



Evaluation of Land Capability for Housing Development at Nachi Built Environment, Enugu State, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Author AAO designed the study, wrote the protocol, set up the field work as well as wrote the first draft of the manuscript. Author UFI interpreted and analyzed the data; while author CNN did the literature searches. All the authors read and approved the final manuscript.

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ABSTRACT

There are criteria that certify the sustainable potentials of any built environment. Low income housing scheme proposed by Enugu state government for its workers is targeted at Nachi, Udi local government area in Enugu state, Nigeria. To assess the capability of this location for the project, site investigation and experimental design methods were adopted to measure the geomorphological and hydrologic features and conduct laboratory tests on the basic and strength properties of the formation respectively. Findings explain that Nachi lies on the slope of 70⁰; hence the average runoff is high. Prolific confined aquifer result to underground water potential for consumption since the formation is porous with high elevation at 221 meters. It is also discovered that the area possesses low shear strength which is capable of resisting the high shear stress measured in the soil sample of the formation. Soil plasticity is measured as 10 indicating high

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erodible potential. The particle size distribution of the formation is poorly sorted with high percentage of sand particles, and very low percentage of gravel, with intercalation of compressible particles in the formation. The rain intensity is measured high with very high rate of runoff potential that is capable of causing erosion on the sloppy terrain with low bearing strength. The study therefore concludes that Nachi as a proposed site for the low housing scheme is not suitable considering the fact that the initial cost involved in preparing standard foundation of the buildings and the surrounding for sustainable housing will make it exorbitant for the low income earners. Any effort to compromise doing the right things from the beginning for a sustainable housing will degenerate the housing to high maintenance culture when in use. In the absence of no other available land the study therefore recommends that edicts and official programmes be enacted and instituted respectively to curb down erosion menace in the area with standard foundation designs that will guarantee safety to the buildings effectively in the area. If the housing scheme must stand for the low income earners the government must as matter of policy subsidize the cost of the houses reasonably such that the workers in the state can easily afford them.

Keywords: Land capability; housing development; low income earners; affordability and sustainability; Nachi location.

1. INTRODUCTION

Enugu state in their effort to accommodate the teeming population of civil servants decided to embark in the construction of low cost housing units for the workers. Nachi, in Udi local government area of Enugu state was selected as the available location for the project. Many criteria were considered such as geology, soil capability, erosion vulnerability, as well as underground water potential. As a proposed housing estate, sustainability of the units is germane so as not to compromise the basic provisions for human comfort nor increase the

maintenance culture of the area. Provision and maintenance of the constituent component of housing which includes the building, physical infrastructures, social amenities, and other developmental external works therefore are areas of concern in the location of housing estate.

Field work was carried out on a traverse bases running Northeast-Southwest, Northwest-Southeast North-South and finally East-West (NE-SW, NW-SE, N-S, and E-W) respectively. It was discovered that Nachi lies on a higher elevation of 221m (725ft) above sea level.

Table 1. Stratigraphic succession of the three formations

Period	Formation	Thickness
Maestrchian	Nsukka Formation	368m
	Ajali Formation	368m
	Mamu Formation	434m

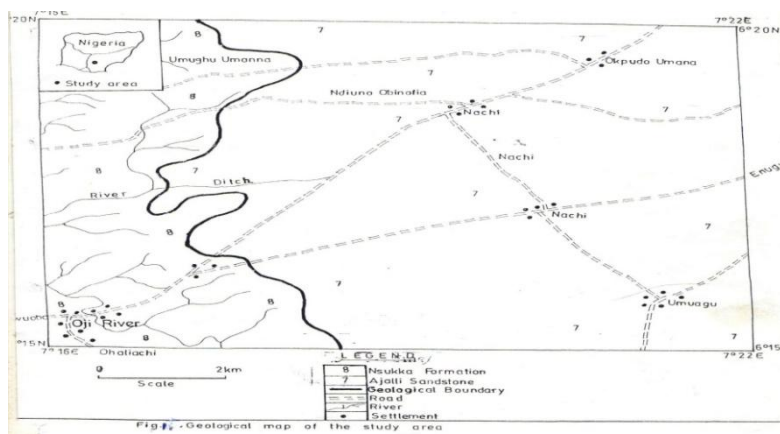


Fig. 1. Geological map of the study area

Source: Adopted from Reyment [3]

