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Competency Rating of Soils for Civil Engineering Structures Around Southern Rayfield, Jos, Plateau State, North Central Nigeria

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ABSTRACT

Competency ratings of soils around Southern Rayfield were carried out in other to determine their competent ratings for civil engineering structures. The engineering tests carried out includes : Sieve analysis, Atterberg limits and compaction tests. Sieve analysis result showed that the incompetent soil samples had a range of 49 – 58 % of the soil passing through sieve no 200 which are fine materials (clay). The competent soil samples had a range of 25 – 35 % passing through sieve no 200 indicating the dominance of sand / gravel in the area. For Atterberg Limit test, the plasticity index for the soil samples that are incompetent had a range of 25 – 35 % which implies high swelling potential indicative of clay while soil samples gotten from the competent areas had a range of 15.5 – 18.4 % which indicates low swelling potential and are basically sand / gravel. For compaction, competent soil samples had maximum dry density range of 1.83 – 1.87 % and optimum moisture contents had a range of 12.3 – 14.3 %. The incompetent soil samples maximum dry density range of 1.67 – 1.84 % while their optimum moisture contents had a range of 16.2 – 26.9 %. Their low range of maximum dry density and optimum moisture content in the incompetent areas show that the soils have low bearing capacities. It equally makes them unqualified for any load to be imposed on them except they are improved upon using any of the soil stabilization techniques. Clay have the ability of failure if any load is imposed on it but soils that are mainly sand and gravel do not have that problem.

Keywords: Geotechnical, Civil Engineering, Engineering tests, Construction, Southern Rayfield

INTRODUCTION

Soils in the Southern Area of Rayfield have found wide applications in the construction industry especially in civil engineering structures like buildings, bridges, roads , culverts and dams. The area under investigation is in parts of the Jos – Plateau State, Nigeria, (Southern Rayfield Area). It is located on Latitudes 9^0 47’ 00” to 9^0 49’ 45” N and Longitudes 8^0 52’ 00” to 8^0 55’ 30” E. Not even the most experienced engineer would attempt to access the strength of concrete without some knowledge of its composition. Some engineers in the past have tried that but failed .

Many building constructions have caused monetary losses largely because the site(s) have been badly selected or because the soils were too weak to support them “Oguara (2001)”. Soils like any other engineering material distorts when subjected to load and pressure. The resultant effect could be shearing, sliding or distortion and compression. “Olounfemi et al (1987)”.

In general, soils cannot withstand tension when placed under load. In a case where the particles are cemented together, a small amount of tension can be beared but not for long periods . Though evidence of engineering problems can be seen in most places (like in movements in buildings known as settlements) all of these

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engineering facilities are founded on or in soils. “Malamo et al. (1983)”.

Lateritic soils are seen in many rock types in different sub – climate and drainage environments. “Macleod et al. (1971)”. Every soil often exhibit unique set of physical, chemical and engineering properties.

Therefore, in other to ensure their sustainability, a thorough knowledge of the characteristics of the soils that are to be used as foundation materials must be acquired prior to its utilisation for any engineering purpose. “Gidigasu 1974 Adeyemi (2000)”. By supplying the pre knowledge of this kind, it is the function of the soil scientist to show how economic waste can be avoided. Geotechnical properties of the soils needs to be determined by carrying out geotechnical analysis on the soils before construction works can be carried out on them. “ Gidigasu 1972: Mesida 1985: Adeyemi 1990: Momoh et al (2008)”.

Location of Study Area and the General Geology

The area under investigation is part of the Jos – Plateau State, Nigeria, (Southern Rayfield Area). It is located on Latitudes 9^0 47’ 00” to 9^0 49’ 45” N and Longitudes 8^0 52’ 00” to 8^0 55’ 30” E . It covers an aerial extent of $26km^2$. The settlements are easily accessible through the major road of Jos – Bukuru express road.

In terms of geology, Biotite Granite rocks dominate the study area. They are plutonic rocks which comprise of alkali feldspars, quartz, mica and small portion of mafic minerals. The rocks found in the study area are classified based on the proportion of the mafic minerals in them. They include:

- Bukuru Biotite Granite
- N’gell Biotite Granite
- Jos Bukuru Biotite Granite
- Rayfield Gona Biotite Granite
- Shell Biotite Granite

The Geologic map of the study area is seen in Figure 1 which shows the various rock types that are delineated.

