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# GEOTECHNICAL ASPECTS OF FLOOD PLAIN DEPOSITS IN SOUTH EAST ASWAN CITY, EGYPT

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## ABSTRACT

Geotechnical aspects of the Flood plain deposits in south east Aswan City were investigated to evaluate their geotechnical behaviour. Flood plain deposits in the study area composed of soft soils which are difficult to both sample and test. The paper describes some geotechnical properties of these soft soils which representing the foundation bed for engineering constructions in south east Aswan City. Laboratory tests were carried out to assess the physical and mechanical properties of the soils. Different types of soft soils were detected by drilling six boreholes all over the studied zones including friable clays, clayey sand with remains of calcareous materials and well graded sand with gravel. The particle size distribution classified samples as clayey sand (SC) and well graded sand (SW). The investigated soil samples which were tested have low to medium water content and the water content were increased with increase the depth. Also the friable clay had low density and classified as loose soil, while well graded sand and clayey sand had medium to high density values and classified as medium to high dense soil. The unconfined compressive strength showed promising values in range of 1.86 - 22.1Mpa. Shear characteristics of the fine grained soils (friable clay) possessed the lowest peak friction angle (17°), while the medium to coarse grained sands had the highest peak friction angle (25°). Clay samples displayed moderate swelling pressure, in the vicinity of 16kg/cm$^2$, pointing to less probability for various problematic situations during and after constructing processes. The extracted water from soil samples under investigation showed not aggressive manner.

**Keywords:** geotechnical aspects, Flood plain deposits, unconfined compressive strength, swelling pressure (Oedometer), shear strength, chemical analysis.

## INTRODUCTION

The continuous growth of population and development projects in Egypt leads to increasing demand for construction. In the last few years, the general plan aiming for constructing a number of new cities in desert areas to accommodate the rapid increase of population. Accordingly, the establishment of new communities and land reclamation projects in Egyptian desert areas to overcome the growing population problem is a national target. One of these innovative communities placed nearby the eastern bank of the Nile River in Aswan City, which considered one of the most important touristic sites in Egypt. The study area is located between longitudes 32° 51̀ and 33° 15̀ E and latitudes 24° 00̀ and 24° 15̀ N (Figure-1). Geotechnical properties of the soils and rocks play an important role in an evaluation of their geotechnical behaviour, which reflected as a result of their physical and mechanical properties. The main objective of geotechnical studies of an engineering site is identifying the rocks and soils are present. McLean and Gribble (1979) stated that good professional practice in the exploration of an engineering site is described in the British Standard Code of Practice CP2001 Site Investigations. Dumbleton and West (1976) recommended a good procedure, which describes the search through records, maps and other literature relevant to the geology of the area under exploration. The exploration of a site assessing the feasibility of a project to plan and design appropriate foundations, and reduce the costs of excavated rocks. Blyth & De Freitas (2001) stated that satisfactory design and construction of an engineering structure can be accomplished only when the character of the soil or rock on which, or within which, it is to be built is known. The present study dealt with the geotechnical properties of the Flood plain deposits, which situated at shallow depths and representing the foundation bed for engineering constructions. These sediments in south east Aswan City were composed of soft soils (YASSEIN, 2006). The soft soil are difficult to both sample and test, also deformation and stability of soft soil layers are the main problems affecting buildings located on these soils, so these soils need to studied carefully before locate any construction on it. More and more civil construction projects have been built on soft soils, which are prone to failure unless properly considered. Such soils are characteristically very variable and the potential for sampling/ testing errors increases the uncertainty and variability of the results (Gao Dazhao, 1992). During the 1970's and 1980's, researchers such as Lumb *et al*. (1974, 1975), Tang (1984) and Vanmarcke (1977) made systematic studies of the variability of rock and soil parameters. Zhang *et al*. (2003) studied the engineering geological properties of soft soil using probability methods.