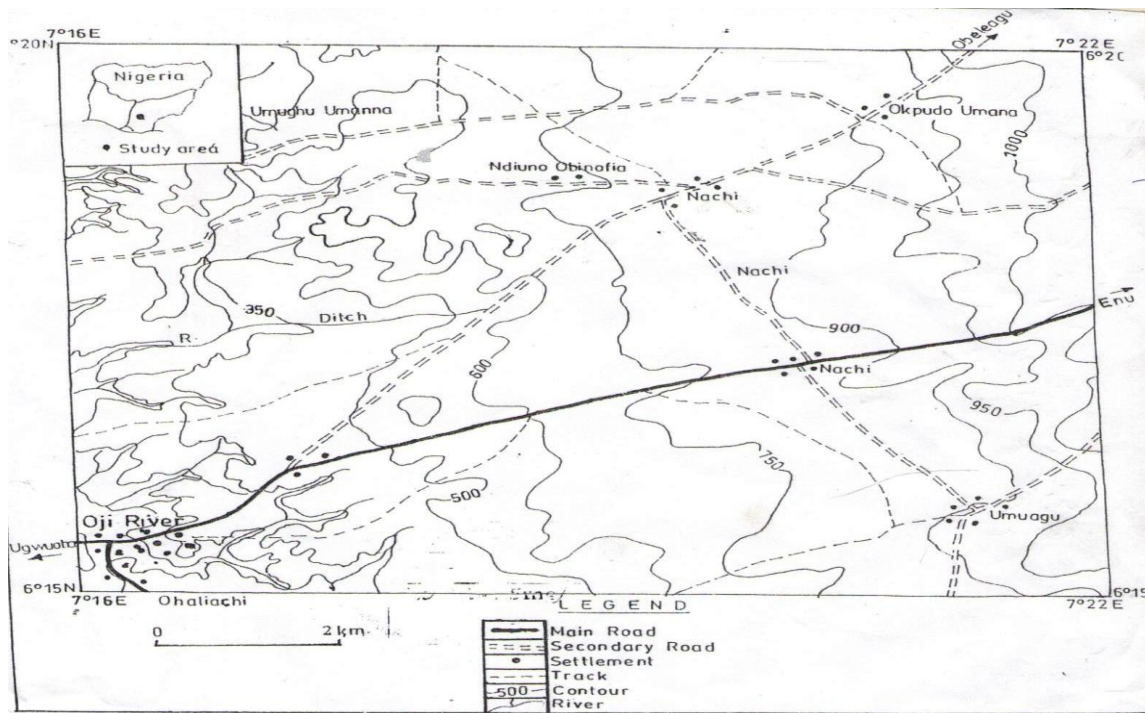


Fig. 1 Topographic map of the study area

Fig. 2. Topographic map of the study area (Adopted from Reyment, [3])

According to Umeji [1], geology of the area is characterized with sedimentary terrain made up of Nsukka Formation, Ajali Formation, and Mamu Formation respectively, as shown in Fig. 1. Egboka [2] observed that the three formations are mastritchian in age. The stratigraphic map of the area is shown in Table 1.

Nsukka Formation is the youngest, while Mamu Formation is the oldest of the formations. According to him, Ajali Formation consists of poorly consolidated bedded medium to coarse sand stone that is fine grained with clay intercalations, giving rise to semi confined condition [4]. The friable nature of the formation makes it erosion prone. Overlaying the Ajali Formation is Nsukka Formation. It lies conformably on Ajali sand stone, occupying broad stretch of the area west of Udi plateau [3]. He observed that south of the area around Enugu-Onitsha road, Nsukka Formation is the type locality, while Ajali sand stone dominates in the area under study. Nsukka Formation has numerous isolated outliers of the basal sand stone, with dark shades and sandy types and coal seams at various horizons [5]. The topographic map showing the position of Nachi is shown in Fig. 2.

