Volume 11 Number 2 2010

NATURAL AND APPLIED SCIENCES JOURNAL

www.naasjournal-ng.org ISSN 1119-9296

ISSN 1119-9296

Natural and Applied Sciences Journal Vol. 11 No. 2
Available online at www.naasjournal-ng.org

GEOTECHNICAL PROPERTIES OF A MIXED GEOLOGICAL TERRAIN FOR ROAD FOUNDATION: A CASE STUDY OF LAPAI-GULU ROAD, NIGER STATE, NORTH-CENTRAL NIGERIA

Idris-Nda, A., Amadi, A. N. and Ismaila, M.
Department of Geology, Federal University of Technology, Minna
E-mail: idrisnda2003@yahoo.com or akoamadi@yahoo.com

Abstract
A mixed geological terrain is one that comprises of both a crystalline basement complex (hard rock) and the sedimentary rocks (soft rocks), even though the contact between the two rock types are not exposed on the surface. A study was conducted on the road from Lapai to Gulu in Niger state that cut through both terrains. Sieve analysis results indicate that the soil in the hard rock areas is made up of 32% gravel, 34% sand and 34% silt/clay, with a liquid limit of 36.0-53.4%, plastic limit of 26.0-32.0%, plasticity index of 9.0-21.4% and a medium shrinkage potential with an average density of 1.96. The soft rock areas are made up of 60% gravel, 23% sand and 22% silt/clay, with a liquid limit of 35.5-39.5%, plastic limit of 25.0%, plasticity index of 10.5-12.2%, low shrinkage potential, with average density of 2.04. The soils of the hard rock area can be classified to be fair to poor and suitable as base course materials, while the soft rock areas are good to excellent and suitable as sub-base and base course materials. Foundation designs in the hard rock area would include among others excavation and improvement on natural soil conditions.

Keyword: Geotechnical Properties, Mixed Geological Terrain, Road Foundation, Lapai-Muye road, Niger State

Introduction

The application of geologic data, techniques and principles to the study of naturally occurring rock and soil materials or subsurface fluids, assures that geologic factors affecting the planning, design, construction, operation and maintenance of engineering structures are recognized, adequately interpreted, and presented for use in engineering practice (Rahn, 1996). A mixed geological terrain can be described as an area underlain by both rocks belonging to the basement complex (hard rock) and sedimentary rocks (soft rock) within a relatively small area of land area. These rocks are formed under varied geological conditions and depositional environment and thus have varied responses to stress imposed on them, and also their use as constructional materials. Despite been subjected to similar environmental and climatic conditions, marked dissimilarities are obvious from the weathering processes which may impact positively or negatively on the structures placed on them. Engineering works may succeed or fail according to how well they fit into their geological environment and how well we understand the geologic processes that might affect those works (Hunt, 1972; Clayton, 1995).

The present study is aimed at determining the geotechnical parameters required for planning and designing a road that will stand the test of time. The area chosen for the study is from Lapai to Muye, both in Niger State, lying within Latitudes 8°40'N to 9°05'N and Longitudes 6°36'E to 6°38'E (Fig. 1). The existing road, covering a total distance of 47km is a major road linking Niger and Kogi States in Central Nigeria. It is completely dilapidated but now under rehabilitated. It is hoped that this study will help the engineers handling the project, and other similar projects in similar terrain to understand the geologic factors that may affect their design and construction of road along transitional zones.

ISSN 1119-9296

Natural and Applied Sciences Journal Vol. 11 No. 2
Available online at www.naasjournal-ng.org

