Evaluation of Treatment Methods Used for Construction on Expansive Soils in Egypt

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ABSTRACT

The soil formation in this arid area is sometimes an expansive problematic soil. Due to the lake of the construction experience on this problematic soil, many defects are appeared in the new buildings established in these arid areas. In this paper, a focusing on the treatment method using soil replacement for expansive soil formation. In the other hand, some case studies were illustrated to show the different types of problems appeared due to the different construction methods used. Finally, a conclusion about how to overcome these defects happened due to this treatment method for this problematic soil is mentioned. Some recommendations are given to civil engineers to be taken into consideration during establishing any constructions on this problematic soil.

INTRODUCTION

Due to gradually increase of population of Egypt and the shrinkage of the Nile valley area, which consists of known soil properties for all expertise geotechnical engineers, new development trend is to propagate all the new residential and factories projects on this desert areas. In the last decades several cases of structural defects or cracks in concrete members, especially in buildings constructed in those arid places, were observed.

The geotechnical studies of these defects showed that, there foundations was moved, as a result of the change of the underneath soil formation. More investigating of this desert soil formation showed that, its formation was different than that for the Nile valley or its delta soil formation. The geotechnical engineers starts to study deeply the reasons for those defects and starts to overcome this problematic soil formation on the superstructure members. They found that one of these problematic soil which is known as expansive (swelling) soil, is the major desert soil formations which cause all construction defects.

These expansive soil formations are characterized by their ability to expand (swell), or shrink when theirs water content increase or decrease. This phenomenon depends mainly on the type of clay minerals present in the soil formation. The most common clay minerals are kaolinite, Illite, and Montmorillonite. Montmorillonite clay has a very high swelling potential than Illite clay, while Kaolinite clay has a low swelling value.

In this paper, some chosen sites in the desert area in Egypt where there is a swelling soils are founded were studied. In these arid places, different characteristics of expansive soils were founded, which cover our present study. Each site was a special one, where the soil replacement treatment method for expansive soil formation was performed to overcome its effect.

In spite of, the soil treatment for all expansive soil places, many defects were appeared to the super structures. In our study, focusing on the soil properties for the expansive problematic soil formation of different chosen sites with their treatment methods and the defects appeared after construction will be discussed. Finally, an evaluation of the all suggested treatments methods was illustrated and explained. Recommendations for the construction on these problematic soils were given to enable geotechnical engineers in overcoming future problems appeared for the superstructures.

EXPANSIVE SOIL FORMATION IN EGYPT

Potentially expansive soils are being founded almost in many places in the world, especially in the desert arid areas or dry-like regions. New sites established last recently decades and nowadays in Egypt, are located at desert arid places outside the Nile valley.

Most of these regions are a problematic soil formation due to their soil structure formation and its dry state conditions. In

this research some locations of these problematic soil formation was chosen as a case studies for our study. New Cairo, Six of October, Katamia, Nasr City, Bader, El-fayoum cites are some of the cities distributed around Nile valley of Egypt which considered as regions which contains these problematic expansive soils.
Construction on this type of problematic expansive soil needs a special requirement recommendations due to the hazard effect of this swelling/shrinking soil with any change of their moisture content.

Physical Properties of Expansive Soils

Expansive soils are found from parent materials which include basalt, basic volcanic ash, gneisses calcareous alluviums and sedimentary rocks containing calcareous shale. Semi arid, hot climate and poor drainage conditions are usually associated with the formation of expansive soils.
They usually have high silica-sesquioxide ratio and also high amount of Fe, Ca, and Mg. Most of the expansive soils met in nature have clay size fraction (less than 2 micron size) varying between 40% and 75%, silt size varied between15% to 30%, sand varied between15% to 30% and gravel size less than 5%. Usually the liquid limits of these soils are in the range of 50% to 110%. Higher more than 110% have been found in many parts. The plastic limit ranges around 30% to 50% while the shrinkage limit was ranged of 8% to 16%. Usually low values of shrinkage limit indicate that the soil have a large range of volume change.

Treatment Methods of Expansive Soils

Several techniques have been proposed for the minimization or complete elimination the swelling effect of the expansive soils on the structure elements. The choice of these different treatment methods is depended on many factors such as: project size, nature and project usage (substructures, buildings, high ways,…..etc), maximum volume changes that can be tolerated, cost comparisons of the alternative methods and the local experience for soil treatments.
Many techniques are used for treatment of expansive soils depending on the engineering experience such as: chemical admixtures, soil replacement, electrochemical soil treatment methods, surcharge loading system and sand cushions. In Egypt, the use of soil replacement by different granule soil replacements beneath shallow foundations is considered as one of the most common and practical techniques which can utilized for treatments of this problematic soil.
This soil replacement was recommended by geotechnical consultant engineers and it depends on the geotechnical engineer expertise and also on the site preparation and execution of the backfilling layers of compaction with highly quality control and accordance to the specification. Beside that, choosing the different backfilling material and its depth with the relation to the problematic expansive soil formation depth and properties is more important.

