

Sudan Subgrade Soils Characteristics

Dr.Mohammed Mahmoud Shallal, Prof. Dr.Salih Elhadi Mohammed Ahmed

Sudan University of Science & Technology

Abstract: - In this paper, Sudan climate and geographic features have been covered. Then a soil survey for Sudan soil types has been carried out. The locations of soil samples have been chosen in accordance with the Climatic Zones Classifications for Sudan. Two basic tests conducted comprising: Grain Size Distribution and Atterberg Limits on each sample. And accordingly the soil classification has been determined for each sample. The soil type of each climate zone has been determined.

Key words: - *subgrade soil, Climate zones, soil testing, soil properties*

I. INTRODUCTION

Subgrade is defined as the soil prepared and compacted to support a structure or a pavement system. It is the foundation for the pavement structure. Subgrade soil or material sometimes is called (basement) or (foundation soil). The change of subgrade properties requires different thicknesses of pavement layers in order to support the same traffic load and produce the same performance. ⁽¹⁾

II. SUDAN GEOGRAPHICAL FEATURES

Sudan encompasses an area of about 1,861,484 sq km. It is composed of vast plains interrupted by a few widely separated ranges of hills and mountains. Northern Sudan, lying between the Egyptian border and Khartoum, has two major district parts, the desert and the Nile Valley. To the east of the Nile lies the Nubian Desert and to the west lies the Libyan Desert. They are similar stony, with sandy dunes drifting over the land escape. There is virtually no rainfall in these deserts, and in the Nubian Desert there are no oases. In the west there are few small watering holes, where the water table reaches the surface to form wells that provide water to nomads, although insufficient for a settled population. Flowing through the desert is the Nile Valley provides lands not more than two kilometers wide as good land for agricultural activities. Western Sudan is a generic term describing the regions known as Darfur and Kordofan that comprise 850000 square kilometers. Western Darfur stands in stark contrast to northern and southern Darfur, which are semi desert with little water either from intermittent streams known as wadis or from wells that normally go dry during the winter months. One of the features of western Sudan is the Nuba Mountains range of southeast Kordofan. Many hills are isolated and extend only for few square kilometers, but there are several large hill masses with internal valleys that cut through the mountains high above the plain. Sudan third district region is the central clay plains that stretch eastward from the Nuba Mountains to the Ethiopian frontier, broken only by the Ingessana Hills, and from Khartoum in the north to the far South of Sudan. Northeast of the central clay plains lies eastern Sudan, which is divided between desert and semi desert and includes Albutana, Qash Delta, Red Sea Hills and the coastal plain. Albutana is an undulating land between Khartoum and Kassala. The Qash Delta originally is a depression filled with sand and silt brought down by the floods of the Qash River, creating a delta above the surrounding plains. In this area the soil is rich moist soil. Northward beyond the Qash Delta lie the Red Sea Hills and they stretch northward into Egypt. Below the hills, sprawls the coastal plain of the Red Sea, varying in width from about fifty six kilometers in the south near Twaker town to about twenty four kilometers near the Egyptian frontier. ⁽²⁾



Figure (1): Sudan Satellite Imagery ⁽³⁾

The Remote Sensing Authority (RSA) of Sudan in collaboration with FAO SIFSA project (Sudan Integrated Food Security Information for Action), and the Ministry of Agriculture, produced a multipurpose Sudan Land Cover database 2003 and 2011. One of its results was Sudan Climate Zones, which were as follows: ⁽⁴⁾

