

THE INFLUENCE OF PARENT ROCK FACTOR ON SOME ENGINEERING INDEX
PROPERTIES OF THREE RESIDUAL LATERITIC SOILS IN SOUTHWESTERN NIGERIA
INFLUENCE DE LA NATURE DE LA ROCHE-MÈRE SUR QUELQUES PROPRIÉTÉS
GÉOTECHNIQUES DE TROIS SOLS LATÉRITIQUES RÉSIDUELS (SUD-OUEST DU NIGERIA)

G. O. ADEYEMI*

Abstract

Soils derived from sandstone, migmatite-gneiss and quartz-schist in the vicinity of sections of the Lagos-Ibadan expressway in Southwestern Nigeria were investigated. The investigation was meant to determine the extent to which the parent rock factor has controlled some basic engineering index properties of the derived soils. Field and laboratory investigations showed that the mineralogy and texture of the parent rocks show distinct variation from one rock type to another.

The study has proved that the influences of the parent rock factor on engineering index properties such as the specific gravity of grains, plasticity index and grain size distribution characteristics of the soils studied were significant. However, a rather weak influence of the genetic factor on the linear shrinkage of the studied soils was noticed. It is thus necessary to take proper cognisance of the parent rock characteristics prior to an adequate understanding of engineering properties and behaviour of residual soils.

Résumé

L'étude a porté sur des sols dérivant d'un grès, d'un gneiss migmatique et d'un schiste quartzeux prélevés le long de la route express Lagos-Ibadan dans le Sud-Ouest du Nigeria. Elle a montré l'influence des roches d'origine sur certaines caractéristiques géotechniques des sols telles que la densité des grains, l'indice de plasticité et la courbe granulométrique. On a par contre noté une faible influence du facteur génétique sur le retrait linéaire des sols étudiés.

Introduction

The influences of geology, especially the parent rock on engineering properties of tropical soils, have been extensively studied (e.g. Gidigasu, 1976; Madu, 1977; Balogun, 1984; Mesida, 1985 and Ogunsanwo, 1989). Most of these workers have, however, paid little or no attention to the quantitative aspect of the influence. It is well known that geotechnical engineers often prefer quantitative to more qualitative study as the former has more relevance to the design of foundations of structures.

The soils being investigated were those employed as both the subgrade and construction materials for significant sections of the Lagos-Ibadan expressway, which is an important highway in Nigeria.

Attempts are made in this study to determine the influences which the parent rock factor has on engineering index properties such as the specific gravity of grains, plasticity index, linear shrinkage and grain size distribution characteristics. The soils were derived from quartz-schist, migmatite-gneiss and sandstone respectively.

The study areas lie in southwestern Nigeria (Fig. 1). The climate is tropical while the natural vegetation is

the rainforest type. The relief of the study area is closely associated with the underlying rocks (Jones and Hockey, 1964). Whereas the relief of the Basement Complex area is gently undulating, that of the sedimentary area is rather rugged.

The rocks in the study areas are sandstone in Ishara where it is in contact with quartz-schist. Migmatite-gneiss crops out mostly in the Ajebo area (Fig. 2). The migmatite-gneiss was formed during the Older Granite orogeny through the introduction of metasomatic material (quartz and feldspar) into gneiss (Jones and Hockey, 1964; Holmes, 1964). Field study showed an intricate 'mixture' of granitic (quartzofeldspathic) and mafic highly foliated bands. The latest event was found to be the cross-cutting fine-grained granitic layer. Petrographic studies showed the major minerals in the gneissic portion to be biotite, hornblende, quartz and plagioclase feldspar. The granitic portion is medium to coarse grained. The minerals in the order of abundance are quartz, biotite, muscovite and microcline feldspar.

The quartz-schist crops out poorly due to its high susceptibility to weathering. The rock is highly foliated. The major minerals are aligned crystals of muscovite, biotite, quartz and feldspars.

