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Research Article

Some Geological and Geotechnical Properties of Lateritic Soils from Muglad Basin Located in the South-Western Part of Sudan

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Abstract: This study reports an investigation of lateritic soils on the geotechnical properties such as sieve analysis, consistency, compaction, California Bearing Ratio (CBR) for the soil. Lateritic soils are highly weathered and altered residual soils formed by the in-situ weathering and/or decomposition of rocks in the tropical and sub-tropical regions with hot, humid climatic conditions. The process of weathering produces a wide variety in the thickness, grade, chemistry and ore mineralogy of the resulting soils. Lateritic soils are rich in aluminum oxides, iron oxides and low silicates but may contain appreciable amounts of kaolinite and due to the presence of the latter element; this soil obtains the red color. The majority of the land areas with laterites are or were between the tropics of Cancer and Capricorn. The results obtained for the aforementioned soil testing experiments showed that the lateritic soils could be used in number of engineering application among which roads, earth embankment and as building material as well.

Keywords: CBR, compaction, geotechnical investigation, lateritic soils, residual soils, Sudan

INTRODUCTION

The soil name "laterite" was coined by Buchanan (1807) in India, from a Latin word "later" meaning brick (Raychaudhuri, 1980). Lateritic soils are highly weathered and altered residual soils formed by the in-situ weathering and/or decomposition of rocks in the tropical and sub-tropical regions with hot, humid climatic conditions. Laterites are rich in iron oxides, aluminum oxides and low silicates but may contain appreciable amounts of kaolinite and due to the presence of iron oxides; lateritic soils are red in color (Amu and Adetuberu, 2010). The process of weathering produces a wide variety in the thickness, grade, chemistry and ore mineralogy of the resulting soils. Lateritic soils are widely used as fill materials for various construction works in most tropical countries. These soils are weathered under conditions of high temperatures and humidity with well-defined alternating wet and dry seasons resulting in poor engineering properties such as high plasticity, poor workability, low strength, high permeability, tendency to retain moisture and high natural moisture content (Maigien, 1966; Gidigasu, 1976; Charman, 1988). Considerable studies have been carried out on the engineering geological properties of the soil by various researchers (Akpokodje, 1986; Alabo and Pandy, 1987; Arumala and Akpokodje, 1987; Leton and Omotosho, 2004; Omotosho and Eze-Uzomaka, 2008).

The scope of work was to study the engineering properties of lateritic soils that prevail in Southern Kordofan State in the Republic of Sudan by obtaining various soil samples extracted from this particular area. The samples were exposed to number of basic soil mechanics testing i.e., sieve analysis and Atterberg limit along with soil strength testing namely Compaction and California Bearing Ratio (CBR).

Location and accessibility: The study area located in the southern Kordofan state as part of the Muglad Basin between latitudes (N 1253000, N 1275000) and longitudes (E 632000, E 640000) with a total area of about 176 Km^2. It can be reached from Khartoum area by asphaltic road until Abu-Zabad and from there by unpaved road (Abu Zabad-Al Fulla). The nearest village to the study area is Albarasaya as shown in Fig. 1.

Geology and stratigraphy of the area: Muglad basin is located in the south-western part of Sudan. Muglad basin is part of the Central African Shear Zone (CASZ). It is bounded to the northwest by the baggara basin, to the northeast by the Nuba Mountain's and extends the south into Anza Basin in Kenya. The study area is characterized by low relief except for sparse isolated outcrops in the northern part of the basin. In general the area is considered flat and surrounded by an elevated basement terrain of Nuba Mountain's to the east and