- Hyper Arid
- Arid
- Semi Arid
- Dry Sub Humid
- Moist Sub Humid

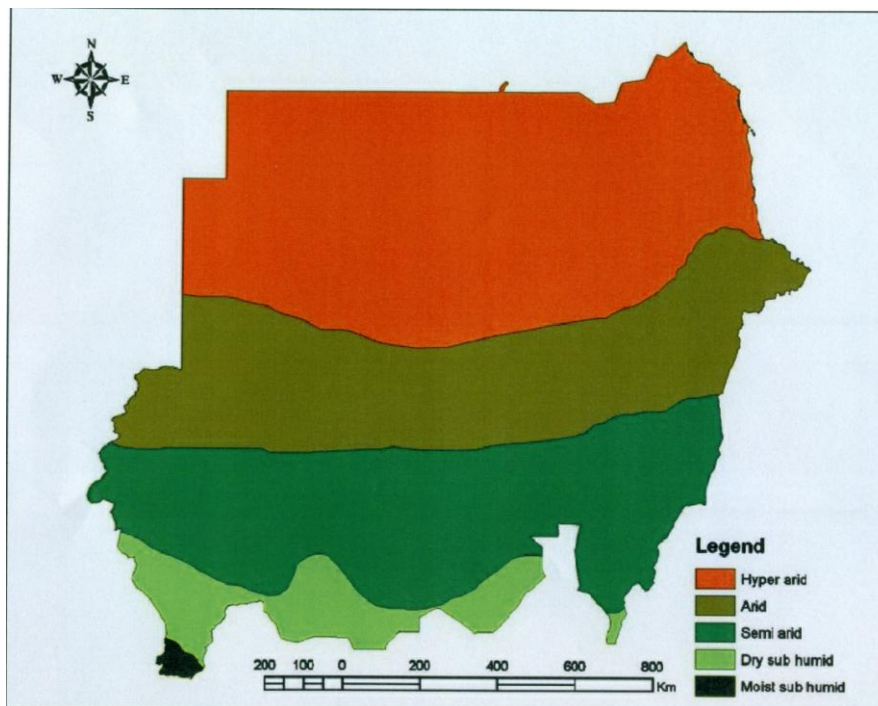


Figure (2): Climate Zones by means of Remote Sensing ⁽⁴⁾

III. SOIL SURVEY

3.1 Locations: A soil survey has been carried out, and 10 samples have been brought from 10 different locations all over Sudan. The samples locations have been determined in accordance with the climatic zones. These locations comprised:

Table (1): Tests Locations:

No.	Sample Location	Climate Zone
1	North East of Karima	Hyper Arid
2	South East of Abuhamad	Hyper Arid
3	Osaif	Hyper Arid
4	South west of Toker	Arid
5	West of Almatama	Arid
6	Kassala	Semi Arid
7	24 Elgurashi	Semi Arid
8	Kadugli	Dry Sub Humid
9	Almujlad	Dry Sub Humid
10	Algardarif	Dry Sub Humid

3.2 Sampling: The types of equipments used in sampling comprised hole diggers and shovels. The depth of each test pit was not less than 1.5 meter. Samples have been kept in sealed containers to prevent moisture loss. Labels have been put inside the containers. Also full description for each sample has been clearly written from outside. ⁽⁵⁾ The following picture shows an example for the soil testing pits:



Figure (1): soil Testing Pit

3.2 Testing:

3.2.1 Testing Criteria: Tests conducted on the samples comprised Gradation, Atterberg Limits (Liquid Limit, Plastic Limit, and Plasticity Index), Compaction Test and CBR Test. Table (3-8) hereunder describes tests designations and the purpose for these tests.

Table (2): Subgrade soil tests criteria: ⁽⁵⁾, ⁽⁶⁾

Common Name of Test	Use	Test Method		Purpose of Test
		AASHTO	ASTM	
Liquid Limit	Classification	T 89	D 4318	To find the water content at the boundary between the liquid and plastic states of a soil.
Plastic Limit	Classification	T 89	D 4318	To find the water content at the boundary between the plastic and semisolid states of a soil.
Plasticity Index	Classification	T 90	D 4318	To find the range of water contents over which the soil is in a plastic state.
Mechanical Analysis	Classification	T 88	D 422	To determine the particle-size distribution of a soil.

3.2.2 Testing Method: The test methods followed in conducting these tests have been concluded as follows:

- **Particle Size Analysis:** This test method covers the quantitative determination of the distribution of particle sizes in soils. The distribution of particle sizes larger than 75µm (retained on the No.200 sieve) is determined by sieving, while the distribution of particle sizes smaller than 75µm is determined by a sedimentation process, using a hydrometer to secure the necessary data. ⁽⁵⁾
- **Liquid Limit and Plastic Limit Tests:** The specimen is processed to remove any material retained on sieve No.40. The liquid limit is determined by performing trials in which a portion of the specimen is spread in a brass cup, divided in two by a grooving tool, and then allowed to flow together from the shocks caused by repeatedly dropping the cup in a standard mechanical device. The multipoint Liquid Limit, Method A, requires three or more trials over a range of water contents to be performed and the data from the trials plotted or calculated to make a relationship from which the liquid limit is determined. ⁽⁵⁾