MATERIALS AND METHODS

Materials used for the sampling includes : Shovel, Digger, GPS, Sampling bags, Measuring tape, Cello tape and a field vehicle.

In terms of methodology, ten samples were collected from the survey area (Sothern Area of Rayfield) which involves digging 10 pits up to 2 meters. The samples were labelled and packaged into sampling bags to avoid loss of moisture. The samples were taken to the laboratory for sieve analysis, Atterberg Limit test and Compaction tests.

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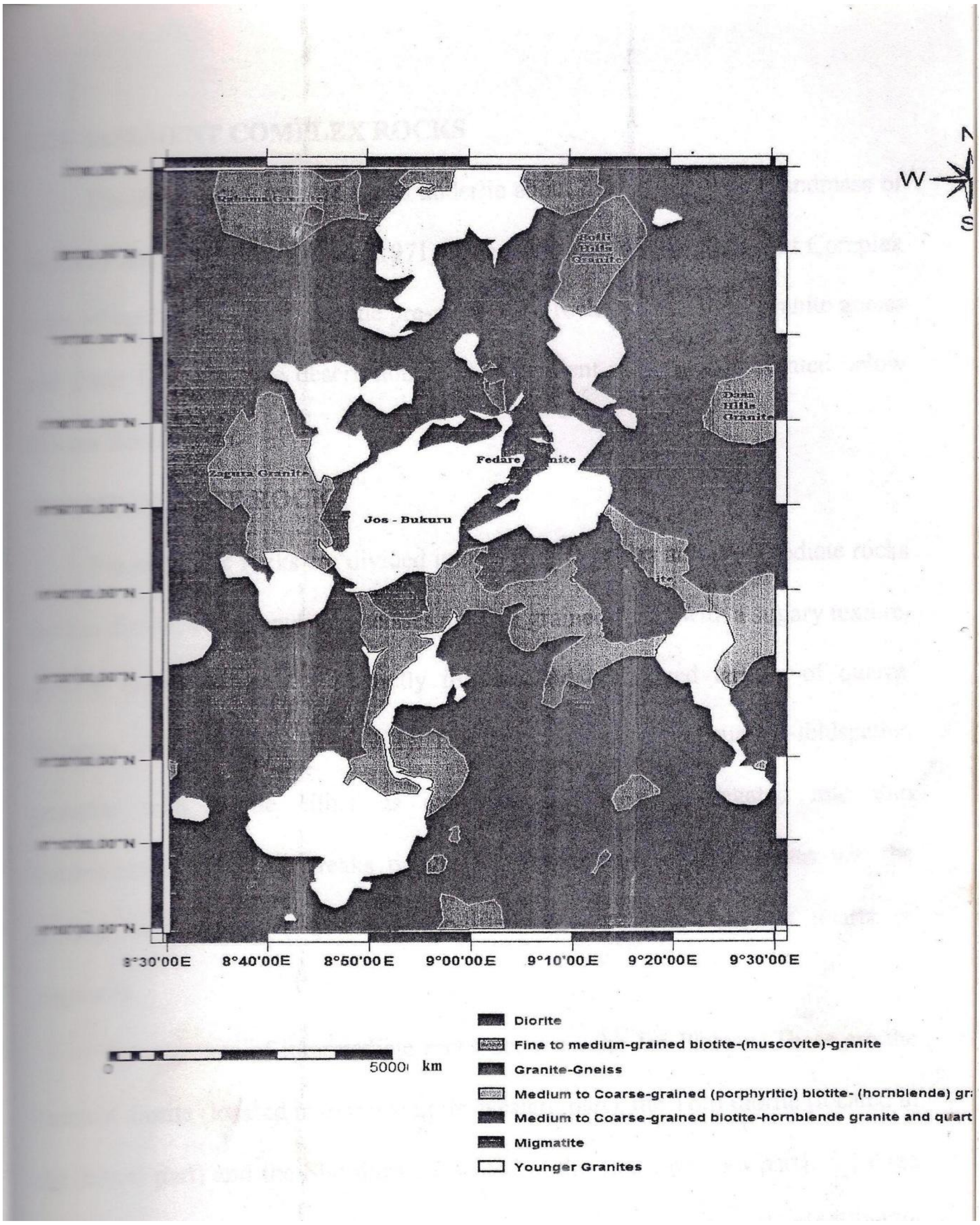

Figure 1: General Geology of the study area

RESULTS AND DISCUSSION

This research involved both field and experimental work. The field work involves collection of soil samples from one place to another which are then taken to the laboratory for analysis.