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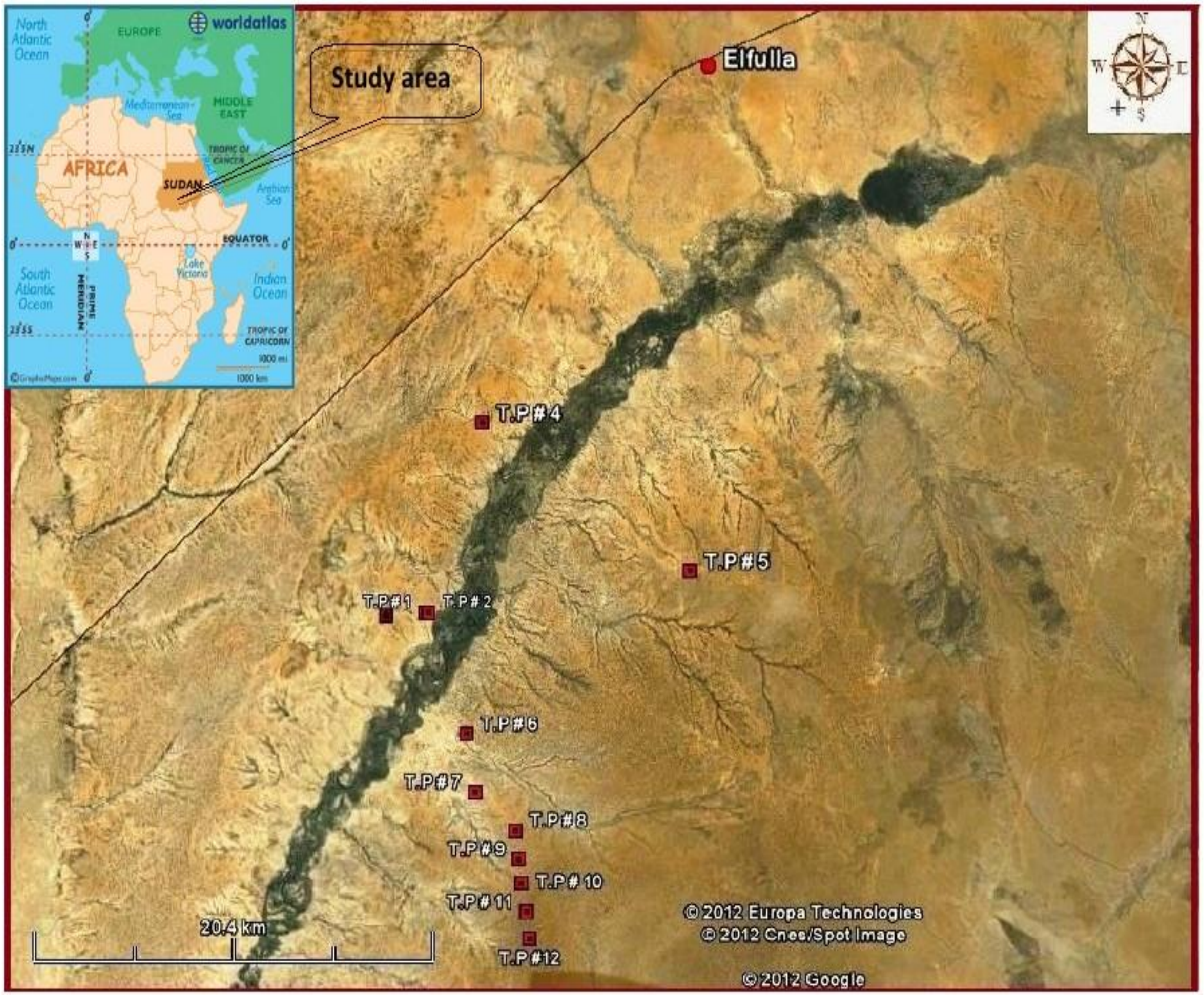

Fig. 1: Location of study area

north east of which represents the main igneous and metamorphic topography feature in the area, Darfur Dome (Jabel Marra) to the north and northwest, the south and southwest is the suds area and there is a basement complex terrain in the south east along the Sudanese and Central African republic border. Stratigraphically, Muglad basin is covered by unconsolidated superficial deposits of Quaternary-Tertiary Umm Rawaba formation which is a group of unconsolidated poorly sorted clastic sediments and alluvium stream to the lake sediments, also there are some isolated outcrops of Nubian sandstone east of the Muglad town. Black cotton soil covers most of the plain, while locally exposed lateritic deposits are scattered in the area between Heglig and Lake Kailak. Alluvium stream, wadi sediments and swamp deposits of the White Nile tributaries cover the southern part of the basin. Bahar Al Arab River is one of the White Nile tributaries controlled by the main accommodation zone in the basin which displays a grabber perpendicular to the rift axis.

