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Engineering Geology of Failed Sections of Isua – Idoani Road Southwestern Nigeria

Daramola Sunday.O[1] Malomo Siyan[2] Asiwaju-Bello Yinusa.A[2].
1. Department of Geography, College of Education, Ikere-Ekiti
2. Department of Applied Geology, Federal University of Technology, Akure

Abstract
There is an increasing incidence of road failures in Southwestern Nigeria Many asphalt roads have failed sections soon after construction and in any case rarely reach their design life before major repair is required.Numerous studies of failed sections of roads in Southwestern Nigeria have suggested the link between underlying geology and road failures.Engineering geological investigations of failed sections of Isua-Idoani road in Ondo State, Southwestern Nigeria has been were conducted with a view to determining the influence of the geology to the incidence of road failure along the stretch of the alignment. The geological mapping of the road alignment reveals that the road stretch was founded on two different lithologies, which are quartz-schist and granite-gneiss. The natural moisture content of the subgrade soils ranges from 6.5 to 19.6%, liquid limit from 24.1 to 55.1%, plastic limit from 9.1 to 21.2, plasticity index 5.2 to 21.2%. The grain size analysis shows that the amount of fines ranges from 29.2% to 60.8%. The linear shrinkage between 5 and 11.4%, free swell between -16.67 and 41.94%, maximum dry density between 1520 Kg/m³ and 1780Kg/m³.The results of the study show that the lithology is not the dominant reason for the failure of the road sections studied. Similar failures occur on stretches founded on the quartz-schist as well as granite gneiss (see Adeyemi 1995 and Jegede 1998). The poor geotechnical properties of the subgrade soils as indicated by the low maximum dry density; high linear shrinkage, high liquid limit values, high amount of fines and particularly poor drainage is the greater culprit in these cases. The results of the study suggest that closer attention need to be placed on the groundwater regimes of streams and rivers valleys along roads.
Keywords: Engineering Geology, Road pavement failure, Geotechnical properties, Southwestern Nigeria

1. Introduction

The importance of good roads to the development of any nation cannot be overemphasized as it enhances the easy transportation of goods and people. Hence the extent of road development and the physical condition of the roads determine the productivity level of the country. Road transport has two major advantages.

The provision of good and motorable roads is one of the critical infrastructures needed to drive the socio-economic development of the nation. The challenge of ensuring quality control in the maintenance of roads, has been linked to the design and construction and adequacy of engineering geological investigation of roads by engineering geologist and the lack of involvement of engineering geologist in the construction of these roads Jegede (1998).

By most accounts, road transportation is the most preferred mode of transportation in Nigeria, as it accounts for 99.5% of the nation's passengers and freight services (Oloniruha, 2013). From available records road failure abounds everywhere in Nigeria.

The road which connects Isua to Idoani is in a bad state. It has various forms of deformation features along the stretch of the road.

There are deep holes in the structural section of the highway thereby limiting human movement and traffic.

The present investigation is to determine the engineering geological properties of the sub grade soils in the study area and the contribution of the subgrade to the failure of the road.

2. Location and Geology of the Study Area

The study area is located within the Southwestern part of Nigeria fig 1. It is situated in Ondo state; the road connects Idoani & Isua and link the entire state to Kogi and Edo state. It falls within longitude E5^{o} 50' and E5^{O} 56' and latitude N7^{0} 18' & 7'27. The study area is underlain by rocks of the basement complex (fig 2). The area consists mainly of Quartzite, Schists, Migmatite and Granite-Gneiss.

Migmatites and Gneiss make up a larger portion of the study area although gneisses forms a larger part of the study area. Migmatites usually occur as low-lying outcrops although around the study area they occur as inselbergs and range of hills, as noted by Rahaman & Malomo (1983). The gneiss within the study area range from Grante-Gnesis and flaggy biotite Gnesis. The banded Gnesis is the most abundant and consist of alternating parallel to sub parallel dark and light bands.

3. Methodology

The aim of the study was achieved through fieldwork and laboratory studies. As part of the field work, a visual reconnaissance survey was carried out to evaluate and asses the physical conditions of the high way pavements. The various forms of pavement distress on the roadway were identifed in doing this. A surface geological mapping of the road alignment was carried out by traversing, noting the geology and using the GPS and compass clinometer, the under lying rocks were identified and their attitudes measured where possible. The mapping was done by noting all the rocks exposed on both sides of the road, the geological map of the road alignment is shown in figure 3.

