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Study on the Effects of Particle Size Characteristics on Compaction Parameters of Fine Grained Soils

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Abstract: Because of the importance of compaction of soil in civil engineering construction works - road construction, foundation, embankments, dams, etc – there has been continuous attempt to study the relationships between easily-determined soil properties and compaction parameters. This study therefore investigated the relationship between particle size characteristics and compaction parameters of fine-grained soils used as fill materials. This was with a view to developing models that could be used for easy and fast determination of compaction parameters of soil. To achieve the aim of the study, lateritic soil samples were obtained from selected locations. Preliminary, particle size analysis and compaction tests were conducted on the soil samples, using standard procedure. Particle size characteristics (effective sizes – D_{10} , D_{30} , D_{60} ; coefficient of curvature, C_c and coefficient of uniformity, C_u) were determined from the particle size distribution curves. Using Microsoft Excel and Xuru's Regression tools, the laboratory test results were used to develop relationships between compaction parameters (optimum moisture content and maximum dry density) and particle size characteristics. Results showed that the optimum moisture content ranged between 6.7 % and 27 %, while the maximum dry density ranged between 1560 kN/m^3 and 2260 kN/m^3 . The results of regression analysis showed that the combination of D_{30} and C_u has a strong correlation with maximum dry density ($R^2 = 0.90$); while the combination of D_{30} and D_{60} showed a fair correlation with optimum moisture content ($R^2 = 0.43$). The study concluded that D_{30} and C_u could be used to estimate the maximum dry density of the soils, by applying the developed equation.

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1. Introduction

Soil is generally categorised as either coarse-grained (gravel and sand) or fine-grained (clay and silt). The characteristics of the coarse grained material are mostly controlled by grain size as well as grain size distribution, and sometimes by particle shape; while the characteristics of fine-grained soil are also governed by clay mineral as well as water content (Peterson, 1946).

Some soils contain a wide range of particle size (referred to as well graded) while others formed by several particle sizes (referred to as gap-graded) and a narrow range of particle size (referred to as uniform graded). The structural arrangement of the particles may be loose, medium dense or dense, depending on the packing of the material. According to Worku and Shiferaw (2004), particle sizes provide quantitative data on the range of sizes of particles and the relative proportions, by weight, of each size. From

particle sizes, it is possible to tell whether the soil consists of predominantly gravel, sand, silt or clay sizes and to a limited extent which of these size ranges is likely to control the engineering properties. The sizes of the soil particles, especially in granular soils, have some effect on the engineering behaviour of a given soil (Masih, 2000).

Compaction of soil is a process of densifying the soil by application of stress which causes expulsion of air in the interstices of soil mass. Compaction of soil is one of the important geotechnical engineering applications in the development of infrastructure projects - construction of roads, flyovers retaining structures and many land reclamation works (Ratnam and Prasad, 2019). As a matter of fact, compaction of soil has applications in almost every field of civil engineering involving soil. The strength and durability of the foundation strata are dependent on the quality of compaction i.e., method of

compaction and the characteristics of the soils used. This means that compaction properties play a big role in deciding strength and durability of foundation material, fill material, etc. It is therefore essential to assess the suitability of soils with respect to the compaction parameters. The compaction parameters of a soil as obtained from a laboratory compaction test are maximum dry density (MDD) and optimum moisture content (OMC). It has been observed that these compaction parameters depend on the nature of soil, including grain size distribution and plasticity characteristics (Kumar *et al.*, 2018).

Thus, for a civil engineer, it is very essential to know the compaction parameters of natural soils, and thereby assess their suitability. In such situations, to obtain compaction parameters, one has to carry out a laboratory compaction test. But laboratory compaction test requires sufficient time and effort. For a preliminary assessment of the suitability of soils required for large project, it is desirable to develop correlations of compaction properties with simple physical or index properties, which are obtained through simple tests known as index tests. Correlations making use of index properties can be quite useful (AASHTO, 2003).