STUDY PROGRAM

A total of twelve test pits were excavated within the aforementioned area at various locations. The excavation depth was variable; test pits number 1 up to number 5 was superficial while test pits number 6 up to 12 were excavated to 3.0 m depth. The locations of the investigated areas are shown in Table 1. The subsoil conditions at test pits number 1 to 12 except for test pit number 3, 4 and 5 revealed a dominant presence of sub soils recognized by the USCS as Clayey Sand reddish in color known geologically as lateritic soils. On the other hand, test pits 3, 4 and 5 revealed a complete different sub soils recognized as poorly graded gravels reddish color as well.

LABORATORY PROGRAM

Laboratory testing was conducted to evaluate the geotechnical properties of the soil samples extracted

Table 1: Locations of the investigated area

Test pit no.	Coordinates (coordinates are based on UTM system) E (m)	N (m)
T.P#1	633445	1270918
T.P#2	633450	1270918
T.P#3	631410	1270878
T.p#4	636378	1280018
T.P#5	646905	1272839
T.P#6	635477	1265011
T.P#7	635870	1262133
T.P#8	637930	1260320
T.P#9	638128	1258957
T.P#10	638286	1257703
T.P#11	638475	1256310
T.P#12	638611	1255140

Table 2: Atterberg limits test results

		Atterberg limits		
Test pit no.	Depth (m)	L.L	P.L	P.I
T.P#1	1.0	25	16	9
	2.0	25	14	11
T.P#2	1.0	24	13	11
	2.0	Non-plastic		
T.P#3	1.0	43	20	23
T.P#4	1.0	34	28	6
T.P#5	1.0	33	18	15
T.P#6	1.0	22	13	9
	3.0	30	14	16
T.P#7	1.0	Non-plastic		
	3.0	34	19	15
T.P#8	1.0	26	15	11
	3.0	32	20	12
T.P#9	1.0	31	16	15
	3.0	35	23	12
T.P#10	1.0	34	18	16
	3.0	38	22	16
T.P#11	1.0	38	19	19
	3.0	36	20	16
T.P#12	1.0	34	19	15
	3.0	36	20	16

Table 3: Sieve analysis test results

Test pit no.	Depth (m)	Passing sieve # 200
T.P#1	1.0	37.1
	2.0	45.3
T.P#2	1.0	37.1
	2.0	45.3
T.P#3	1.0	0
T.P#4	1.0	0
T.P#5	1.0	0
T.P#6	1.0	39.8
	3.0	49.5
T.P#7	1.0	28.5
	3.0	32.3
T.P#8	1.0	41.5
	3.0	27.0
T.P#9	1.0	47.4
	3.0	36.9
T.P#10	1.0	47.4
	3.0	41.9
T.P#11	1.0	51.4
	3.0	44.6
T.P#12	1.0	34.3
	3.0	43.0

from the excavation of the test pits. The laboratory testing procedures were in general conformance with those recommended in British Standard BS 1377 (1990)

Table 4: Compaction test results

Test pit no.	Depth (m)	M.D.D (g/cm^3)	O.M.C (%)
T.P#1	1.0	2.10	9.70
	2.0	2.12	9.94
T.P#2	1.0	2.05	10.00
	2.0	2.14	7.50
T.P#3	1.0	2.13	9.55
T.P#4	1.0	2.11	9.50
T.P#5	1.0	2.18	7.44
T.P#6	3.0	2.03	10.50
T.P#7	3.0	2.15	9.29
T.P#9	3.0	2.09	10.79
T.P#10	3.0	2.08	11.16
T.P#11	3.0	2.00	13.10
T.P#12	3.0	1.85	16.60

Table 5: California bearing ratio test results

Test pit no.	Depth (m)	CBR @ 2.5%
T.P#1	1.0	9
	2.0	5
T.P#2	1.0	7
	2.0	14
T.P#3	1.0	70
T.P#4	1.0	139
T.P#5	1.0	52
T.P#6	3.0	7
T.P#7	3.0	19
T.P#8	3.0	6
T.P#9	3.0	15
T.P#10	3.0	5
T.P#11	3.0	10
T.P#12	3.0	19

and the soils were classified according to the Unified System for Classifying Soils (USCS).

