Investigating Sand as Wearing Course in Rural Roads

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Abstract: Road transportation in rural areas is one of the main means of conveying people, farmers, farm implements and farm produce from the rural dwellings and farms unfortunately the dearth of investment and maintenance of road infrastructure in rural communities and also the growing use of these roads has made the plying of such roads to be worrisome because of its implication on the safety of those using the road. The consequence of the badly rutted, sandy or muddy roads is the increase in the cost of transporting agricultural produce to farm which will inevitably contribute to increasing food prices. The need to make sandy rural road to have a suitable wearing course necessitated the collection of sand samples from a community in Yewa South Local Government Area of Ogun State Nigeria. Particle size distribution, in-situ density, compaction, relative density, relative compaction and California bearing ratio (CBR) were conducted on the sand samples. The soil profile was 300mm thick at the point the sample was obtained. The results obtained from the tests indicated that; the sand was well graded (SW) in accordance to the unified soil classification system. The CBR values obtained were 23.23% and 22% and the result of relative compaction was 65% which is less than the 90-95% stipulated by relevant standard and this can be attributed to the natural compaction of the soil done by the flowing water as against when a compactive effort is applied. For the sandy road to be plied all year round, the moisture content of the sand should be kept at a value well above 1.3% and the thickness of the wearing course should not be less than 300mm.

Keywords: California Bearing Ratio, Infrastructure, sandy, Rural Road, Transportation, Wearing Course

I. Introduction

Rural roads exist in many parts of the country with low traffic volume and despite this, many of them are in deplorable state, especially earthen road and some lead to farms. Network of good roads linking the rural and the urban areas helps in transporting farm produce to the markets without ant stress but when the roads are bad, this will affect the production and distribution of the farm produce, this will invariably impact on the achievement of the Sustainable Development goal 2; targets 3 and 4 and this will have direct implication on SDG 1.

Most rural areas with sandy road network have always experience nightmares especially during the months of dry season, when the sand becomes so loose that traffic (especially cars and motorcycles) abandoned the routes for alternatives, because they have become when almost impassable (due to its looseness in density).

Solutions to problems associated with rural roads with earthen and surface dressing are sought daily and this research will open a new vista in the design and construction of rural road. Lack of maintenance of these roads has worsened their state, thereby making life difficult for traffic plying them in those categories and on the economy.

A lot of materials had been suggested and used, leading to various modifications and researchers are not relenting in finding solutions to problems associated with rural roads which earthen and surface dressing roads that are the hallmark of rural roads.

Sand is a granular material from the weathering of rock mostly made of silica with sizes between 2.0mm to 0.06mm. However, the Unified Soil Classification system classified sand as material between 0.075 and 4.75mm whereas the southern African and American roads terminology stipulated a minimum size at 0.075mm. It's worth noting that few sands are within this range, either with fineness less than 0.075mm or a small coarse constituents greater than 2mm

The weathering process and the material's nature determined the composition of the sand which is an indicator of the mineralogical composition of the sands, silts and clays present. Further modifications of these materials will be by the transportation through water and wind thereby influencing the particle sizes, shapes and sorting. Also, the compaction, degree and type of consolidation influence its geotechnical behaviors in road construction.

Due to the fact that sand as a non-cohesive soil would not absorb water for a very long time, this has been a serious problem for all forms of traffic playing the road from time to time. During wet seasons, the road is much more motor able, but during dry season, it is almost impossible for vehicles to ply that road due to the looseness of the sand as a result; inadequate moisture content.

Most rural roads in Ilaro town have sand as a wearing course, some of these areas are Gbogidi, Pahayi, Oke-Ola, Ikosi, Oke-Ela to mention few but focus of this work will be on one, which apart lead to dwelling places also lead to farmlands. This research investigates the factors that are favorable for the use of sands as wearing course for rural roads using Gbogidi sandy soil as a case study and information obtained to determine the suitability of sandy soil as a road construction material.