### Previous studies in the investigation area

Many geological and geotechnical studies had been carried out in the present study area (e.g., Hume, 1964; Issawi, 1968; El Shazly, 1974; Anon, 1978; EGSMA, 1981; Kleb and Török, 1994; Yassen, 2006; Khedr, 2010 and Selim, 2014). Hume (1964) adjusted and extrapolated indicated that the rock formation on the surface is the Nubian Sandstone that is mainly of

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Cretaceous in age. Issawi (1968) and El Shazly (1974) have deliberated the geology of Aswan area. Anon. (1978) was prepared geological map of the Nile valley in between Esna-Aswan. EGSMA (1981) generalized geological map of the Aswan district, shows the geological formations comprise metamorphic and igneous rocks of Precambrian age, sandstone and clay of the Nubian Sandstone series of Upper Cretaceous age divided into lower, middle, upper groups and ancient gravels, sands, river sands and Nile mud of Pleistocene and Recent ages. Kleb and Török (1994) authorized engineering geological survey of a railway line along the Nile valley between Edfu and Aswan has been carried out to analyze the engineering geological problems related to doubling the railway line. Yassein (2006) described the sediments in south east Aswan City; they were composed of soft soils, required for the development of 250 houses at Aswan for the Egyptian-Danish friendship. This area covers 250 Feddans. Clayey sand is occasionally found but sandy clays are not so common. Khedr (2010) studied the tectonic-stratigraphic subdivision of the clastic sequence of Aswan area, southern Egypt and summarized that the stratigraphic sequence is lithologically classified into three-fold vertical-groups; from base upwards these are, the Pre Late-Jurassic “Infra Nubia Group”, the Late Jurassic-Maastrichtian “Nubia Group”, and the Campanian-Paleocene to Recent “Ultra Nubia Group”. Selim (2014) showed the rise in the level of the groundwater in the Quaternary aquifer at Aswan City, Upper Egypt. Also the variation in the groundwater level, from 1971 up to 2014, where the water table rising ranges between 12.55 and 13.69 m. Also, it shows an abrupt increase in the water levels in 2010 continuing up till now.