* Department of Earth Sciences, Ogun State University, P.M.B. 2002, Ago-Iwoye, Nigeria.

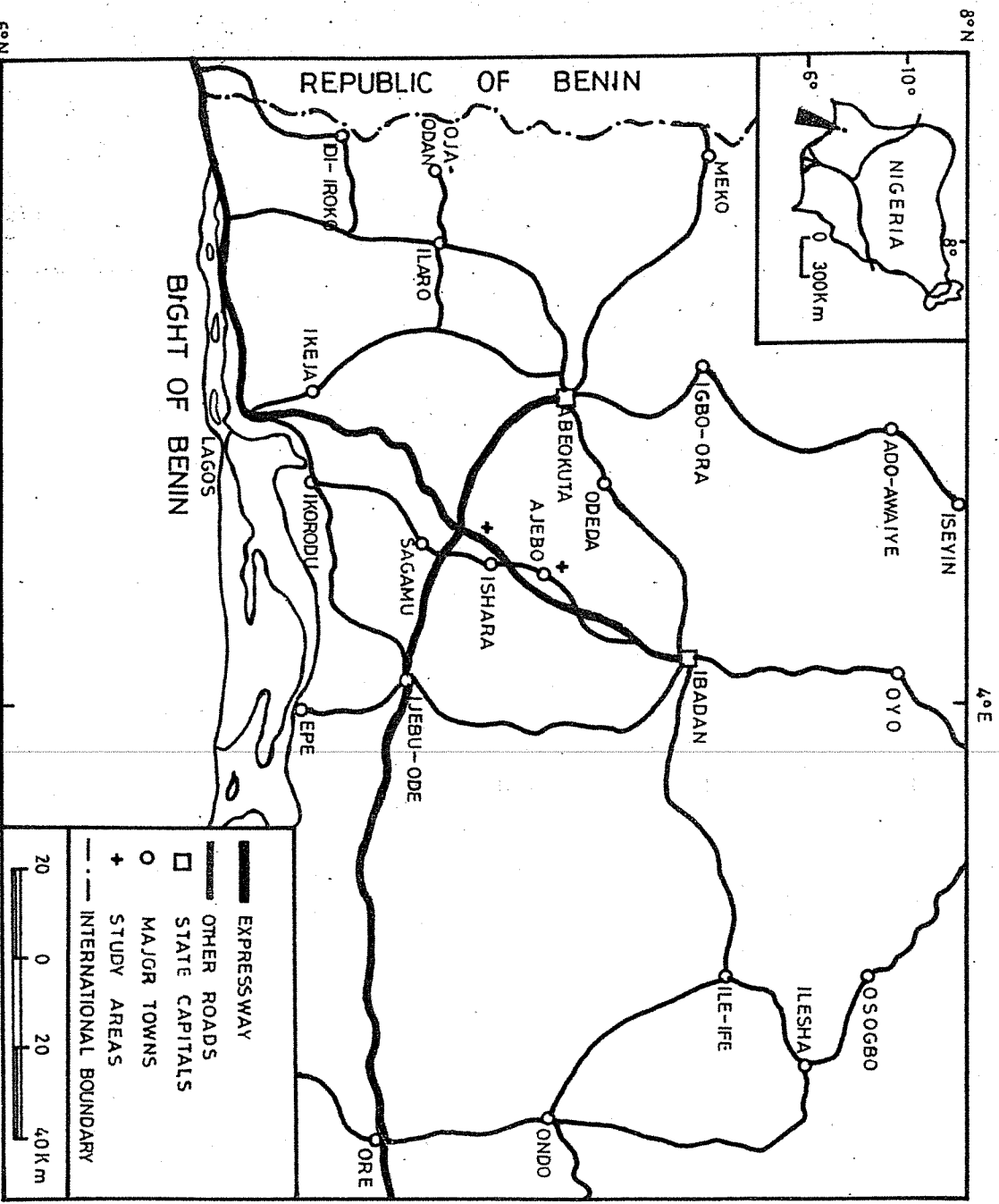


Fig.1 : Map of parts of south western Nigeria showing the study area.