Soil samples were taken from sites that were established during the reconnaissance aspect of the field work. Disturbed soil samples were collected from borrow pits along the road sides adjacent to the failed sections in such a way that the soil samples represent the different topographic condition of the alignment. These samples were collected into large polythene bags labeled appropriately and later tied to prevent the loss of moisture. The natural moisture content of each of the samples collection was determined immediately it was takes to the laboratory, this was followed by air drying of all the samples for one week to obtain fairly constant moisture content. The samples were loosened carefully using mallet. Finally, sieving of the soils was done depending on the kind of laboratory test to be carried out on each. The laboratory tests for the geotechnical parameters followed British standard institution (BSI) methods of testing for civil engineering purpose.

4. Result and Discussion

4.1 Geological Mapping

The geological mapping of the road alignment was carried out by traversing from the Idoani and end of the road and identifying the rocks on both sides of the road. A summary of the geological map of the road is shown in fig 3. Two major rocks types were identified. Granite-Gnesis were identified at the Isua end of the road. Schist was identified at Idoani junction and shortly before Ifira, the main mineral recognized is quartz and the shist is stongly foliated.

4.2 Geotechnical Characteristics

4.2.1 Grain Size Distribution Characteristics

Although grading characteristics has little relevance in the characterization of fine grained soils, the classification of soils is enhanced by their grain size distribution character with their constitency limits. The grain size distribution characteristic is given in table 1. According to the grain size distribution curves (figures 4 & 5), the fractional of percentages of the various constituents are shown in table 1, it is observed that they all contain clay, silt, sand & gravel fractions. A comparison of the test result with Nigeria specification which requires subgrade soils to possess less than 35% fines indicates that most of the samples did not meet the requirement as they possess fines greater than 35%.

4.2.2 Consistency Limits

On their own, the Atterberg limits do not mean very much, but as indexes to significant properties of a soil they are very useful (Sowers and Sowers, 1970). The consistency limits characteristics is an important factor in the selection of soils as both subgrade and subbase materials (Adeyemi, 1995). The consistency characteristics of the soils are shown in the Cassagrande chart, figure 6, majority of the soils plots within the field of organic clays while only two plot in the field of inorganic clays. Also, most of the studied soils plot within the field of medium plasticity while few plots within the field of low and high plasticity. The liquid limit values range from 24.1 to 55.1. This can be adjudged as high and this fact is supported by the low plasticity index value recorded by the soils. Soils with high liquid limits tend to possess low bearing capacity, the Nigerian specification for road materials recommend that for a material to be suitable as a subgrade it should possess a liquid limit less than 40%, most of the soil samples does not satisfy this specification. The plastic limit range from 21.4% to 34.6% while the plasticity index range from 8% to 21.2%. Only two samples do not satisfy the 20% benchmark set by the Federal Ministry of Works and Housing (1974) for plasticity index of subgrade soils.

4.2.3 AASHTO Classification

A combination of the grain size distribution characteristics of a soil with the consistency characteristics enhances an easy classification of soils. Classification of the soils based on the AASHTO mode indicate that most of the soils classify on A7 soil type while samples 2, 8, and 10 classify as A—2—4, A5 and A6 respectively. Based on this classification, majority of the soils possess fair to poor characteristics as subgrade materials.

4.2.4 Linear Shrinkage and Free Swell

The linear shrinkage is also an important parameter in the evaluation of soils as highway materials. The linear shrinkage values of the tested soils range from 5% to 11.43%. Many of the studied soil samples possess linear shrinkage values greater than 8% which is the maximum value suggested by Madedor (1983) for soils to be used as base, subbase and primary subgrade materials. Some of the samples have linear shrinkage values greater than 10%. The soil would therefore pose field compaction problems (Gidigasu, 1973). The studied soil samples recorded free swell values ranging from 16.7 to 41.94 which shows that they have low to moderate expansion potential based on Holtz and Gibbs (1957) and fall within the range of kaolinite and illite according to Popescu(1986).

