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Geotechnical Evaluation of Sub-grade Soils at the Cemeteries Area, New Tiba City, Luxor, Egypt

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Abstract This work dealt with geotechnical investigations on the sub-grade soils of the Cemeteries area roads (new Tiba city, Luxor) to classify these soils and to evaluate their geotechnical behaviour and their suitability for constructing the roads at the study area. One of the most important aims of this work was to determine the problematic soils and to suggest the suitable treatment. To achieve these scopes, 119 disturbed samples were collected from 15 mechanical drilling boreholes (105 samples) and from 7 open pits (14 samples). The studied soils were belonging to Quaternary age. Gradation parameters (coefficient of uniformity, Cu and coefficient of concavity, Cc), plasticity, California bearing ratio (CBR) and free swelling percent of the studied soils were measured. Chemical and mineralogical analyses of the studied sediments were conducted. Petrographical description of some representative gravel pebbles was carried out. The results showed that the studied Quaternary soils at the study area were mainly composed of gravels, sands and clayey silts. The studied gravels were classified as well graded gravels (GW) and poorly graded gravels (GP) according to USCS (Unified Soil Classification System) and as A-1-a to A-1-b according to AASHTO (American Association of State Highway and Transportation Official). The studied sands were classified as well graded sands (SW) and poorly graded sands (SP) according to USCS and as A-1-a to A-2-4 according to AASHTO. The studied fine grained soils (clayey silts) were occurred as two lenses at the study area and were classified as low to medium plastic clayey silts (ML) according to USCS and as A-6 according to AASHTO. The results showed also that the sub-grades at roads no. 2, 3, 5, 6, 8, 9 and 10 were excellent to good and the sub-grades at roads no. 1, 4 and 7 were fair to poor. CBR-values of the fine grained soils were ranging from 1.00 to 7.00%. Free swelling percent of the studied fine grained soils were ranging from 60 to 80% and they were classified as expansive soil. Replacement and/or chemical stabilization (using lime and cement kiln dust) of the problematic fine grained soils were recommended to reduce their swelling and to avoid the possible heave.

Keywords California Bearing Ratio, Free Swelling, Gradation Parameters

1. Introduction

To overcome the problem of the population increase in the Nile valley, the Egyptian government tends to construct new cities in the western and eastern deserts and Sinai Peninsula. New Tiba city is one of these new cities at the border between Nile valley and the eastern desert (Figure 1). Ten roads were constructed at the study area (the Cemeteries area) as infrastructures. A roadway section consists of a complete pavement system[1] as shown in Figure 2. The sub-grade refers to the *in situ* soils on which the stresses from the overlying roadway will be distributed. The sub-base or sub-base course and the base or base course materials are stress distributing layer overlying sub-grade layer and underlying of the pavement layer. The pavement structure consists of a relatively thin wearing surface constructed over a base course and a sub-base course, which rests upon an *in situ* sub-grade. In this work, geotechnical behaviour and classification of Quaternary sediments used as sub-grade soils at the studied area were investigated.

1.1. Previous Works

The studied area was geologically investigated by many authors such as[2],[3],[4],[5],[6],[7],[8],[9],[10],[11],[12],[13],[14],[15],[16],[17],[18],[19],[20],[21],[22],[23],[24],[25],[26],[27] and others. Little of geotechnical investigations were carried out on the studied area like[28],[29],[30] and[31].

1.2. Scope of the Present Work

The present study focused on geotechnical investigations on the sub-grade soils of the Cemeteries area roads at new Tiba city to classify these soils and to evaluate their geotechnical behaviour and their suitability for constructing the roads at the study area. This work dealt also with exploration of the problematic soils especially the clayey soils and with determination of the geotechnical problems to

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recommend the suitable solution.