The major mineral in the sandstone is quartz whose grains have been intensively coated with iron compounds. The quartz grains are fairly angular which may be an indication of a short distance transport.

Field observations showed remarkable differences in the colours of the soils studied. While the sandstone-derived soil is reddish brown, the quartz-schist-derived soil is greyish brown and the soil derived from the migmatite-gneiss is mottled reddish brown and greyish brown.

Methods of Investigation

Bulk soil samples were collected from test pits dug on flat terrain for each of the three genetically different soils.

Engineering properties of air-dried soils were determined following the British Standard procedure 1377 of 1975. However, modifications were made whenever necessary. For instance, in the determination of grain

size distribution characteristics the soils were soaked in 2% calgon (sodium hexametaphosphate) solution for 24 hours during which time each soil was regularly agitated and squeezed. This was meant to effect adequate segregation of the soil into the 'actual' grain sizes (Mesida, 1985).

Results and Discussion

The results of the various tests carried out are presented in this section. The results are subjected to statistical (*t*-test) analysis at 5% level of significance in order to quantify the influence of the parent rock factor.

Specific gravity of Grains

The specific gravity of grains of any soil is important in estimating its degree of weathering (laterization) (e.g. Tuncer and Lohnes, 1977).

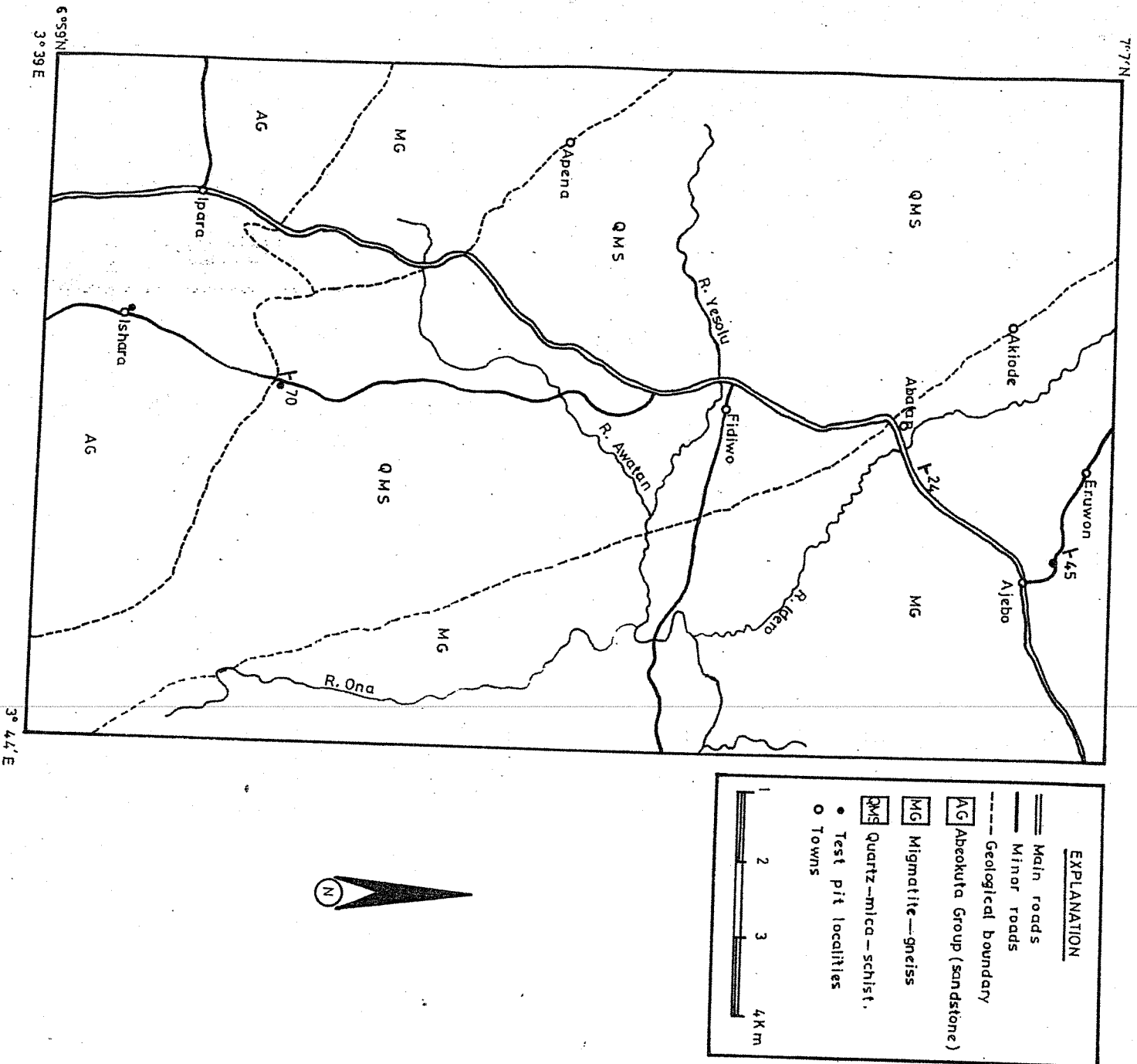


Fig. 2 : Geological map of the study area.

Table 1 shows that there exist some degrees of overlap in the values of the specific gravity of grains of the soils studied. However, samples of sandstone-derived soil give the highest while samples of quartz-schist-derived soil exhibit the lowest values.