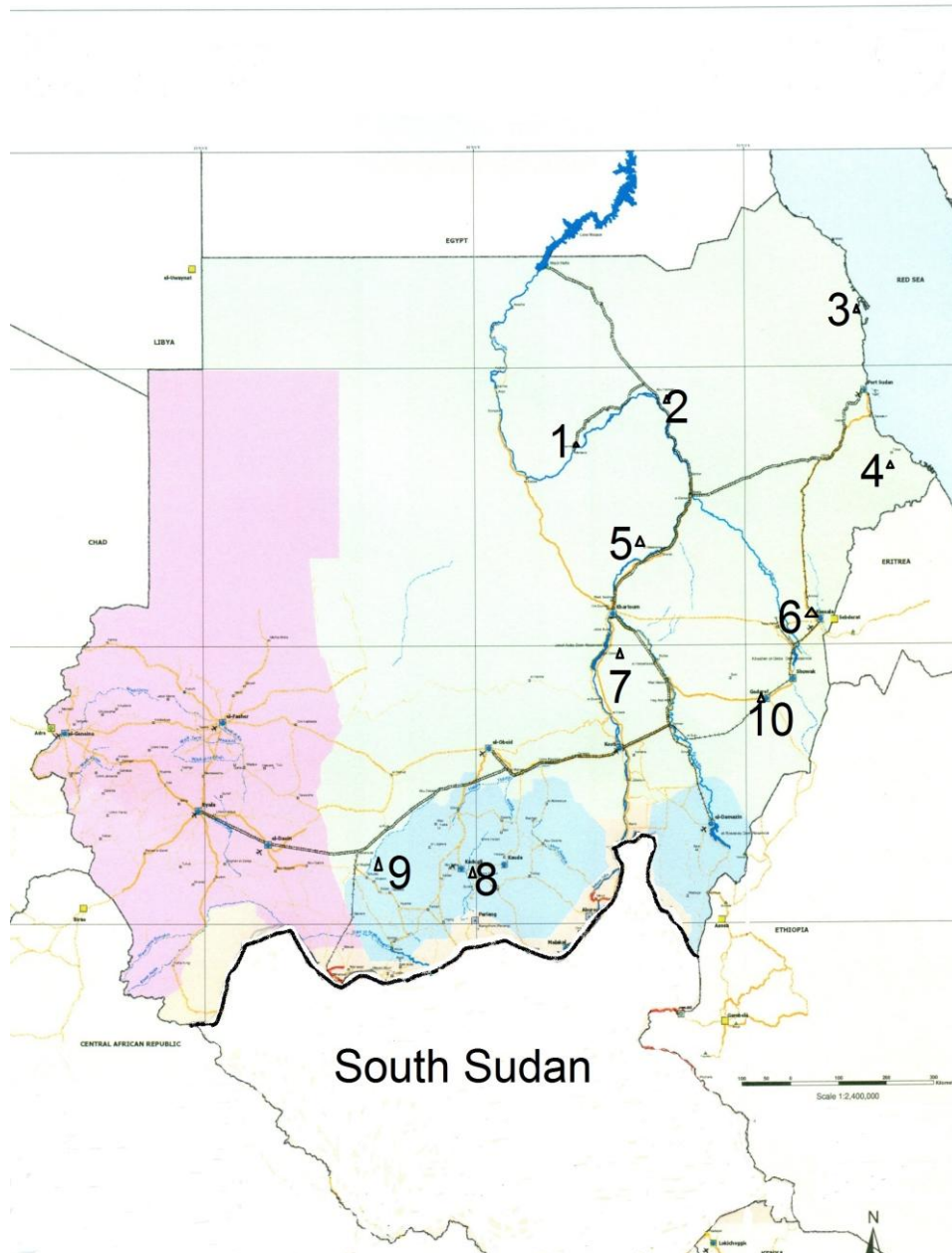
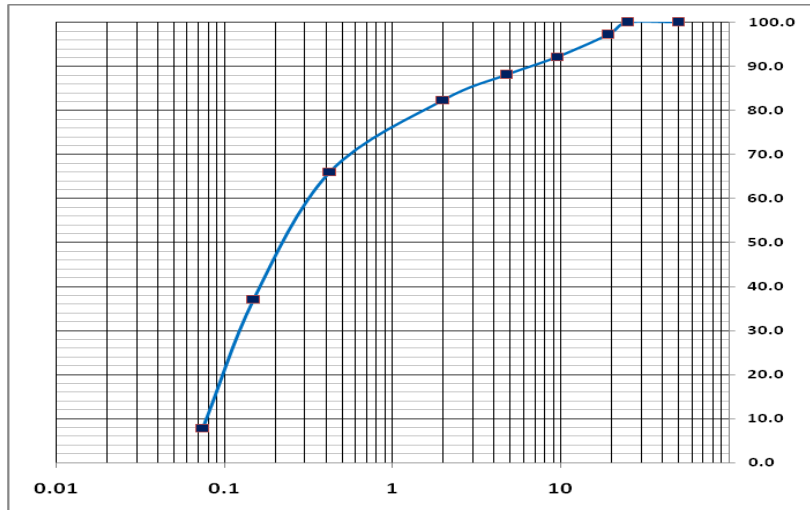