4.2.5 Specific Gravity and Activity

The specific gravity is also a very useful index in the identification and evaluation of laterite aggregates for pavement construction, an increase in specific gravity has been found to be associated with a decrease in voids ratio (Jegede 1998). The specific gravity values of the tested soils range from 2.52 to 2.63, the values for each samples are average of their determination. Activity values of the studied soils range from 0.19 to 0.87, this indicates that they are either inactive or normally active clays. According to Skempton (1953), they possess low to medium expansion potential. This is also reflected in the free swell values of the soils.

4.2.6 Moisture-Density Relationship

The moisture-density relationship (compaction characteristics) are shown in the compaction curves presented in figure 7, which shows that the maximum dry density of the studied soils range from 1570 to 1780 kg/m^3 and the optimum moisture content range from 12-23%. Theoretically & practically the best soils are those that have high MDD values at relative low OMC (Jegede 1998). According to Woods (1938) and Underwood, (1967), the soils have a fair to poor foundation characteristics based on the maximum dry density recorded.

4.2.7 California Bearing Ratio

The CBR is indication of strength; it has been widely accepted as a useful adhoc test for evaluating the of suitability of soils for highway construction. The result of the CBR shows that the samples recorded a CBR value rating between 6 and 18%. These values are relatively low although most of the samples recorded CBR values which satisfy the 10% benchmark recommended by the FMWH (1974).

5.0 Conclusion

Field observation and various laboratory tests carried out on the soil samples collected from the failed sections of the road revealed that road failures in the study area are due to following reasons:

a. Lack of provision of drainage on the highway lead to the reduction in strength character of the soil as a result of ingress of water.

c. The linear shrinkage values of most of the soil are greater than 8%, this indicate that there will likely be shrinkage problem; some of the samples have linear shrinkage values grater 10%, hence would pose field compaction problem.

c. Based on the AASHTO classification, majority of the soils classify has A-2-6 A-5 and A-7 soil which have fair to poor subgrade propertis.

d. The maximum dry density values of the soil samples classify them as poor high way foundation materials. This poor compaction character can also result in the failure of the sections the road,

e. The higher liquid limit values recorded by most of the soil may have contributed to the failure of those sections as liquid limit correlate to the compressibility of soils.

f. The studied soils possess percentage fines greater than the 35% limit specified by the Federal Ministry of Works and Housing (1974), this might have alslo contributed to the failure of the sections of the road.

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Figure 1: Roadmap of southwestern Nigeria showing the highway under study(modified after Spectrum map 2002)