Statistical treatment of the values of this parameter (Table 2) shows that the influence of the parent rock factor is fairly strong. Since the soils are in a similar weathering environment, the difference in the value of specific gravity can only be due to a genetic factor.

Consistency limits

Consistency limits characteristic is an important factor in the selection of laterite soils both as subgrade and sub-base materials. Excessively high plasticity often leads to a common type of road failure in the tropics called waviness – a failure which results from plastic flow of wet soil on the application of load.

Figure 3 is the Casagrande chart classification of the soils. The chart shows that virtually all the samples of

Table 1 : Mean values of the specific gravity of grains of the soils taken from flat terrains

Depth (m)	Parent rock	Specific Gravity
0.50	Sandstone	2.85 ± 0.06
1.00		2.48 ± 0.06
1.50		3.09 ± 0.04
2.00	Migmatite-gneiss	2.74 ± 0.08
0.50		2.69 ± 0.05
1.00		2.89 ± 0.08
1.50		2.60 ± 0.01
2.00	Quartz-schist	2.75 ± 0.02
0.50	Sandstone & quartz-schist	2.40 ± 0.07
1.00		2.37 ± 0.05
1.50		2.56 ± 0.08
2.00		2.37 ± 0.02

Table 2 : Results of T-test treatment of the values of specific gravity of grains of the studied soils.

Parent rock	Computed T	T in table	Nature of difference
Sandstone migmatite-gneiss	0.383	1.943	Not significant
Migmatite-gneiss & quartz-schist	4.079	1.943	Significant
Sandstone & quartz-schist	2.676	1.943	Significant

Table 3 : Results of T-test carried out on values of plasticity index of the studied soils

Parent rock	Computer T	T in table	Nature of difference
Sandstone & migmatite-gneiss	0.994	1.943	Not significant
Migmatite-gneiss & quartz-schist	4.640	1.943	Significant
Sandstone & migmatite-gneiss	5.533	1.943	Significant

both sandstone and quartz-schist derived soils have medium plasticity while a great majority of samples of migmatite-gneiss-derived soil have high plasticity. Table 3 shows that the influence of the parent rock factor on the plasticity index is fairly strong.