Soil Replacement Method

The using of soil replacement method is one of the common methods used for the treatment of expansive soils in Egypt. Thus many soil replacements using sand or sandy gravel replacement techniques were used at these locations of the expansive problematic soil. In spite of using this technique, some structures at these sites are suffered from cracks in its concrete members. So, this research was focused and prepared to study why these defects in structures are appeared in spite of using the soil replacement technique to overcome the effect of the swelling soil pressure. Many sites in Egypt were chosen as an example for this study to evaluate and discuss this matter. In the following paragraphs a case studies of three site locations of different locations in the new cites area where some buildings was effected by the change of underneath problematic soil conditions in spite of using the replacement treatment method.

Case Study: Site (1).

The first case of study was for a site located at Katamia region (east of Cairo) where swelling soil was founded. In this site, a five boreholes around the main building which more cracks appeared in its concrete structures (beams and columns) was done to investigate the underneath soil properties. It was found that the swelling soil formation was in wetted case. Thus, dry samples was taken from additional test pits which were digging in un-wetted areas near the defected main building to get a dry samples for perform the laboratory swelling pressure test. The swelling soil pressure was very high and ranged from 6-12 kg/cm2 for dry soil and the soil bulk density was ranged from 1.96–2.00 t/m3. Free swelling index readings were in the range of 110% to 170%. Fig.1 illustrates the value of the laboratory swelling pressure achieved on the dry soil samples (two samples were shown) which collected from test pit excavation near the defected building. The defected structure was a governmental building having a nearly 1000 workers and was consists of three adjacent building parts with a structural joint between each part. The shallow foundation type was an inverted T-Beam (shallow strip footings). In this site, the soil replacement was sand cushion material which was backfill just under each strip footings without any extension width outside the footing area from each side, as shown in Fig. 2. Also, there was no backfill soil under and around the perpendicular smells.
And due to the lake of sand cushion of the soil replacement in the area between the strip footings an there smells, the swelling soil in this area was still active and gives upward pressures on the foundation and the smells above especially when water leakage from the adjacent water tank which was two meters distant from the main building. And thus, with the change in the underneath soil moisture content, expanded soil in volume moved the footings up and causes the shown cracks and the horizontal movement shown between the parts of the main building. The horizontal movement was observed each floor and increased at the top of the building. Also, cracks

were observed at the different structure elements as showed in photo 1.

By investigating the expansive soil under and around the main governmental building, it was found in a wet condition, and this was due to water leakage from the nearest groundwater tanks and the irrigation around the building directly. Also it was found that the location of the main building was in a depressed location of the whole site, which enable the rain water and leakage ground water tank to be collected under its footings which was not surrounded with enough replacement soil.

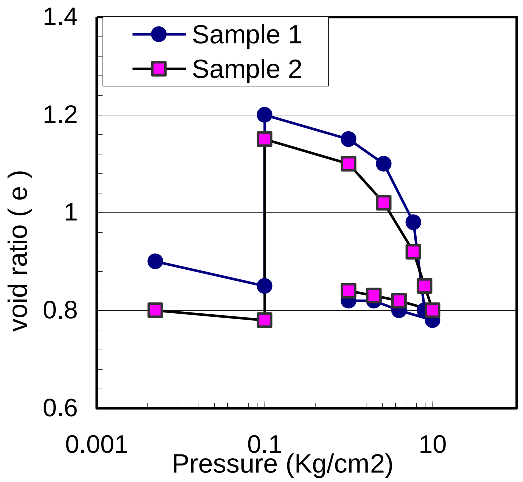

Fig. 1: Swelling pressure test for soil, site 1.

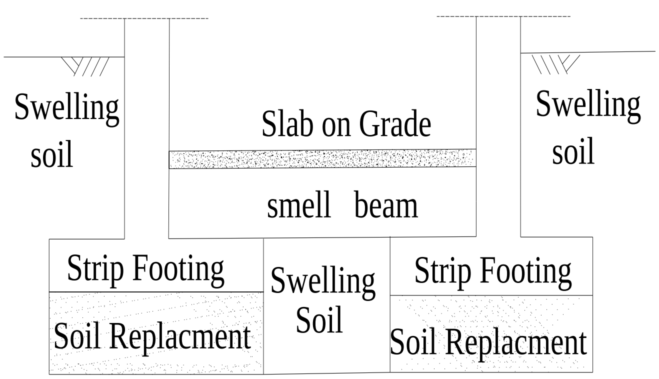

Fig. 1: Soil replacements under strip footing.