Sieve Analysis

Sieve analysis is also known as gradation test. It is carried out using the standard BS 1377 Brirtish Standard Sieve. It involves the use of 500 grams of natural soil sample which was dried in the oven by passing them through series of sieves with different aperture sizes. Sieve number 200 is the last one placed at the bottom. The sieves are powered electrically to shake for some minutes. Soils samples which are retained are weighed and recorded. The percentage passing and the percentage retained in each of the sieves are calculated. The percentage passing is plotted against the grain size using the semi log graph sheet.

Atterberg Limits

Atterberg limits are boundaries that define the several states of consistency for plastic soils. This boundaries can be determined by the gradual addition of water the soil needs to move from the plastic to the liquid state boundaries. The boundaries are called the plastic limit and the liquid limit, and the difference between them is called the plasticity index. The shrinkage limit is also very important in the determination of the Atterberg limits of soils. When cohesive soils are wet, they change into any shape without the appearance of any cracks on them (i.e. they can be moulded). The results of this test can be used to infer other engineering and geotechnical properties of the soils. Only the air-dried samples that passed through the British standard sieve number 36 (0.425 mm) can be used for the tests. The samples were them mixed with ordinary tap water until it reached plastic limit for a duration of five minutes and left-over night for 24 hours.

Liquid Limit Test

The soaked soil samples are mixed thoroughly with ordinary tap water to a uniform paste mixture. This mixture was placed in the liquid limit cup and levelled off parallel to the base. A standard Casagrande grooving tool was used for grooving the soil paste through the centre. The handle (crank) of the liquid limit device was turned and the number of blows necessary to close the groove in the soil was noted. It was necessary to close the groove by flow of the material and not by slippage. At intervals samples were also taken from the centre of the closed groove for moisture content determination. This is repeated four times for each of the properly mixed paste with addition of dry powdered samples. The number of blows that closed each groove and corresponding moisture content for the soil is also noted and recorded. As a result, their moisture content values were plotted (on an ordinary scale) against the number of blows (on logarithmic scale). The best straight line between these points was drawn, and the moisture content corresponding to 25 blows on this line was taken as the liquid limit of the sample.

Plastic Limit Test

The same sample used for the liquid limit test was the same as that for the plastic limit test. In this test, sample paste of about 20 to 30 g was broken into several smaller portions and rolled back and forth under the palm on the surface of a glass plate with sufficient pressure to form a thread of uniform diameter. The sample was weighed wet and then weighed dry. The moisture content at which the soil crumbled as its diameter approached 3mm (1/8 m) was determined. This test was repeated thrice and average moisture content was calculated as the plastic limit of the soil investigated.

Plasticity Index

The plasticity index was calculated from the liquid limits and the plastic limits of the soil. Plasticity index gives an index of how much water the soil is capable of absorbing. In classifying the soil, the plasticity index was plotted against the liquid limit on the semi log paper. Plasticity Index is the Liquid limit minus the Plastic limit.

Compaction Test

Compaction can be seen as a mechanical process whereby mechanical energy is applied on the soil to rearrange the particles and to reduce the void ratio usually by driving out air particles. It is a process whereby mechanical means is used to constrain soil particles together by reducing the air void of the soil, the compaction of a soil is a measure of the dry density of the compacted soil which is the weight of the wet soil divided by the volume of the soil. This test is used to determine the maximum dry density and the optimal water content a soil can achieve for a given compaction effort.

One standard was used in the compaction test, the British standard (BS). The material used in each case was that passing through the 5 mm (3/16 inches). British Standard sieve. The retained portions were discarded. The soil was air dried before the test. In the British Standard test a certain percentage of water was added to the soil and mixed very well until uniform moisture distribution is attained. The mixture was compacted into three layers of a Standard proctor mould by the application of 25 blows / layer of a 2.5 kg rammer falling from a height of about 0.3005 m. The sample which was levelled to the top of the empty mould gave the weight of the compacted material. The experiment was repeated by gradual addition of water for each of the percentage mixtures.

DISCUSSION

Sieve Analysis

It involves the use of sieves. According to the Highway and Transport Officials (AASHTO), in 2012, soils that pass through sieve number 200 mesh are high in silt and clay and are grouped as poor or incompetent soils. If the percentage of the soil material passing through the sieve of mesh size 200 is greater than 35 %, it renders that particular soil incompetent.

