Journal of Mining and Geology Vol. 56(1) 2020. pp. 125 - 131 1116-2775

Evaluation of Some Lateritic Soils of Basement Complex Rocks From Ado Ekiti and Environs, Southwestern Nigeria for Road Construction

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Abstract
Suitable soils for road pavement construction are getting depleted. Highway Engineers are constantly in search of locally-available and suitable soils for construction of pavement layer road. This work investigates the engineering properties of lateritic soil derived from Charnockites, Migmatites, Pegmatitic Schists and Gneisses rocks, in Ekiti State, and were evaluated for their suitability for road construction. Eight (08) soil samples were randomly taken (two each from the four different rock types). They were subjected to geotechnical analyses which included particle size analyses, specific gravity, Atterberg limits, compaction, and California bearing ratio (CBR) tests. Values obtained were compared with Federal Ministry of Work Standard and Specification. Results of the study show that lateritic soil derived from Charnockitic rock have percentage fines ranging from 26.9-28.6%, Specific Gravity: 2.52-2.57, Liquid Limit (LL): 26.35-26.5, Plasticity Index (PI): 8.57-11.81%, Maximum Dry Density (MDD): 2.09-2.12 and CBR value (soaked): 17.2-29.2%; Migmatite had percentage fines varying from 43.1 to 45.5 %, Specific Gravity: 2.52-2.57, LL: 28.3-47.5%, PI: 13.88-23.36%, MDD: 1.67-1.77 and CBR (soaked) 7.8-13.8%; Pegmatitic Schist also had percentage fines varying from 36.49-56.74%, Specific Gravity ranged from 2.44-2.53, LL: 45.5-46.6, PI: 17.44-19.3%, MDD 1.59-1.67 and CBR (soaked) from 8.2-14.1%; Gneiss showed percentage fines varies from 28.1 to 45.1%, Specific Gravity: 2.5-2.55, LL from 29.2-40.01, Plasticity Index 8.16-18.97%, MDD 1.73-1.96 and CBR (soaked) from 17.1-25.2%. Comparison of the results with the standard specifications of Federal Ministry of Works for pavement materials: LL <36, PL ≤ 12, % fines < 30, CBR (soaked) >30 %, and MDD ≥ 2 shows that only the lateritic soils derived from Charnockitic rock obtained at Ado-Ekiti and Ikere-Ekiti satisfy every aspect of the geotechnical properties except CBR values (test results less than the standard). Although they have the highest values compared with soils derived from others. Lateritic soils derived from Migmatitic rock, Pegmatitic Schist, and Gneissic rock do not satisfy all plasticity and strength properties requirements (values of LL < 36%, PI ≤ 12 %, % fines < 30%, and MMD ≥ 2). They are therefore likely to deteriorate faster than soils derived from Charnockitic rock.

Keywords: *Charnockite, Migmatite, Pegmatitic Schist, Gneiss and Lateritic soil*

Introduction

Lateritic soil is highly weathered and altered residual soils formed by the in-situ weathering and decomposition of rocks under tropical condition, which are rich in sesquioxide and low in bases and primary silicates but may contain appreciable amounts of quartz and kaolinite (Zelalem, 1999). Due to the present of iron oxides, lateritic soil is red in colour ranging from light through bright to brown shade. Lateritic soil is formed from the leaching of parent sedimentary rocks, metamorphic rocks and igneous and mineralized proto-ores, which leaves the more insoluble ions, predominantly iron and aluminium. The mineralogical and chemical compositions of lateritic soil are dependent on their parent rocks.