There is therefore a growing research interest on the prediction of soil properties using mainly grain size distributions, void ratios, and soil particle characteristics (Marquette University, 2000). Studies have been done in the past to establish relationships between the compaction parameters and simple soil properties like the grain-size distribution. The objective has been to predict the compaction parameters for quick applications, without the need to perform laborious compaction tests.

Worku and Shiferaw (2004) predicted the MDD of granular fill materials using the specific gravity and the gradation coefficients that characterised the grain size distribution of the soil samples. They observed that, for the tested samples, a strong correlation existed between the MDD and the specific gravity; while there was a weak correlation between the MDD and the gradation coefficients (C_c and C_u) is weak. They also observed that, a test on a soil of relatively high solid density showed that the developed relation loses its power of prediction when applied on soils of specific gravity beyond the range studied.

Mujtaba *et al.* (2013) developed a predictive model between gradation characteristics, compaction energy (CE), and compaction parameters (MDD and OMC) of sandy soils. The multiple regression analyses carried out on the experimental data yielded a

predictive model to express compaction parameters in terms of C_u and CE. After validating the developed models, they observed that, the variation between experimental and predicted values of MDD is within the $\pm 5\%$ confidence interval, and that of the OMC is within ± 3.0 . They concluded that the proposed models are useful for quick estimation of MDD and OMC without performing the laboratory compaction tests.

Kumar *et al.* (2018) employed gradation and plasticity characteristics (i.e. grain size distribution and plasticity index) to predict the compaction parameters of red soils. They concluded, among others, that the models developed by multi linear regression analysis (MLRA) for correlating OMC and MDD values with gradation have shown strong relationships.

The purpose of compacting earth fills such as earthen dams, embankments in highway, railway and canal constructions is to produce a soil mass that will result in increasing the strength and stability apart from reducing the permeability. For preliminary design and assessment, correlations with simple index properties have been attempted by various investigators. Though many a researcher focused on developing empirical correlations between basic properties and compaction parameters, it has not yet been possible to bring out the functional relationships in a unified and coherent manner. This study therefore seeks to add to the body of knowledge on the development of relationships between particle characteristics and compaction parameters of soils. This work presents the concluding part of a study reported earlier (Adunoye *et al.*, 2020). The specific objectives were to: (i) characterize selected soil samples; (ii) determine the compaction parameters of the soil samples; and (iii) develop quantitative relationships between particle size characteristics and compaction parameters.

Description and geology of the study area

The study area is the Obafemi Awolowo University (OAU) campus, Ile-Ife, Southwestern Nigeria (Figure 1). Ile -Ife lies between Latitudes $7^{\circ}28'0''N$ and $7^{\circ}45'0''N$ and Longitudes $4^{\circ}30'0''E$ and $4^{\circ}34'0''E$. The OAU campus is located within the Ife-Ilesha Schist Belt. The campus falls within the Basement Complex area of Nigeria (Durotoye, 1983). The rock types are primarily made up of Gneisses and Mica Schists into which some minor granitic and basic rocks have intruded (Boesse, 1989; Adunoye *et al.*, 2018). Figure 2 is the geological map of OAU, Ile-Ife.