Table 1 shows the sieve analysis results of the soil samples investigated and their interpretation.

Table 1 : Sieve analysis results

Sample Location	% Pasing Through Sieve No 200	Type of Soil Infeered	Remarks
Sample 1	27.0	Sand / Gravel	Competent
Sample 2	51.0	Clay	Incompetent
Sample 3	57.0	Clay	Incompetent
Sample 4	58.0	Clay	Incompetent
Sample 5	51.0	Clay	Incompetent
Sample 6	30.0	Sand / Gravel	Competent
Sample 7	25.0	Sand / Gravel	Competent
Sample 8	49.0	Clay	Incompetent
Sample 9	28.0	Sand / Gravel	Competent
Sample 10	35.0	Sand / Gravel	Competent

From the results, soil samples collected at locations 1, 6, 7, 9 and 10 are competent since they are made up of sand and gravels. Soil samples collected at locations 2, 3, 4, 5 and 8 are incompetent , they are basically clayish. As a result, civil engineering structures like buildings, bridges , roads etc can be constructed in areas that the soil samples are competent. The sand and gravels that characterise these areas do not pose any threat to civil engineering structures rather they help in concretising and solidifying them. The clay material that characterise the incompetent areas makes them to be susceptible to frequent shrinkage and swelling during variations in climatic conditions. This makes the soli to be mechanically unfit for any form of construction and can lead to total collapse.

Atterberg Limits

Atterberg limit looks at the degree of consistency of the soil with gradual increase or addition of water. With gradual increase in water, it tends to liquid limit (LL) and plastic limit (PL). The difference between the liquid limit and the plastic limit gives the plasticity index, (PI) of the soils. The specifications for roads and bridges , Ministry of works, Benue – Plateau, 2017 established a direct link between plasticity index and swelling potential of soils.

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Table 2: Swelling Potentials of Soils (Gidigasu, 1974)

Plasticity index %	Swelling potencial	Type of material
0-15	Low	Sand/gravel
15-25	Medium	Silty clay
25-35	High	Clay
>35	Very high	Clay

The results of the plasticity indices of soils examined and interpreted compared to Table 1 is displayed in Table 2.

From the results, soil samples collected at locations 1, 6, 7, 9 and 10 are competent since they are made up of sand and gravels since they have low swelling potentials. Soil samples collected at locations 2, 3, 4, 5 and 8 are incompetent , they are basically clayish. They have high swelling potentials. As a result, civil engineering structures like buildings, bridges , roads etc can be constructed in areas that the soil samples are competent. The sand and gravels that characterise these areas do not pose any threat to civil engineering structures rather they help in concretising and solidifying them. The clay material that characterise the incompetent areas makes them to be susceptible to frequent shrinkage and swelling during variations in climatic conditions. This makes the soli to be mechanically unfit for any form of construction.

Atterberg limit is used to determine the consistency limits of the soils which is useful in determining their settlement and strength characteristics for civil engineering constructions in the construction industry.

Table 3 : Atterberg limit test results

Sample Location	Liquid Limit(%)	Plastc Limit(%)	Plasticity Index (%)	Swelling Potencial	Type Of Soil	Remarks
Sample 1	51.7	38.3	13.4	Low	Sand / Gravel	Competent
Sample 2	40.3	24.3	16.0	Medium	Silt / Clay	Incompetent
Sample 3	45.2	28.5	16.7	Medium	Silt /Clay	Incompetent
Sample 4	48.2	29.8	18.4	Medium	Silt /Clay	Incompetent
Sample 5	42.5	25.0	17.5	Medium	Silt /Clay	Incompetent
Sample 6	52.5	39.0	13.5	Low	Sand / Gravel	Competent
Sample 7	50.0	38.5	11.5	Low	Sand / Gravel	Competent
Sample 8	39.8	24.3	15.5	Medium	Silt / Clay	Incompetent
Sample 9	37.2	25.3	11.9	Low	Sand / Gravel	Competent
Sample 10	39.0	25.4	14.3	Low	Sand / Gravel	Competent

Compaction

Compaction is purely a mechanical process that involves the application of mechanical energy to the soil in other to rearrange the particles and to reduce the entire void ratio usually by driving out air from it. The process involves the use of mechanical means to constrain soil particles together by reducing the air void of the soil. The compaction of a soil is a measure of the dry density of the compacted soil which is the weight of the wet soil divided by the volume of the soil sampled. Compaction test is used to determine the maximum dry density and the optimal water content a soil can achieve for a given compaction effort for each soil sample test.