2. RESEARCH METHODS

The study primarily relied on experiments for data generation towards arriving at solutions to the problem of the study. Nevertheless, some related information from previous studies and values from meteorological agency, southeast zone, Akanu-Ibiam airport road, Enugu were used to complement data obtained from the field on hydrogeology and hydrology. Geophysical survey method of subsurface investigation by way of Vertical Electric Sounding (VES) was used to delineate the subsurface for effective water bearing formation, using Terrameter SAS. Index properties of soil (grain size distribution, dry density, optimum moisture content and atterberg limits) were carried out using sieve shaker, weighing balance, and water injector respectively; while detailed properties of the soil (shear and normal strengths) were conducted with additional equipment like; compactor, and timer in the study.

3. DATA PRESENTATIONS AND DISCUSSIONS

Data are presented on hydrogeology, hydrology, shear and normal stresses, atterberg limits, optimum water content of the formation and dry density for assessment on capability of Nachi land for the housing scheme.

Table 2. Average rainfall data in enugu near Nachi

S/N	Month	1991/92 (mm)	1992/93 (mm)	1993/94 (mm)	1994/95 (mm)	1995/96 (mm)	1996/97 (mm)	1997/9(mm)	1998/99(mm)	1999/2000(mm)	2000/2001(mm)
1	Jan	-	-	33.8	1.6	-	-	-	18.4	52.4	-
2	Feb	-	-	3	-	26.7	-	6.1	15.7	-	28.1
3	March	111.5	68.8	9.7	90.2	48.6	111.6	25.8	30.0	32.3	72.5
4	April	200.9	48.9	150.7	194.4	160.9	261.3	161.1	103.6	202	65.3
5	May	194	109.9	211.2	263.9	170	376.1	188.7	223.5	357.5	273
6	June	354	263.7	140	356.7	289..6	345	285	316.8	206.1	188
7	July	313	186.7	216	340.2	368.3	226.8	259.2	206.4	298.5	152
8	Aug	149.3	389.8	388.2	432.1	268.4	235	96.2	200.2	331.8	130
9	Sept	249.7	243.5	331,9	192.4	176.3	392.3	256.6	195.1	339.7	407
10	Oct	105.3	72.9	181.6	261.7	303.4	242	217.4	313.4	226.5	118
11	Nov	28.8	82.9	-	35	-	68.1	-	24.3	-	-
12	Dec	-	111.6	-	-	-	4.1	-	-	-	-
13	Total	1706.5	1572	1663.1	2165.2	1642	2262.6	1496.1	1647.4	2026.8	
14	Ave	142.21	131.02	138.6	180.7	136.9	188.6	124.7	137.3	168.9	117

Source: Authors' Field Survey, (2021)