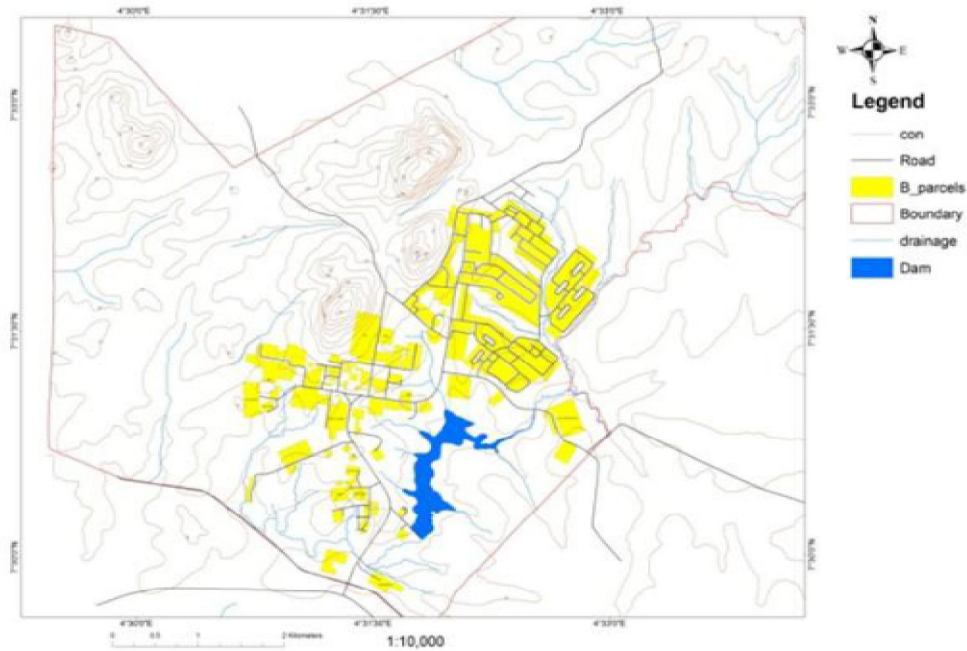


Figure 1: Map of Obafemi Awolowo Unuversity campus (OAU, 2015)

2. Material and Methods

Soil sampling

Lateritic soil is the main material used in this study. Ten sample points were identified in the study area; and in each of the identified sampling points, test pits were dug and excavated with the aid of digger and shovel. Samples were collected at a depth ranging between 0.3 m and 0.6 m (Adunoye *et al.*, 2020). 20 - 25 kg of each sample was collected into a nylon, sealed and immediately taken to the Geotechnical Laboratory of the Department of Civil Engineering, Obafemi Awolowo University (OAU), Ile-Ife, for analyses.

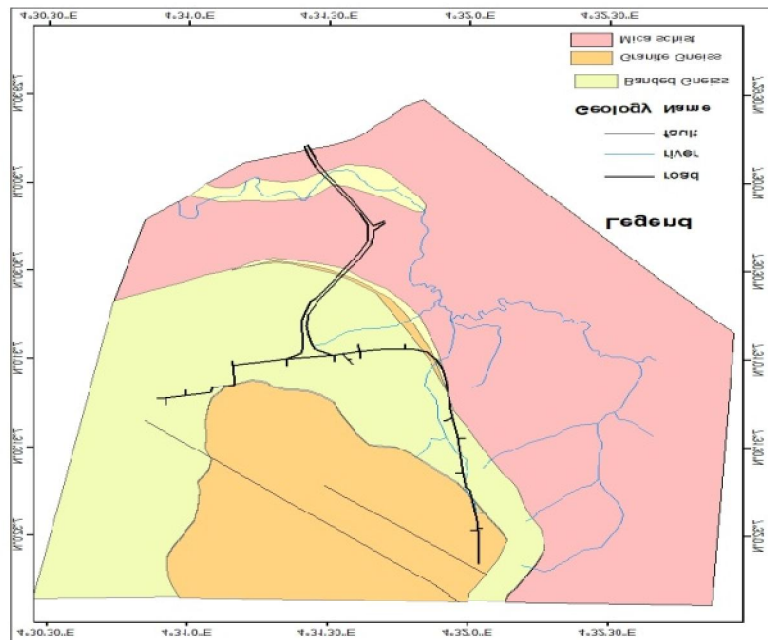


Figure 2: Geological map of Obafemi Awolowo University, Ile-Ife (After Boesse, 1989)

Laboratory analyses

Samples were prepared for laboratory analyses by air-drying and grinding to pass 2 mm sieve. Thereafter particle size analysis and compaction tests were conducted on the soil samples. The tests were carried out in accordance with British standard code of practice (BS 1377:1990). Standard Proctor method was used for the compaction. From the particle size distribution curves (generated from the particle size analysis), coefficient of uniformity (C_u) and coefficient of gradation (C_c) were determined using equations 1 and 2 respectively.

