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Geotechnical Characterization of Subsoil Deposits at Cairo

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SYNOPSIS: As a result of considering the historical aspects in Cairo subsoil at different stages of its development, soil deposits in the alluvial plain in Cairo area could be identified and classified on their origin into limited number of major types. Their distribution could be produced on maps on which classes of engineering significance are recognized. The boundaries between map units have been drawn separating areas of equal origin and characteristics. Verification of soil profile from field investigation indicated complete agreement with the previous characterization based on theoretical considerations.

INTRODUCTION

Cairo is one of the few great symbolic cities with their extended history and current vitality. In all probabilities, the earliest development of civilization had took place near to this strategic site and, as a capital of Egypt, Memphis of the Pharaohs, in the vicinity of Cairo antedates almost every other human conglomerate larger than a village. The parade of historical monuments preserved in and around Cairo span a period of more than five thousand years and express the entire civilization of the country. There is no one epoch of history which had not left within it numerous and precious traces.

The wonder of Egypt is not only in its history but also in its site. At the meeting point of the three big continents of the ancient world, Europe, Asia and Africa lies Egypt. Here also two waterways meet, important in history and commerce of the world: The Mediterranean and the Red sea. The former brings Egypt in direct contact with the West, while the latter joins it with the Far East. And just as Egypt stands astride East and West, so, Cairo, its capital stands astride Egypt linking, as well as dominating, the two subregions - Upper Egypt to its South and Lower Egypt to its North. Its dominance is ciaallenged only by The Nile, the river that bisects both Cairo and the nation but paradoxically unifies as it divides.

Its location is 30° 4' North latitude and 31° 17', East longitude 20 kilometers to the South of the point where the Nile divides into the Rosetta on Dametta branches. To the East, Cairo reaches the Hughattam Hills, announcing the Eastern Desert, in the West it crosses the Nile into Giza to the Western Desert which eventually extends to the Libyan Desert.

Cairo today, home for more than 10 million inhabitants, presents, to the geotechnical engineer, primary problems and enormous challenge. It is a city with a pressing problem of land use inefficiencies. Most good building sites have already been exploited and more will have to be made of sites with less favourable conditions. Many structures will have to go underground and installation of services beneath existing building will necessitate tunneling.

As a result, a great volume of routine investigation has been carried out and still going on by several public bodies, private companies and consultants for different important projects such as Cairo Underground Metro, and Greater Cairo Sewerage Plan.

Because boring records and reports for each site or project are generally very detailed and no or a little exchange of information has been experienced, soil deposits in Cairo may give the impression that they are of extreme complexity and countless variety. Therefore duplication of effort is likely to be extensive.

The primary aim of the present work is to improve that situation by making clear the ground formation in Cairo area. This would develop the knowledge of subsoil conditions, help in recognizing potential soil problems; and guide in good planning of site investigation work. Thus the time and effort donated to field work and laboratory testing can be greatly reduced.

The implicit goal is to extract a form or a pattern from what appears to be capricious disorder. However, if order is to be found, more than the traditional methods must be employed to uncover the hidden framework.

Geology and history, envisaged to be of relevance of the present work, were used to separate the accidental from the essential and to trace the chains that bind present with past and links part with whole. This to uncover the orderly patterns and sequences in Cairo's growth and development that yielded the present soil formations and have given rise to its particular characteristics.
GEOGRAPHY

Egypt may be divided into four geographical regions: The Eastern Desert, The Western Desert, The Nile River and Delta, and the Sinai Desert. Cairo covers portions of the first three regions (see Fig. 1).

The Nile is a perennial stream which flows South to North and divides Egypt into the Eastern and Western Deserts. The relatively flat alluvial plain and the gently sloping terraces to the higher desert areas form the Nile Valley. At the site of Cairo the Nile Valley is 10 to 15 kilometers wide.

Through Cairo area, the Nile passes by the high Mukattam Plateau of the Eastern Desert. On the Western side, beyond the valley, the cliffs are lower and form the Pyramids Plateau. Just downstream from Cairo, the valley widens and forms a large delta tributary to the Mediterranean sea. Two branches of the Nile meander through the delta area; the western branch enters the Mediterranean Sea at Rosetta and the eastern branch at Damietta.

