function for structural support, water and solute movement, and soil aeration. Bulk densities above thresholds in indicate impaired function. Bulk density is also used to convert between weight and volume of soil. It is used to express soil physical, chemical and biological measurements on a volumetric basis for soil quality assessment and comparisons between management systems. Bulk density is changed by crop and land management practices that affect soil cover, organic matter soil structure, and/or porosity. Plant and residue cover protects soil from the harmful effects of raindrops and soil erosion. Cultivation destroys soil organic matter and weakens the natural stability of soil aggregates making them susceptible to damage caused by water and wind. When eroded soil particles fill pore space, porosity is reduced and bulk density increases. Cultivation can result in compacted soil layers with increased bulk density.

The effects of soil compaction on the soil strength, compressibility, hydraulic conductivity,

And structures have been well-studied (Assouline et al. 1997, Bowles 1992, Lambe and Whitman 1969, Seed and Chan 1959 Wendi et al 2001) and a series of standardized testing procedures have become widely adopted by professionals (Hunt 1986). The corresponding optimum moisture contents for the granular and silty to clayey soils are generally on the order of 5 to 15 percent and 20 to 35 percent, respectively (Abramson et al. 1995 Wendi et al 2001). It has been suggested that a growth-limiting bulk density (GLBD) might exist for each given soil texture. Daddow and Warrington (1983). Coppin and Richards (1990) agree that the critical dry density depends on the soil texture and suggest values of about 87 lb/ft3 (1.4 g/cm3) for clay soils and 106 lb/ft3 (1.7 g/cm3) for sandy soils. Jaramillo-C et al. (1992) studied the development of moisture-conducting tissues in the new roots of bean plants under varying compaction regimes. Results showed that soil compaction not only limited the length of roots, but the roots failed to properly develop the usual size and shape of metaxylem in high soil bulk densities, resulting in severely reduced transport capacity for water and nutrients. Compacted soils limit capillary radius of roots, which according to Poisseuille's law are able to transport water as a function of the fourth power of the radius. This effect is clearly an issue with new seedlings, and results suggest that problems in early development may persist as plants mature. Gale, Grigal, and Harding (1991) used a soil productivity index to predict white spruce growth. Their study suggested that soil compaction limits root development and hence nutrient and moisture uptake for younger trees, but that the forest floor becomes the dominant source of nutrients and intercepted rainfall provides moisture as trees mature. Landhaeuser et al. (1996) studied the effects of soil compaction on the depth and lateral spread of marsh reed grass.

Shear strength is also increased through root cohesion. The density of roots within the soil

Matrix, as well as their orientation, tensile strength, and length, affect the ability of soils to

Resist shear stress. As deformation begins to occur within a mass of soil, any roots that extend across the zone or plane of movement are placed under tension. Assuming that roots are well-anchored and do not pull out, the shear force is resisted by the tensile properties of the roots (Greenway 1987). In practice, the presence of roots often serves to significantly increase the strength of soils, in some cases by more than an order of magnitude. The shear strength of unsaturated soils can be assessed within conventional slope analyses by using the total cohesion method. The total cohesion (cT) includes three components: effective cohesion (c'), suction cohesion (cy) and root cohesion (cR) (Silva 1999). A common best management practice, especially for slopes, is to establish and derived from soil structure, which is promoted by biological activity, rather than the attributes readily analyzed through conventional testing (Burmister 1965). Soil systems that are ellvegetated and maintain fundamental physical properties including normal ranges of bulk density can perform biogeochemical functionsm which poorly managed soils cannot (Parr et al. 1992 Wendi et al 2001). Although these functions may not be a recognized priority in all current design considerations, they are becoming more widely understood.

2. Theoretical Background

Theoretical background for 3rd degree polynomial curve fitting

General: $y = a_0 + a_1 x + a_2 x^2 + a_3 x^3 + ... + a_n x^n$

If the above polynomial fits the pair of data (x, y) it means that every pair of data will satisfy the equation (polynomial).