$$C_u = \frac{D_{60}}{D_{10}} \quad (1)$$

$$C_c = \frac{D_{30}^2}{D_{60} \times D_{10}} \quad (2)$$

Where, C_u = coefficient of uniformity

C_c = coefficient of gradation

D_{10} = diameter corresponding to 10 % finer

D_{30} = diameter corresponding to 30 % finer

D_{60} = diameter corresponding to 60 % finer

Relating compaction parameters and particle size characteristics

Variations of compaction parameters (OMC and MDD) and particle size characteristics (C_u and C_c) were studied, using excel tool. Also, using Xuru's regression tools (2020), relationships (equations) were developed between the following properties of the soil samples: (i) OMC and particle size characteristics, and (ii) MDD and particle size characteristics.

3. Results and Discussion

Results of laboratory tests and analyses on the soil samples are presented in Table 1.

Compaction test results

As presented by Adunoye *et al.* (2020), the results of the compaction tests (Table 1), values of OMC ranged from 6.7 % (sample L3) to 27 % (sample L1). The values of MDD also ranged from 1560 kN/m³ (sample L8) to 2260 kN/m³ (sample L10). With the results of the compaction test, the soils could be said to fall between silty clay and sandy clay (O'Flaherty 1988; Bello and Adegoke, 2010; Adunoye and Agbede, 2013).

Table 1: Particle size characteristics and compaction parameters of soil samples (Adunoye *et al.*, 2020)

Sample ID	D ₁₀	D ₃₀	D ₆₀	C _u	C _c	MDD (kN/m ³)	OMC (%)
L1	0.5	1.8	5	10	1.3	1570	27
L2	1.1	2	4	3.64	0.91	1722	22
L3	0.43	1.2	2.36	5.55	1.44	1850	6.7
L4	0.21	1.2	2.5	11.79	2.72	1680	15.5
L5	0.38	1	1.8	4.74	1.46	1900	13.8
L6	0.35	1.2	3	8.57	1.37	1620	35
L7	0.28	1.42	2.5	8.93	2.88	1630	16.1
L8	0.71	2.12	3.9	5.49	1.62	1560	17.25
L9	0.23	1.2	1.95	8.48	3.21	1740	18.5
L10	0.29	0.72	2.7	9.31	0.66	2260	15.6

Particle size analysis

The particle size characteristics of the soil samples (see Table 1) have the following values: D_{10} ranged between 0.212 (L4) to 1.10 (L2); D_{30} ranged between 0.72 (L10) to 2.12 (L8); D_{60} ranged between 1.80 (L5) to 5.0 (L1); C_u ranged between 4.74 (L5) and 11.79 (L4); C_c ranged between 0.66 (L10) and 3.21 (L9). According to Ismail (2008), $C_u < 3$ indicates a uniform soil and $C_u > 5$ indicates a well-graded soil. Also, most well-graded soils

will have grading curves that are mainly flat or slightly concave, giving values of C_c between 0.5 and 2.0. $C_c < 0.1$ indicates a possible gap-graded soil (Ismail, 2008). Therefore, it could be concluded that majority (80 %) of the soil samples are well-graded. Meyerhof (1963) observed that well graded soils form a denser packing and thus have higher dry density as compared to gap and uniform graded soils because in well graded soils, the finer particles fill the void formed by coarse particles resulting in a more compacted material, and providing more interlocking within the material. This further confirms the fact that the soils are good subgrade material.

Effect of particle size characteristics on optimum moisture content (OMC)

Figures 3 and 4 show the variations of compaction parameters – OMC and MDD – with particle size characteristics, respectively. It was observed that none of the particle size characteristics singularly gave a predictable relationship with either OMC or MDD of the soils. Consequently, a trial of the combined effects of the particle size characteristics and multiple regression analysis gave the following mathematical equations:

$$OMC = -22.923D_{30}^2 + 8.18D_{30}D_{60} - 3.40D_{60}^2 + 31.51D_{30} + 18.16D_{60} - 33.82 \quad (R^2 = 0.43) \quad (3)$$

$$MDD = 610.01D_{30}^2 - 2.37D_{30}C_u + 2.81C_u^2 - 2157.84D_{30} - 54.08C_u + 3717.12 \quad (R^2 = 0.90) \quad (4)$$