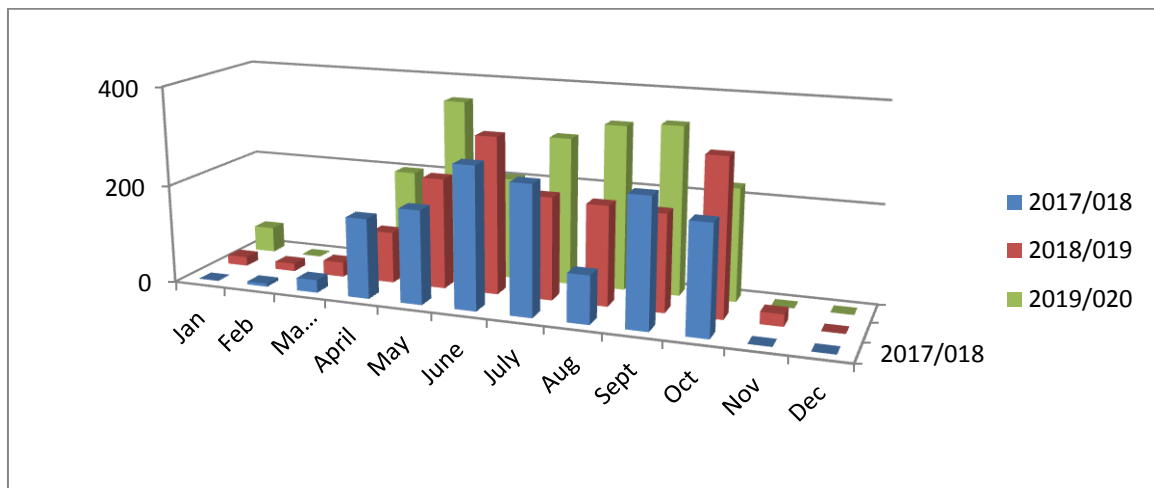


Fig. 3. Average Monthly Precipitations (mm) from the Year 2017/018 - 2019/020 in the Study Area

Hydrogeology:- Information from the meteorological agency as contained in Table 2 and Fig. 3 respectively shows that the precipitation is high in the area [6]. He concluded that precipitation was much higher in the months of September, June and in October respectively but, very little in February, December and January respectively. In the study however, September, July and June are measured as the months of highest precipitation on the average of three years from 2018 to 2020. The months of very little or no precipitation are December, February and January respectively on average.

Where; Q (Runoff Coefficient) = C (Average x 1.4 Catchment Area)
 A = 107.8km from the map, C = 0.44 (44%). I = 0.15mm/yr
 $Q = 0.44 \times 0.15 \times 107.8 = 7.115m^3/yr.$

The rainfall intensity is high as shown in Table 2.0. Iloeje, [6] measured the slope of Nachi to be 70°, and the runoff is also measured high [7]. As seen in Fig. 3, it is evident that the rainfall is high in Nachi as confirmed by Akanu Ibiam meteorological station.

Hydrology:- Ajali Formation is the prolific confined aquifer in Nachi. This makes underground water available for consumption through exploration. Egboka [2] observed that the formation is porous and harbor significant quantity of ground water. The only problem of the area is that elevation is high as much as 221m (725ft) based on GPS reading. In this case, underground water is available but costly to drill due to high elevation, as shown in Table 3, and

Fig. 4 respectively. Thus, the Vertical Electrical Sounding (VES) in Nachi is shown in Table 3 and Fig. 4.

Table 3. The geophysical survey (VES) at Nachi

S/N	Resistivity (ohm-m)	Depth (m)
1	9300	0.3
2	3160	24.7
3	3650	60.8
4	3560	117.0
5	11000	-

Source: Authors' Field Survey, (2021)

The depth to water aquifer is measured at 383ft in the study area. Nevertheless, the resistivity measurement for the information contained in Table 3.0 using tetrameter measurement as shown in Fig 4.

Ajali Formation in the area occupies about 90% of the land surface making the zone vulnerable to erosion. This singular phenomenon makes the area not good for building development since the soil is friable and is easily washed away by runoff [7]. According to Iloeje [6] high slope of about 70° is another factor aiding runoff. Hunt, [8] concluded that steepness of a slope affects stability of the earth surface during runoff by increasing erodible potential of the surface. He also noted that the steeper the slope, the faster the runoff. This is the major cause of high runoff in the area; hence gully erosion is dominant in the area. According to Iloeje [6] this Formation has the three major factors that promote gully erosion; they are texture, structure and cohesion.