Most unpaved rural roads surfacing is not covered with asphalt or concrete but left to be plied with just the natural soil. Some surfaces may be of sand, gravel, stone, crushed slag, clay or combination of clay and any of the granular materials. There is need for improving rural unpaved roads because it links so many rural dwelling and are of economic significance to the development of the nation Phillip Paige Green (2007, 2014). These roads must be improved upon, and one of such is stabilization, bio cementation of loosely soils was carried out by Sharaky, A. M *et al* (2018) so as to improve their mechanical properties. Different treatment methods were adopted and there was significant improvement on the soil. Santoni, R. L. (2003) in his work considered the use of multi-purpose (MP) mat, hexagonal plastic mat, and sand-geo fiber stabilization in evaluating different road construction techniques on sandy soils. The potential of these methods were then determined by loading the pavements on the sandy soils with a 5-ton military truck laden to an 18869.76 kg gross vehicle weight, the results showed the restriction of the test vehicle after 25 passes when the loose sand was trafficked without any reinforcement or surfacing. The red sandy soil was used by Metcalf, J. B., & Wylde, L. J. (1984) so as to re-assessed the specification parameters for the use of sand as base materials. Their results were showed that test methods were indicators of the performances, thereby aligning with the work of Salhi, R., & Messaoudi, K. (2021) that the design of the unpaved roads is reliant on several procedural documents which is as a result of the predominant conditions of each area such as the climate, materials availability, the soil support quality, and the water content of the soil. Omar, H. M. *et al* (2022) researched on two local materials; tuff and sandy residues as road based materials by determining their physical parameters and mechanical characteristics in accordance with French standards. The results showed an optimal formulation consisting of 70% tuff and 30% sandy residues, thereby confirming that there is a great similarity in the characteristics of tuff-sand mixtures

II. Methodology

Soil samples were collected from a sandy road located at Gbogidi area of Ilaro (6.8954° N, 3.0126° E) in Yewa South Local Government area of Ogun State, Nigeria (see figure 1). The samples were air-dried and the following tests; Particle size distribution, Proctor Compaction and In-situ density tests were then carried out on the sample in the laboratory. Two thickness of the soil profile considered for this work was 300mm which was determined based on the location the sample was taken.

Figure 1: Map of Ilaro in Yewa South LGA of Ogun State

Source: Ilaro - Map - Mapcarta

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2.1 Particle Size Distribution

This was carried out so as to determine the percentage by weight of particles within the different size ranges of the soil sample thereby helping in determining the suitability or otherwise of the soil sample in engineering usage; Subgrade, Sub – base and Base in road construction.

200g of the soil sample was weighed out and was poured into the sieving column and agitated vigorously for about 7 minutes. The percentage passing each sieve and corresponding sieve size was used in plotting the particle size distribution.

2.2 In-Situ Density Test

Excavation was made with hand tools and the template to form a hole equal to that of the hole of the plate at about 150mm in depth with smooth walls and rounded bottom edges. Care was taken not to allow any materials be lost. The apparatus was sat (already with the sand in itself) on the hole of the tray. The valve was opened and after the sand has stopped flowing, the valve was closed. The apparatus with the remaining sand was weighed with the remaining sand and the weight of the sand occupying the cavity was weighed as well. The material was thoroughly mixed and a representative was weighed for moisture sample determination as shown in figure 2.

Figure 2: In-situ density test

2.3 Proctor Compaction Test

The 3kg of sand was weighed, 6% of water sample was weighed too, added and thoroughly mixed until all the water is uniformly absorbed. With the collar attached to the mold, the specimen was compacted in three equal layers so as to have total compacted depth of approximately 130mm determined from 27 blows of the rammer per layer. During the compaction, it was ensured that the mould rests directly on the concrete floor of the laboratory and not on the mixing pan. The compaction procedure was repeated so as to obtain the moisture content of the sample. This procedure is repeated until two successive decreases in the value of the wet density of the compacted sandy soil were observed.

2.4 California Bearing Ratio

The California Bearing ratio test will be determined immediately from the compacted samples at optimum moisture content on five layers of the sample with 56 blows using a 4.90kg rammer that will be equally distributed and dropped from a height of 450mm above the soil sample. The readings of the penetrations will be between 0 and 12.5 as seen in the figure 3 below