Linear shrinkage

The linear shrinkage is an important parameter in the evaluation of soils as highway sub-base material. Gidigasu (1973) suggested that any soil with linear shrinkage below 10 % would not pose a field compaction problem. Madedor (1983) also suggested that a linear shrinkage below 8 % indicates a soil that is good as a sub-base material.

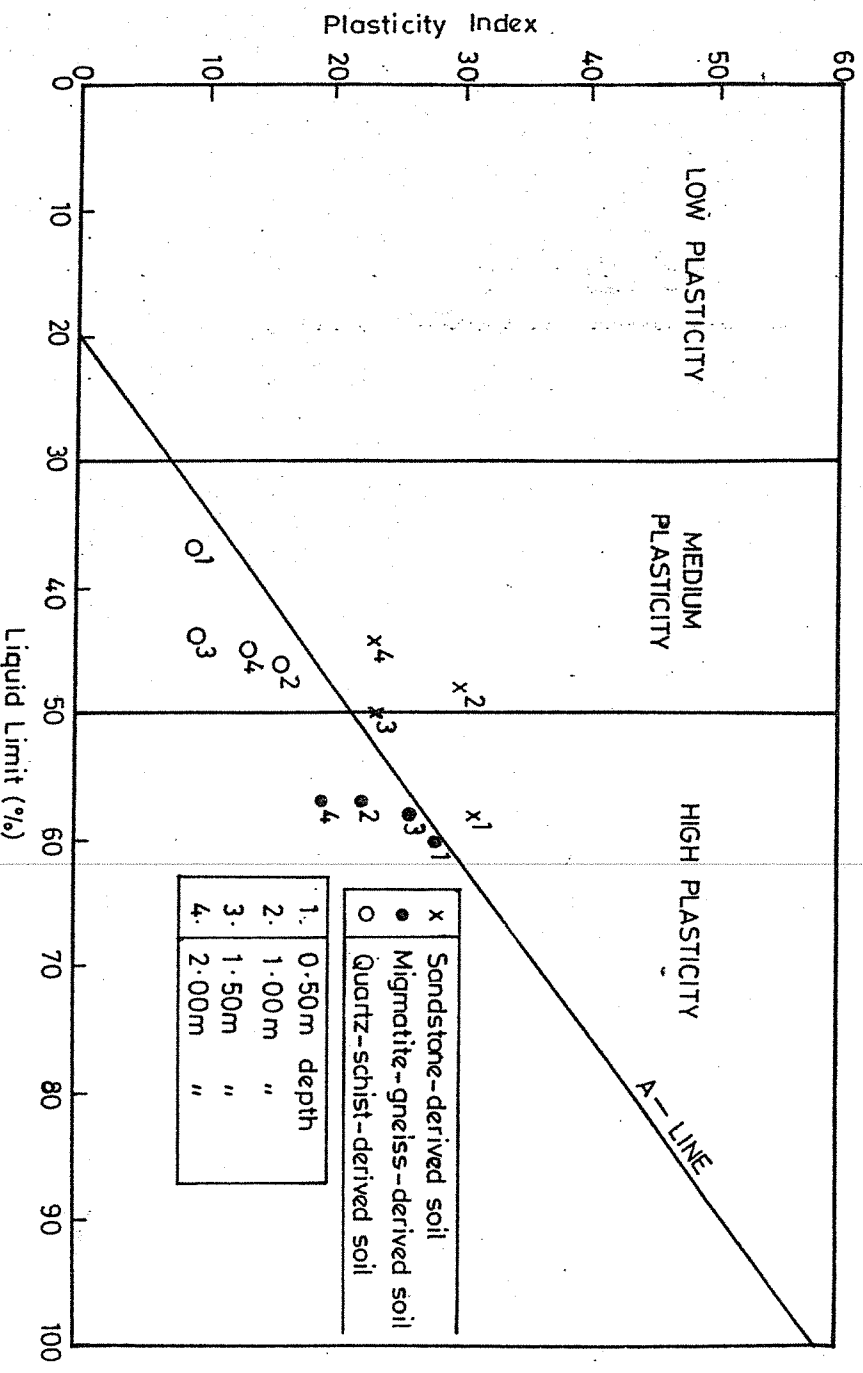


Fig. 3 : Casagrande chart classification of the studied soils (Flat Topography) using mean values of consistency limits.