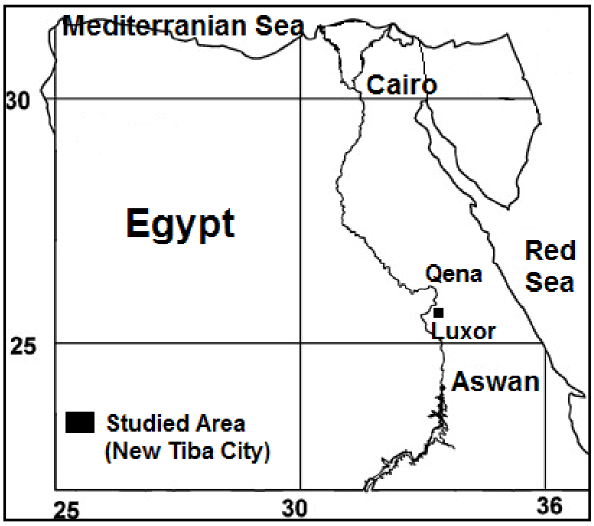

Figure 1. Location map of the studied area

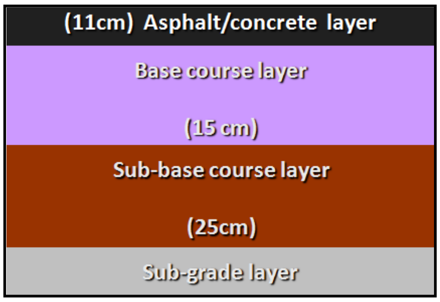

Figure 2. Typical flexible pavement structure

2. Geographical and Geological Setting

The study area (New Tiba City) lies about 10km to the northeast of Luxor city and about 50km to the southeast of Qena city. It lies between latitudes 25° 43¯and 25° 46¯ N and longitudes 32° 45¯ and 32° 47¯E (Figure 1 and Table 1).

The first stage of this new city covers a surface area of about 240 acres while the second and the third stages cover a surface area of about 460 acres with the ability of expansion in the near future[27]. The area situated to the east and southeast of Qena constitutes an area of a wide variety of sediments belonging to the Upper Cretaceous-Lower Tertiary succession as well as the Pliocene-Recent sediments [26]. The surface of the study area is covered by Quaternary sediments in the form of alluvial sands, gravels, clays or mud and wadi deposits. The distribution of the studied soils (Quaternary sediments) is mapped in some details in a geological map (Figure 3). The studied area is located within the transitional zone between the eastern desert and the Nile valley. It is characterized by a simple topography follows the regional northwest slope towards the Nile. The area surrounding the New Tiba city is dissected by many large wadies like wadi Madamoud to the south of this city, wadi Banat Biri and wadi Khozam to the north and east. The courses of these wadis are running from the southeast to the northwest following the dominant fault trend in the area that make sure enough that these wadis are structurally controlled.

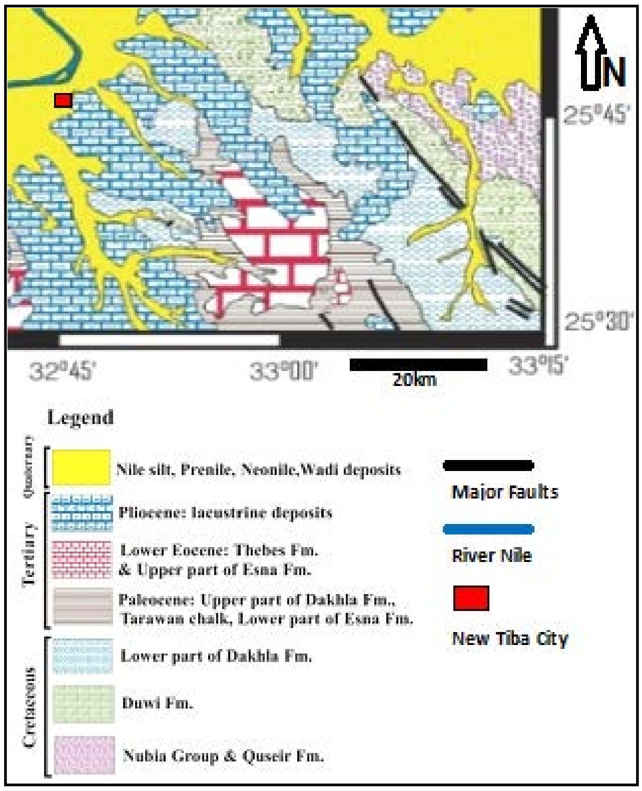

Figure 3. Geological map of the studied area modified after [37]

3. Materials and Methods

3.1. Materials

119 disturbed samples were collected from 15 mechanical drilling boreholes (105 samples) and from 7 open pits (14 samples) (Figure 4 and 5). The studied soils were belonging to the Quaternary age.