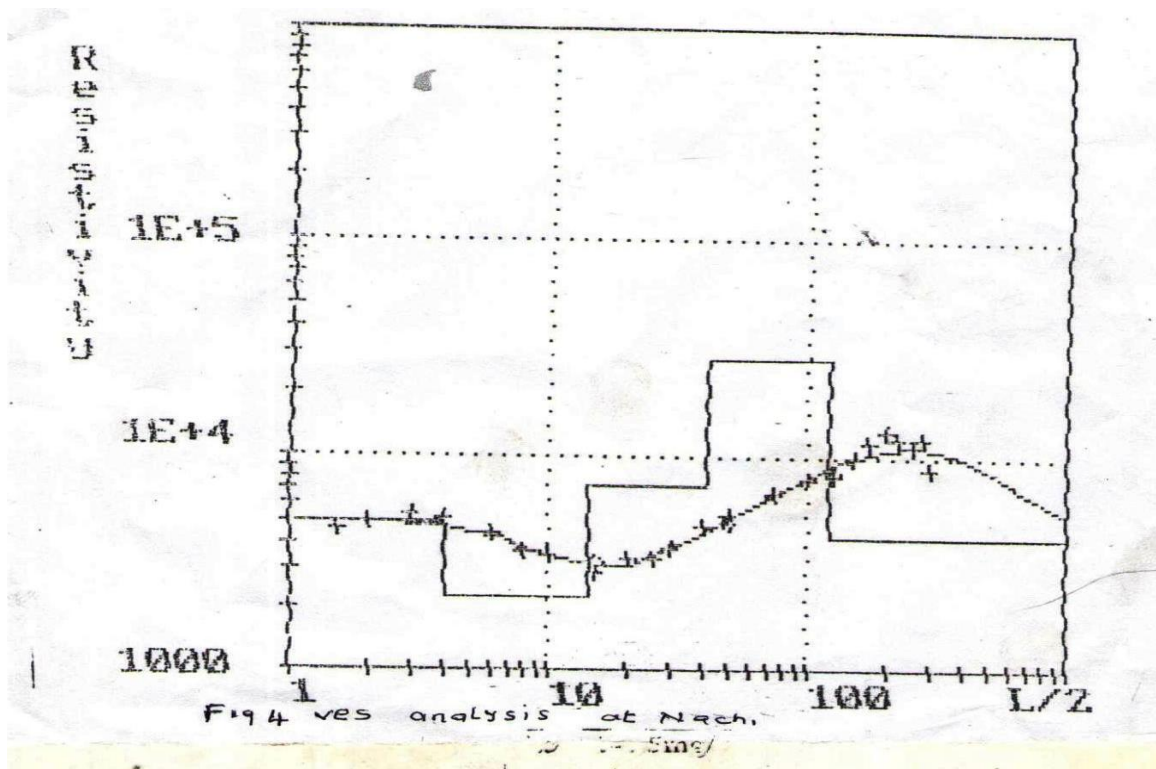


Fig 4. Graph of VES analyses at Nachi using terrameter SAS

In more details, geotechnical tests carried out to identify the nature of index (basic) properties and strength (detail) properties of the formation to ascertain its level of suitability for foundation construction works. These tests include Atterbeg limits, Grain size distribution, Optimum moisture content, Dry density and Shear strength in the study. Geology, vegetation, climate, physical properties of the soil are other contributory factors encouraging soil erosion in the area. These factors according to Ogbukagu [5] do not support stability of foundations for effective building development in the area.

The results of the soil grain size distribution as contained in Table 4 shows the soil is sandy because of high percentage content of sand in the formation. Hence, the reason the formation is characterized with poor cohesion and encouraging erodible potential in general, as shown in Fig. 5.

Shear Strength:- The shear strength characteristics for 24kg of the soil sample collected from the area of study are presented in Table 5.

Table 4. Sieve analysis of the soil sample of nanka formation

S/N	Sieve No. (mm)	Mass Retained (g)	Mass Passed (g)	Percentage Mass of Sample Passing (%)
1	2.00	0.10	227.10	99.96
2	1.18	4.30	222.80	98.06
3	0.85	12.60	210.20	92.52
4	0.60	13.10	197.20	86.75
5	0.425	93.50	103.60	45.59
6	0.30	78.20	25.40	11.18
8	0.017	8.10	2.40	1.56
	Pan	0.20	2.20	0.009

Source: Authors' Laboratory Results, (2021)