The dominant clay minerals in most laterites and lateritic soils are kaolinite. Occasionally, laterites and lateritic soils may contain montmorollitic clay mineral, and when this occurs, the soil may develop the tendency to swell when in contact water, thereby becoming a problem soil (Gidigasu, 1973; Gromko, 1974; Ola, 1981). Lateritic soils are widely used in the construction industry for road construction (highway sub-base and base course materials) and fills in dams, building foundations and levees (Simon, Giesecke and Bidlo, 1973; Gidigasu, 1976). During the planning of road, railroad and airfield construction, materials selection for earthwork plays a vital role toward the efficient execution of such construction and the functional operation of the resulting infrastructure. It is essential to identify and use suitable soil materials for earthworks. However, conventional sources of suitable soil materials for the earthwork of such construction are fast getting depleted (Kinuthia et al., 1867), (Obuzor et al., 2012), if not already depleted. Where there are suitable materials, some are very far from proposed project sites, consequently adding transportation or haulage cost and thereby increasing the overall project cost. Highway Design Engineers favour the use of locally-available and suitable materials in order to minimize overall project costs of road pavement constructions. It is, however, necessary to investigate the engineering properties of locally-available soils in order to know how best to use them for road, railroad and airfield pavement construction. Consequently, this research work investigates the potential use of lateritic soils in selected areas of Ekiti State, Southwestern Nigeria, from different parent rocks, as road pavement layer materials.

Location of the Study Area

The study area is located in Ekiti State between latitudes 07°31′ and 07°49′ North and longitudes 05°07′ and 05°27′ East (Fig. 1).

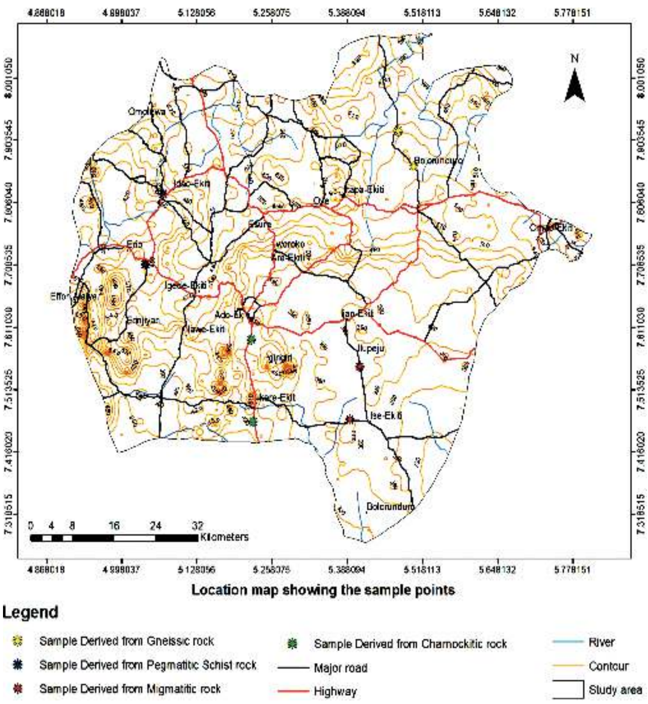

Fig. 1: Location map of the study are showing the sampling points, drainage and topography.

Geology of the Study Area

Ekiti State belongs to the Precambrian Basement Complex of Nigeria. There are three major groups of crystalline rocks lies within this area (Fig. 2). They are:

i. **Pan African Older Granite Series:** This comprises rocks varying in composition from Granodiorite to true Granites and Syenite; and Charnockitic rocks; Unmetamorphosed Dolerite Dykes, which is believed to be the youngest.

ii. **Meta-Sedimentary, Meta – Igneous Rock:** This comprises rock slightly migmatized to unmigmatized poraschists and meta-igneous rocks, which consist of Pelitic Schists, Quartzites, Amphibolites, Metaconglomerates Marbles and Calc-Silicate rocks.

iii. **Magmatite – Gneiss Complex:** The Migmatite-Gneiss Complex is most widespread in the basement complex of South Western Nigeria. It comprises of Gneisses, Biotite Hornblende Gneisses, Quartzites and Quartz Schist, and small lenses of Calc-Silicate rocks.