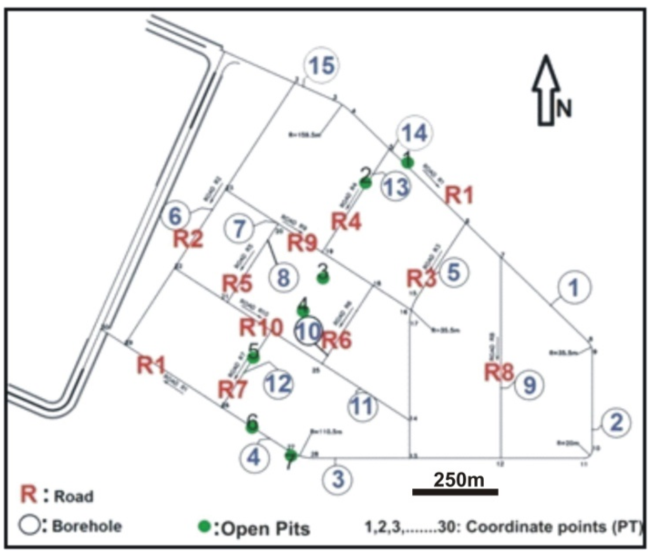

Figure 4. Layout of the studied roads at the studied area, modified after layout of the cemeteries area project

3.2. Methods

Subsurface exploration methods including both open pits and washing mechanical drilling boreholes were carried out to collect the studied specimens. Four geotechnical tests including grain size analysis[32 & 33], plasticity[34], California bearing ration (CBR)[35] and free swelling percent[36] were conducted on the studied soils.

Petrographical description of the studied pebbles (gravels) using polarized light microscope with digital camera was conducted to describe the lithology. Chemical (x-ray fluorescence, XRF, type of the instrument is JEOL, JSX 3222, Japan) and mineralogical (x-ray diffraction, XRD, PW1710 BASED diffractometer with a generator operating at 40 KV, 30 mA) analysis of the investigated fine grained soil and some representative gravel pebbles were also carried out to understand the geological origin and the sources of these pebbles. The representative gravel pebbles were selected according to the variation of the lithology.

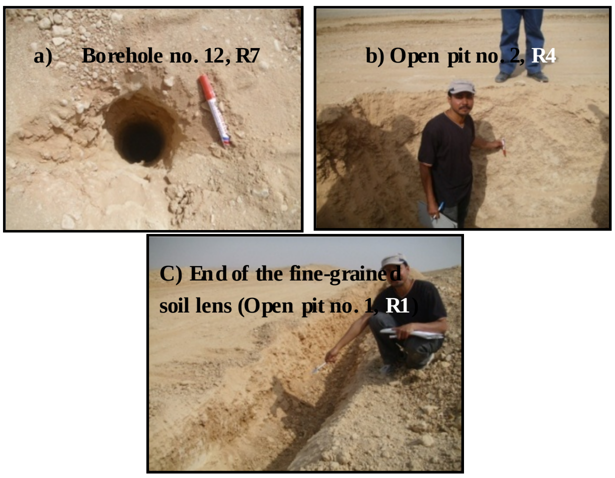

Figure 5. Borehole (a), open pit (b) and lens of fine-grained soil (c) at the studied area

4. Results

4.1. Results of Mineralogical and Chemical Analysis

XRD results showed that the studied Quaternary gravels were composed of quartz, calcite and albite as major components and of anhydrite and kaolinite as traces. The studied sands were composed of quartz, orthoclase, albite as major components and kaolinite as traces. The results showed also that the clayey silts were composed of quartz, albite and calcite, hematite as major components and illite, montmorillonite and gypsum as minor components. Chemical analysis (XRF) results showed that the Quaternary gravels at the studied area were mainly composed of silica (about 63.25%), calcium (about 10.46%) and other elements as traces. The sands were composed of silica (93.30%), aluminum (3.01%) and other elements as traces. The results showed also that the clayey silts were composed of silica (56.34%), aluminum (11.77%) and iron (13.11%) as major elements and other elements as traces (Table 2).

4.2. Results of Petrographical Study

The petrographical examination of fifteen representative pebbles of the studied deposits (studied gravels) showed that these pebbles were composed of granite, rhyolite, gabbro, basalt, andesite (igneous rocks), gneiss, schist (metamorphic rocks), partially crystalline limestone, organic limestone, mudstone, sandstone, flint and some phosphorites (sedimentary rocks). The petrographical description of some other representative gravel pebbles showed that they included amphibole and mica minerals which were not appeared in the XRD analysis. Figure (6) illustrated photomicrographs of some studied pebbles under the polarized light microscope.

