Damage of Governmental Building Due to Geotechnical Properties (Case History)

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6th International Conference on
Case Histories in Geotechnical Engineering, Arlington, VA, August 11-16, 2008

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ABSTRACT

This paper is a case study for a governmental building in a site located at Katamia zone (an extension of Great Cairo, Egypt). The site is belonging the Great Cairo Bus Station under the authority of Ministry of Transportation. It consists of two buildings and a shed for buses cleaning and lubrication. The buildings had been constructed since 15 years. However after two years of construction many cracks were noticed in the main building. Furthermore, after another few years, sever cracks had appeared in different parts of the building and the concrete water tank on the roof of same building had suffered from failure. The aim of this study is to know and examine the reasons of these cracks and damages which happened to the building, particularly the other building suffered no cracks or damages although it was built on the same soil and under the same conditions. Observation of the building movements were recorded over several years as well as soil investigation around and under the building. A structural analysis and an estimation of stresses under foundation have been calculated using a three dimensional finite element program before and after deformation. At the end of study the causes of the failure had been determined and conclusions were drawn.

INTRODUCTION

During the last few decades, a number of building failure defects which affect the appearance or the serviceability of the structure to the collapse of the structure has been recorded.

Building failures were attributed to many causes. Among which were the design deficiencies, material deficiencies, and soil foundation problem. One of major soil problems are the heave and settlement, Abdell [1995], Chen [1975], and Fredlund [1965].

The present paper describes a case history in which problematic soils resulted in significant damages to the structure under consideration.

DESCRIPTION OF THE BUILDING

The building under investigation is a 4 story building built in 1987 in an arid area on the boundary of Great Cairo. It is a reinforced concrete skeleton type with a reinforced concrete strip footing. A concrete water tank is built on top of the building. It is carried on four concrete columns. The building length is about 64.0 m and its width is about 14.0m.

SOIL CONDITION

In order to determine the causes of cracks and the movement of the building, two types of investigation were made, firstly two boreholes and one open pit were done. Figure (1) shows the location and level of them. Secondly, excavation around representative numbers of footing was made Fig. (2).

Soil Investigation

To investigate soil properties under the foundation undisturbed samples were obtained for routine laboratory tests. Consolidation tests were carried out on specimens at different depths to obtain soil swelling pressure.

Soil properties and soil profile at the building location are shown in Fig. (2), Fig. (3) and Tab. (1). Soil stratifications can be summarized as follows: From the ground surface to depth 2.0m a fill (particles of hard yellow clay and medium to coarse sand with traces of fine gravel and calcareous pebbles).