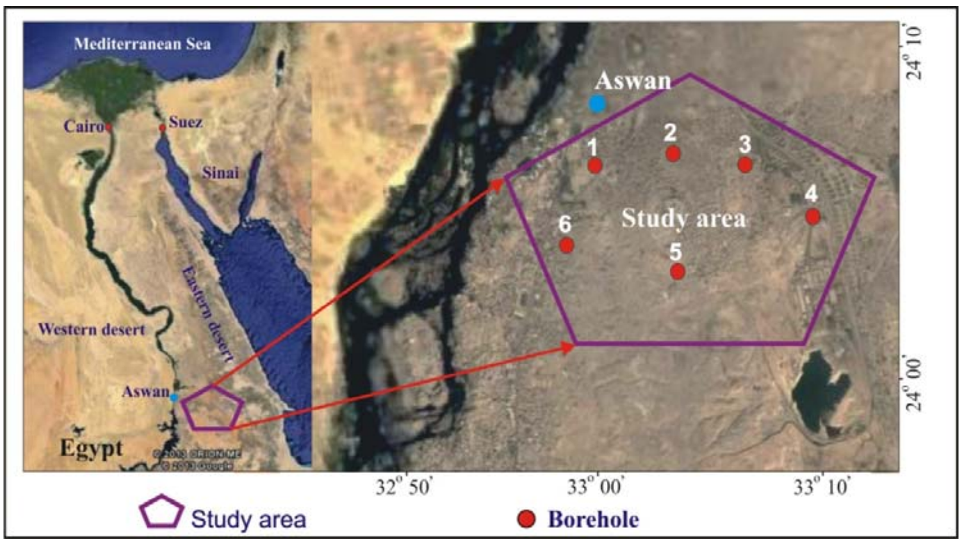


**Figure-1.** Location map of the study area south east Aswan City.

## MATERIALS AND METHODS

Determination of soil parameters of the area under investigation was performed by field and laboratory work. The field work is including soil sampling, where six boreholes were drilled during the summer of 2012. The laboratory work focused on the measurements of various parameters using various types of analyses. The methodological approach used for the investigation and analysis of the geotechnical properties of the soils includes physical and mechanical properties. In order to assess the physical properties of the studied soils, the following soil mechanical tests were undertaken: water content (ASTM D 2216- 10), Density (ASTM D 6683- 01), Specific gravity (ASTM D 854- 06) and (25100-95) Unified Soil Classification. Grain size analysis was performed (ASTM D- 422, 2007). Mechanical properties were included the unconfined compressive strength (ASTM D- 2216, 2013), Shear strength (ASTM D- 3080, 2005), Free swelling test, Swelling Oedometer test (Egyptian Code, 2001) in addition to chemical analysis for soil - water extracts along the study area (Anonymous, 1985) while Chloride ion ($Cl^-$) concentration in soil-water extracts (BS 1377, 2005) and the results were conducted according to (Russian Code №10178-76 and № 22266-76, 2011).

### Geomorphology

An isometric map and contour map (Figure-2) have been constructed for the whole area under investigation. To create a geomorphological model of the Aswan area, eleven topographic maps have been used. A number of 4575 sites are considered for measurements of their elevation above the sea level (A.S.L). The isometric map shows gradual westward and northward decreases in elevation and it is obviously differentiated between the spatial elevation of three regions in the study area (low, medium, and high relief regions). The obtained isometric map and contour map of the study area illustrate the relative differences in elevation of the Eastern and the Western Deserts (Figure-2) (Khedr *et al*., 2010). Despite the unique thickness of different stratigraphic formations, there are large differences in elevations above the sea level (A.S.L) attaining 172 meters which facilitate the detection of major fault zones in the study area. It also explained the absence of some formations and repeated unconformity planes due to pen planation of unstable fault-blocks.

**Topographic and geologic setting**

The topography of the study area is an extensive plateau varying in level from 150m above sea level adjacent to the Nile valley and increasing in level towards the East to reach 200 meters above sea level. The Nile valley level in Aswan district is roughly 100 meters above sea level and the area under investigation consists of irregular hills separated by some drainage lines (Khors) (Yassein, 2006). The main route starts from the valley and ascends the slope to the plateau surface crossing the site from north to south. Land reclamation projects in desert regions become an important national target for establishment of new communities. Many authors (e.g., Issawi, 1968, El Shazly *et al*., 1974) have deliberated the geology of such area. These studies indicated that the study area consist of thick sedimentary section of Nubian Sandstone Formation of Upper Cretaceous age which underlain by the Precambrian basement rocks (EGSMA, 1981and Hume, 1964). The generalized geological map (Figure-3), shows the geological formations, metamorphic and igneous rocks of Precambrian age, sandstone and clay of the Nubian Sandstone series of Upper Cretaceous age [divided into lower, middle, and upper groups] and ancient gravels, sands, river sands and Nile mud of Pleistocene and Recent ages. The strata forming the selected site belong to the lower group of the Nubian Sandstone series. This group of strata overlies the Precambrian igneous and metamorphic rocks with thickness ranges between 35 and 40 meters. It consists of ferruginous sandstone, sandstone, clays, ancient gravels, sands, river sands, and Nile mud of Pleistocene and Recent ages. Clays existed as beds and lenses of widely varying dimensions within the sandstone beds. Clayey sand is occasionally found but sandy clays are not so common. Prospecting boreholes indicated more details about the stratigraphy in the site. Generally conglomerates, pebble beds, kaolinitic clays and sandstones are characteristic features of this group but they are not necessary found everywhere. Grits may be met with sandstones of various grain sizes and clays are common (Yassein, 2006). These borings show that there are various alternating strata of clayey siltstone, sandy siltstone, clay stone and sandstone. Layers of silty clay, sometimes included between rock layers may have medium swelling potential.