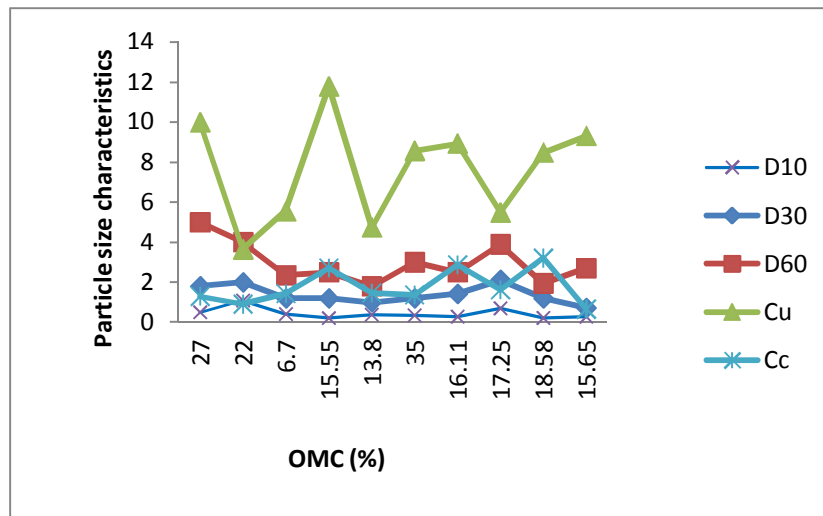


Figure 3: Variation of optimum moisture content with particle size characteristics

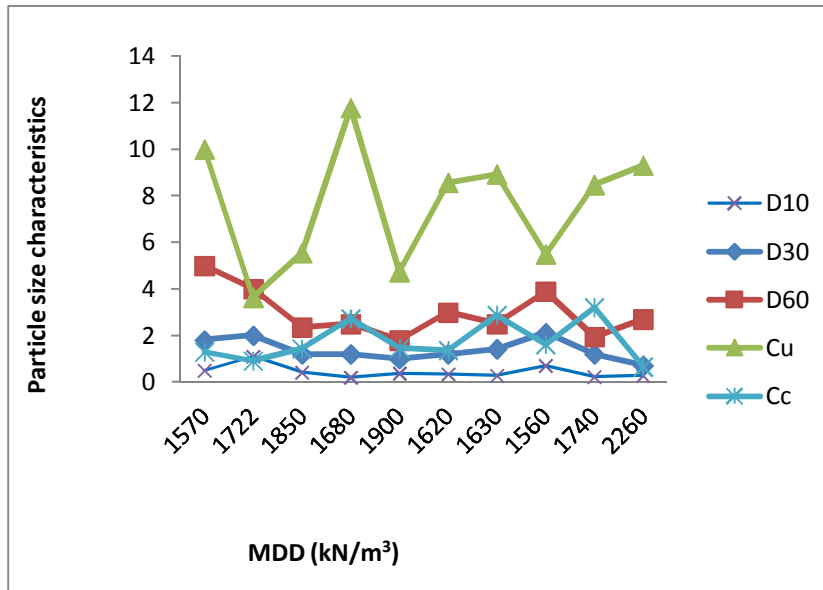


Figure 4: Variation of maximum dry density with particle size characteristics

From the values of coefficients of determination (R^2) in the generated equations, it could be said that the combination of D_{30} and D_{60} has a fair correlation with OMC; while the combination of D_{30} and C_u has a strong correlation with MDD (Shahin *et al.*, 2009).

4. Conclusion

Relationships between compaction parameters (OMC and MDD) of selected soil samples had been studied. The following conclusions are made in relation to the set objectives: (i) none of the particle size characteristics singularly had a good relationship with the compaction parameters; and (ii) only the combination of D_{30} and C_u has a strong correlation with maximum dry density.