Thus;

$$y_1 = a_0 + a_1 x_1 + a_2 x_1^2 + a_3 x_1^3 + ... + a_n x_1^n \tag{1}$$

$$y_2 = a_0 + a_1 x_2 + a_2 x_2^2 + a_3 x_2^2 + ... + a_n x_2^n \tag{2}$$

$$y_3 = a_0 + a_1 x_3 + a_2 x_3^2 + a_3 x_2^2 + ... + a_n x_2^n \tag{3}$$

$$y_4 = a_0 + a_1 x_4 + a_2 x_n^2 + a_3 x_n^2 + ... + a_n x_4^n \tag{4}$$

Summing all the equations will yield

$$\sum_{i=1}^{i=n} y_i = \sum a_0 + \sum_{i=1}^{i=n} a_1 x_i + \sum_{i=1}^{i=n} a_2 x_i^2 + \sum_{i=1}^{i=n} a_3 x_i^3 + \sum_{i=1}^{i=n} a_4 x_i^4 + ... + \sum_{i=1}^{i=n} a_n x_i^n$$

$$\boxed{\sum_{i=1}^{i=n} y_i = n a_0 + a_1 \sum_{i=1}^{n} x_i + a_2 \sum_{i=1}^{n} x_i^2 + a_3 \sum_{i=1}^{n} x_i^3 + ... + \sum_{i=1}^{n} x_i^n} \tag{5.}$$

To form the equations to solve for the constants $a_0, \, a_1, \, a_2, a_3, \, ...a_n$.

We multiply equations (5) by $x_{i,} \; x_i^2 \, , \; x_i^3 .... \; x_i^n$.

Multiply equation (6) by x_i

$$x_i \sum y_i = na_0 \, x_i + a_1 \, x_i \sum x_i + a_2 \, x_i \sum x_i^2 + a_3 \, x_i \sum x_1^3 + ... + a_n \, x_i \sum x_i^n$$

$$\sum y_i \, x_i = a_0 \sum x_i + a_1 \sum x_i^2 + a_2 \sum x_i^3 + a_3 \sum x_i^4 + ... + a_n \sum x_i^{n+1} \qquad (7)$$

Multiply equation (6) by x_i^2

$$x_i^2 \sum y_i = na_0 \, x_i^2 + a_1 \, x_i^2 \sum x_i + a_2 \, x_i^2 \sum x_i^2 + a_3 \, x_i^2 \sum x_i^3 + ... + a_n \, x_i^2 \sum x_i^n \qquad (8)$$

$$\sum y_i \, x_i^2 = a_0 \sum x_i^2 + a_1 \sum x_i^3 + a_2 \sum x_i^4 + a_3 \sum x_i^5 + ... + a_n \sum x_i^{n+2} \qquad (9)$$

Multiply equation (3.84) by x_i^3

$$x_i^3 \sum y_i = na_0 \, x_i^3 + a_1 \, x_i^3 \sum x_i + a_2 \, x_i^3 \sum x_i^2 + a_3 \, x_i^3 \sum x_i^3 + ... + a_n \, x_i^3 \sum x_i^n$$

$$\sum y_i \, x_i^3 = a_0 \sum x_i^3 + a_1 \sum x_i^4 + a_2 \sum x_i^5 + a_3 \sum x_i^6 + ... + a_n \sum x_i^{n+3} \qquad (10.)$$

Multiply equation (5,6 and 7) by x_i^n

$$x_i^n \sum y_i = a_0 n \, x_i^n + a_1 \, x_i^n \sum x_i + a_2 \, x_i^n \sum x_i^2 + a_3 \, x_i^n \sum x_i^3 + ... + a_n \, x_i^n \sum x_i^n$$

$$= a_0 \sum x_i^n + a_1 \sum x_i^{n+1} + a_2 \sum x_i^{n+2} + a_3 \sum x_i^{n+3} + ... + a_n \sum x_i^{n+n} \qquad …….. \; n$$

Putting equations (5, 6, 7, 8, and 9) to n into matrix form

$$\begin{bmatrix} n & \sum x_i & \sum x_i^2 & \sum x_i^3 & \ldots\ldots \sum x_i^n \\ \sum x_i & \sum x_i^2 & \sum x_i^3 & \sum x_i^4 & \ldots\ldots \sum x_i^{n+1} \\ \sum x_i^2 & \sum x_i^3 & \sum x_i^4 & \sum x_i^5 & \ldots\ldots \sum x_i^{n+2} \\ \sum x_i^3 & \sum x_i^4 & \sum x_i^5 & \sum x_i^6 & \ldots\ldots \sum x_i^{n+3} \\ \ldots & \ldots & \ldots & \ldots & \ldots \\ \sum x_i^n & \sum x_i^{n+1} & \sum x_i^{n+2} & \sum x_i^{n+3} & \ldots \sum x_i^{n+n} \end{bmatrix} \begin{bmatrix} a_0 \\ a_1 \\ a_2 \\ a_3 \\ \ldots. \\ a_n \end{bmatrix} = \begin{bmatrix} \sum y_i \\ \sum y_i x_i \\ \sum y_i x_i^2 \\ \sum y_i x_i^3 \\ \ldots \\ \sum y_i x_i^n \end{bmatrix}$$