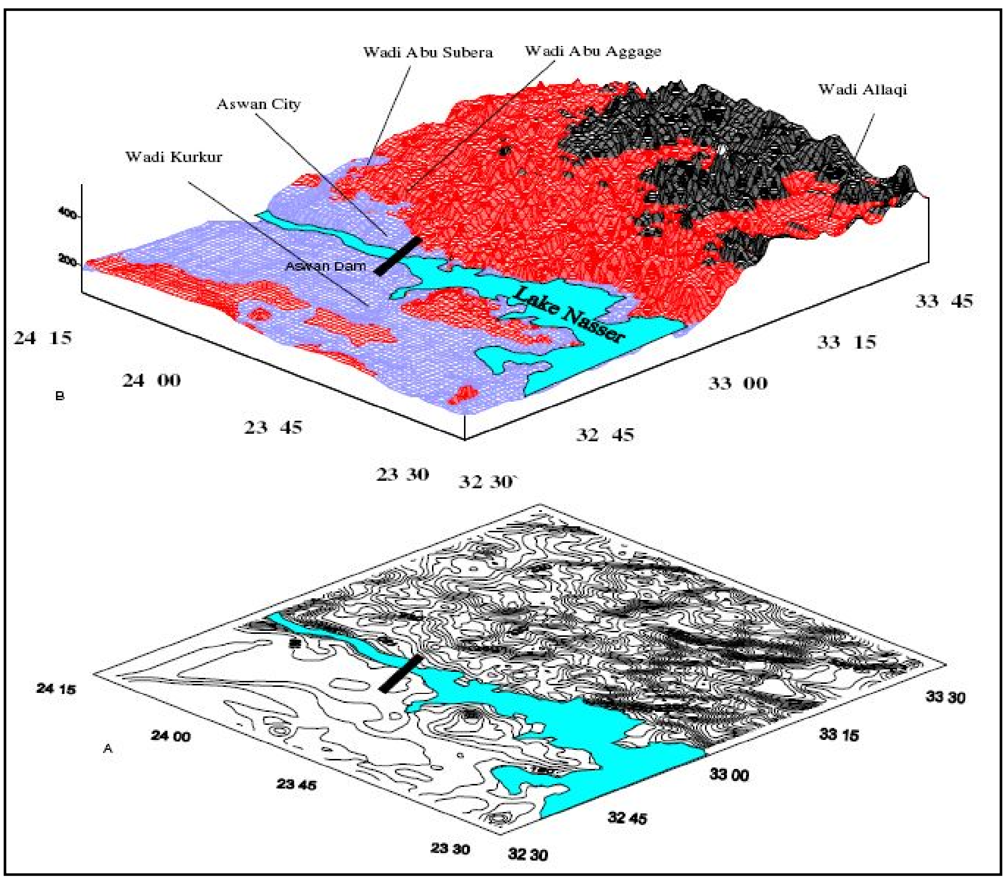


**Figure-2.** Isometric map (A) and contour map (B) portraying the relative differences in elevation of the study area. Note: contour intervals = 10m. (After Khedr *et al*., 2010).

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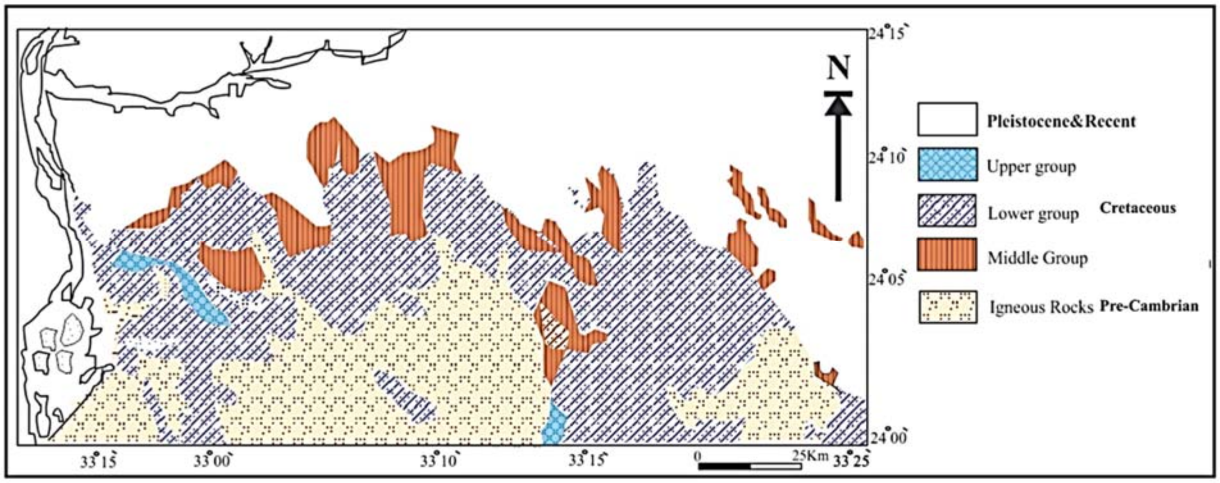