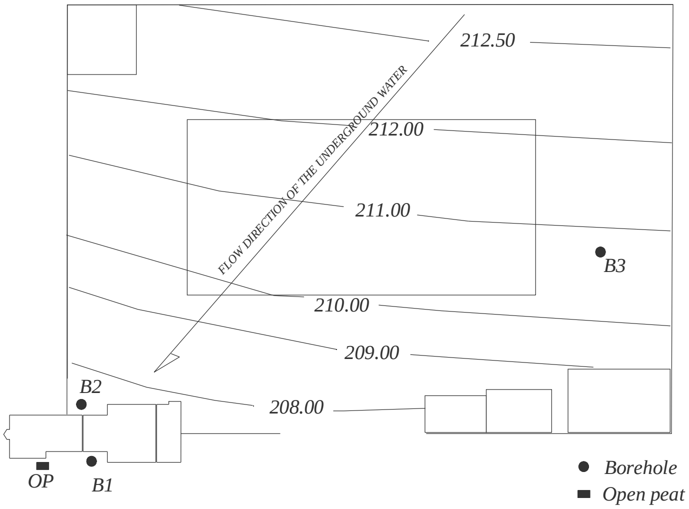

FIG. 1 The General Layout and Borehole Locations and Leveles

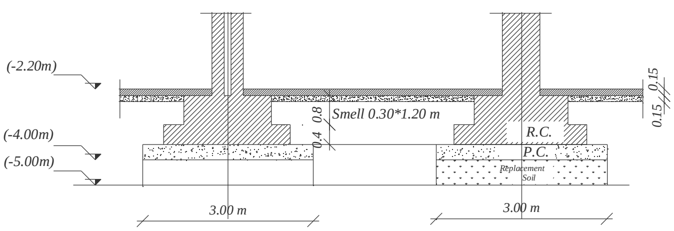

Fig.(2) Excavation around foundation

Table 1. Soil Profile

	Fill
	Yellow Silty Clay Traces of Fine Sand
	Hard Yellowish Silty-Clay
	V. Hard Yellowish to Gray Silty-Clay

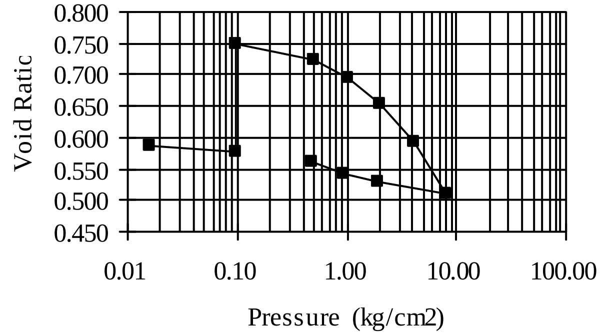

Fig. 3. Consolidation test for a clay sample

A layer of hard yellow silty-clay with traces of fine sand extended to a depth 3.5m below the ground surface. Its pocket penetrometer was more than 300 kg/m2. Then, a second hard yellowish silty-clay with thickness 2.5m until a depth of 6.0m. Another layer of very hard yellowish to gray silty–clay with traces of gypsum was found and extended to the end of borings. No water table was founded.

Excavation Around Footings

Around representative number of footings excavation were made until the replacement soil. It was found that the level of plane concrete is 5.5 m below the ground surface. The thickness of replacement soil was about 0.75-1.0m beneath the foundation which consisted of sand and gravel (coarse gravel and medium sand). It was found mixed with water and oil. The reinforced concrete was strip footing, Fig. (2).

BUILDING CONDITION

Monitoring of Inclination

Observation of the building movements were recorded over 5 years from 1996 through 2001. The horizontal and vertical movements were observed at 12 points as shown in Figs. (4 & 5). They were recorded by an optical teodolite, and the increase in the width of the construction joint was also measured.

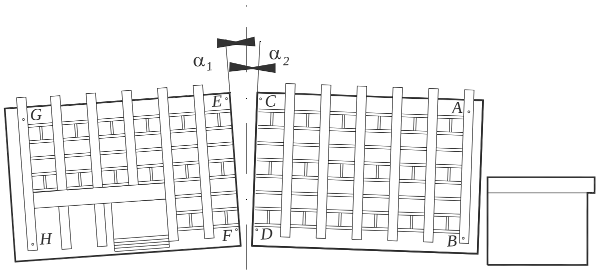

Fig.(5) The Locations of The monitoring Points as well as The Direction of movement of the Building

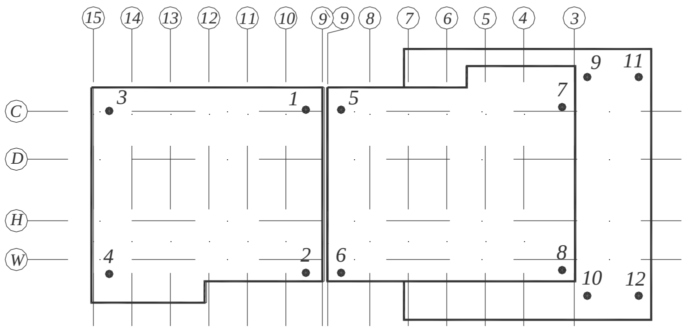

Fig.(6) Plan of The Locations of The monitoring Points and the Axis

Monitoring of Cracking

Hundreds of cracks appeared in the brick walls and some concrete elements of the building as shown in Pho. (1, 2 & 3). In addition to the big displacement of the expansion joint of the building not only wide opening with significant damage to wall and concrete element were recorded, but also adjacent rupturing of the conduits and other services in the building were found. This analysis of crack pattern in the walls proved to be crucial in order to judge the cause of the problem.