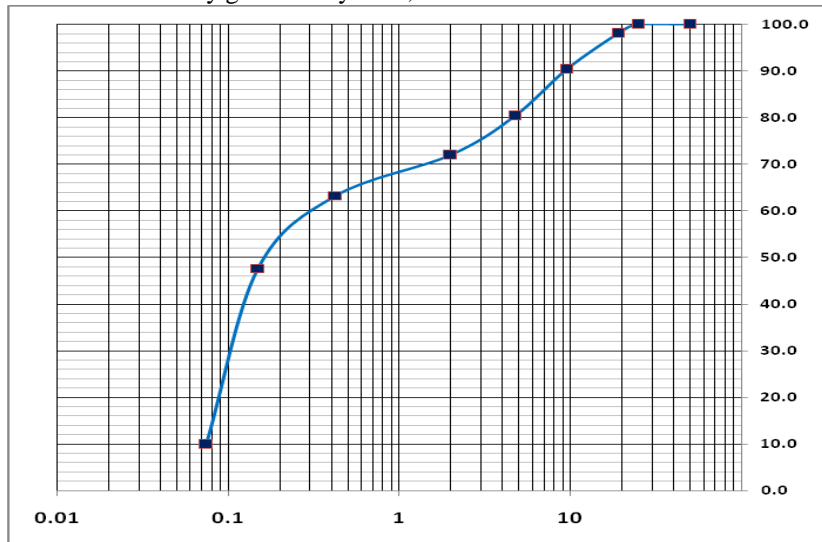
Figure (3): Samples Locations

3. Soil Investigation Results and Analysis: The Grain Size Distribution, and Atterberg Limits. The results were as follows:

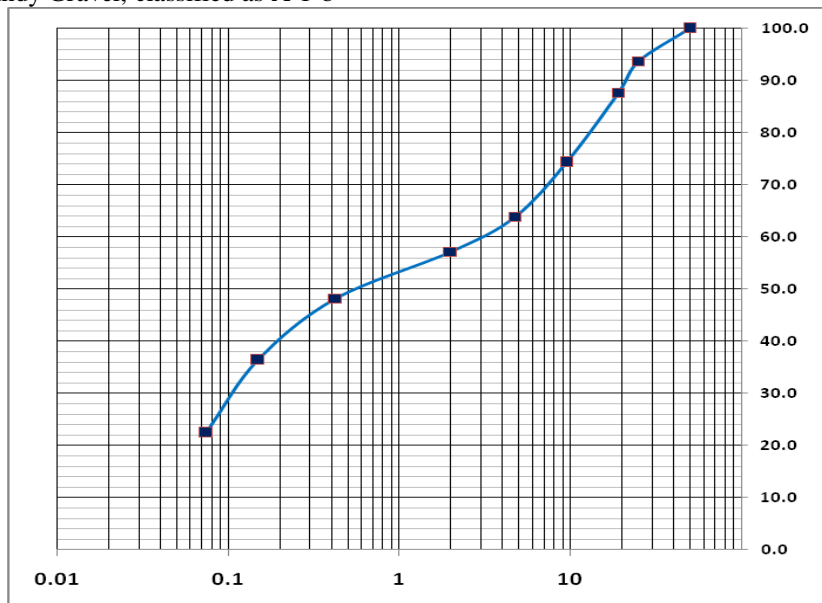
- 1. North East of Karima:** Poorly graded sand, classified as A - 3