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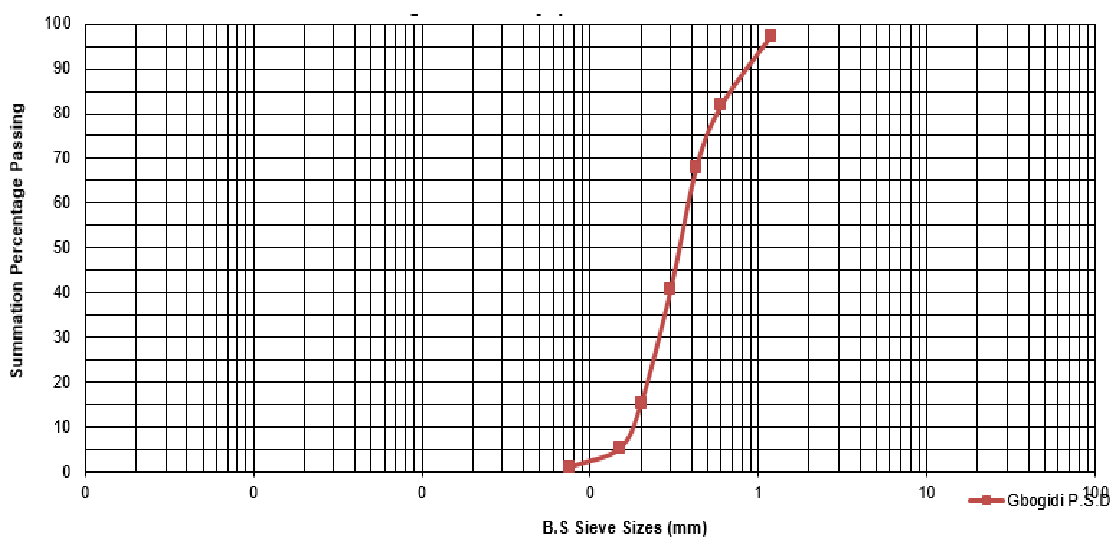
Figure 3: California bearing Ratio test being carried out in the laboratory

III. Result and Discussion

3.1 Particle Size Distribution



CLAY	fine	medium	coarse	fine	medium	coarse	fine	medium	coarse	COBBLES
	SILT			SAND			GRAVEL			

Figure 4: Particle size distribution for the fine aggregate

From the chart shown in figure 4, it could be inferred that; Gbogidi sand is composed of about; 4% fine sand, 15% medium sand and 81% coarse sand and having finess modulus of 3.1 knowing fully well that for fine aggregate, its finess modulus lies between 2-4. The results of $C_c = 1$ and $C_u = 2$ showed that Gbogidi sand sample is well graded sand (SW), according to the unified standard classification of soil. The above values are of significant importance in understanding how the gradation of the samples will affect

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the stability of the wearing course because soil samples that are not well graded can lead to the formation of voids in the wearing course thereby making the road to be susceptible to deformation. Also, the sieve analysis values play major roles in determining their suitability for use and how durable the course will be. The soil sample tested did not faltered in all the aforementioned

3.2 In-Situ Moisture Content and Corresponding Dry Density

Table 1 shows the relationship between the in-situ moisture content, the corresponding dry density and the wet density of the Gbogidi sand, having a wearing course thickness of about 300mm.

Table 1. showing the in-situ moisture content, the corresponding dry density and the wet density

Dry Density (kg/m^3)	Moisture Content (%)	Wet Density (kg/m^3)	Days
1800	18.4	2131	1
1560	17.6	1835	2
1510	14.2	1724	3
1500	10.2	1713	4
1200	5.8	1270	5
887	1.3	900	6

As shown in the table above, infiltration and percolation are less, due to the thickness of the wearing course.