Atterberg limits: The Atterberg Limits comprise the liquid limit, the plastic limit and the shrinkage limit. These define the boundaries between four stages of a consistency. The Atterberg Limits tests were carried out on representative samples from different depths of the test pits. The results are shown in Table 2.

Sieve analysis: The sieve analysis tests were carried out on representative soil samples taken at different depths from the test pits. The results are shown in Table 3.

Compaction test The results of compaction test carried out on soil samples are presented in Table 4.

California Bearing Ratio test (CBR): The results of CBR test carried out on extracted soil samples are presented in Table 5.

DISCUSSION OF RESULTS

Test pit number 1 and 2: Four samples were collected from two test Pits at two different depths in this borrow area. The results of Atterberg Limits indicated that a clay layer of low plasticity is present in this site. The value of liquid limits at this layer reaches 25% (>50% highly plastic). This indicates that the fines (i.e., silt and clays) are of low plasticity. The recorded P.I. values are less than 50. Values of CBR between 7 and 14 are obtained from laboratory testing. The values of the CBR indicate the presence of clayey layers. This soil can be used only as filler material for embankment construction and not preferable to be used for road construction.

Test pit number 3: The materials at this location has high values of CBR but unfortunately the P.I. value is relatively high (= 23). This material can be used as base or sub base material for roads construction if the PI is reduced to become less than 9 or 15 for respectively. This material can be used for earth embankment construction without any precautions if the previous condition stated has been fulfilled.

Test pit number 4: The material at this site has a value of CBR of 139 and P.I. of order 6. It can be used safely as base material as well as sub-base materials for road construction.

Test pit number 5: The value of CBR sample taken from this location is 52 and the P.I. is 15 which allow it to be used as sub-base material for road construction without any precautions.

Test pit number 6, 8 and 10: The results of Atterberg Limits indicated that a clay layer of low plasticity is present in this site. The value of liquid limits at these test pits varies in between 30 to 38% (>50% highly plastic) in which the first value corresponds to test pit no 6 and the latter value corresponds to test pit no 10. This indicates that the fines (i.e., silt and clays) are of low plasticity. Values of CBR between 5 and 7 are obtained from laboratory testing. The values of the CBR indicate the presence of clayey materials within the soil samples extracted from these test pits. This soil can be used only as filler material for embankment materials and not preferable to be used for road construction.

Test pit 7, 9, 11 and 12: The results of Atterberg Limits at these test pits have almost convergent values. The values of P.I vary in between 12 for test pit no 9 to 16 for test pit no 11 and 12. The CBR values range in between 10 for test pit no 11, 15 for test pit no 9 and 19 for test pit number 7 and 12. Such materials can be used for embankment construction; on the other hand blending such materials with gravels can improve the CBR values.

CONCLUSION AND RECOMMENDATIONS

This study deals with the engineering properties of lateritic soils from Muglad basin located in the south-western part of Sudan. According to the numerous tests carried out on these soil samples, it turned out that lateritic soils are generally recognized as being well-graded reddish brown, sandy-silt-clay of medium plasticity and compressibility type of soil. These soils have fines content ranging from 27 to 49.5% and contain extremely low gravels percentage of less than 10% which renders them unsuitable for granular road base and sub-base courses in their natural state. The plasticity index ranging from 6 to 16% which indicates that the soils are of low swelling potential. The CBR values have a wide range at different locations (5 to 139%). This indicates that these soils can be used for embankment purposes; on the other hand blending such materials with gravels can improve the low CBR values.

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