Solving the matrix equation yields values for constants $a_0, a_1, a_2, a_3, \ldots\ldots a_n$ as the case may be depending on the power of the polynomial.

From the above matrix; for our particular case; i.e. polynomial of the third order:

$$y = a_0 + a_1 x + a_2 x^2 + a_3 x^3 \qquad (11)$$

The equivalent matrix equation will be; ($n = 3$).

$$\begin{bmatrix} n & \sum x_i & \sum x_i^2 & \sum x_i^3 \\ \sum x_i & \sum x_i^2 & \sum x_i^3 & \sum x_i^4 \\ \sum x_i^2 & \sum x_i^3 & \sum x_i^4 & \sum x_i^5 \\ \sum x_i^3 & \sum x_i^4 & \sum x_i^5 & \sum x_i^6 \end{bmatrix} \begin{bmatrix} a_0 \\ a_1 \\ a_2 \\ a_3 \end{bmatrix} = \begin{bmatrix} \sum y_i \\ \sum y_i x_i \\ \sum y_i x_i^2 \\ \sum y_i x_i^3 \end{bmatrix}$$

3. Results and Discussion

Tables: 1 Comparison of predictive Data values at Different Depths

Depth mm	Predictive	Measured Predictive values
200	2.33	2.13
400	2.32	2.11
600	2.31	2.07
800	2.3	2.02
1200	2.26	1.88
1400	2.23	1.8
1600	2.2	1.71
1800	2.17	1.61
2000	2.13	1.5

2500	**2.02**	**1.2**
3000	**1.88**	**0.88**
4000	**1.53**	**0.22**
5000	**1.08**	**-0.35**

Tables: 2 Comparison of predictive Data values at Different Depths

Depth mm	Predictive values 1	Measured predictive values 2
200	**2.28**	**2.2**
400	**2.27**	**2.18**
600	**2.26**	**2.14**
800	**2.25**	**2.09**
1200	**2.21**	**1.96**
1400	**2.18**	**1.87**
1600	**2.15**	**1.77**
1800	**2.12**	**1.67**
2000	**2.08**	**1.57**
2500	**1.97**	**1.27**
3000	**1.83**	**0.95**
4000	**1.49**	**0.29**
5000	**1.04**	**-0.29**

Tables: 3 Comparison of predictive Data values at Different Depths

Depth mm	Predictive values 1	Measured predictive values 2
200	**2.32**	**2.32**
400	**2.32**	**2.33**
600	**2.33**	**2.33**
800	**2.34**	**2.34**
1200	**2.37**	**2.38**
1400	**2.39**	**2.39**
1600	**2.42**	**2.42**
1800	**2.45**	**2.45**
2000	**2.48**	**2.48**
2500	**2.57**	**2.57**
3000	**2.97**	**2.68**
4000	**2.96**	**2.96**
5000	**3.31**	**3.31**

Tables: 4 Comparison of predictive Data values at Different Depths

Depth mm	Predictive values 1	Measured predictive values 2
200	2.14	2.02
400	2.13	1.99
600	2.12	1.95
800	2.11	1.91
1200	2.07	1.77
1400	2.04	1.69
1600	2.02	1.51
1800	1.98	1.49
2000	1.94	1.38
2500	1.83	1.09
3000	1.69	0.76
4000	1.34	0.1
5000	0.89	-0.47

Tables: 5 Comparison of predictive Data values at Different Depths

Depth mm	Predictive values 1	Measured predictive values 2
200	1.29	1.29
400	1.72	1.61
600	1.88	1.88
800	2.11	2.1
1200	2.43	2.42
1400	2.54	2.53
1600	2.61	2.6
1800	2.66	2.65
2000	2.68	2.67
2500	2.64	2.63
3000	2.51	2.51
4000	2.2	2.19
5000	2.17	2.17