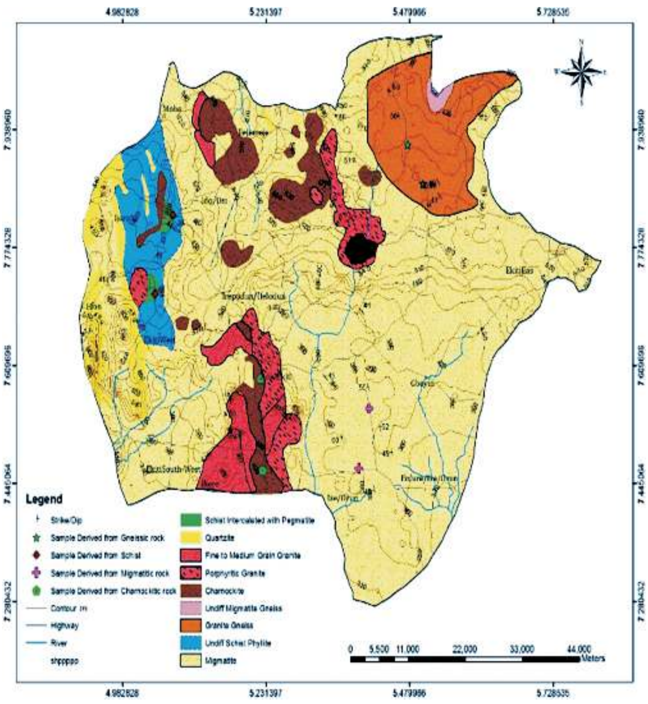

Fig. 2: Geological Map of Ekiti State showing the sampling points

Material and Method

Total of number Eight (08) lateritic soil exposure samples were randomly collected within the study area at a depth of about 1-2m. The locations of the sampling points were selected to represent lateritic soils derived from various rock bodies in the study area. Two major types of soil samples were collected: (a) disturbed samples and (b) undisturbed samples to test for soil index properties and strength properties respectively. Samples specimens shall be prepared in accordance with BS 1377 (1990), AASHTO specification and FMW (1997).

Laboratory tests such as: Specific gravity, Grain size analysis, Consistency tests, Compaction test, California Bearing Ratio (CBR), were carried out on each of the samples. All the tests were carried out in accordance with British standard code of practice (BS1377:1990). Methods of test for soils for civil engineering purposes: All the tests were also carried out at Geotechnical Engineering Laboratory in University of Benin, South western Nigeria.

Result and Interpretation

Particle Size Distribution

On the basis of Federal Ministry of Works (FMW) (1970) standard, only soils derived from Charnockitic rock and Gneissic rock at Bolorunduro Ekiti have acceptable percentage fines (<30 %). Soils derived from Migmatitic rock, Pegmatitic Schist and Gneissic rock at Itapaji-Ekiti have excess % fines that may reduce the strength of the compacted laterites (Matheis and Pearson, 1982; Singh, 2004).