Relationship Between Wet Density and Dry Density

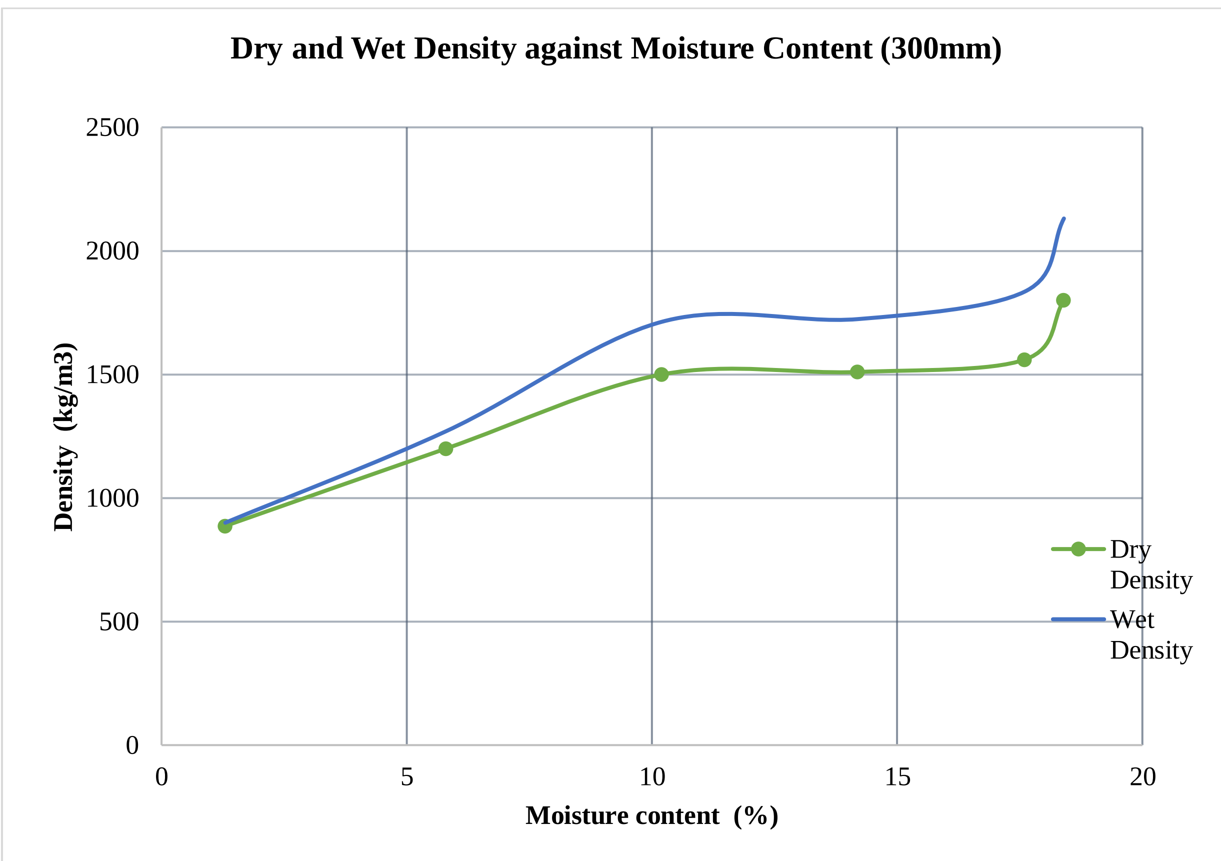

Figure 5: Relationship between wet density and dry density of a specific location with a thickness of about 300mm wearing course.