STRESS CONDITION AND FOOTING

Estimation of Stresses

The building has two expansion joints which were divided into three parts. Twelve points have been used for monitoring the deformation and vertical movement of the building as shown in Figs. (4&5). For the third part, the vertical movement of points (1,2,3,and 4) was greater than the other two parts.

An estimation of the stresses under the foundation was carried out and the stress distribution was drawn before deformation.

After the deformation of the building and making up the monitoring of the vertical movement, a structural analysis for the building as well as estimation of stresses under foundation have been calculated using a three dimensional modeling (SAP 90program) for the finite element whereas the soil was modeling using springs and as shown in Fig. (6).

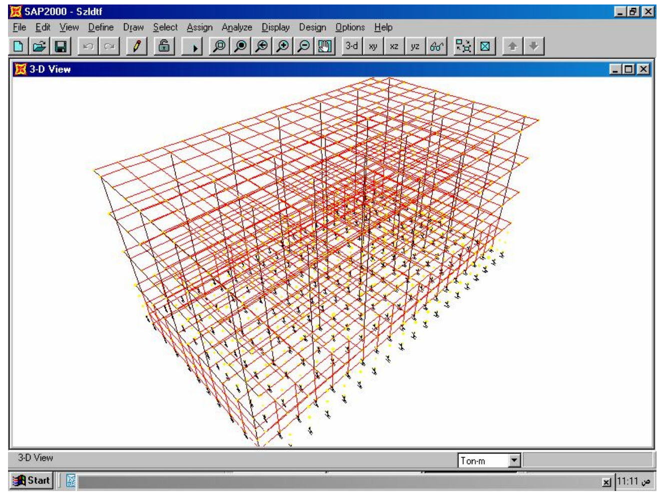

Fig. 6. Idealization of the Structure (F.E. Program)

The trial and error technique has been adopted to simulate or to result in equal movements of compared to the vertical movement, which has been recorded from the monitoring program. The stress distributions were calculated and plotted as shown in Fig. (7).

As it was noticed the biggest settlement occurred at points 3 and 4 on axis number 15, where there was a big change in stresses. An increment nearly about 50% and sometimes is more than that. For the column at point (1) beside the expansion joint at axis number 9', it was broken near the beam as shown in Pho. (2).

On the other side of the expansion joint at axis 9 there was a small settlement, at the column at point 5 (in the other side of column 1) .

ANALYSIS OF THE RESULTS

The building was constructed on the lowest level of the site beside a ground water tank as shown in figures. Also replacement of sand and gravel was used under the foundation since the underlying soil was expansive, Tab. (1).

Expansive soils swell when subjected to water producing vertical pressure , as well as lateral pressure. These pressures act on the overlaying foundation in the form of up lifting forces pushing it upwards. On the other hand as the replacement soil had a relatively small thickness (0.75m).

As well as no field tests were performed on it. This resulted in an engineered fill with low relative density. Moreover, the replacement soil has absorbed water and oil from changing the oil and washing of the buses which infiltrated in the soil and was collected under the foundations. Also the seepage of water from the ground water tank near the building increases the problems to this stage.

The water and the oil were mixed with the replacement soil and loose a big part of its strength and it settled due its small relative density. As a result ,the soil under the foundation had no clear trend, as noticed from the patterns of cracks and deformation which happened to the super structure in the form of swelling and /or settlement and rotation.