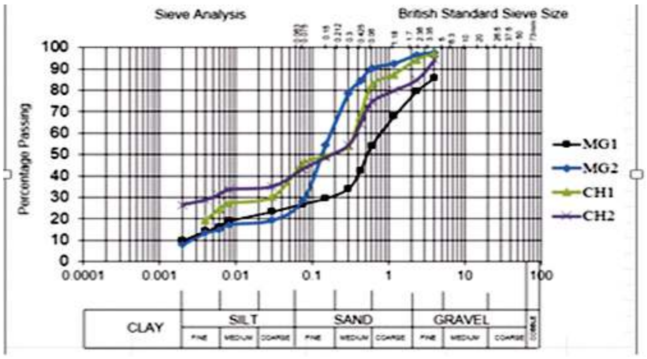

Fig. 3: Particle Size distribution Curve for MG1, MG2, CH1, and CH2

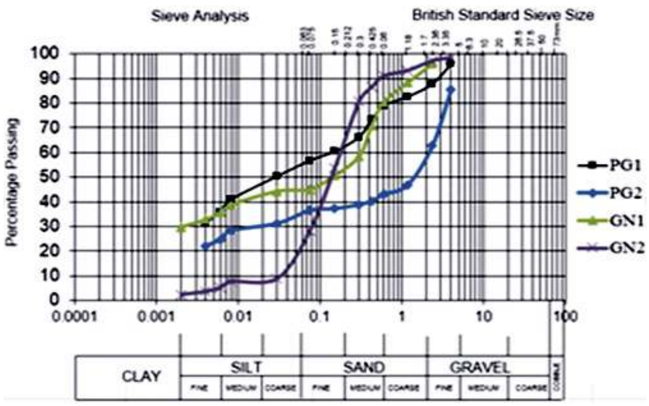

Fig. 4: Particle Size distribution Curve for PG1, PG2, GN1, and Gn2

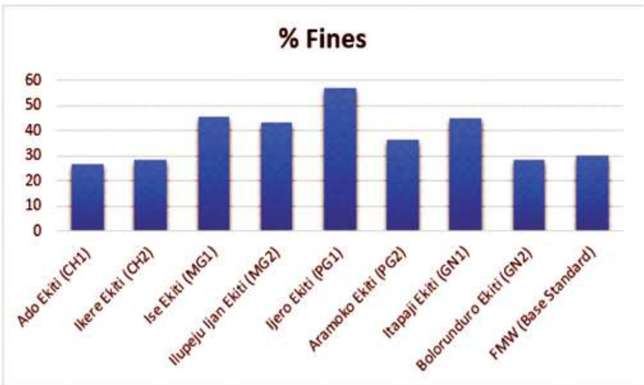

Fig. 5: Percentage fines of samples

Determination of Specific Gravity

According to Gidigasu (1976) a soil is good subgrade if its specific gravity (Gs) ranges between 4.60 – 2.50. Thus, Samples from derived from Charnokitic rock, Magmititic rock, Gneissic rock and Pegmatitic Schist (at Aramoko Ekiti) are fine grained soils (good subgrade) with fairly high specific gravity. However, because of narrow range of specific gravity, it's not particularly useful for this evaluation.

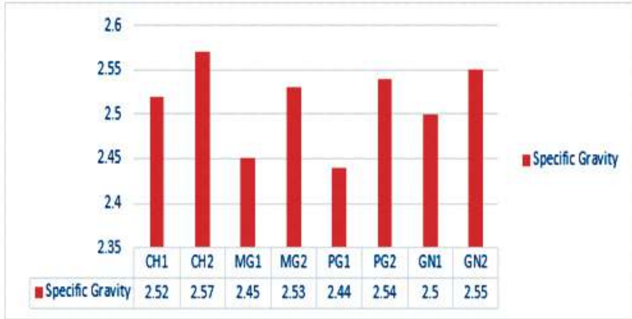

Fig. 6: Specific gravities of Soil samples

Atterberg Limit Tests

Fig. 7 also shows that only soils derived from Charnockitic rocks, and Gneissic rocks collected at Bolorunduro Ekiti satisfy the FMW standard for liquid limit (≤ 35 %) and plasticity index (<12 %) while soils derived from Migmatitic rocks, soils derived from Pegmatitic Schist rock and Soils derived from Gneissic rocks collected at Itapaji-Ekiti do not satisfy the FMW standards for liquid limit and plasticity index. Plots of liquid limit against plasticity index (plasticity chart) of the results (Fig. 8) also confirm that soils from Charnockitic rocks, and Gneissic rocks collected at Bolorunduro Ekiti have low plasticity, while soils from Migmatitic rocks, Pegmatitic Schist and Gneissic rocks collected at Bolorunduro-Ekiti all have medium plasticity.

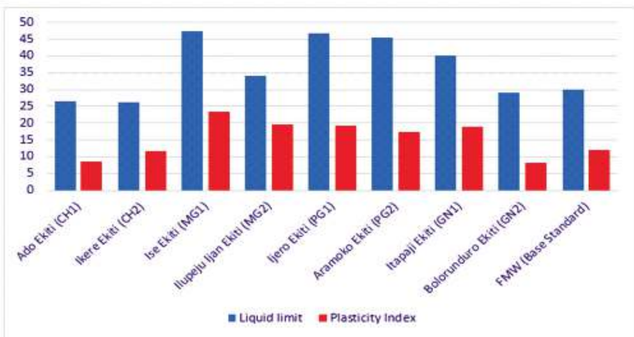

Fig. 7: Chart comparing the LL and PL to FMW standard

Compaction Test

The importance of compaction test is to improve the desirable load Bearing Capacity of the soil. The higher the Maximum Dry Density (MDD), the lower the Optimum Moisture Content the more suitable. Comparing these values with the standard specifications