Relationship Between Dry Density and Relative Density

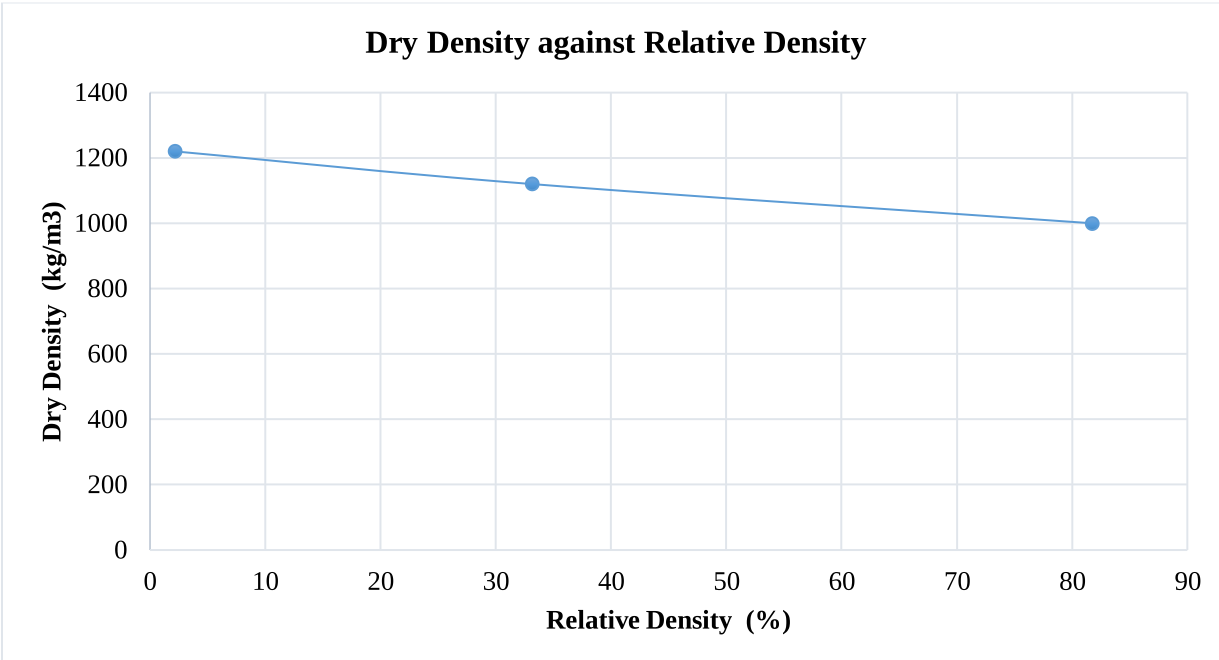

Figure 6: Showing the relationship between the dry density and the relative density.

As shown from the figure 5 and 6 above, an increase in the value of the dry density shows a corresponding decrease in the percentage of the relative density.

Relationship Between Dry Density and Relative Compaction

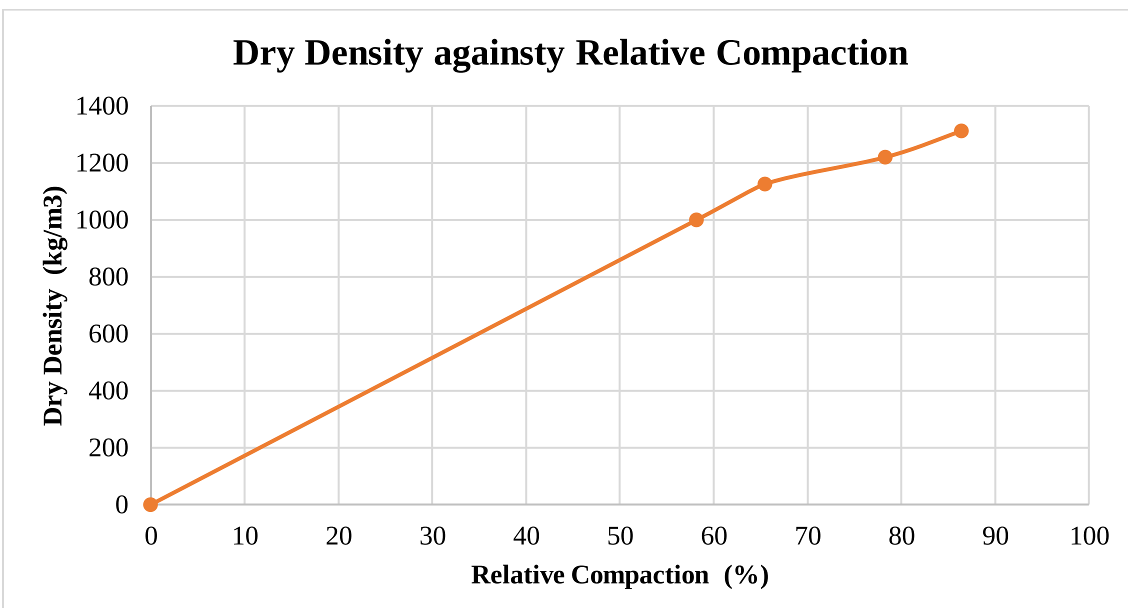

Figure 7: The relationship between the dry density and relative compaction.

Unlike the previous chart, there is a corresponding increase in the percentage of the relative compaction as the values of the dry density increases