**Figure-3.** General geological map of the Aswan district (modified after EGSMA, 1981).

## RESULTS AND DISCUSSIONS

### SOIL COMPOSITION

The present study demonstrates the geotechnical properties of the flood plain deposits, which are located at shallow depths south east Aswan City. Six boreholes were drilled attending soils composed of friable clays, clayey sand with remains of calcareous materials and well graded sand with gravel Further increasing in soil depths showed coarse grains with growing percentages of gravels and decreasing ratios of fines.

### GRAIN SIZE ANALYSIS

Particle size distribution of the collected samples was performed according to (ASTM D- 422, 2007). The uniformity coefficients (Cu) for sands ranged from 7.2 to 13.5 and decreased with increasing the depth (Table-1). By further depth increment, coarse grains enriched with plenty of gravels were appeared linked with significant depression of sand (Figure-4). According to Unified Soil Classification (ASTM D- 2487-10, 2010 and Jerry Vandevelde, 2008), these soils classified into Clayey sand (SC) that mainly composed of sands with clays and well graded sand (SW) that seemingly contains sands blended by gravels. These types of soils especially the coarse grained soils have good load bearing capacities, good drainage qualities, and their strength volume change characteristics are not significantly affected by change in moisture conditions.

### PHYSICAL PROPERTIES OF THE SOILS

In order to assess the physical properties of the studied soils, the following soil mechanical tests were undertaken: water content (ASTM D 2216- 10), Density (ASTM D 6683- 01), Specific gravity (ASTM D 854- 06) and (25100-95) Unified Soil Classification. The results showed that the investigated samples of the soils had slightly different values of specific gravity, were ranged from 2.52 to 2.71 g/cm$^3$ (Table-2). The value of natural water content were ranged from8.55% -15.83%. The bulk density was ranged between 1.1 g/cm$^3$ and 1.7 g/cm$^3$. Based on previous results, the tested soil samples have low to medium water content and the water content were increased with increase the depth. Also the friable clay had low density and classified as loose soil, while well graded sand and clayey sand had medium to high density values and classified as medium to high dense soil.

**Table-1.** Grain size distribution parameters.

| **Depth** (m) | **Test no.** | **Fines** (%) | **Sand** (%) | **Gravel** (%) | **Soil description** | **Uniformity coefficient** |
|---|---|---|---|---|---|---|
| 4 | 1 | 13 | 81.4 | 5.2 | Clayey sand (SC) | 5.5 |
| 9 | 2 | 3.2 | 80.7 | 15.0 | Well Graded sand (SW) | 13.5 |
| 13 | 3 | 2.2 | 72.3 | 25.5 | Well Graded sand (SW) | 7.5 |
| 15 | 4 | 2.3 | 69.7 | 28 | Well Graded sand (SW) | 7.4 |
| 20 | 5 | 2.1 | 67.4 | 30.2 | Well Graded sand (SW) | 7.2 |