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References

1. AASHTO (2003), *American Association of State Highway and Transportation Officials, User Benefit Analysis for Highways*.
2. Adunoye, G. O. and Agbede, O. A. (2013) Geotechnical evaluation of Opa dam, Obafemi Awolowo University, Ile-Ife, Nigeria. *The International Journal of Engineering and Science* 2(2), 160 – 165.
3. Adunoye, G. O., Badmus, A. B., Sagbele, S. A. (2018). Experimental Investigation of the Influence of Gradation Parameters on Atterberg Limits of Soil. *Archives of Current Research International*, 15(4): 1-6.
4. Adunoye, G. O., Ojo, A. A., Alasia, A. F., Olarewaju, M. O. (2020). A study on the correlation potential of compaction compaction characteristics and Atterberg limits of selected lateritic soils. *International Journal of Physical Research*, 8(1): 22-26.
5. Bello A. A. and Adegoke C. W. (2010) Evaluation of geotechnical properties of Ilesha East Southwest Nigeria's lateritic soil. *Pacific Journal of Science and Technology* 11(2), 617-624.
6. Boesse, J. M. (1989). A Geological map of the Obafemi Awolowo University Campus (Unpublished), Department of Geology, Obafemi Awolowo University, Ile-Ife.
7. British Standard (1990). *Methods of test for soils for civil engineering properties*. London, UK: British Standard Institution.
8. Durotoye, A.B. (1983). *Quaternary Sediments in Nigeria*. Edited by Kogbe C.A.
9. Federal Ministry of Works and Housing (1997). *Nigerian General Specification for Roads and Bridges (Revised Edition) 2*, 137-275.
10. Ismail, M. M. (2008). Mathematical correlations between the effective diameters of soil and other properties. *Eng. & Technology*, 26(10): 1274-1281.
11. Kumar, C. V., Satyanarayana, P. V. V. and Satyanarayana, B. (2018). Prediction of Compaction Characteristics Gradation and Plasticity Characteristics of Red Soil. *SSRG-International Journal of Civil Engineering*, 5(12): 22-26.
12. Marquette University, Department of Civil and Environmental Engineering (2000). "*CEEN 043-Behavior, and Properties of Engineering Materials: Statistical Analysis and Quality Control Review Notes*".
13. Masih, R. (2000), "*Formula to Get Desired Density*", *Journal of Geotechnical and Geoenvironmental Engineering*, ASCE, Volume 126, Issue 12, pp 1145-1150.
14. Meyerhof, G. G. (1963). Some recent research on the bearing capacity of foundations. *Canadian Geotech. Journal* 1(1): 16.
15. Mujtaba, H., Farooq, K., Sivakugan, N., Das, B.M. (2013). Correlation between gradational parameters and compaction characteristics of any soils. *International Journal of Geotechnical Engineering* 7, 4, 395-401. DOI:10.1179/1938636213Z.00000000045.
16. Obafemi Awolowo University, Ile-Ife (2015). *Map of Obafemi Awolowo University, Ile-Ife*.
17. O'Flaherty CA (1988) *Highway engineering 2*. Edward Arnold Publishers, London, UK.
18. Peterson, J. B. (1946). The role of clay minerals in the formation of soil structure. *Soil Science* 61:247-256.
19. Ratnam, U. V. and Prasad, K. N. (2019). Prediction of Compaction and Compressibility Characteristics of Compacted Soils. *International Journal of Applied Engineering Research*, 14(3): 621-632.

20. Shahin, M. A., Jaksa, M. B. and Maier, H. R. (2009). Recent Advances and Future Challenges for Artificial Neural Systems in Geotechnical Engineering Applications. *Advances in Artificial Neural Systems* 2009, 1-9, <https://doi.org/10.1155/2009/308239>.
21. Worku and Shiferaw (2004). Prediction of Maximum Dry Density of Local Granular Fills, *Journal of EEA*, Vol. 21, 59-70.
22. Xuru's regression tools. Available: <http://www.xuru.org>. Accessed on 10 October 2020.

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