Photo 1: Cracks observed at foundation elements.

Case Study: Site (2).

The second studying site was located at Six of October city, south west of Cairo. In this site, dwelling buildings were constructed on the problematic soil, and most of the places were expansive/shrinking soils. Total of nearly seventeen buildings were investigated due cracks appeared in the concrete members of the buildings. Each building was investigated by digging two boreholes and two open test pits around it to get soil samples in its wet and dry cases. Also digging around and bellow the sallow footings to get samples from soil and the soil replacement used for the treatments of the problematic soil. Samples from the filed works send to the laboratory for performing swelling pressure and grain analysis. The swelling soil pressure was very high and ranged from 4-10 kg/cm2 for dry soil and the soil bulk density was ranged from 1.98–2.05 t/m3. Free swelling index readings were in the range of 120% to 180%The geotechnical reports done for this site, recommended of using well graded sandy soil replacement as a soil treatment for the underneath problematic soil. It was observed that all structure defects appeared after using the buildings. Some structure defects were observed on the dwelling buildings which were classified in different categories. Some defects were observed as cracks in the walls of the first and second floors and some cracks in the beams. Higher defects observed in a two adjacent buildings, where a tilting of one of them on one side was occurred. The investigations showed that the problematic soil below one of the two buildings was heaved due to the change in its moisture content. Investigations also showed that, the well graded sandy soil replacement was not compacted well or protected as recommended in the geotechnical reports, and consequently problems was appeared as soon as there is a leakage from the potable water and sewage water pipelines underneath this dwelling buildings and/or from the irrigation system of the around them. Fig.3 shows the tilting of one building appeared due to soil heave. These defects were increased as the expansive soil under the soil replacement was higher impermeable material in the deep direction and also in the horizontal direction. And thus the whole excavation area below the foundation looks like a swimming pool full of water which give a high chance for the underneath swelling soil to be active and starts to heave. And consequently the foundations above are pressured and forced up and cause the observed cracks in the superstructure members.

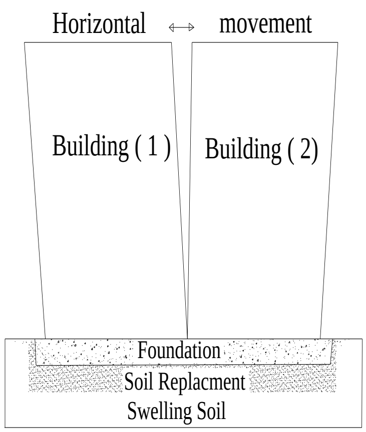

Fig.3. Soil replacement and horizontal movement

Case Study: Site (3).

The third study case was at Baddr city region, which is located in the north east side of Cairo city. In this site, many governmental and private buildings were established on the problematic swelling/shrinking soils.
Soil treatment was done by using a sandy soil replacement soil type. Due to defects and cracks appeared in some building, an investigation program for soil investigation was performed. Mechanical rotary boreholes and open test pits were done to get wet and dry samples.
The tests for soil samples in the laboratory showed that the swelling pressure was very high and was ranged from 8-16 kg/cm2 for dry soil and the soil bulk density was ranged from 1.97–2.03 t/m3. Free swelling index readings were in the range of 100% to 160%, as shown in Fig. 4.
Also, most of the structure cracks and defects in concrete members were appeared after people started to live and using the dwelling buildings, and water starting to leakage from water pipes and irrigation system around the buildings.

RESULTS AND DISCUSSION

Geotechnical investigations works were re-prepared for all above mentioned sites at the places where the cracks was appeared in its walls and structural members. In all studies it was found the problem come from the underneath movement of the foundation members due to the change in the underneath soil properties and characteristics.
That change in underneath soil properties was due to the change in the moisture content of the problematic swelling soil from the dry state condition to the wet one. This means that there is a change in the volume of the expansive soil below the underneath shallow footings.
The defects were shown at first as cracks in the outer and interior walls and then cracks propagate with time until effect on the concrete members. Photo 2 shows the cracks observed in a light weight building in its outer walls and concrete members.
Also, from the geotechnical investigations work program, it was found that the thickness and the type of the soil replacement material used under the footings sometimes was not adequate enough and not effective to overcoming the behaviour of the expansive soils when exposed to water sources around the building.
It was found in site (2) that the thicknesses of the replacement soil material was ranged between 0.30 to 0.60 meters which was less thickness compared to the previous reports prepared for this site by the consultant engineer which recommended a thickness of 0.75 m for the soil replacement, and that means the quality control also a shared problem beside the leakage of water to the expansive soil layer.
In addition, there were no enough protection systems for preventing any leakage of water to the problematic soil below the foundations from any source.