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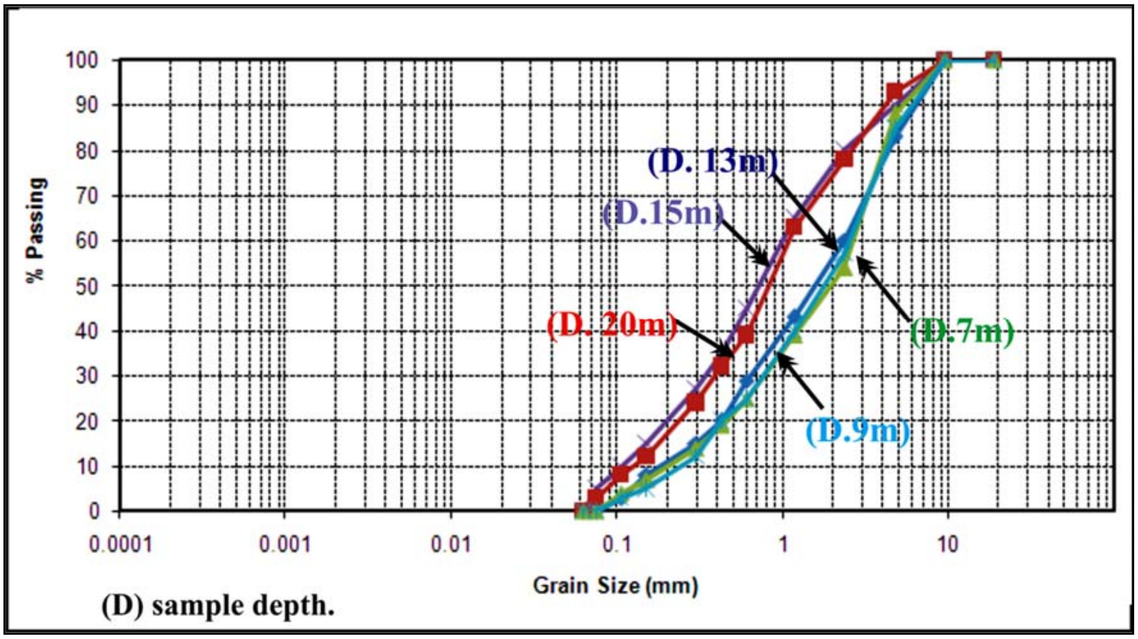


**Figure-4.** Grain size distribution curves of the samples along different depths.

## UNCONFINED COMPRESSIVE STRENGTH TEST

Unconfined compressive strength was determined according to (ASTM D- 2216, 2013). The results of this test were shown that the average value of unconfined compressive strength as low as 1.86 Mpa for friable clays. Clayey sand samples had the average value 22.1Mpa and medium to coarse grained sand had the average value 15.0 Mpa (Table-2). The friable clay had low strength and cannot bear construction, rather have to be removed before constructing. The clayey sand and medium to coarse grained sand have medium to high strength and can bear construction or inhabitancies.

## SHEAR CHARACTERISTICS OF THE SAMPLES

Direct shear tests were performed according to investigate the shear strengths of the soils (ASTM D-3080, 2005); It was found that the fine grained soils (clayey sand) possesses the lowest peak friction angle 17$^{o}$, whereas the medium to coarse grained sands exhibits the highest peak friction angle 25$^{o}$ (Figure-5). This difference in peak friction angle is likely to be due to the grading and the proportion of swelling clay minerals. Also, peak strength and frictional clay angle decay associated by increment in clay mineral swelling as well reduction in grain size, (Table-2).

## SWELLING CHARACTERISTICS OF THE SAMPLES UNDER INVESTIGATION

## FREE SWELLING TEST

This test considered as a qualitative indicator for expansive soils. Free swelling test was performed by putting 10cm3 of dry soil into 100cm3 of distilled water into a gradual cylinder. After 24 hours the volumes of settled and swelled soil were recorded (Egyptian Code, 2001). It is worth mentioning that these soils develop moderate swelling percentage, being ranged between 50 - 62%, pointing most probable to various problematic situations during or after constructing processes.