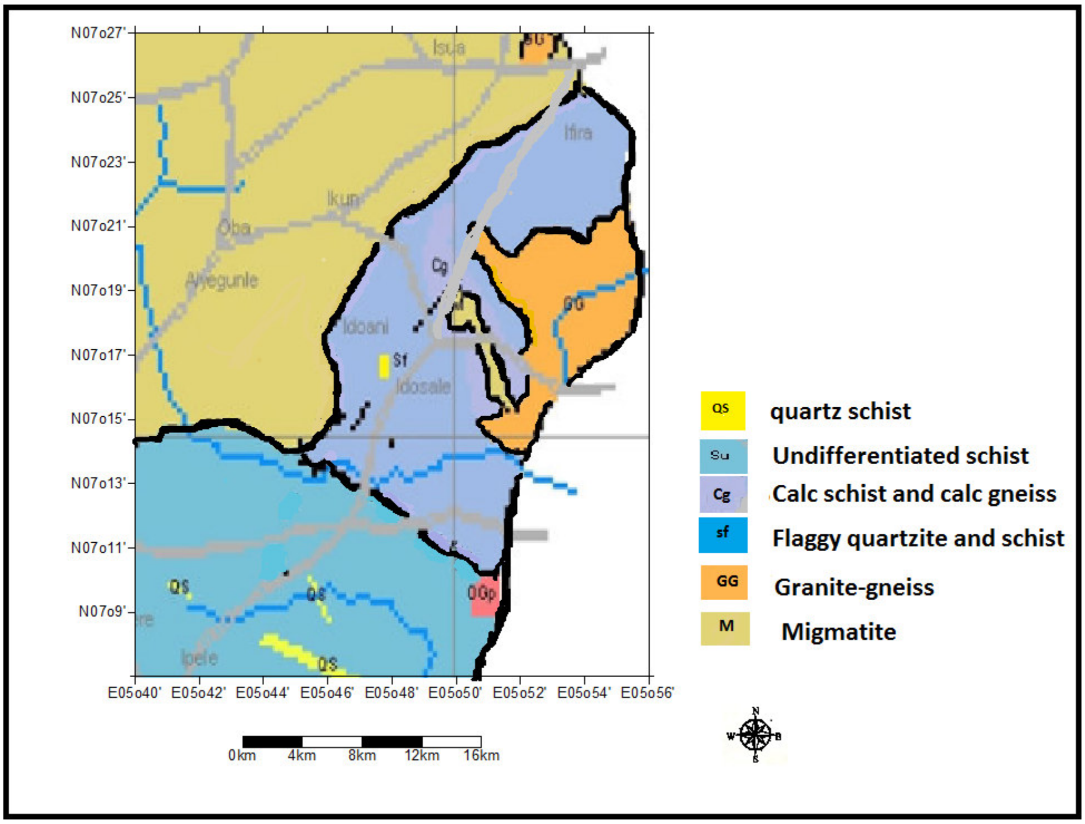

Figure 2: Geological map of the study area(NGSA,2006)