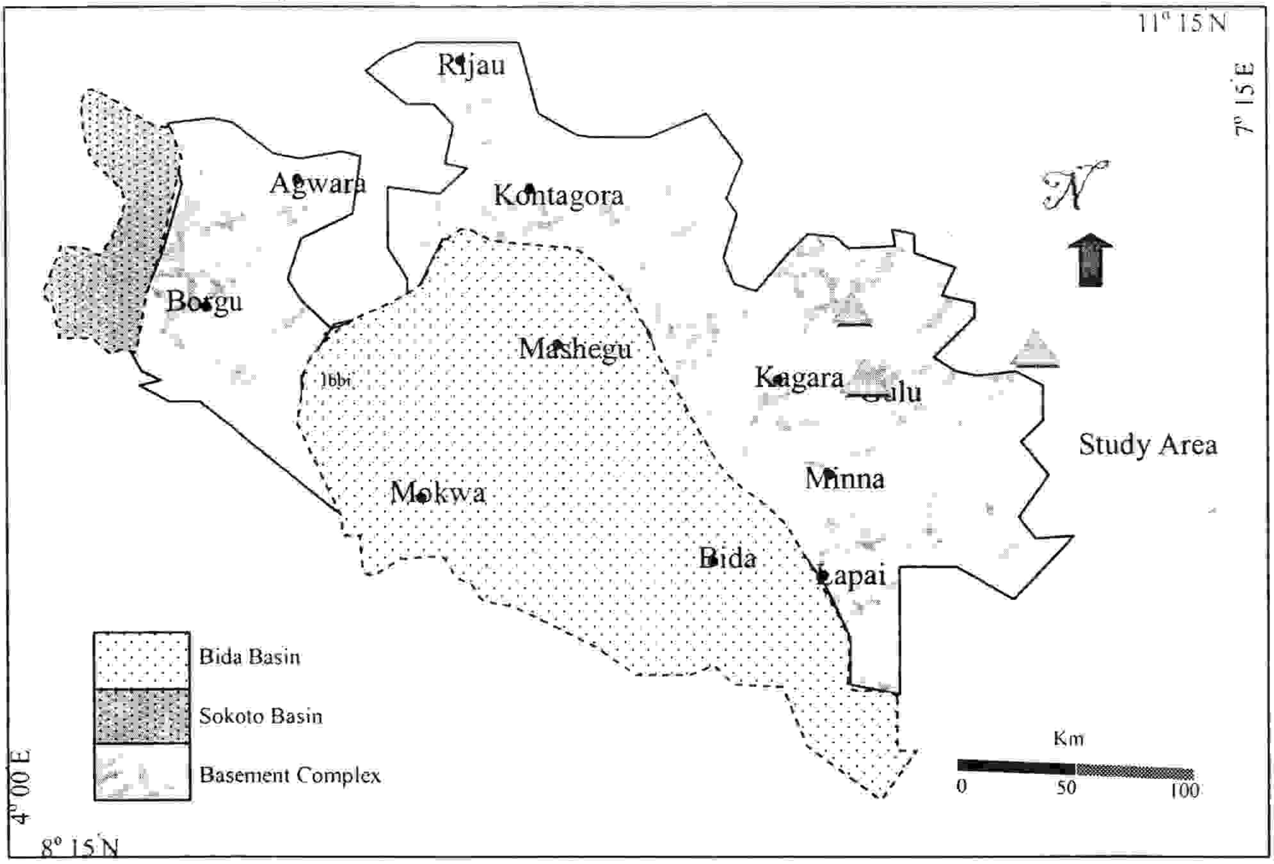

Fig.1: Geological Map of Niger State showing the Study Area

Geology and Hydrogeology of the Area

The study area falls within the Precambrian to Lower Paleozoic rocks of the Nigerian Basement Complex system and the Cretaceous edimentary terrain of the Middle Niger (Bida) basin. The Basement Complex rocks consist of migmatites and gneisses that are characterized by a variety of structures and textures, highly foliated, fractured, jointed and easily weathered. The older granites that occur as plutonic igneous rocks comprising of medium to coarse grained granitic rocks and porphyritic granodiorite, such as the Minna Batholith; and low grade schist belt/quartzite which are made up of low grade amphibolites and green-schist facies, (Ajibade and Woakes, 1976).

These rocks have been variously faulted, jointed and in different stages of weathering. The granites weather mostly into sands and clays, while the migmatites and gneisses as well as the schist weather more into clays.

The sedimentary basin is described as down warped because it hasn't been subjected to much orogenic activities. It is characterized by rocks belonging to the Bida Sandstone Formation comprising of fine to medium grained sandstone, silt and clay deposits. They have clear bedding plane with a near horizontal to slight dips that seldom exceed 45°. Groundwater moves through the weathered portion of the hard rocks and travels along the contact zone between the soil and the rock. Groundwater flow is a factor of the porosity and permeability of the material it passes through, its hydraulic conductivity and hydraulic gradient. While water flows freely through sandstone, clays on the other

ISSN 1119-9296

Natural and Applied Sciences Journal Vol. 11 No. 2
Available online at www.naasjournal-ng.org

hand impede groundwater flow, it holds water but does not transmit it (Rahn, 1996; Curtin, 1997). The hydraulic property plays a very important role in the development of the engineering characteristics of materials. Porous sediment, if loaded, will deform when its grains move under influence of an applied load. The closure of voids and fractures such as pores and joints is influenced by the ease with which fluids residing in them may be displaced. Thus well-drained materials behave as strong materials while poorly drained materials are weak materials.

