



Engineering properties of soil/Rocks and their significance in the integrity status of infrastructure (Building, Bridges, Roads) in Tashan kaji – Toro LGA, Bauchi state

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Abstract

Analysis on the properties of soil/rocks that lead into the cause of road failure has been carried out along 78km in Tashan –kaji highway area of Toro L.G.A, Bauchi, and Northeastern Nigeria. Geotechnical, geochemical, mineralogical and geophysical analyses were conducted to evaluate the cause of the failure in the study area. The results of the laboratory tests showed that the percentage amount of fines ranges from 14.2 to 71.3%, natural moisture content from 8.8-15.2%, liquids limit is in the range of 16.5-37.5%, linear shrinkage between 0.7-5.0%, plastic limit range from 16.5-18.0%, plasticity index ranges from 18.5-22.5%, maximum dry density ranges from 1.84-1.97g/cm³, specific gravity ranges from 2.23-2.43%, coefficient of uniformity (Cu) is 0.93-3.8% and the coefficient of curvature (Cc) is between the range of 4.5-6.5%. The cone penetrometer Test (CPT) shows a resistance value of 21-143kgf/cm². The major mineral that is predominant in the studied area is kaolinite. The major oxides that are present are CaO, SiO₂, Na₂O, Al₂O₃, Fe₂O₃, K₂O and MgO. The result of the Electrical Resistivity revealed a low resistivity values at the profile 5 and 7 ranging from 120Ωm-200Ωm, between a distance of 15m-170m along the profile to a depth of 6.8 and a low resistivity value ranging from 60Ωm-121Ωm, between a distance of 70m-110m along the profile to a depth of 13m. It was concluded that geotechnical investigations of the soil samples around the study area have shown that the grain size distribution characteristics of the soils range from poor-fair hence will not be used for foundation and fills materials.

Keywords: Road deformation, Road, Failure, Soil, Geophysical investigation, Plastic limit, Liquid limit

Introduction

The most important key area in the field of engineering geology and the geotechnical engineering investigation is the stability of structure such as roads, bridges, buildings, slopes, tunnels, and dams to withstand high resistance to failure (Roodposhti *et al.* 2019). Road network plays a vital role in the socio economic development and progress of many nations; this aids the linkage of all enterprises/markets and leads to employment creation driving trades and equal wealth distribution. Road transport generally dictates the distribution of economic practices across the world and any country with bad network of road are still under developed regardless of the mineral resources that the country has. Records has indicates loss of several lives and properties abound resulting from road accidents. Foundation soils and highway pavements are inseparable when it comes to good road network, duo toward the development of any country [3]. Several road failure features are noticeable within a short period of time after its commissioning. Roads are actually constructed on geological materials (rocks or soils), and these materials' properties influence their performances as transport medium. Subgrade, sub base, base course and riding surfaces are the major components of several typical flexible highway pavements from the base to the top. Most often loss of lives and properties has been associated to the ill-design and weak construction activities relative to non-compliance with relevant standard measures and recommendations. However, road failures are usually preceded by the following destructive signs such as cracking, rutting, potholes, differential heave, deformation and peeling. Many causative factors attributed to the increasingly recorded road failures include geological, geomorphological and geotechnical factors, road usage, design and construction inadequacies, and maintenances.

Climatic factors particularly temperature fluctuations and acid rain attacks.

Geotechnics is the branch of civil engineering concerned with the study and modification of soil and rock. The fields of geotechnical engineering and engineering geology have knowledge areas that overlap, however, while geotechnical engineering is a specialty of civil engineering, engineering geology is a specialty of geology: They share the same principles of soil mechanics and rock mechanics, but differ in the application, both of them are used to find a solution to the rock failure as a material in the construction industry. To analyse the engineering properties of rocks/soil, some important parameters need to be determined some of the important properties of soils that are used by geotechnical engineers to analyze site conditions and design earthworks, retaining structures, and foundations are: Specific weight or unit weight, Porosity, Void Ratio, Permeability, Compressibility, Shear strength and Atterberge Limits.

In geotechnical engineering, soils are considered a three-phase material composed of: rock or mineral particles, water and air. The voids of a soil, the spaces in between mineral particles, contain the water and air. The engineering properties of soils are affected by four main factors: the predominant size of the mineral particles, the type of mineral particles, the grain size distribution, and the relative quantities of mineral, water and air present in the soil matrix. Fine particles (fines) are defined as particles less than 0.075 mm in diameter.

1. Study area

The work starts with a review of previous work, reconnaissance survey, followed by detailed survey in the study area where samples of rock and soil were collected.

The study area falls within latitude 10° 12' 59.1''N, longitude 009° 33' 22.3''E with elevation of 667m in Tashan Kaji, Toro local government area Bauchi state. It is characterized by two distinct seasons [the rainy season (April–October) and dry season (November–March)]. The road site is a 78-km-long stretch in northwestern to southeastern direction, from Buzaye to Tashan-kaji of Toro L.G.A in Bauchi. The site is undulating with an uneven topography and daily accessed by motorcycles and cars conveying commuters as well as farm produces.

Geotechnical test on samples

The geotechnical test performed on the sample were; Particle size distribution test (grain size analysis), Atterberg limits test, Compaction test, and California bearing ratio test (CBR).

1. Particle size distribution (grain size)

This was done with the aim of finding the distribution of grain size within the soil sample that was collected. The result was use in determining the sorting characteristics of the soil The apparatus use for the analysis include; British standard sieves, a heavy duty balance, a wire brush, rubber hammer, electric oven, large metal tray, sample container of known weight and trowel.