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3.3 Proctor Compaction Test

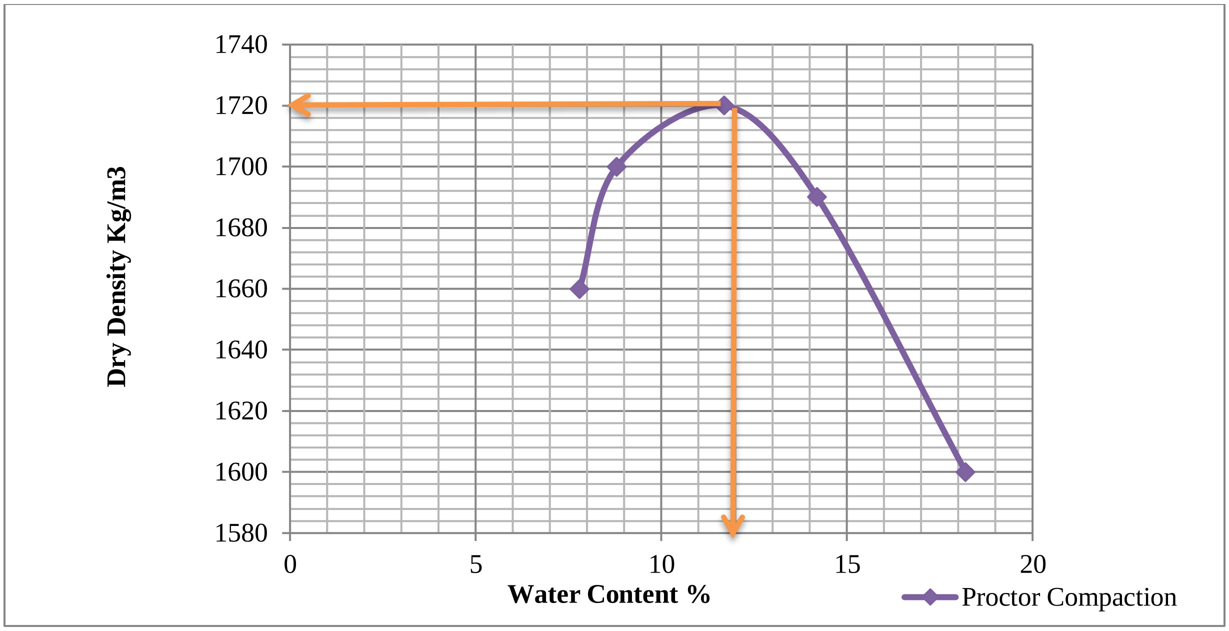

Figure 8: Compaction test showing the results obtained from Gbogidi sandy soil

As shown in the figure 8, above, the optimum moisture content is about 12%, while the maximum dry density is 1720 kg/m^3. The minimum dry density of the sand was D_{min} = 1.23 kg/m^3. The desired level of stability and durability of wearing course can be determined from the test carried out here. Compaction is an essential part of road construction that results in a smooth surface that is less prone to cracking and potholes when done correctly.