The general slope of the Nile flood plain is to the North, Elevations along the river flood plain range, from 22 m at the South end of Cairo area to 13 m at the Northern end. The highest elevation of the Mukattam Hills on the Eastern side of the river is 213 m at point Southeast of the Citadel. To the North, but Southeasterly from Heliopolis, elevations in the 200 to 218 m range are found.

HISTORICAL ASPECTS

Because Cairo is a very old city, historical elements dictated the city pattern of growth and they are the key to the pattern of formation of deposits in alluvial plain. Therefore, in the following, the telescopic lense of history is used in studying the Cairo subsoil at different stages of its development. Three main elements are considered in the study; they are: 1) the geographic features of the site; 2) the River Nile and its changes; 3) Man's occupation of the area. Although the history of Cairo spans more than 7000 years, the more recent history with impact upon subsoil and relevance in explaining soil conditions can be traced from the founding AD 641 of Al-Fustat which lies towards the Southern boundary of the existing city.

The references consulted for historical information were numerous. However, we relied heavily on three notable original sources. They are: 1) the Khittat of Al-Maqrizi; 2) Description de l'Egypt of the French Expedition; and 3) Al-Khittat Al-Tawfiqiah Al-Gadida by Mubarak.

Geographic Features in the Seventh Century

At the site of Cairo, the boundary of the Nile flood plain is fixed by two sudden escarpments of the Mukattam Hills on the East and the Pyramids plateau on the West. The ridge which divides valley from desert in the Eastern end is nearest to the river at the site of Qasr Al-Shama before it pivots Northeast until it disappears when the valley opens at the site of Al-Fustat; then it becoming increasingly broader to the North. Furthermore, in the seventh century the Eastern border was farther to the East than it does now. Therefore, the flood plain area on the East bank was much narrower.

The River Nile and its Changes

From verbal description of early historians (Al-
successive recessions and transgressions of the Nile were the result of natural siltation, diversion of flood waters through a system of canals and lakes; and complex dam storage upstream.

Man's Occupation of the Area

Man's occupation of the area has given rise to considerable deposits of human debris to overlie the alluvial Nile plain.

Firstly, the destruction of Al-Qataie (Capital of Tulunids) in AD 905 and the burning of Al-Fustat in AD 1168 caused a big area of land to be abandoned. This included Al-Qataie, a big portion of Al-Askar (Cepital of Abbasids). Since that date and down to the present day, this area has been the site of rubbish. And with progressive accumulation of filling on the ruin mounds it became one connected area of rubbish heap that cover the entire terrain where Al-Fustat, Al-Askar, and Al-Qataie once stood.

Secondly, during the time of Mohamed Ali (1805-1848), changes in the city were directed toward cleaning up the abuses which had rendered the city less habitable. Among the changes introduced were the leveling of the rubbish mounds on the Western edge of the city and filling in the lakes, ponds depressions and swamps.

 ROLE OF HISTORICAL ASPECTS IN CHARACTERISATION OF SOIL DEPOSITS IN ALLUVIAL PLAIN

As a result of considering the previously mentioned historical aspects in subsoil development, soil deposits in alluvial plain could be classified on their origin and mode of formation into a limited number of major types. Their distribution could be produced on a map on which classes of engineering significance are recognized. The boundaries between map units have been drawn separating areas of equal origin and characteristics (Fig. 7). They are: 1) Terrace Alluvium; 2) Flood Silting; 3) Channel Deposition; 4) Island Formation; and 5) Fill or Mode Ground.

1) Terrace Alluvium

This unit represents the older flood deposits or the last Nile terrace. It exists on both sides of the Nile and is bounded on one side by the geological boundaries and on the other side by the Nile border in the seventh century (AD 641).

After transposition of the Nile course and shift of river bed in historical times, flood waters began to fill the land left by the receding Nile allowing the coarser grains to settle first. Therefore a layer of fine sand overlain by stiff silty clay (old deposits) is conceivable.