The volume change of soil resulted in movement of the building and caused the expansion joint to open and displaced at the top by 43 cm ,the inclination, Pho. (1) This combined movement caused the redistribution of loads and stresses under the foundation as shown in Fig. (7) which caused some concrete elements to break Pho. (2). This was the main reason that caused the damage to the building and the failure of the upper water tank Pho. (3). Beside, the lack in the number of ground beams (semelles) connected to the foundation, especially those near the expansion joint resulting in decrease the rigidity of the foundations.

CONCLUSIONS

Based on the obtained data and results, the following conclusions can be drawn:

The building must be built on a leveled horizontal site or at least on its higher level.

The thickness of soil replacement is considered as an effective way in reducing the effect of swelling provided that it must be compacted to the required relative density and must be horizontally confined.

All precautions must be undertaken to prevent water and other liquids to infiltrate to foundation soil and/or replacement soil.

Intensive care should be paid to assure that the foundations are adequately tied together, especially near the locations of expansion joints. This would result in the increase of the rigidity of the foundations and consequently, the overall rigidity of the structure to resist differential settlement.

LESSONS LEARNED

Generally, the geotechnical engineer who designs foundation over problematic soil particularly expansive clay should pay more attention to the following lessons:

He should study the landscape and the topography of the site.
He should know the function of each building in the site.
He should expect and search for any source of water in the site particularly in the arid areas.
Precautions should be suggested and implemented to avoid water to reach the foundation soil or near the swelling soil.

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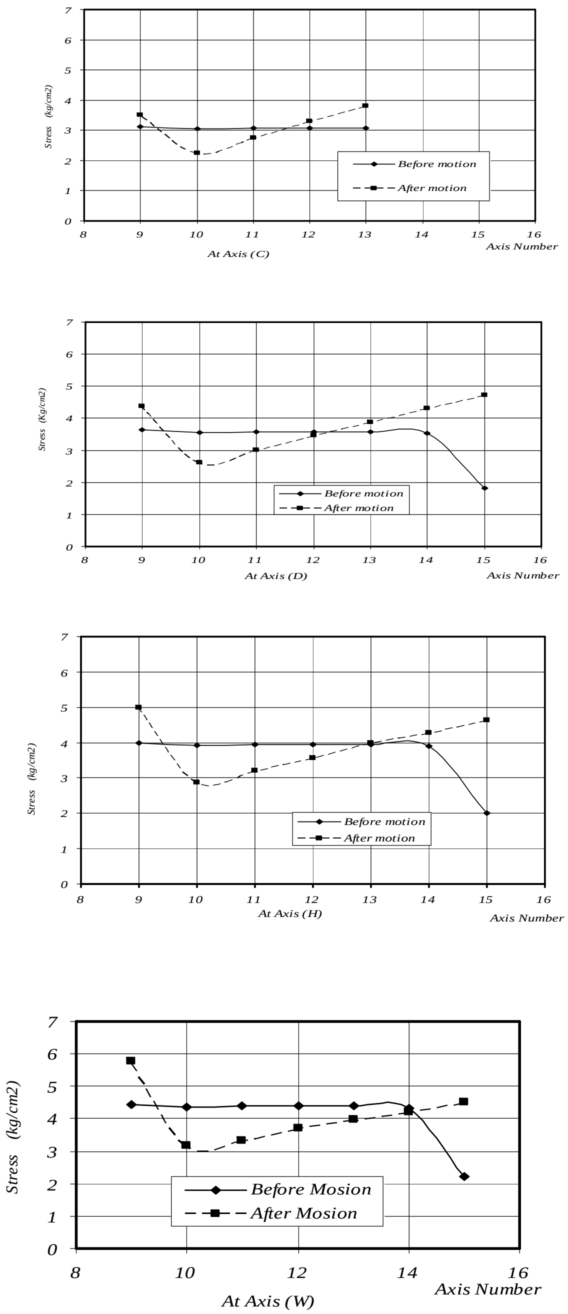

Fig. 8. Stresses before and after movement

Photo 1 An increase of expansion joint

Photo 2 Break of beam and column near expansion joint.

Photo 3 Failure of tank at the roof