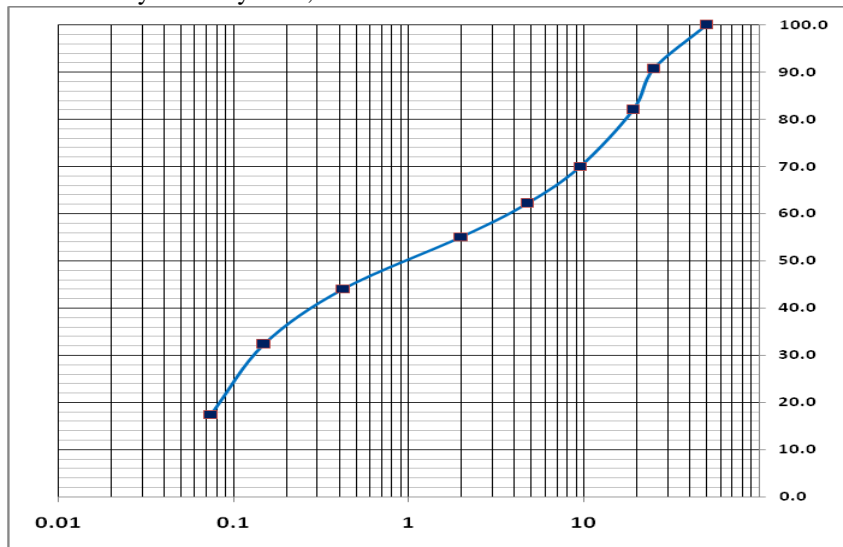
2. South East of Abuhamad: Poorly graded silty sand, classified as A - 3



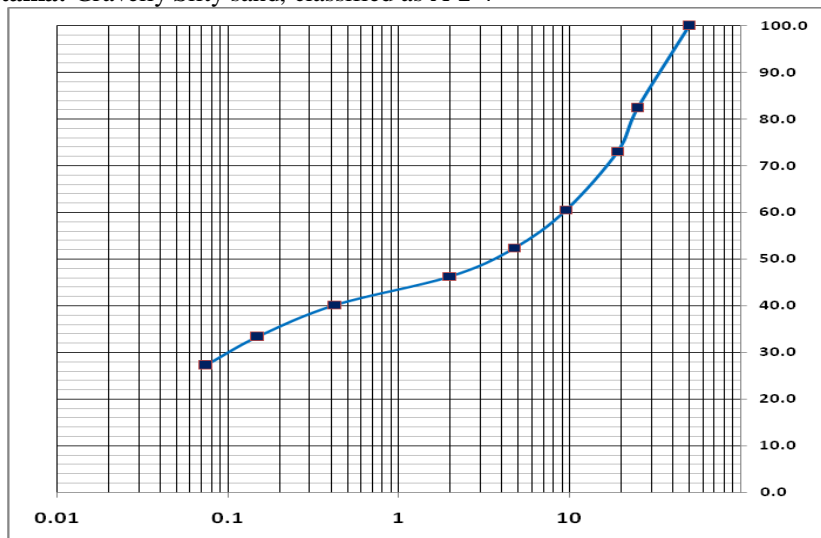
3. Osaif: Silty sandy Gravel, classified as A-1-b



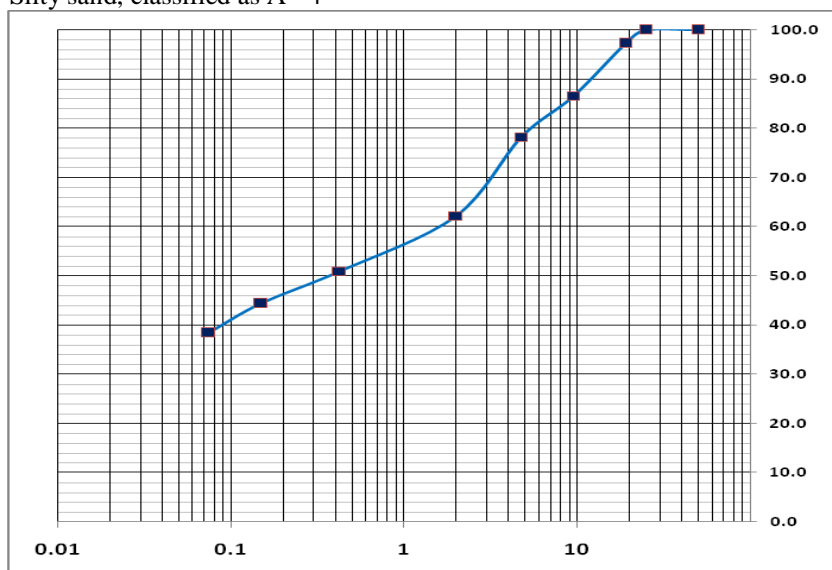
4. South west of Toker: Silty Gravelly sand, classified as A-1-b