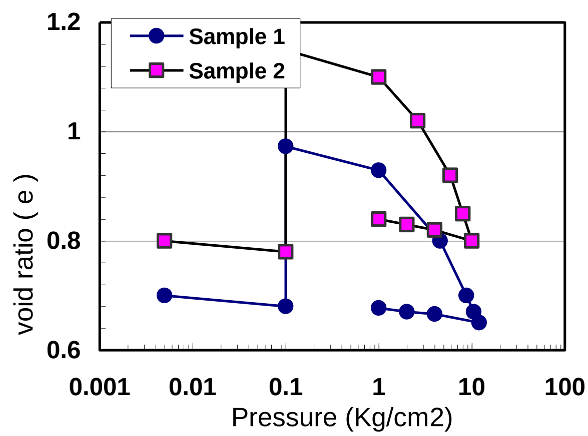

Fig.4. Swelling pressure test for soil, site 3

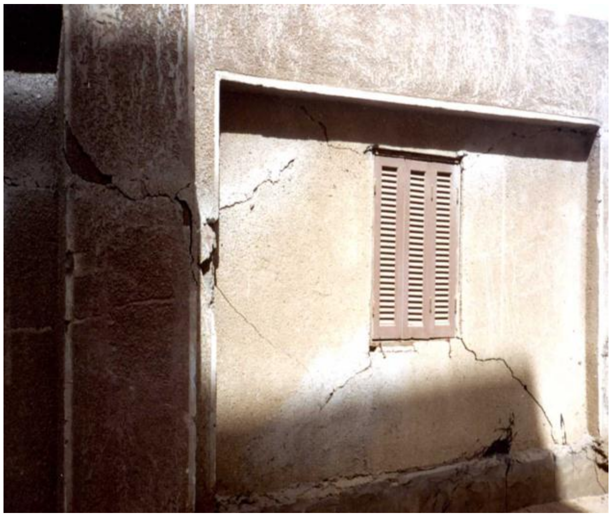

Photo 2. Cracks observed at light structures

CONCLUSION

The case histories evidence showed in this study covered the different problems appeared due to using the different soil replacement materials as a treatment technique to overcome the effect of underneath swelling/shrinkage soils below shallow footings.

The expansive soil characteristics are closely related to their origin, geological processes. And in any type of this problematic soil, any change in its moisture content from the dry state to the wet induces a volume change and thus an effect on the superstructure members.

Different treatments methods were recommended for the construction on these different types of the problematic arid expansive soils.

In Egypt a huge amount of buildings now were established on this problematic expansive soils and treated by using the soil replacement technique. Different material types and thicknesses of the soil replacement material were recommended to be used depending on the geotechnical investigation and the consultant experience.

It was noticed that, some buildings established on this problematic soils treated by using soil replacement technique suffered of different defects after the actual usage of these buildings and not during the construction.

These defects were categorized as minor to major cracks in the structure members. Investigation of those buildings showed that, all cracks appeared in walls or concrete members were happened after using the buildings and hence the arrival of the water from any source such as: (water and sewage pipelines, irrigation systems, and rains) to the underneath problematic soil through any weak portion of the soil replacement material.

Thus a special precaution must be taken into consideration during the using of any type of soil replacement methods such as:

(1) Good-choosing of the soil replacement grading analysis distribution material which will be suitable for the structure height and expansive soil deep thickness without any effect on the foundation and the structure members and avoid using the problematic soil available at site as a soil replacement. In same time the choosing replacement soil material should be able to be compacted to the desired density for prevent water leakage to the underneath expansive soil.

(2) Choosing the suitable thickness of the soil replacement material to be adequate enough for reducing the effect of the underneath swelling soil and that can be achieved by knowing the swelling potential, the characteristics and the downward depth below the foundation level.

(3) Good quality of the compaction site works must be achieved in the site by applying good supervision by the engineer on the field works to enhance the soil replacement technique as prepared by the geotechnical expertise and follow his recommendation to fulfil the using the soil replacement technique .

(4) Making sure that the soil replacement is covered the whole entire site below the foundation area and extended outside the foundation area to a width not less than the depth of foundation or as recommended by geotechnical engineer to ensure that, there is no water leakage from any water source to the deepest problematic soil and hence effect on the structure.

(5) Making sure that, for light weight structures established on such expansive soils, a more careful should be considered to using the suitable thickness and type of soil replacement and in the same time, making sure that the foundation is more rigid.

(6) Preventing leakage of water from the potable water pipes or the sewage pipelines sources to the soil replacement material underneath the footings and consequently to the underneath problematic swelling soils. Also, prevent any irrigated areas established directly around the buildings to prevent the irrigation water from arriving to the underneath problematic soils.

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