Materials and Methods

Disturbed samples were obtained from trial pits dug up to a depth of 1m from nine locations cutting across the two terrains. Trial pits 1-5 were in the basement complex while trial pits 6-9 were in the sedimentary rock terrain. Soil parameters measured in the laboratory were according to British Standard test for soils for civil engineering purposes: the liquid limit test using the Casagrande apparatus; compaction test using the rammer method; plastic limit test using a flat glass plate and palette knives; determination of particle size distribution by sieve analysis using the British standard test devices test sieves and the California Bearing Ratio (CBR) using the method of mould assemblage with collar and base plate.

Results and Discussion

Table 1 shows the summary of the results of particle size analysis which shows the percentage passing while Table 2 shows the summary of sieve analysis for grain size distribution. Tables 3 and 4 show the average percentage distribution and summary of results obtained from Atterberg Limits test respectively while Table 5 shows the average dry density at percentage optimum moisture content of 2.0 to 14%. Particle size distribution indicates that the hard rock areas have a higher content of sand and clay, while the sedimentary areas equally have higher percentage of gravel. Sand and clays have a low porosity and permeability, therefore impeding the flow of water through them. Gravels on the other hand are porous and permeable and are therefore well drained.

The degree of weathering depends on the chemical composition of the rocks and climatic factors prevailing in the area. Both the Atterberg limit and compaction tests conducted indicate that the basement complex areas have geotechnical properties that are considerably below that of the sedimentary rock areas. Sedimentary rocks are derived from pre-existing rocks and have undergone transportation before being deposited; they are not affected much by weathering. The California Bearing Ratio (CBR) is a measure of the supporting value of the sub-base. The hard rock areas are quite suitable for a base course, while the sedimentary areas are suitable for both base course and sub base.

ISSN 1118-9296
Natural and Applied Sciences Journal Vol. 11 No. 2
Available online at www.naasjournal-ng.org

Table 1: Summary of Result of Particle Size Analysis Test/Sieve Analysis % Passing

Trial Pit No.	Location	Depth (m)	50.0	20.0	14.0	10.0	6.3	5.0	2.0	1.18	0.6000	0.425	0.3000	0.150	0.065
1	Ganamadi	1.0	100.0	100.0	98.02	94.89	90.99	88.59	75.53	66.55	56.33	51.98	48.42	42.27	36.12
2	Dangana I	1.0		100.0		92.60		73.00	52.90	44.10	38.60	36.00	33.70	30.00	26.60
3	Dangana II	1.0		100.0		99.60		96.20	72.90	55.60	46.30	42.60	39.70	35.20	31.00
4	DanganaIII	1.0		100.0		93.90		86.50	70.20	57.50	49.00	45.60	43.20	39.10	35.40
5	DanganaIV	1.0	100.0	97.6		92.30		78.10	60.40	49.20	41.80	39.10	37.10	34.00	31.10
6	Gulu I	1.0		100.0	96.45	82.72	60.90	51.57	28.09	25.62	24.24	23.72	23.19	22.09	21.01
7	Gulu II	1.0		100.0	93.52	85.54	68.70	59.56	32.04	28.16	25.99	25.21	24.50	22.87	21.35
8	Gulu III	1.0			100.0	97.38	84.37	73.85	32.85	25.68	22.50	21.35	20.24	18.26	16.6
9	Gulu IV	1.0			100.0	99.40			98.30	92.60	84.00	68.80		48.30	33.40
	Range		100.00 to 100.00	97.60 to 100.00	93.57 to 100.00	82.72 to 99.40	60.90 to 90.94	51.57 to 96.20	32.04 to 98.30	25.60 to 92.60	22.50 to 84.00	21.35 to 68.80	20.24 to 48.42	18.26 to 48.30	16.62 to 36.12
	Average		100.00	99.66	97.0	93.14	76.23	75.94	58.13	49.45	43.19	39.37	33.76	32.45	28.07