Table 1. Thirty coordinate points (PT) of the study area

PT.	East	North
1	792839.346	337024.432
2	793024.537	336942.126
3	793119.198	336900.054
4	793165.551	336868.712
5	793258.592	336778.339
6	793447.637	336594.714
7	793535.187	336509.674
8	793750.922	336300.124
9	793781.687	336274.660
10	793761.687	336030.000
11	793742.187	336010.500
12	793535.187	336010.500
13	793308.687	336010.500
14	793308.687	336104.122
15	793326.514	336408.201
16	793312.846	336378.050
17	793308.687	336348.019
18	793218.483	336439.329
19	793091.844	336521.570
20	792982.817	336592.373
21	792856.461	336397.801
22	792726.047	336482.493
23	792852.404	336677.064
24	792965.775	336327.441
25	793092.127	336244.758
26	792842.127	336137.039
27	793009.530	336028.327
28	793069.712	336010.500
29	792602.687	336292.534
30	792543.242	336331.138

Table 2. Chemical composition of some representative studied samples

Location / Oxides (%)	Gravels Open pits 3 & 4 at 1m depth	Sands boreholes 8 & 10 at 5m depth	Clayey silts Open pits 2 & 6 at 1m depth
Sio_2	63.25	93.30	56.34
Tio_2	0.47	0.01	1.70
Al_2o_3	4.84	3.01	11.77
Fe_2o_3	2.96	0.44	13.11
Mno	0.05	0.05	0.22
Mgo	1.36	0.04	2.02
Cao	10.46	0.09	4.95
Na_2o	1.54	0.19	1.03
K_2o	0.82	0.90	1.60
P_2o_3	0.24	0.06	0.31
Cl	0.81	0.22	0.12
So_3	3.62	0.03	2.33
LOI	9.58	1.66	4.50

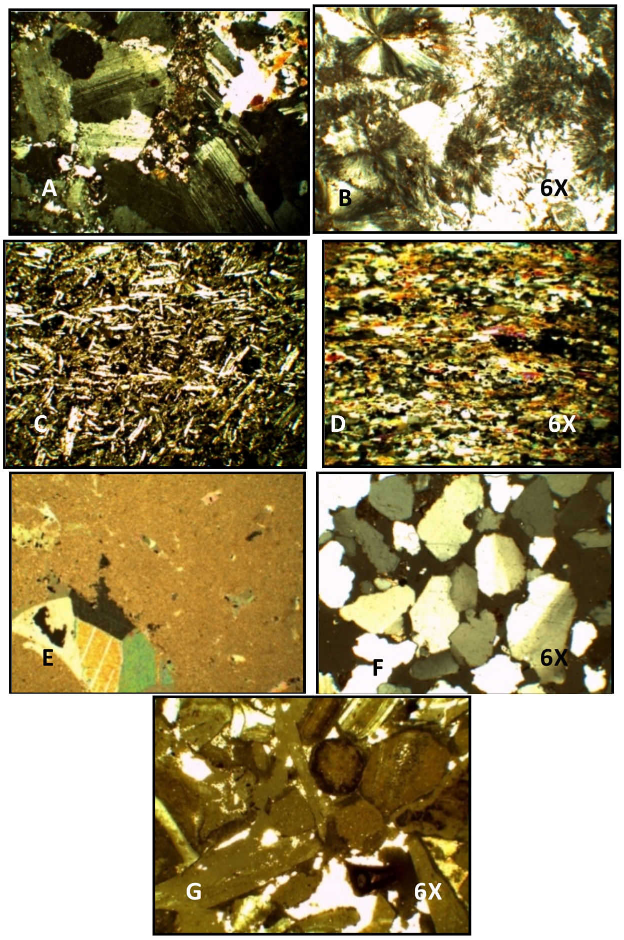

Figure 6. Photomicrographs illustrate mineral composition and texture of some studied pebbles (gravels) at the study area. A) Holocrystalline quartz and plagioclase in granular texture (Granite). (B) Cryptocrystalline quartz and alkali feldspars in spherulitic texture (Rhyolite). (C) Plagioclase and amphibole in fluidal texture (Andesite). (D) Mica and quartz in schistosity texture (Schist). (E) Micrite with spary calcite and calcite crystals are observed due to diagensis (Partially Crystalline Limestone). (F) Quartz grains cemented by hematitic cement (Sandstone). (G) Collophan grains and bone fragments in siliceous and hematitic cements (Phosphorite)