Note that Average grain size is $4.73/8 = 0.59\text{mm}$; where error is 2.20

$$\text{Thus, } \Sigma\% = \frac{22 \times 100}{227.2} = 0.87$$

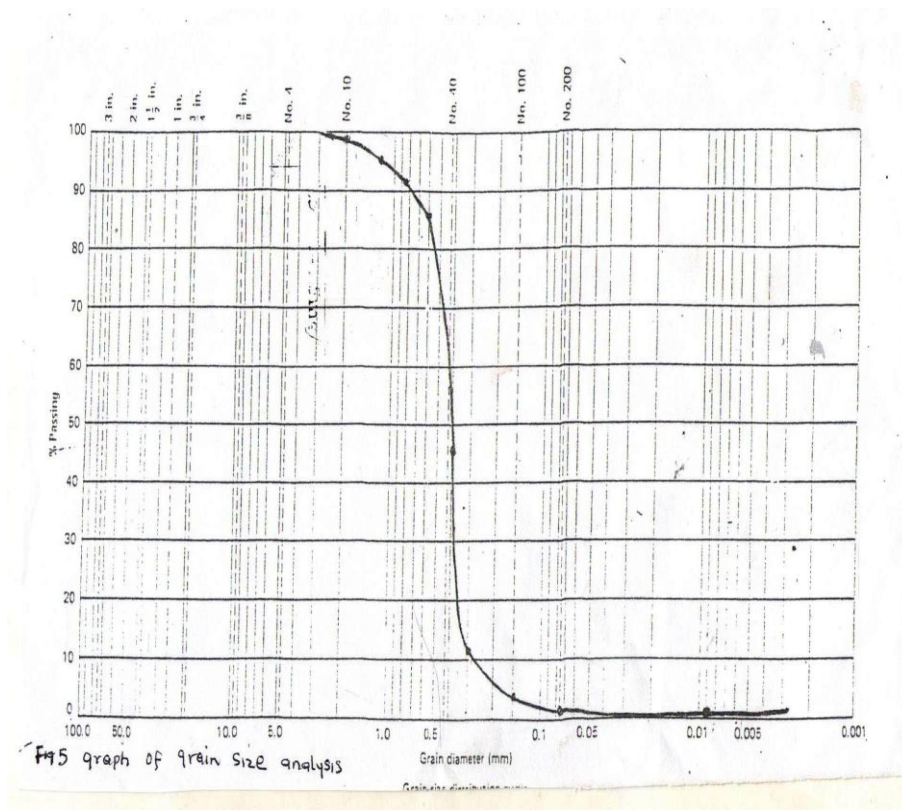


Fig. 5. Graph of particle size distribution analysis of ajali formation at Nachi

Table 5. Measurement shear strength value on the soil sample

S/N	Time	1 (X) H.R	2 (Y) H.R x 0.002	3 (Z) F x 0.88	Shear Stress (2) / 0.0036Kn/m ² Constant
1	30	0	0	0	0
2	60	0	0	0	0
3	90	0	0	0	0
4	120	0	0	0	0
5	150	10	0.020	0.126	4.89
6	180	12	0.240	0.2112	5.87
7	210	18	0.036	0.03168	8.80
8	240	20	0.040	0.03108	8.80
9	270	20	0.040	0.0352	9.78
10	300	35	0.070	0.452	9.78
11	330	48	0.096	0.0616	17.11
12	360	52	0.114	0.08448	23.47
13	390	57	0.118	0.10032	27.87
14	420	59	0.130	0.10384	28.84
15	450	65	0.150	0.1144	31.78
16	480	77	0.154	0.13552	37.64
17	510	77	0.154	0.13552	37.64
18	540	77	0.154	0.13552	37.64Kn/m ² (constant value for shear stress)

Source: Authors' Laboratory Results, (2021)

$$\text{Normal Stress} = \frac{\text{Load}}{\text{Area}} = \frac{0.24\text{Kn}}{0.0036\text{m}^2} = 66.67\text{Kn/m}^2$$

Result of the experiment on shear strength which is the resistance to shear strain as shown in Table 5 is not large enough to help the soil erosion [9]. The area therefore is confirmed prone to erosion because of the low shear strength.

Test results on another sample of soil within the area using 44kg of soil are shown in Table 6.

Nevertheless, the normal stress of the other soil of the formation is 122.22Kn/m². According to the work of Ogbukagu [5], cohesion is 12, and the $\tan\Theta$ becomes 202.63Kn/m². The result of the experiment shows that cohesion is very small

with the value of 12. This refers to the binding force between soil particles, which according to the study is not enough to withstand erosion [10]. This indicates that the soil of the area has low resistance to detachment.