Table 4 : Mean values of linear shrinkage of the studied soils.

Depth (m)	Parent rock	Linear shrinkage (%)
0.50	Sandstone	3.60 ± 1.02
1.00		5.76 ± 0.14
1.50		5.04 ± 0.16
2.00		5.76 ± 0.13
0.50	Migmatite-gneiss	8.90 ± 0.61
1.00		7.15 ± 0.50
1.50		6.40 ± 0.46
2.00		6.00 ± 0.34
0.50	Quartz-schist	6.37 ± 1.09
1.00		5.19 ± 0.68
1.50		6.09 ± 0.03
2.00		5.40 ± 1.53

Table 5 : Results of T-test analysis showing the influence of parent rock on linear shrinkage of the studied soils

Parent rock	Computed T	T in table	Nature of difference
Sandstone & migmatite-gneiss	2.527	1.943	Significant
Migmatite-gneiss & quartz-schist	1.931	1.943	Almost significant
Sandstone & quartz-schist	1.239	1.943	Not significant

Table 6 : Grain size distribution characteristics of the studied soils

Depth (m)	Parent rock	% gravel	% sand	% silt	% clay	Amount of fines (%)
0.50	Sand-stone	18	40	32	10	42
1.00		7	45	38	10	48
1.50		3	49	39	9	48
2.00		10	42	41	7	48
0.50	Migmatite-gneiss	4	22	62	12	74
1.00		3	29	55	13	68
1.50		1	37	49	13	62
2.00		6	34	32	28	60
0.50	Quartz-schist	53	29	13	5	18
1.00		12	40	30	18	48
1.50		8	44	27	21	48
2.00		7	44	28	21	49

Tables 4 and 5 depict a rather weak influence of parent rock factor on the linear shrinkage of the soils. However the linear shrinkages of migmatite-gneiss derived soil appear generally to be the highest while those of sandstone derived soil are the lowest.

Grain-size Distribution Characteristics

A combination of grain size distribution characteristics of a soil with the plasticity enhances an easy classification of the soil.

Although grading characteristic has little relevance in the characterisation of fine-grained soils, most of the engineering properties of coarse-grained soils are closely associated with the predominant particle size (e.g. Gidlagasu, 1976).

Tables 6 and 7 show that the parent rock factor has some remarkable influence on the grain size distribution. Table 7 shows that the difference between the amount of fines in sandstone and quartz-schist derived soil is not high enough to be significant. This phenomenon is due to the fact that quartz-schist has some genetic relationship with sandstone.

Table 7 : T-test treatment of the influence of parent rock on the amount of fines in the studied soils

Parent rock	Computed T	T in table	Nature of difference
Sandstone & migmatite-gneiss	9.971	1.761	Significant
Migmatite-gneiss & quartz-schist	6.481	1.761	Significant
Sandstone & quartz-schist	0.080	1.761	Not significant

Conclusion

It has been shown in this study that differences in textural and mineralogical characteristics of parent rocks could be responsible for significant differences in the engineering properties of the derived soils. The parent rock factor has caused remarkable differences between the specific gravity of grains plasticity index and grain-size distribution characteristics of most of the pairs of soils studied. However, rocks that are genetically related (such as quartz-schist and sandstone) have been transformed into soils with some engineering properties (such

as amount of fines) that are not significantly different from each other. This study emphasises the need to take proper cognisance of the nature of the parent rock in order to understand properly the engineering properties of residual soils.

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