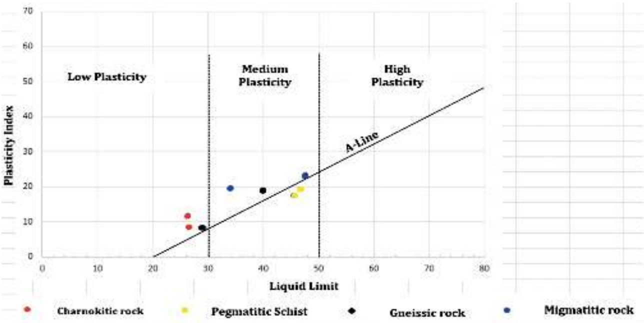

Fig. 8: Plot of the studied soils on Casagrande Plasticity Chart (Adapted from Casagrande, 1943)

of materials for road by Federal Ministry of Works (1970), Maximum Dry Density (MDD) ≥2 for sub-base and base materials; only samples CH1 and CH 2 derived from charnockitic rocks satisfies the requirements for use as subbase layer material for road pavement construction (Fig. 11).

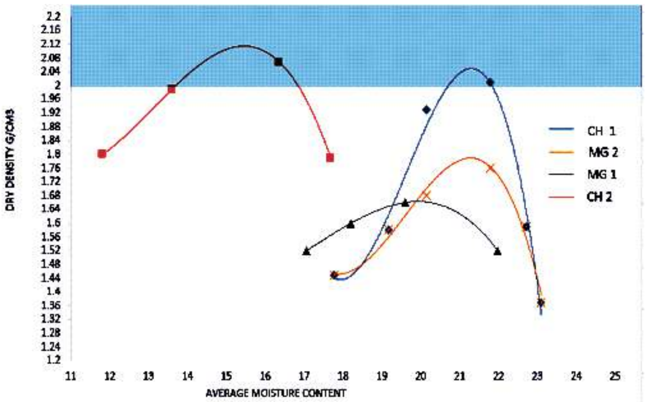

Fig. 9: Compaction curve for CH1, CH2, MG1, MG2

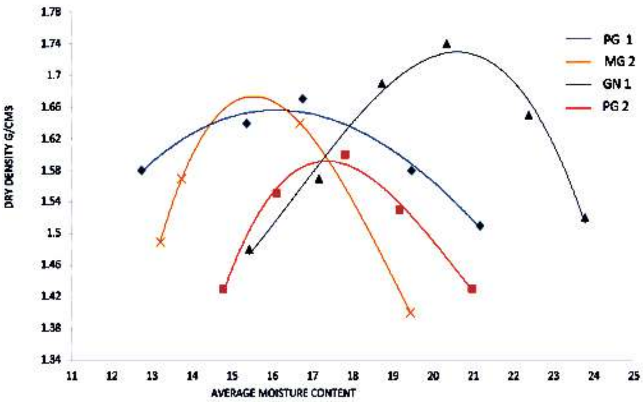

Fig. 10: Compaction curve for PG1, PG2, GN1, GN2

California Bearing Ratio (CBR)

Fig. 12 shows that soils derived from Charnockitic have the highest values of CBR (unsoaked and soaked: 36.3 % and 29.2%), compared with values obtained for soils

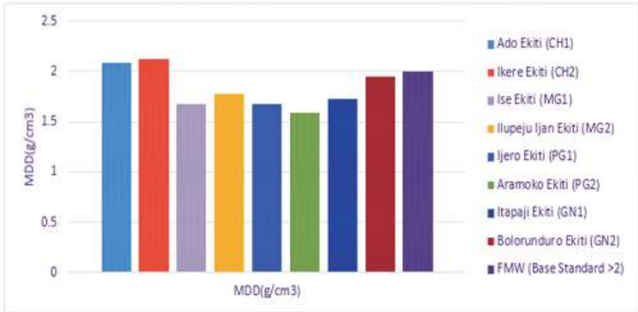

Fig. 11: Maximum Dry Density (MDD) of Samples

derived from Gneissic rock (unsoaked and soaked: 33.38% and 25.2 %), Pegmatitic Schist rock (unsoaked and soaked: 18.8% and 14.1%), and migmatitic rock (unsoaked and soaked: 18.7% and 13.8%), none of the values satisfy the FMW standard requirement of ≥30% (soaked CBR value) and ≥80% (unsoaked CBR value) for sub-base and base coarse materials respectively.