Table 2: Summary of Sieve Analysis for Grain Size Distribution

TRIAL PIT NO	DEPTH RANGE (M)	% OF GRAVEL	% OF SAND	% OF SILT/CLAY
1	1.0	25	42	33
2	1.0	21	25	27
3	1.0	28	40	32
4	1.0	40	25	35
5	1.0	40	29	31
6	1.0	72	7	21
7	1.0	89	11	21
8	1.0	75	9	16
9	1.0	2	66	32

Table 3: Average Percentage Distributions

Terrain	% Gravel	% Sand	% Silt/Clay
Basement	32	34	34
Sedimentary	60	23	22

ISSN 1119-9296

Natural and Applied Sciences Journal Vol. 11 No. 2
Available online at www.naasjournal-ng.org

Table 4: Summary of Results obtained from Atterberg Limit Test

TRIAL PIT NO.	LOCATION	DEPTH (m)	SOIL CONSISTENCY				
			4%	PL%	PI%	SP	LL Liquid limit
1	Ganamadi	1.0	53.4	32.0	21.4	Medium	PL- plastic
2	Dangana I	1.0	36.0	29.0	7.0	Low	PL- plastic limit
3	Dangana II	1.0	38.0	29.0	9.0	Medium	Sp-shrinkage potential
4	Dangana III	1.0	35.0	26.0	9.0	Medium	
5	Dangana IV	1.0	37.0	28.0	9.0	Medium	
6	Gulu I	1.0	37.2	25.0	12.2	Low	
7	Gulu II	1.0	39.5	25.0	14.5	Low	
8	Gulu III	1.0	36.0	25.0	11.0	Low	
9	Gulu kandi	1.0	35.5	25.0	10.5	Medium	

Table 5- Average density (dry) in gm/cm3 at percentage water contents of 2.0 to 14% (compaction test)

No	Location	Depth (M)	Av. Dry Density Gm/Cm3	Cbr General Rating	Use
1	Ganamadi	1.0	1.94	Excellent	Base course
2	Dangana I	1.0	1.99	Good	Sub Base
3	Dangana II	1.0	1.89	Fair to poor	Base course
4	Dangana III	1.0	2.84	Fair to poor	Base course
5	Dangana IV	1.0	1.84	Fair to poor	Base course
6	Gulu I	1.0	2.05	Good	Sub Base Base course
7	Gulu II	1.0	2.17	Good to excellent	Sub Base Base course
8	Gulu III	1.0	2.06	Good to excellent	Sub Base Base course
9	Gulu kandi	1.0	1.86	Good to excellent	Sub Base Base course
Average Dry Density/ Cbr					
Basement			1.96	Fair to poor	Base course
sedimentary			2.04	Good to excellent	Sub Base and Base course

Conclusion

From the investigation carried out, it can be ascertained that the road cut across two different geological terrains. Since the geological and geotechnical properties of rocks that make up the two terrains are different, foundation for roads passing through the two terrains should be designed to take these into consideration. Hard rock may need to be excavated and gravel placed as the base course.

References

Ajibade, A. C. and Woakes, M., (1976). Proterozoic crustal development in the Pan- African Regime of Nigeria. In: C. A. Kogbe (Editor) Geology of Nigeria. Published by Rock View (Nigeria) Ltd, pp 57–63.

British Standard Code of Practice for Foundations, 1986. BS 8004. Published by the British Standards Institution, pp 4–110.

British Standard Methods of Test for Soils for Civil Engineering purposes. BS 1377: Part 1–9, 1990. Published by the British Standards Institution, pp 8 – 200.

Casagrande, A. A., (1950). Development of CBR flexible pavement design method for Airfields.

Clayton, C. R., Matthews, M. C. and Simons, N. E., (1995). Site investigation. Published by Blackwell Science Ltd., Great Britain, pp 1-59.

Curtin, W. G., Shaw, G., Parkinson, G. I. & Golding, J., (1997). Structural foundation designer's manual. Published by Blackwell Science Ltd, U. K., pp 1 – 300.

Hunt, C. B., (1972); The Geology of the PreCambrian to Lower Paleozoic rocks of

Rahn, P. H. (1996): Engineering Geology: an environmental approach, 2nd edition. Prentice Hall inc. NJ U.S.A. Pp 11-12.

Tomlinson, M. J., (1999). Foundation Design and Construction. Pitman Publishing Ltd, 6th edition. Singapore, pp 52–59.