**Table-2.** Geotechnical properties of the soils along the study area.

| Soil type | Water content (%) | Specific gravity, (g/cm$^{3)}$ | Bulk density (g/cm$^{3)}$ | Uniaxial compressive strength, (Mpa) | Effective friction angle, Φ (°) | Shear strength, (Mpa) | Effective cohesion, C (Mpa) | Swelling percent (%) | Swelling pressure oedometer, (Kg/cm$^2$) |
|---|---|---|---|---|---|---|---|---|---|
| Friable clay | 8.25 | 2.71 | 1.1 | 1.86 | 17 | 5.2 | 3.3 | 62 | 10 |
| Clayey sand | 10.34 | 2.66 | 1.7 | 22.10 | 22 | 6.7 | 3.5 | 59 | 11 |
| Medium to coarse sandstone | 15.83 | 2.52 | 1.5 | 15.7 | 25 | 8 | 5.3 | - | - |

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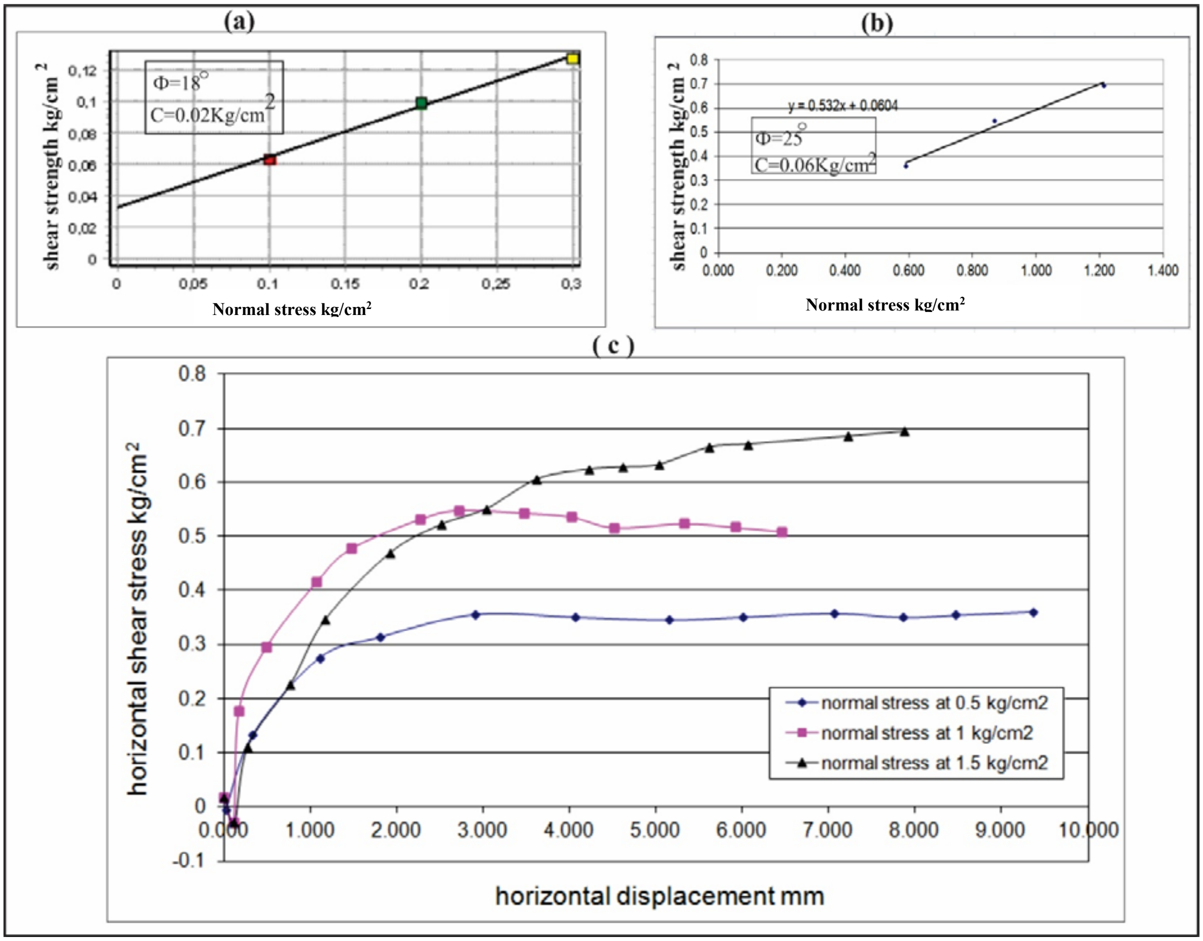