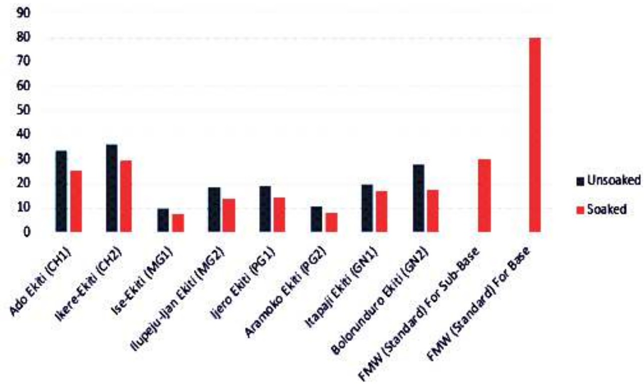

Fig. 12: CBR value of the soil samples

Conclusion and Recommendation

Conclusion

The geotechnical properties of Eight (08) lateritic soil from four different rock bodies in Ekiti state were determined and the results evaluated in terms of the influence of the parent rock on the quality of the lateritic soils as road construction materials. The geotechnical properties used in the study include Atterberg limits (liquid limit, plastic limit, plasticity index), particle-size distribution, Maximum Dry Density (MDD) and California Bearing Ratio (CBR). Results of the study shows that lateritic soil derived from Charnockitic rock have percentage fines ranging from 26.9 to 28.6 %, Specific Gravity ranged from 2.52-2.57, Liquid Limit (LL) from 26.35-26.5, Plasticity Index (PI) 8.57-11.81%, Maximum Dry Density (MDD) 2.09-2.12 and (CBR) California Bearing Ratio (soaked) from 17.2-29.2%.

The values for lateritic soils derived from Migmatite had percentage fines varying from 43.1-45.5%, Specific Gravity ranged 2.52-2.57, Liquid Limit 28.3-47.5, Plasticity Index 13.88-23.36%, MDD 1.67-1.77 and California Bearing Ratio value (soaked) 7.8-13.8%.

The values for lateritic soils derived from Pegmatitic Schist also had percentage fines varying from 36.49 - 56.74%, Specific Gravity ranged from 2.44 - 2.53, Liquid Limit 45.5 - 46.6, Plasticity Index 17.44 - 19.3%, MDD 1.59 - 1.67 and California Bearing Ratio (soaked) from 8.2 - 14.1%.

The values for lateritic soils derived from Gneiss showed percentage fines varies from 28.1 - 45.1%, Specific Gravity ranged from 2.5-2.55, Liquid Limit from 29.2-40.01, Plasticity Index 8.16 - 18.97%, MDD 1.73 - 1.95 and California Bearing Ratio (soaked) from 17.1 - 25.2%.

Comparison of the results with the standard specifications of Federal Ministry of Works for sub-base and base course materials (pavement materials: LL ≤35, PL ≤ 12, % fines < 30, CBR (soaked and unsoaked) ≥ 30 and 80% respectively, and MDD ≥2, shows that only the lateritic soils derived from Charnockitic rock satisfy every aspect of the geotechnical properties except CBR values. Although they have the highest values compared with soils derived from Migmatitic rock, Pegmatitic Schist and Gneissic rock.

Lateritic soils derived from Migmatitic rock, Pegmatitic Schist rock and Gneissic rock do not satisfy plasticity and strength properties requirements (with values of LL > 35%, PI >12 %, % fines >30%, and MMD <2). They are therefore likely to deteriorate faster than soils derived from Charnockitic rock. When used as road pavement materials, for sub-base and base course.

This work, thus, provides a quick reference material (for soil selection), accessible to relevant local government agencies, highway engineers, geologists and contractors, while planning for road pavement construction using soils similar to those used in this study.

Recommendation

All the Samples will need to be stabilized before they can meet the requirement for use as base or subbase materials. Conventional soil stabilizers that can be used include Portland cement and lime. However, recent research works have favoured the use of waste materials as low-cost stabilizers.

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