3.4 California Bearing Ratio

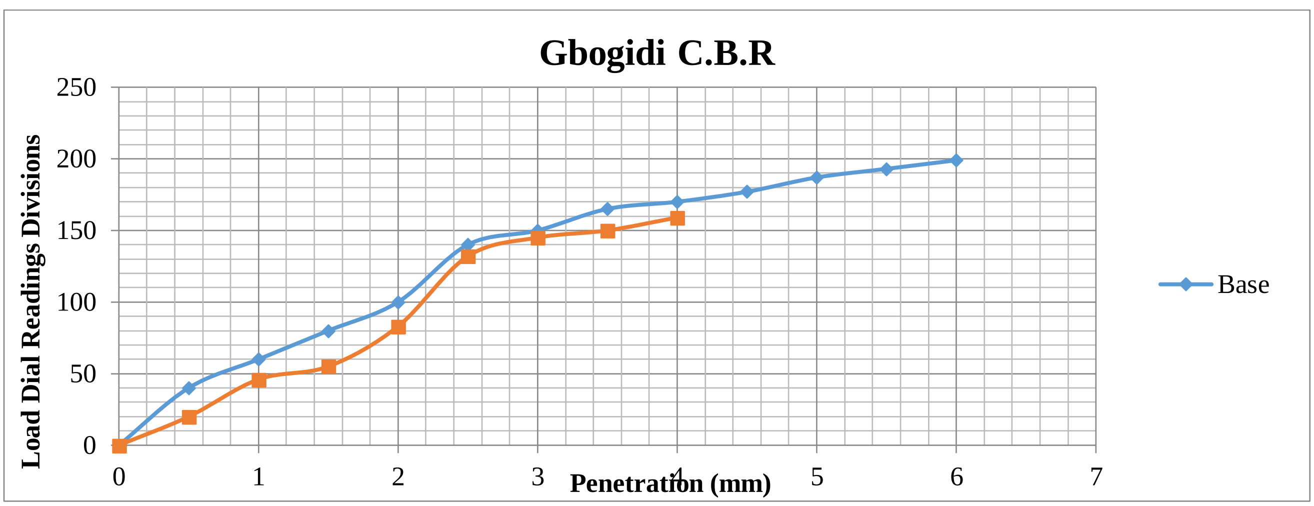

Figure 9: Results of the C.B.R test

The C.B.R. test was performed at 12% moisture content with the results showing the significance of the moisture content percentage on CBR value and how the value is maximized under the optimum moisture content and compaction. The results as shown in figure 9, showed that the threshold value of the thickness of the sand layer depend on the strength of subgrade soil, which is also dependent on the compaction moisture and soaking condition. The CBR values increases with the hardness of the surface. If the C.B.R. values are lower, the thickness of layers will be higher and vice-versa

IV. Conclusion and Recommendation

4.1 Conclusion

The conclusion inferred from this research work is that; sand can be used as a wearing course in rural roads if it adheres to the following conditions:

- Its moisture content should not be below 1.3%.
- The thickness of the wearing course should be at least 300mm.
- Such wearing course should be irrigated at least once in 5 days during dry seasons
- Such Irrigation is not necessary during raining season, except in a situation of short time drought.
- The longitudinal and cross-sectional slope should be 2.0% and 0%.
- The sand should be well graded.
- The C.B.R value is adequate being 23.33% for Gbogidi sand samples respectively. This is true because, the strength is between 20-70% in the standard unified soil classification system.

4.2 Recommendation

The horrendous conditions of most rural roads have negative impact on the productivity of farmers and this can be ameliorated through the fixing and upgrading of the roads as this will attract extension workers and investment to the farms and rural dwellings, thereby increasing the economic values of the areas. Also, the transporting of goods to those in the urban areas will be easy and quicker and precious time will not be lost on the road.

In order to economize cost in a most effective and efficient method when considering sand as a road construction material for rural roads, it would be wise to erect an irrigation system with sprinklers (spaced at a distance of 6m center to center along on the side of the road) with under groundwater, which would be mechanically powered to wet the soil for a considerable amount of time. This is because; based on the research work carried out, for a wearing course thickness of about 300mm, it would take approximately 5 days before the moisture content reduces completely after which the process could be repeated. In that wise, during dry season, the sand would be irrigated 6 times in a month (6 months dry season), and 36 times in a year (short time drought exclusively).

Irrespective of where this innovation is to be incorporated, the sand must meet the following requirement as obtained from the above conclusion; well graded sand (SW) and a C.B.R value between 20-70%. A longitudinal and cross – sectional slope of 2.0% and 0% respectively should be adopted. With good road networks industries, especially agriculture-based industries could be encouraged to have branches or main plants in rural locations. More financial institutions and recreational centres would also be established, thereby, brightening up the rural environments.

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Reference

1. Omar, H. M., Zentar, R., Akacem, M., Mekerta, B., & Mouli, M. (2022). Co-valorization of Tuff and Sandy Residues in Roads Construction. Civil Engineering Journal, 8(5), 1029-1045.
2. Paige-Green, P. (2014). Sustainability issues surrounding unpaved roads. Climate Change, Energy, Sustainability and Pavements, 335-351.
3. Paige-Green, P. (2007). New perspectives of unsealed roads in South Africa. Road & Transport Research: A Journal of Australian and New Zealand Research and Practice, 16(3), 56-62.
4. Salhi, R., & Messaoudi, K. (2021). The Effects of Delays in Algerian Construction Projects: An Empirical Study. Civil and Environmental Engineering Reports, 31(2), 218-254.
5. Santoni, R. L. (2003). Enhanced coastal trafficability: Road construction over sandy soils. ENGINEER RESEARCH AND DEVELOPMENT CENTER VICKSBURG MS GEOTECHNICAL AND STRUCTURES LAB.
6. Sharaky, A. M., Mohamed, N. S., Elmashad, M. E., & Shredah, N. M. (2018). Application of microbial biocementation to improve the physico-mechanical properties of sandy soil. Construction and Building Materials, 190, 861-869.
7. Metcalf, J. B., & Wylde, L. J. (1984). A reexamination of specification parameters for sandy soil roadbase materials. Bulletin of the International Association of Engineering Geology, (30).