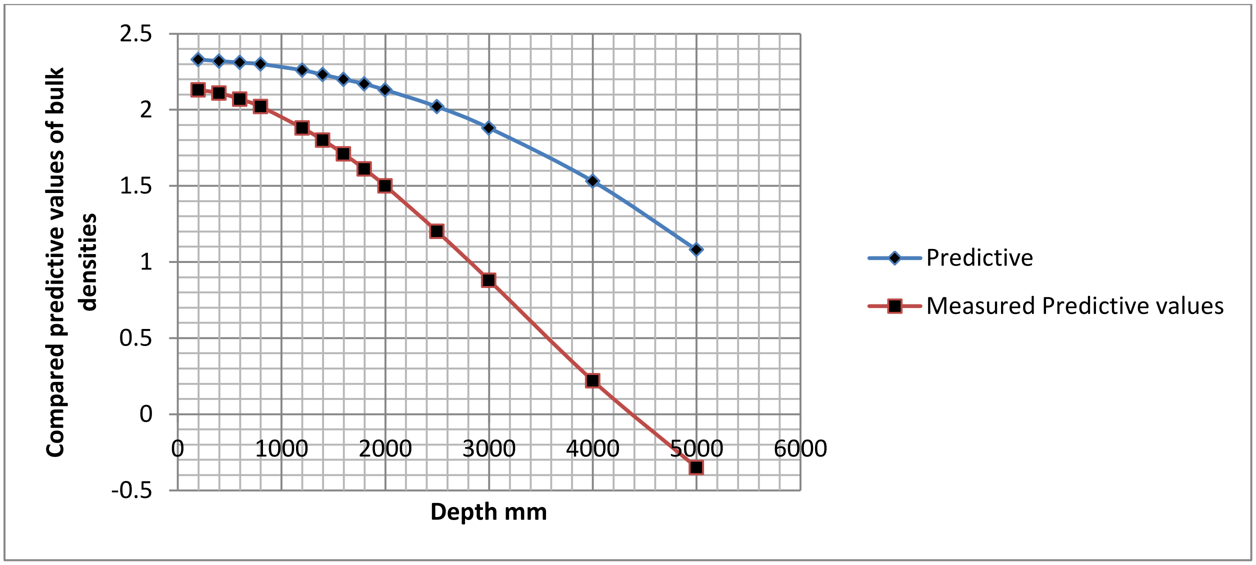

Figure: 1 Comparison of predictive Data values at Different Depths

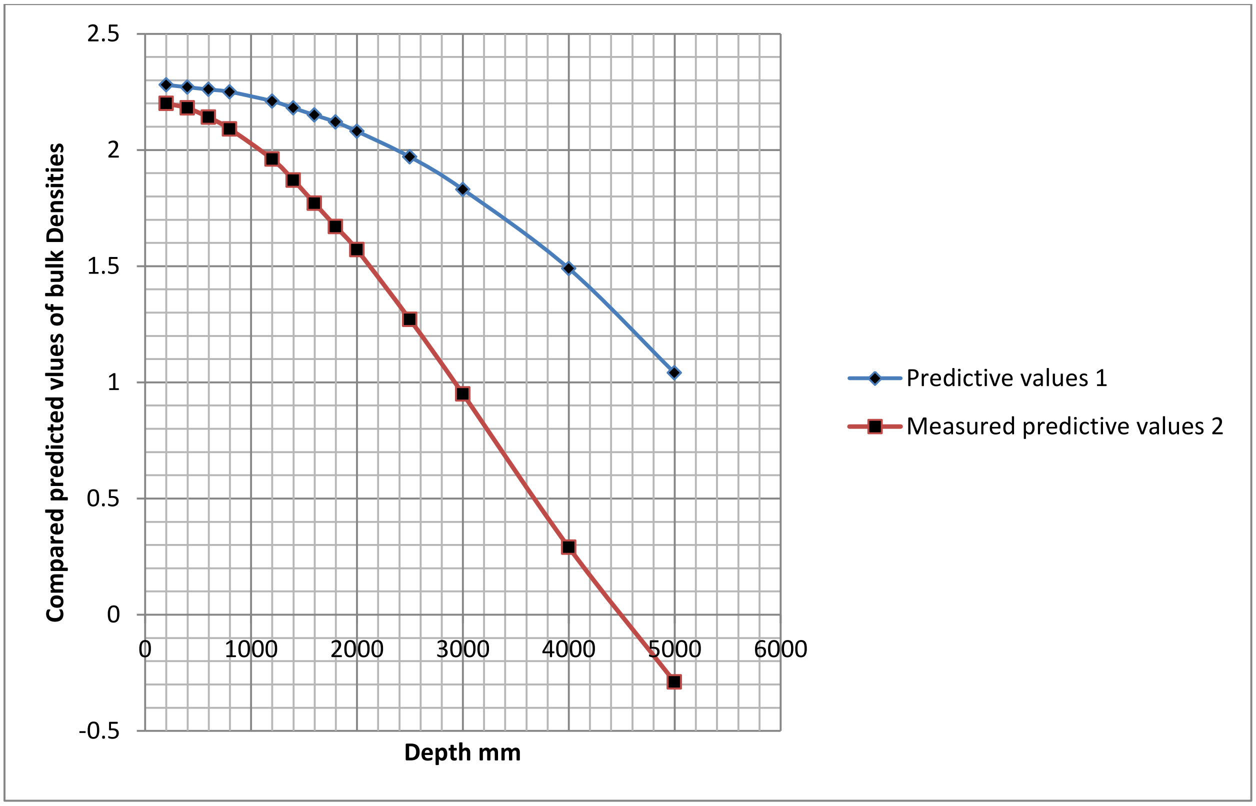

Figure: 2 Comparison of predictive Data values at Different Depths

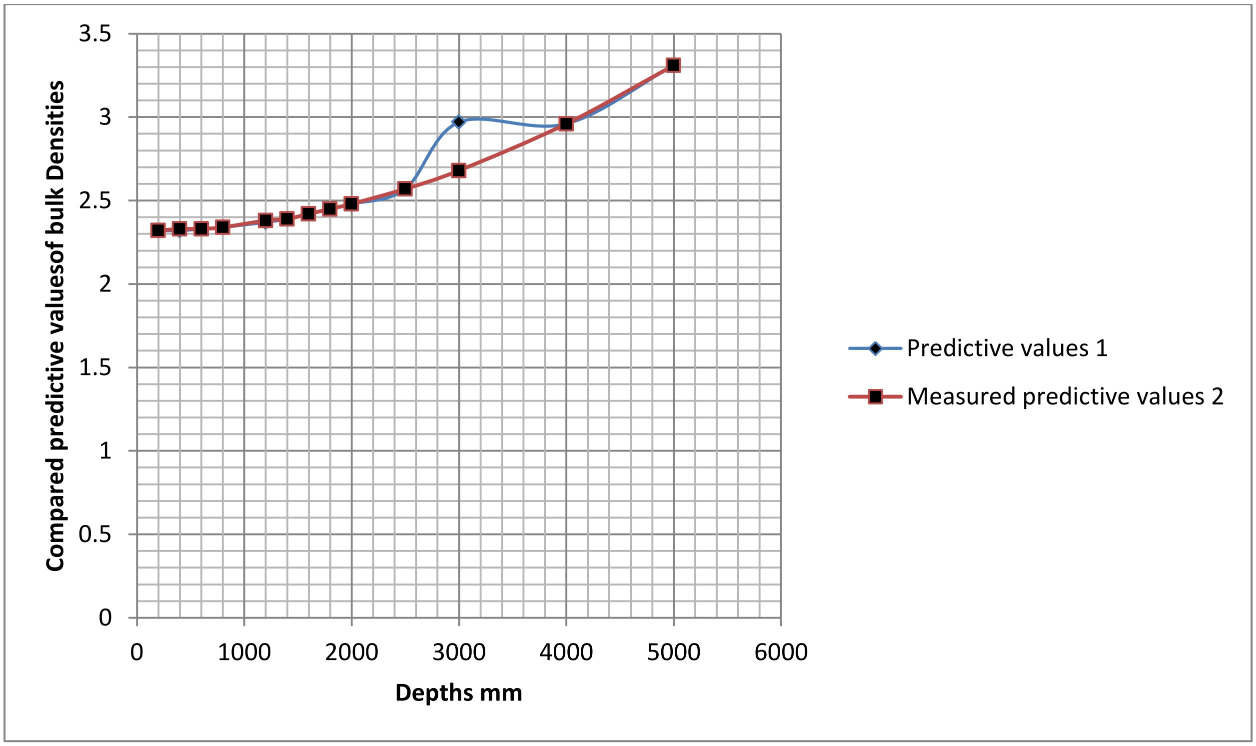

Figure: 3 Comparison of predictive Data values at Different Depths

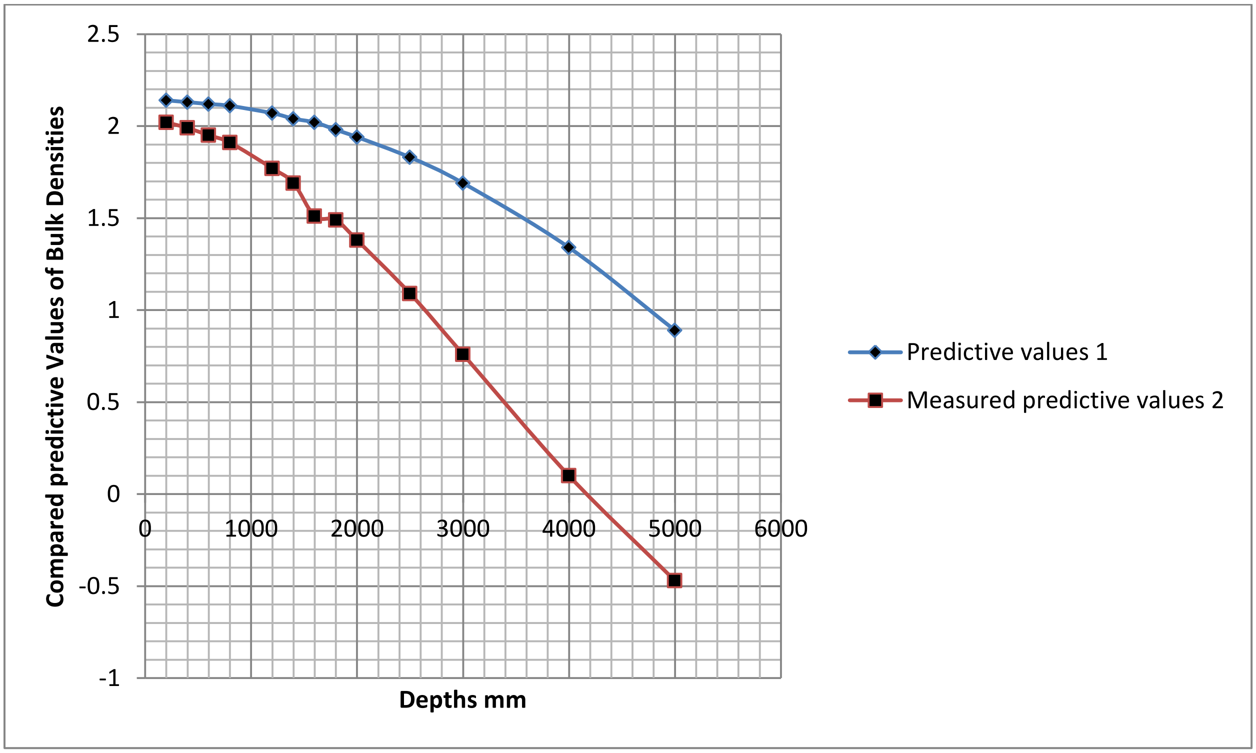

Figure: 4 Comparison of predictive Data values at Different Depths

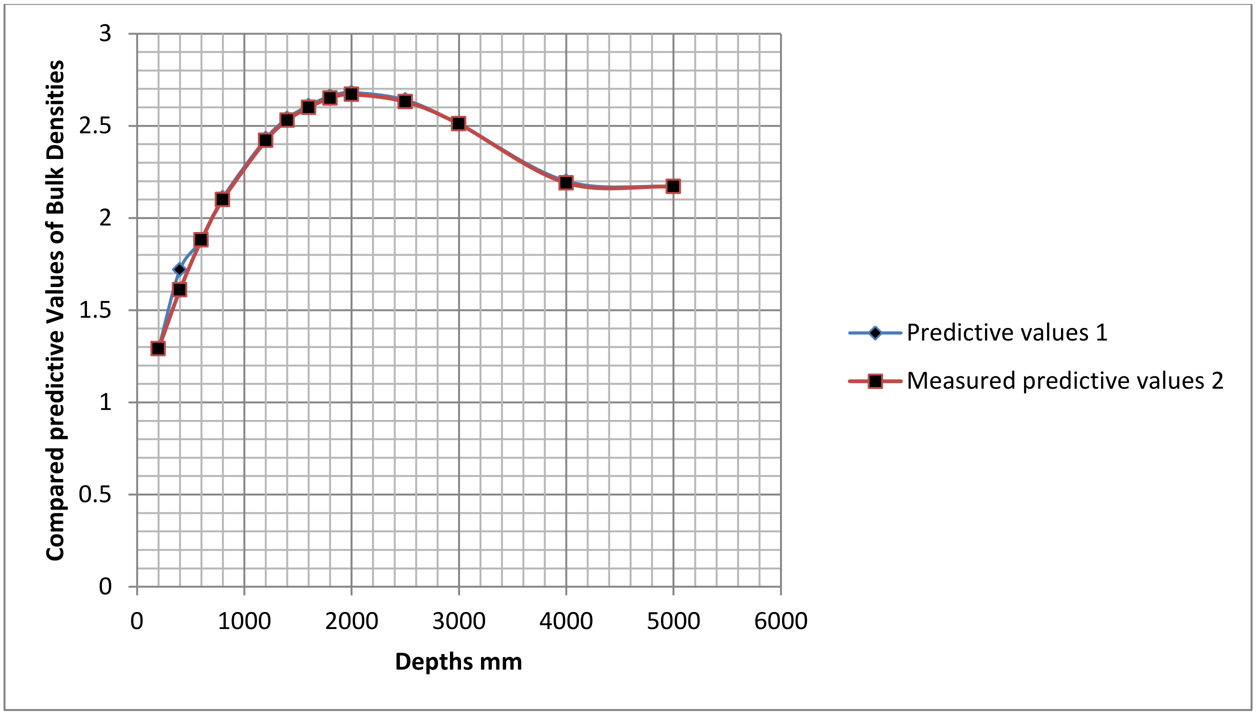

Figure: 5 Comparison of predictive Data values at Different Depths

Maximum density does not represent a soil condition with no voids remaining, rather one where the tightest possible packing arrangement is achieved given compaction conditions. Soil compaction is defined as the method of mechanically increasing the density of soil. In construction, this is a significant part of the building process. If performed improperly, settlement of