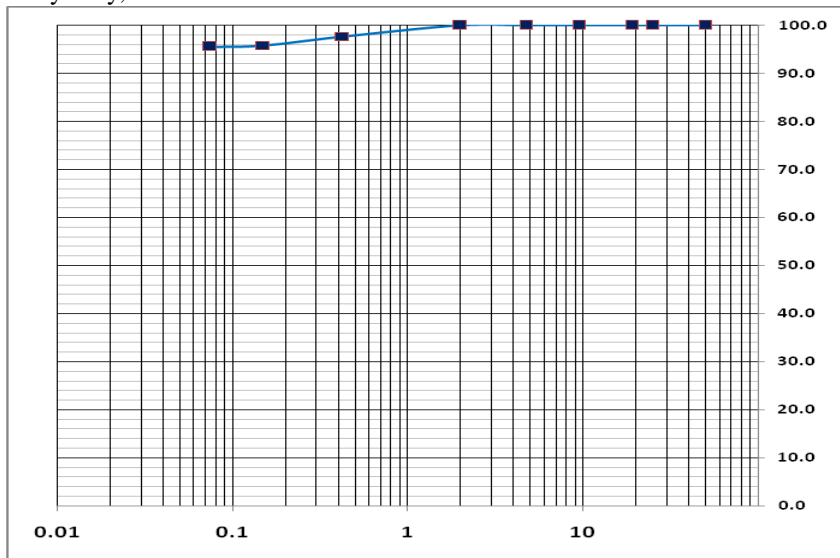
5. West of Almatama: Gravelly Silty sand, classified as A-2-4



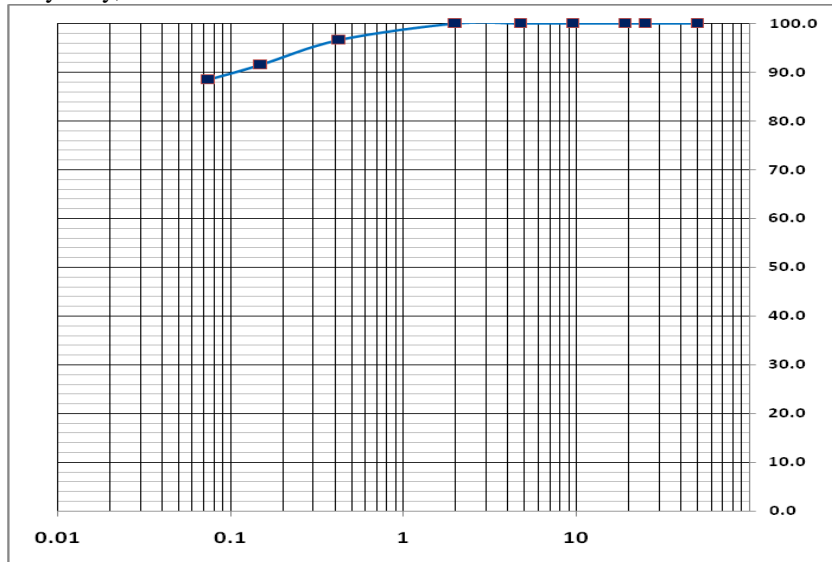
6. Kassala: Clayey Silty sand, classified as A - 4



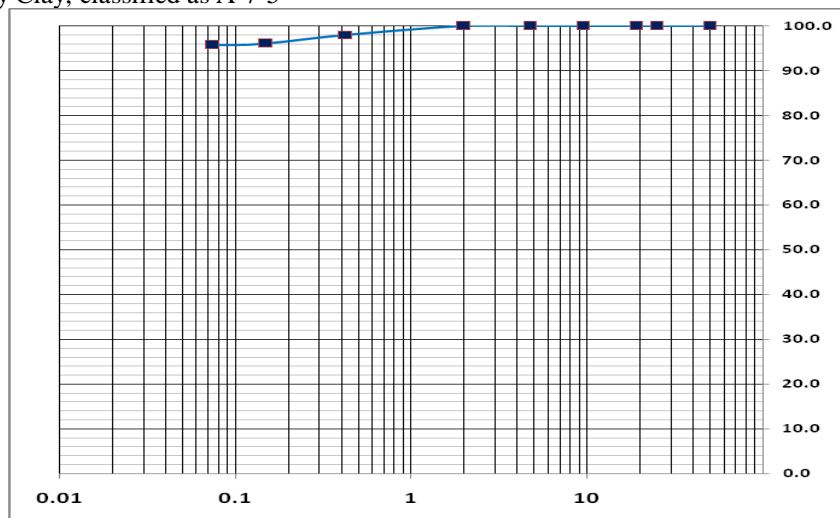
7. (24 Elgurashi): Silty Clay, classified as A-7-6