2) Flood Silting

It is the land that came into existence after the seventh century due to gradual recession of the Nile and successive flooding and sedimentation. This unit occurs only on the East bank of the Nile. It is bounded on the East by the Nile border in AD 641 and on the West by the Nile border at the time of the French Expedition (AD 1800).

In this unit, a sequence of layers similar to the previous unit is conceivable due to the similarity in sedimentation mechanism. However, this type is relatively modern Nile deposits when compared to the previous type. Therefore upper clay layer, had not been consolidated as the previous type, it is expected to be soft to medium.

3) Channel Deposition

It is the land formed on both sides of the Nile banks in the nineteenth century after forcing the main flow of the river to its present course. This was done by filling up the Western channel in the area between the Nile border in AD 1800 and the present one; and strengthening the Eastern level of the Nile.

The sites of this unit is near the river banks and the main deposits expected are silts and fine sands overlying the coarse sand and gravel which had previously formed the bed of the river channel.

4) Island Formation

This unit comprises all the lands that came into existence in the form of islands. They are Geziret Al-Rowdah (Al-Rowad); Geziret Al-Fil (Shoubra); Geziret Sulan (Boulaq); and Geziret Arwy (Zamalek).

Due to sedimentation mechanism encountered in island formation, a considerable layer of silt is expected at a depth near to ground surface followed by fine sand overlying the coarse sand and gravel. After the island had been formed and the velocity of water flow became slower, the clay particle would be allowed to settle particularly in the middle and in the upstream. Therefore, a top clay layer as well as clayey intercalations in the upstream of the island are expected to occur.

Fill or Mode Ground

This unit varies from place to place. It is the heritage of urban development in Cairo area throughout its history. On the East bank of the Nile, the occurrence of fill deposits and their thicknesses must be remarkably significant when compared with the West bank. They are the product of old channels (Khalig), lakes (Birkah) and ruin mounds of early settlements. It is worth-noting that some areas in Cairo are still known by their early land marks such as: Al-Azabkiya; Birket El-Fil, and Birket El-Ratif; They were previously lakes.

The old channels and lakes were filled in the nineteenth century with near by mounds. The site of old channels (e.g. El-Khalig El-Masri),...
Fig. 2 Nile Border in the Seventh Century (AD 641)

Fig. 3 Nile Border (AD 1126)

Fig. 4 Nile Border (AD 1252)
Fig. 5 Nile Border (AD 1271)

Fig. 6 Nile Border at the Time of the French Expedition (AD 1800)

Fig. 7 Developed Subsoil in Cairo Area
must therefore, form at present on elongate basin of fill underlying Port Said street with a depth of about 10 m as that of El-Khalig. Similarly the depth of fill at the site of old lakes must range between 5 and 10 m.

The filling on ruin mounds of early settlements had began to form just South the Mosque of Ibn Tulun. According to chronology and description of historical events, the ruin segment must had got a triangular slope with the mosque of Ibn Tulun as apex and one side striking South parallel to El-Khalilaf cemetery and the other side striking South-West parallel to Qasr-Al-Shama and Mosque of Amr.

Another segment of fill must exist extending parallel to Muqattam edge to the North-East where it had served for a long time as a rubbish mound.

CONCLUSION

1- As a result of considering the historical aspects in Cairo subsoil at different stages of its development, soil deposits in alluvial plain could be identified and classified on their origin and mode of formation into five major types. They are 1) Terrace Alluvium; 2) Flood Siting; 3) Channel Deposition; 4) Island Formation; and 5) Fill or Made Ground. Their distribution could be produced on maps on which classes of engineering significance are recognized. The boundaries between map units were drawn separating areas of equal origin and characteristics.

2- Borings and subsoil sections passing through different types of alluvial deposits have been in complete agreement with the characterization based on the consideration of historical aspects.

3- An analysis of the experience of the present work for the city of Cairo can be taken as a model for study of other old cities whose growth and development were affected by historical aspects.

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