Test procedure

To determine the type of method to be done, the soil sample is passed through a 75mm sieve. When more than 10% of the total sample passes through, a wet sieving is done (Hydrometer method) but when less than 10% of the total sample passes through, dry sieving will be done.

Apparatus: set of sieves, weighing balance, mechanical shaker.

Procedure

- 150g of oven-dried soil sample was weighed.
- The stacked set of sieve was arranged in a decreasing order including the bottom pan at the base.
- The soil sample was carefully poured into the top sieve and the cap was placed.
- Then the set of sieve was placed in a mechanical shaker for 10minutes.
- The sieves were then removed from the shaker.
- The soil retained on each sieve was weighed and recorded accordingly including the soil in the bottom pan.

Table 1: Showing sample location, coordinate, and elevation

Sample location	Elevation (m)	Cordinates
A	667m	10° 12' 59.1'' N 009° 33' 22.3'' E
B	698m	10° 13' 10.3'' N 009° 33' 19.1'' E
C	700m	10° 13' 15.0'' N 009° 33' 19.0'' E
D	690m	10° 13' 18.2'' N 009° 33' 18.1'' E
E	693m	10° 13' 18.2'' N 009° 33' 19.4'' E

Result and discussion

1. Presentation and interpretation of results

This section Comprises of two parts: the result presentation and interpretation. The presentation of result is simply the display of various data sets obtained from the study using statistical tools like tables, graphs, etc.

The interpretation of results on other hand entails the interpretation of the results obtained from the study by analyzing and comparing them with some standards and previous works.

2. Field geology

The major rock types were observed from the geologic mapping of the area, they are: Granite and pegmatite. Granite had been the predominant rock covering over 80% of the area, with pegmatite.

3. Result of the geotechnical analysis carried out on the different soil samples

Table 2: showing the Coefficient of Curvature (Cc) and Coefficient of Uniformity (Cu) of represented soil samples

location	Δ60(mm)	Δ30(mm)	Δ10(mm)	Cu	Cc
A	0.71	0.9	0.15	4.7	3.6
B	1.13	0.425	0.175	6.5	2.15
C	0.78	0.3	0.12	6.5	0.93
D	0.68	0.385	0.15	4.5	3.8
E	0.701	0.31	0.14	5.1	3.2

According to unified soil classification system (USCS) state that when $Cu = A_{60}/A_{10}$ should be greater than 6 and $Cc = A_{30}/A_{60} \times A_{10}$ should be between 1 and 3. The soil should be well graded and if result is not within this standard, therefore they do not meet all graduation requirements for well graded soil.

4. Atterberg limit for representative soil samples

Table 3: showing the Atterberg limits which comprises of liquid limits, plastic limits and plasticity index.

Sample location	Liquid limit (ll)	Plastic limit (pl)	Plasticity index (pi)
A	28.5	18.3	23.4
B	37.5	16.0	26.8
C	16.1	11.0	27.1
D	28.5	17.4	22.9
E	18.0	15.3	16.7

The classification ASTM, 135 5130 (1981) state that liquid limit <35, is low compressibility and liquid limit between 35% to 50% is medium compressibility. The plastic index ranges from 8-54 are slightly plastic soil, ASTM.BS 5130, (1981). Results are in appendix.

Plasticity index

The plasticity index (PI) is a measure of the plasticity of a soil. The plasticity index is the size of the range of water contents where the soil exhibits plastic properties. Plasticity index is the difference between the liquid limit and the plastic limit.

PI and there meanings:0- Non plastic,1 - Slightly plastic,5-10 Low Plasticity,10-20 Medium Plasticity,20-40 High Plasticity, >40 - Very high Plasticity

5. Optimum moisture content (OMC) and maximum dry densities (MDD) values for representative soils samples (compaction test)

Table 4: Showing Moisture Content of Representative Soil Sample

Sample location	Compaction	
	OMC %	MDD mg/m ³
A	11.5	1.97
B	11.1	1.89
C	8.8	1.86
D	10.1	1.84
E	15.0	1.85

The recommended MDD, OMC standard, however, depends on specific use. For instance, the Nigerian Specification for Road and Bridge Materials (Nigeria Federal Ministry of Works and Housing, 1997) recommends that for a material to be used as generally as fills its should possess MDD >0.047mg/m³ however from the result of the geotechnical analysis carried out, all the representative sample meet the requirement in road construction.

In general, compacted granular soils will have higher densities in the range of (1.18 to 2.16 g/cm³) than those of clayey to silty soils, which are in the range of (1.36 to 1.84 g/cm³). Results are in appendix.

Conclusion and recommendations

1. Conclusion

Based on the geological field mapping the area can be said to be underlain by two major rocks types namely: Granite and Migmatite. The geotechnical investigations of the soil samples around the study area have shown that the grain size distribution characteristics of the soils range from fair-good hence will be used for foundation and fills materials. When some techniques and modification can be employed sample 2 and 3 can be used as subgrade and sub-base material. However from the result of the geotechnical analysis carried out, the entire representative sample (1-5) for compaction test meets the requirement in road construction. Also the medium to high plasticity indices with the corresponding liquid limit values of most of the soils samples suggest that's they are suitable as subgrade and sub-base materials.

2. Recommendation

Though, most of the soils understudied, location 2,3, would be suitable as Sub-grade when some technique are applied and soils from location 1,4,5, as sub-base when some technique stabilization and modification are applied on the soil which was suitable as foundation, borrow pit or fill materials for construction purposes. The rocks in the study area are essentially crystalline, they are therefore highly resistant to weathering and hence construction industries can make use of them as valuable raw material in the construction.

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