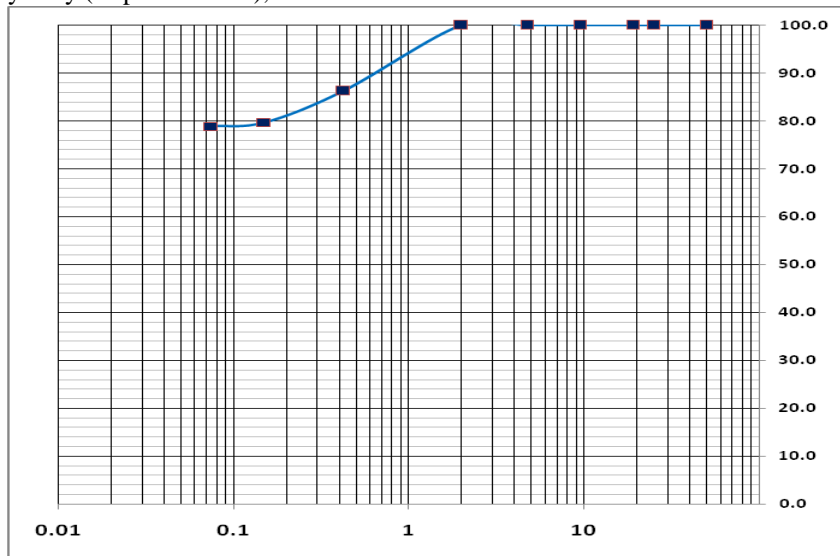
8. Kadugli: Sandy Silty Clay, classified as A-7-5



9. Almujlad: Silty Clay, classified as A-7-5



10. Algardarif: Silty Clay (Expansive Soil), classified as A-7-6



4. Summary of Results: The results summary is as follows:

No.	Sample Location	Climate Zone	Classification	Description
1	North East of Karima	Hyper Arid	A - 3	Poorly graded sand
2	South East of Abuhamad	Hyper Arid	A - 3	Poorly graded silty sand
3	Osaif	Hyper Arid	A-1-b	Silty sandy Gravel
4	South west of Toker	Arid	A-1-b	Silty Gravelly sand
5	West of Almatama	Arid	A-2-4	Gravelly Silty sand
6	Kassala	Semi Arid	A-7-6	Silty Clay
7	24 Elgurashi	Semi Arid	A-7-6	Silty Clay
8	Kadugli	Dry Sub Humid	A-7-5	Sandy Silty Clay
9	Almujlad	Dry Sub Humid	A-7-5	Silty Clay
10	Algardarif	Dry Sub Humid	A-7-6	Silty Clay (Expansive Soil)

IV. CONCLUSION

The subgrade soil survey and investigations carried out have shown the following:

- The Hyper Arid Climate Zone: the soil types encountered are **poorly graded sand**, become **Silty sandy Gravel** in the area of Red Sea Mountains.
- The Arid Climate Zone: the soil types encountered are **Silty Gravelly sand** and **Gravelly Silty sand**.
- The Semi Arid Climate Zone: the soil types encountered are **Silty Clays**.
- The Dry Sub Humid Climate Zone: the soil types encountered are **Sandy Silty Clay**, **Silty Clay** and **Silty Clay (Expansive Soil)**.
- Generally Sudan has large expanses of homogeneous soils, expansive clay in the east-central area and Qoz sands in the center.

V. RECOMMENDATIONS

1. The data obtained is very helpful in the designing of roads at the various locations in Sudan, and correct assumptions can be obtained at the reconnaissance surveys with no need for sampling and testing.
2. More effort is needed in studying the different soil types in Sudan to arrive at very precise soil map.

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