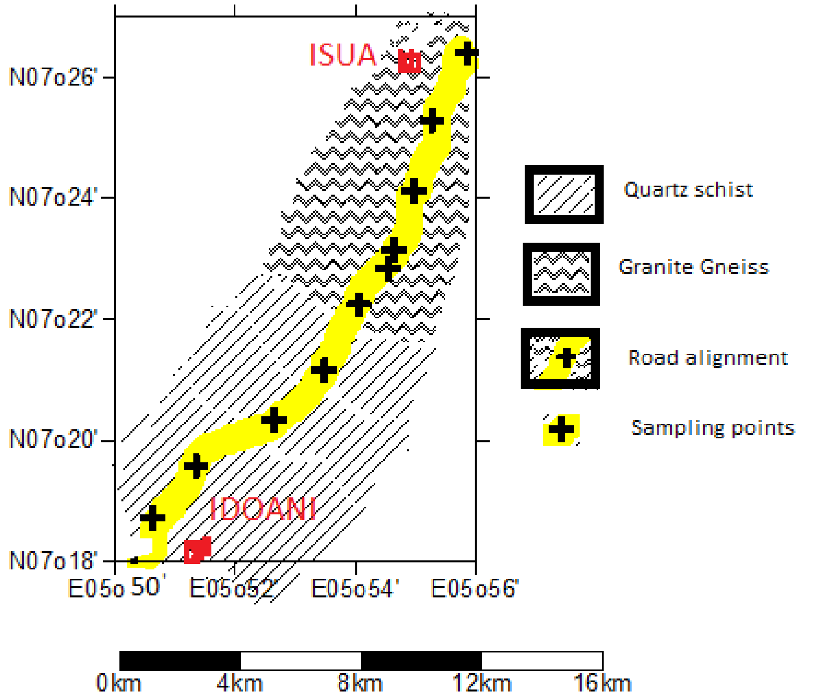

Figure 3: Geological map of the road alignment showing the sampling points

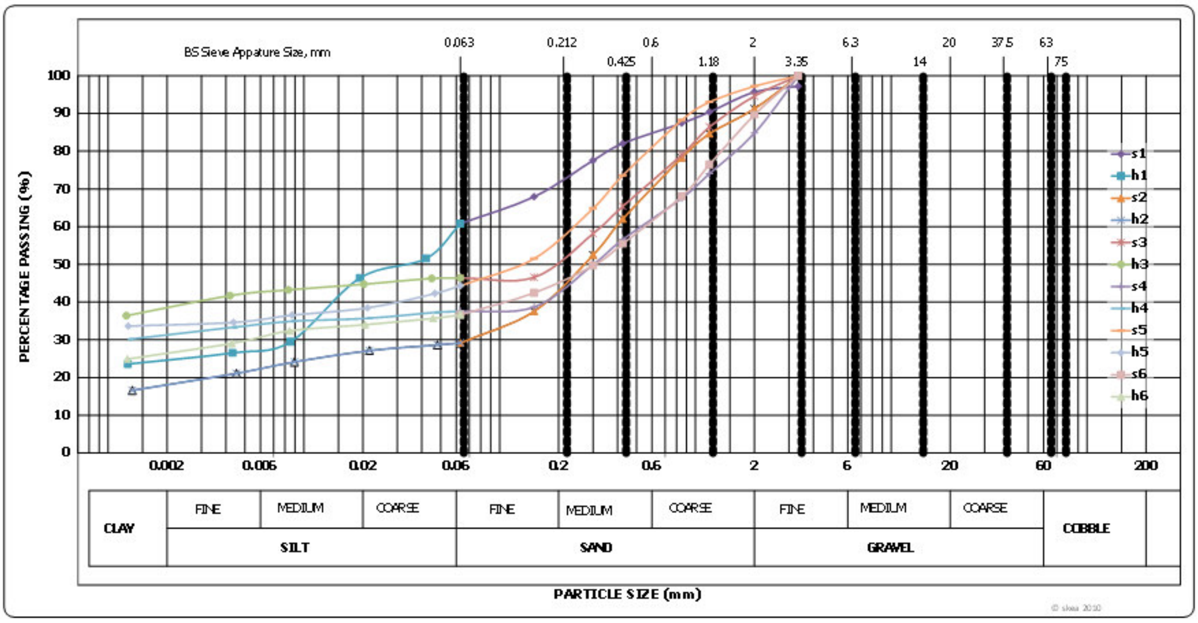

Figure 4: Grain size distribution of samples 1-6

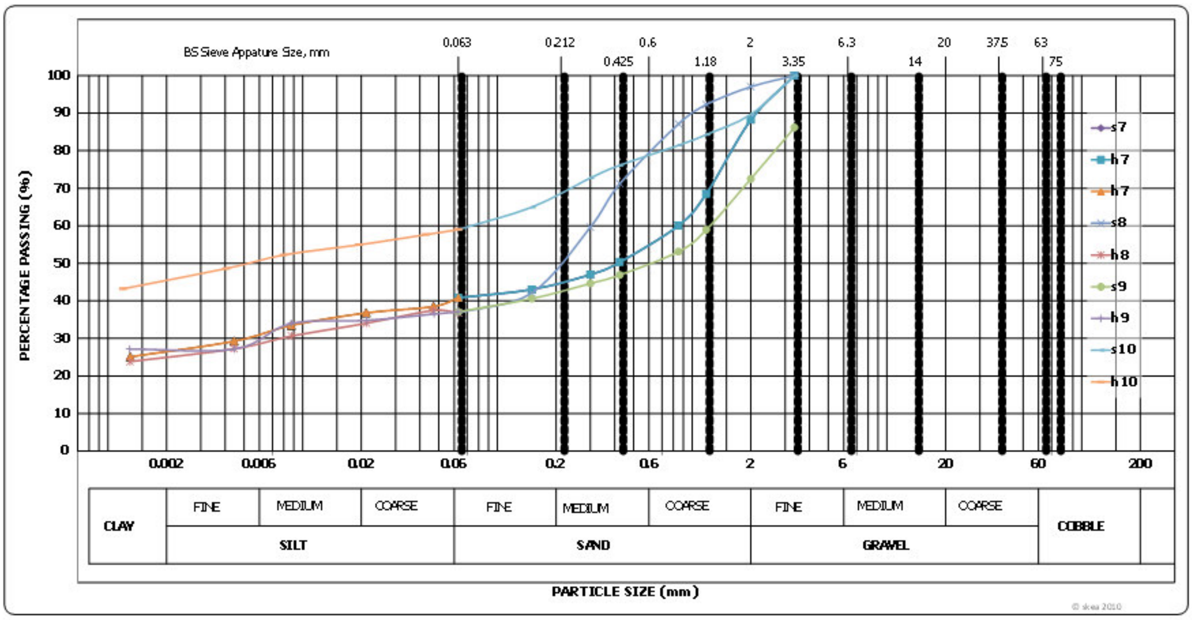

Figure 5: Grain size distribution of samples 7-10

Table 1: Result of the geotechnical tests conducted on the studied samples

S/no	%clays	silt%	%fines	%sand	%gravel	mc %	free swell(%)	LS	SGravity	liquid limit	plastic limit	PI	ACTIVITY	MDD(Kg/m3	OMC	CBR %	USCS	AASHTO	soil group
S1	25.1	35.7	60.8	35	4.2	15.8	30	10	2.63	55.1	34.6	20.46	0.87	1520	23	8	MH	A7	sandy silt
S2	17.5	11.7	29.2	62.1	8.7	10.6	20	7.14	2.53	29.4	21.4	8	0.48	1750	13	12	CL	A-2-4	clayey sand