4.3. Results of Geotechnical Tests

4.3.1. Grain Size Analysis Test Results

Results of the grain size distribution test of the coarse grained sediments (Gravels and Sands) showed that the gradation parameters of the studied sediments including coefficient of uniformity (Cu) were less than 4 for gravels and less than 6 for sands according to the USCS specifications, these soils were classified as poorly and gab-graded gravels and sands. Some samples especially at boreholes no. 6 and 9 were corresponding to the later (Cu greater than 4 for gravels and greater than 6 for sands), they were classified as well graded gravels and sands, Figure 7.

4.3.2. Plasticity Test Results

The plasticity test results showed that the plasticity index of the fine grained sediment (collected from open pits no. 1, 2, 5, 6 & 7 and boreholes no. 4, 12, 13 & 14, see Figures 4 & 5 and Table 3) was ranging from 9.00 to 12.00%, they are low to medium plastic clayey silts.

4.3.3. California Bearing Ratio Test Results

Results of California bearing ratio (CBR) test showed that CBR-unsoaked values of the investigated fine grained soils were ranging from 7.00 to 25.00%, in contrast CBR-soaked (4 days water soaking) values of these soils were ranging from 1.00 to 7.00% (Table 3).

Table 3. Geotechnical properties of the studied fine grained soils

Road No./ Open pits No.	Consistency Limits (%)			Free Swelling (%)	CBR Un-soaked (%)	CBR 4-days Soaked (%)
	LL	PL	PI			
R1/1	22	11	11	80	12	2
R1/6	27	18	9	60	25	7
R1/7	23	11	12	80	7	1
R1/2	27	18	9	70	22	5
R1/5	22	12	10	75	8	4

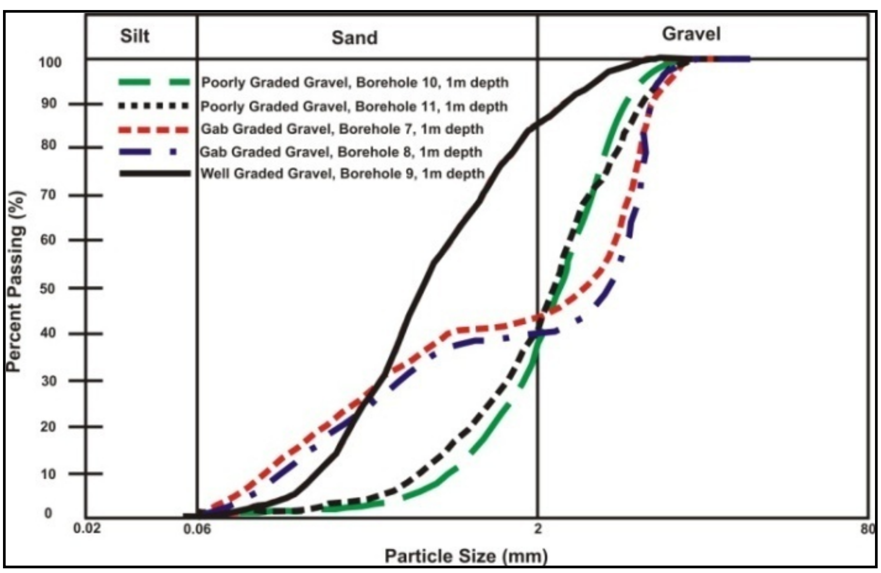

Figure 7. Grain size distribution curves of the studied sands and gravels

4.3.4. Free Swelling Percent Test Results

Free swelling test results showed that the free swelling percent of the studied fine grained sediments was ranging from 60.00 to 80.00%. The tested samples having free swelling percent more than 50% were corresponding to[36]. They are classified as expansive soils (Table 3).