Results of experiments on moisture content and dry density however are shown in Table 7.

Fig. 6 shows the graph plot of dry density against the moisture content for a given compaction effort. The dry density of 1.99Kg/m³ measured in the area is the maximum value at the point where the water content is optimal. This value is small [9], and can lead to erosion in the area.

Table 6. Measurement on another soil sample of different weight within the area

S/N	Time (s)	1 (X)	2 (Y)	3 (Z)	4 (Shear Stress)
	1	H.R	H.R x 0.002	(2) x 0.88	(3) /0.0036Kn/m ²
1	30	0	0	0	0
2	60	0	0	0	0
3	90	12	0.240	0.0352	9.78
4	120	18	0.036	0.03168	8.80
5	150	21	0.042	0.03696	10.27
6	180	26	0.052	0.04576	12.71
7	210	30	0.060	0.0528	14.67
8	240	32	0.064	0.05636	15.66
9	270	40	0.080	0.0704	19.56
10	300	57	0.114	0.10032	27.87
11	330	65	0.139	0.1144	31.78
12	360	74	0.148	0.13024	36.18
13	390	82	0.164	0.14432	40.09
14	420	91	0.182	0.16016	44.49
15	450	102	0.204	0.1752	49.87
16	480	110	0.22	0.1936	53.78
17	510	110	0.22	0.1936	53.78
18	540	110	0.22	0.1936	53.78Kn/m ² (constant value for shear stress)

Source: Authors' Laboratory Results, (2021)

$$\text{Normal Stress} = \frac{\text{Load}}{\text{Area}} = \frac{0.4 \text{ Kn}}{0.0036\text{m}^2} = 122.22 \text{ Kn/m}^2$$

Table 7. Optimum Moisture Content with the Corresponding Dry Density of the Soil in the Study Area

Trial No.	W ₁ Wet Soil (g)	W ₂ Dry Soil (g)	W _c Weight of Can (g)	W _d Weight of Dry Soil (g)	W _w Weight of Water (g)	W _m Moisture Content (%)	Dry Density (δ)
1	29.1	28.7	19.4	9.30	0.40	4.30	1.87
2	47.0	45.3	21.3	24.0	1.70	7.10	1.97
3	38.7	37.1	20.9	16.2	1.60	9.90	1.99
4	59.2	54.4	19.1	35.3	4.80	13.6	1.95
5	50.8	47.0	22.6	24.4	3.80	15.6	1.87

Source: Authors' Laboratory Results, (2021)