One standard was used in the compaction test is the British standard (BS). The material used for each test is the sample passing through the 5 mm (3/16 inches). British Standard sieves are used for this analysis. The retained portions are usually discarded. The soil was air dried before the test is carried out. In the British Standard test a certain percentage of water was added to the soil and mixed very well until uniform moisture distribution is attained. The soil mixture was compacted into three layers in a Standard proctor mould container using 25 blows / layer of 2.5 kg rammer falling from a height of 0.3005 m. The sample was then levelled to the top of the empty mould which gave the weight of the compacted material. The experiment was repeated with gradual addition of water for each of the mixtures.

The dry densities of the soils and the maximum dry density, moisture contents of the soil and optimum moisture content of the soils were also calculated and determined.

Table 4 shows the soil samples sampled, their maximum dry density and their respective moisture content. According to the specifications for roads and bridges by Attimeyer and in collaboration with the Department of Scientific and Industrial Research in 2017, a table was put forward to establish a link between the type of material, their optimum moisture content and their correspondent maximum dry density as seen in Table 4.

Table 4: Attimeyer : Relationship between the MDD, OMC and the Soil Type (Department of Scientific and Industrial Research, 2017)

Type of material	Maximum dry density	Optimum moisture content
Clay	1.440-1.680	20-30
Silty clay	1.680-1.840	15-25
Sand/gravel	1.840-2.160	8-15

The results of the compaction test results were examined and interpreted by comparing them with table 4.

Table 5: Compaction test results

Sample Location	Maximum Dry Density	Optimum Moisture Content	Type of Soil Infereed	Remarks
Sample 1	1.83	13.4	Sand /Gravel	Competent
Sample 2	1.84	18.6	Silty Clay	Incompetent
Sample 3	1.76	17.8	Silty Clay	Incompetent
Sample 4	1.67	21.2	Silty Clay	Incompetent
Sample 5	1.67	26.9	Clay	Incompetent
Sample 6	1.85	12.5	Sand /Gravel	Competent
Sample 7	1.87	14.3	Sand /Gravel	Competent
Sample 8	1.81	16.2	Silty Clay	Incompetent
Sample 9	1.84	13.3	Sand / Gravel	Competent
Sample 10	1.86	12.3	Sand / Gravel	Competent

From the interpretation above, soil samples collected at locations 1, 6, 7, 9 and 10 are referred as the competent soils since there are made up of sand and gravel materials. Soil samples collected at locations 2, 3, 4, 5 and 8 are incompetent , they are basically clayish. In terms of optimum moisture contents, the incompetent soil materials had a range of 16.2 to 26.9 % while the competent soil samples had a range of 12.3 to 14.3 %. In terms of maximum dry densities, soils in the incompetent areas had a range of 1.67 to 1.84 % while the soils in the competent areas had a range of 1.84 to 1.87 %. According to the specifications for roads and bridges in 2017, soil samples from the incompetent areas have high optimum moisture content and low maximum dry density. As a result, civil engineering structures like buildings, bridges , roads etc cannot be constructed in areas that the soil samples are incompetent. The sand and gravels that characterise the competent areas do not pose any threat to civil engineering structures rather they help in concretising and solidifying them. The clay material that characterise the incompetent areas makes them to be susceptible to frequent shrinkage and swelling during variations in climatic conditions. This makes the soli to be mechanically unfit for any form of construction.

CONCLUSION

High clay content found in the incompetent areas of the study area (samples 2, 3, 4, 5 and 8) makes them to unsuitable for the construction of any civil engineering structure. This is because clay has the ability of expansion when wet and contraction when dry. This frequent expansion and contraction due to variations in seasons leads to cracks and with time the collapse of the structure erected on it.

Soil samples collected from the competent areas of the study area (1, 6, 7, 9 and 10) are made up of sand and gravel. Sands and gravels generally do not pose any engineering threat to any civil engineering structure rather they help in solidifying and consolidating them.

It will be advised to erect civil engineering structures only in the competent parts of the study area since they are not capable of posing any engineering threat.

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