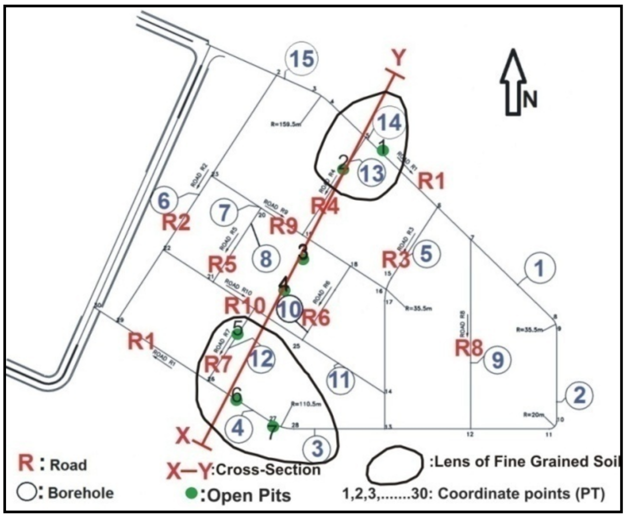

Figure 8. Layout of the studied roads illustrates cross-section (X-Y) and boundary of two fine grained-soil lenses

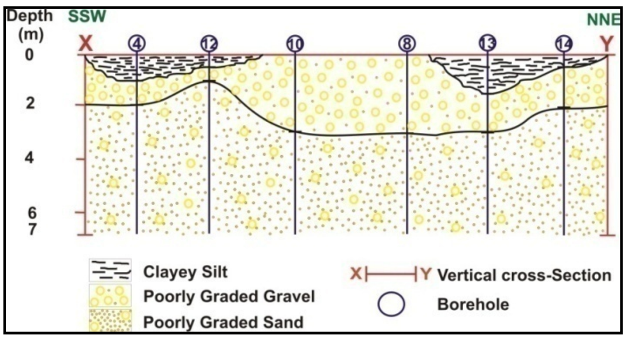

Figure 9. Vertical cross-section at the studied area illustrates three different layers of soils

5. Conclusions and Recommendations

1- A vertical cross section of the studied area in X-Y direction was constructed by a correlation between the studied mechanical drilling boreholes data. This vertical cross section showed that the studied area composed of two layers. The upper layer was gravels ranging in thickness from 0.5 to 3m (Figures 5c, 7 and 8). The lower layer was sands ranging from 4 to 6m in thickness. The cross section showed also that there were two lenses of the clayey silts, the first lens at NNE was 1.5m in thick and the second lens at SSW was 1m thick.

2- The studied Quaternary gravels were composed of quartz, calcite and albite as major components and of anhydrite and kaolinite as traces. The lithology of the studied gravels was of granite, rhyolite, gabbro, basalt, andesite (igneous rocks), gneiss, schist (metamorphic rocks), partially crystalline limestone, organic limestone, mudstone, sandstone, flint and some phosphorites (sedimentary rocks). Minerals and chemical compositions of the studied gravels pebbles as well as the lithology indicated that the sources of the studied gravels pebbles were the basement complexes along the red sea coast and the Upper Cretaceous-Lower Tertiary succession.

3- The gradation parameters of the studied sediments including coefficient of uniformity (Cu) were less than 4 for gravels and less than 6 for sands according to the USCS (Unified Soil Classification System) specifications, they were classified as poorly and gab-graded gravels and sands. Some samples especially at boreholes no. 6 and 9 were corresponding to the later (Cu greater than 4 for gravels and greater than 6 for sands), they were classified as well graded gravels and sands The studied gravels were classified as A-1-a to A-1-b according to AASHTO (American Association of State Highway and Transportation Official). The studied sands were classified as A-1-a to A-2-4 according to AASHTO. The general rating of the studied gravels and sands was good to excellent.

4- The plasticity index of the fine grained sediment which occurred as two lenses at the studied area was ranging from 9.00 to 12.00%. They were low to medium plastic clayey silts. The studied clayey silts were classified as low plastic clayey silts (ML) according to USCS and as A-6 according to AASHTO. The general rating of the studied clayey silts were poor to fair. CBR-soaked (4 days water soaking) values of the fine grained soils were ranging from 1.00 to 7.00%, they were classified as very poor to fair sub-grade according to[38]. The clayey silts had free swelling percent more than 50% corresponding to[36]. They are classified as expansive soils.

5- The sub-grades at roads no. 2, 3, 5, 6, 8, 9 and 10 (Gravels and Sands) were good to excellent. The sub-grades at roads no. 1, 4 and 7 (Clayey Silts) were poor to fair. The clayey slits are problematic expansive soils and may be lead to a heave of the roads.

5.1. Recommendations

Replacement and/or chemical stabilization (using lime and cement kiln dust) of the expansive clayey silts were recommended to reduce the swelling and to avoid the heave of the roads.

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