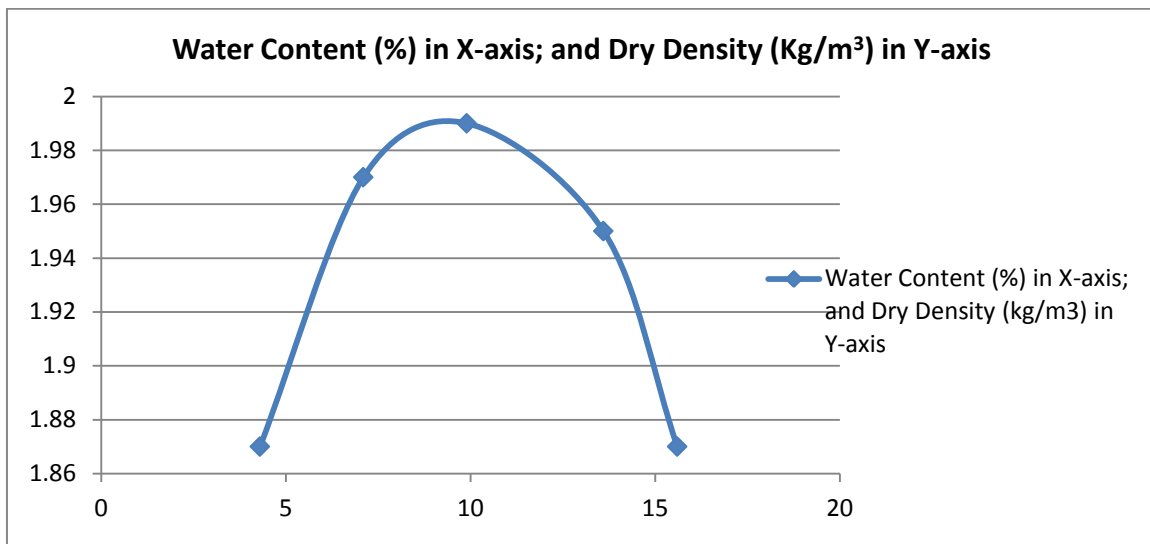


Fig. 6. Maximum dry density at the optimum water content during compaction of the soil sample

Fig. 6 shows that increase in water content of the soil resulted to increase in the dry density of the soil, implying that water helps to reduce the frictional forces between the surfaces of the soil grain in the compaction process. As the compaction process continues at a point, further increase in the water content of the soil no longer bring about increase in dry density. Since density is the ratio of mass to volume of a unit measure of a sample, the volume of the soil sample seizes to reduce which brings about increase in density. This is because all the spaces around the soil particles has been closed up, and the soil grains touching one another to the extent that they cannot move closer again except in consolidation process where the structures and shapes of the grains are affected. As the water content continues to increase however hydrostatic pressure is developed; and the sample is left with no other choice than to begin to disperse the soil particles from one another as a result of the increasing volume of water overcoming the void capacity of the soil. Hence, the volume of the sample increases with decreasing values of the density.

Atterberg Limits:- Experimental results on Atterberg limits are presented as follows: Liquid Limit = 30, Plastic Limit = 20, and Plasticity Index = 10.

Base on the results, the plastic index is high; and from studies erodible soil has higher plasticity index [10].

4. RECOMMENDATIONS

Nachi is an erosion prone zone. If low cost houses must be developed in the area, the foregoing factors must be considered and designed against for sustainable objective. Habit of grading roads must be avoided as it encourages erosion. Pot holes and breakups on un-tarred roads should be filled up, and appropriate drainage channels be provided at the sides. Houses should also not be built to alter the building lines and any other physical developmental conditions that regulate the physical development in the area to avoid obstructing flood channels and affecting the drainage patterns. In extension, there should be zoning where big gullies and canyons have developed, and government should consult erosion control experts to provide relevant expertise in such cases.

Nevertheless, flow of surface runoff down the slope can be reduced by placing barriers, such as sand bags or barrier wall; while effort to reduce the slope of the road surface reduces the speed of the runoff. Appropriate dam construction provides gully control measure that is capable of trapping sediments at the upstream. Soil conservation practice should employ the classification of agricultural and forest land spaces according to land capacities in the area. Efforts should also be made to make a realistic cost estimate of funding erosion menace on a continuous basis. Measurements of rainfall intensity and duration should always be taken

periodically for effective control of runoff. Keeping records of these measurements annually should be maintained for extensive research and basis for design of big projects on drainage control and road/erosion works, at a particular duration.

5. CONCLUSION

Findings in the study imply that Nachi in Udi local government area in Enugu State, Nigeria is not a good area for sighting low cost houses for civil servants of the state. However, when land is not available, Nachi site can be used if only the state can adopt the measures addressed in the study. The soil properties and the geology of the environment do not favour the sighting of low cost housing project in the state. Government should search for a more suitable site for implied affordability and sustainability of the housing development; otherwise edicts and statutory programmes are provided to curb down erosion in the area. However, if buildings are constructed with caution and appropriate foundation design to accommodate the unsuitability of the area, increased financial resources will be involved in the project. Beyond this, well planned and closely spaced drainage channels as well as appropriate design would be applied with accompanying high maintenance culture for the sustainability. The housing proposal therefore should by implication of nature of the formation of the proposed location not be categorized as low income housing project. Since the cost of procurement can never be less than the cost of construction, affordability of such project with increase cost of development by the low income earners will not be realistic in the state; except where in a special arrangement the Government significantly subsidizes the procurement cost of the housing scheme.

COMPETING INTEREST

Authors have declared that no competing interest exists.

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