S3	38	8.4	46.4	48.3	5.3	19.6	22.22	10	2.52	46.77	28.2	18.6	0.51	1560	20	16	MI	A-7	clayey sand
S4	30.2	7.3	37.5	47.3	15.2	11	22.22	11.43	2.52	44.4	30.4	14	0.46	1630	17	12	MI	A-7	clayey sand
S5	33.7	10.7	44.4	52.8	2.8	15.2	30	10	2.52	43.86	27.9	16.3	0.43	1510	20	12	MI	A-7	clayey sand
S6	26	10.4	36.4	53.3	10.3	18.7	25.93	11.43	2.54	46.9	27.5	19.4	0.78	1630	18	10	CI	A-7	clayey sand
S7	25.5	15.4	40.9	47.3	11.8	11.9	41.94	9.29	2.54	50.2	29	21.2	0.85	1750	12	10	MI	A-7	clayey sand
S8	23.8	13	36.8	60.3	2.9	6.5	1.01	5	2.57	24.1	18.9	5.2	0.22	1780	12	8	CL-ML	A-4	clayey sand
S9	27.2	9.9	37.1	35	27.9	14	-16.67	5	2.58	40.7	27.7	13	0.48	1650	15	6	MI	A-7	gravelly sand
S10	45.9	13.1	59	30.7	10.3	13.25	20	9.29	2.63	40.4	30.5	9.9	0.19	1670	18	18	MI	A-6	sandy clay