**Figure-5.** Stress- Shear strength behaviour of the clay (a) and sand (b and c).

**Swelling pressure (Oedometer)**

Swelling pressure test using oedometer instrument, in accordance to (Egyptian Code, 2001) indicate that friable clay, and clayey sand exhibit pronounced swelling pressure ranged between 10 and 16 kg/cm$^2$, while swelling pressure for medium to coarse sandstone was vanished, (Table-2).

**Chemical analysis for soil-water extracts**

Six soil water extracts were prepared for chemical analysis, which include; Chloride (Cl-) and Sulphate (So4⁻⁻) ions in addition to pH, conductivity and Total dissolved salts (Table-3). Samples were analyzed at the laboratory according to the standard analytical procedures (Anonymous, 1985). Chloride ion ($Cl^-$) concentration in soil-water extracts as per (BS 1377, 2005). The results were conducted according to (Russian Code №10178 - 76 and 22266-76, 2011).

Based on previous results, water extracts soil samples along the studied area were non aggressive indicating presence of neutral soil of pH ~7 with much lower conductivity values associated by poor total dissolved salts (TDS) besides reduced concentrations of chloride and sulphate ions.

**Table-3.** Chemical analysis for soil- water extracts along the study area.

| **TDS** (ppm) | **$CL^-$ mg/l** | **$SO_4^{--}$ mg/l** | **pH** | **Conductivity mS/m** |
|---|---|---|---|---|
| 1000 | 350 | 20 | 7.4 | 20 |
| 1200 | 370 | 18 | 7.5 | 22 |
| 1100 | 290 | 21 | 7.4 | 20 |
| 1000 | 320 | 22 | 7.3 | 24 |
| 1000 | 340 | 20 | 7.4 | 25 |
| 950 | 350 | 19 | 7.4 | 22 |

**CONCLUSION AND RECOMMENDATIONS**

Analysis and interpretations of the laboratory results and the field observations led to the following results:

a) The soil composed of friable clays, clayey sand with remains of calcareous materials and well graded sand with gravels. Further increasing in soil depths showed coarse grains with growing percentages of gravels and decreasing ratios of fines.
b) The investigated soil samples had slightly different specific gravity, ranged from 2.52-2.71 g/cm$^3$, attributing probably to their corresponding mineral composition. The tested soil samples which were tested have low to medium water content and the water content were increased with increase the depth. Also the friable clay had low density and classified as loose soil, while well graded sand and clayey sand had medium to high density values and classified as medium to high dense soil.
c) The fine grained soils (friable clay) performed the lowest peak frictional angle 17°, whereas the medium to coarse grained sandstone developed advanced peak frictional angle 25°. Such difference in peak frictional angle is likely to regard to the grading and the proportion of swelling clay minerals. Moreover, the peak strength and the friction angle of the clays showed marked reduction with elevation in swelling clay minerals and diminishing in grain size.
d) The friable clays were inapplicable to bear huge constructions. Thus, it is noticeable to elicit those clays. On the other hand, clayey sand samples and medium-to-coarse grained sands exhibited medium to high strength posing them to tolerate grand constructions and inhabitancies.
e) The clayey soils along the study area enveloping friable clays and clayey sand possessed medium swelling sensitivity and proplems may be occur during or after the construction process. Ground improvement recommended by vibro-replacement (gravel columns) of the ground a depth of up to 0-5m.
f) The water extracts soil samples along the study area were non aggressive.

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