the soil could occur and result in unnecessary maintenance costs or structure failure. Almost all types of building sites and construction projects utilize mechanical compaction techniques. Several reasons projected why bulk densities should be done in soil formations, these are base on different condition that definitely needs the determination of bulk desensitizes in soil, base on these developments the following figures express compared predictive values in this form, figure one and two developed there optimum values at 200 mm and gradually decrease with depths to the lowest recorded at 5000 mm, while figure three developed different results compared to one and two there was an increase from 200mm to the where the optimum was recorded at 5000mm, but figure four establish different condition as the optimum values was recorded at 5000mm, developing gradual increase with increase in depths, figure five of both parameters express fluctuation, the optimum values was recorded at 2002mm, it finally maintained a constant trend from 4000 to 5000mm, this condition are base on the variation of stratification as expressed in the formations of the soil.

4. Conclusion

Bulk density in a soil is a measurement of the total volume of both the particles and pore space within a sample. Sands have higher bulk densities than clay soils because the clays have more pore space and are lighter by volume. Loamy soils, a mixture of sand, silt and clay have moderate bulk densities between that of sands and clays. The addition of organic matter to a soil is typically a low percentage that does not significantly influence the measurement of bulk density. Soil scientists use one of several methods to determine the bulk density of a sample including the clod method, core method, excavation method or the radiation method, which all involve determining the mass and volume of the sample. More so Bulk density is an indicator of soil compaction. It is calculated as the dry weight of soil divided by its volume. This volume includes the volume of soil particles and the volume of pores among soil particles. Bulk density is typically expressed in g/cm3.Why it is important: Bulk density reflects the soil's ability to function for structural support, water and solute movement, and soil aeration. Bulk densities above thresholds indicate impaired function. Bulk density is also used to convert between weight and volume of soil. It is used to express soil physical, chemical and biological measurements on a volumetric basis for soil quality assessment and comparisons between management systems. This increases the validity of comparisons by removing error associated with differences in soil density at time of sampling.

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