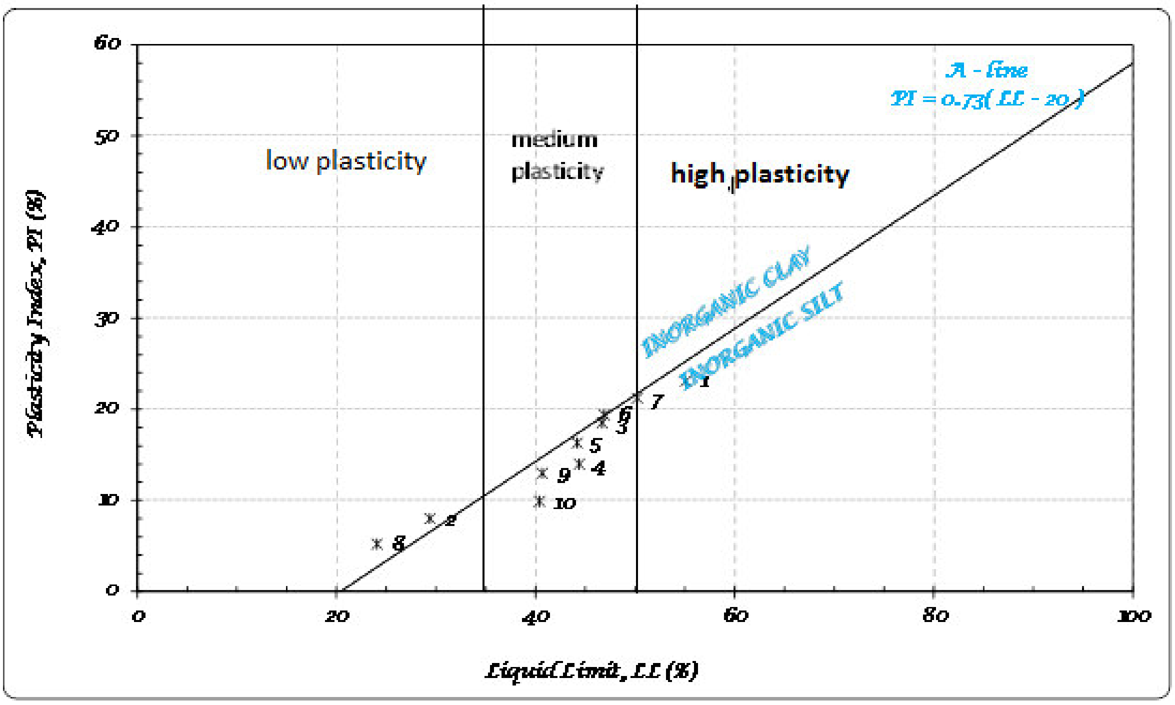

Figure 6: Position plots of the studied soils on Cassagrande plasticity chart

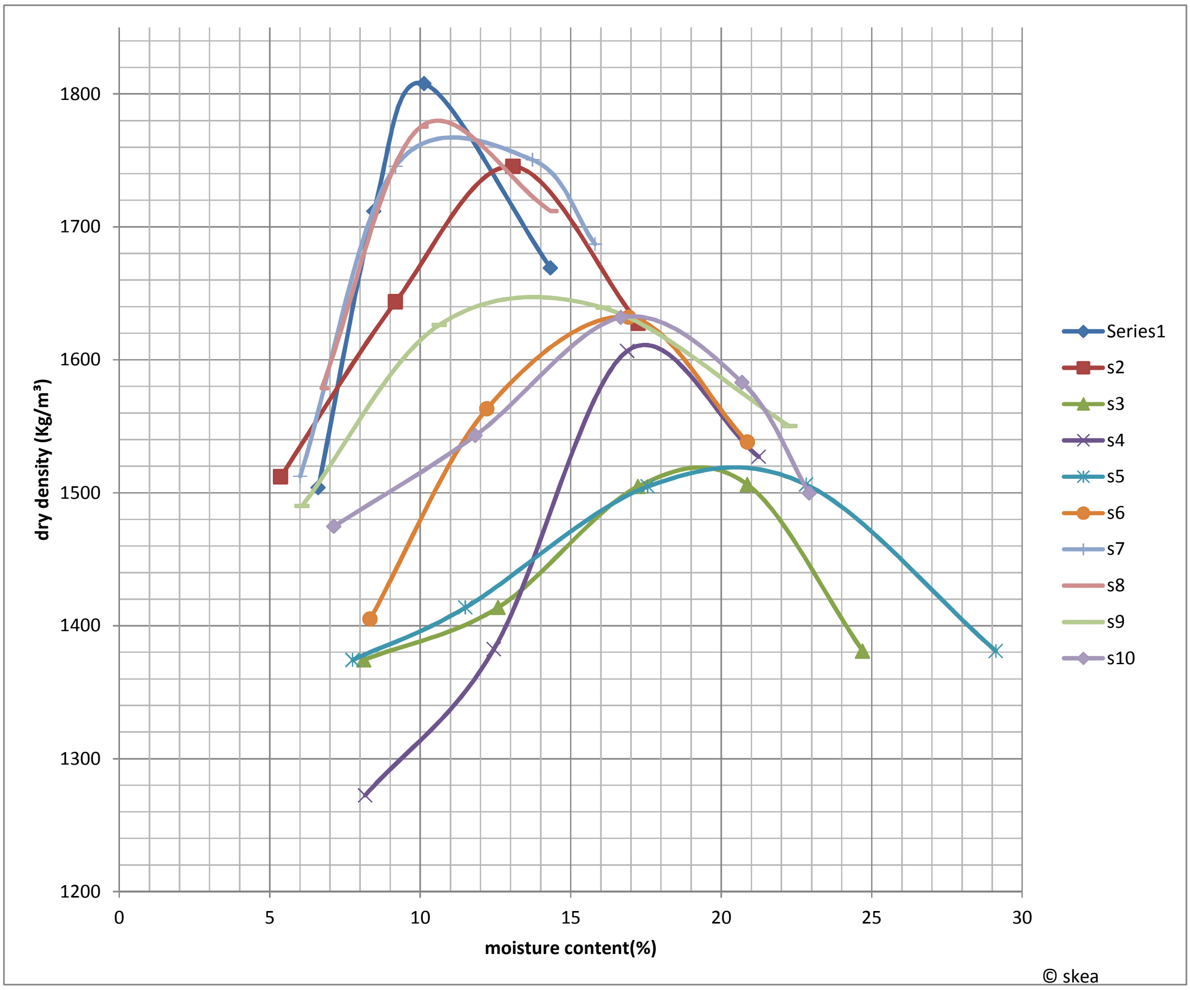

Figure 7:Compaction characteristics of the studied soils