

Control of groundwater aggression on an Egyptian temple

Contrôle d'agression d'eaux souterraines sur un temple égyptien

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ABSTRACT

The city of Esna in Upper Egypt is built over a thick highly permeable fill layer. In the past decade, a new barrage was built across the River Nile leaving the city directly in the upstream side of the barrage. In the city center, a unique, of its architectural design, Pharos temple exists. The Temple stands about 12.00m below the ground level of the surrounding urbanized area. The increase of water level in the barrage upstream caused an increase in the groundwater level in the whole city. Due to the low level of the temple, a considerable amount of water continued to percolate towards the temple area and its surroundings causing rapidly increasing impacts on the temple walls. In order to diagnose the problem and recommend the solution, an intensive geotechnical study was undertaken. The soil in the top 30 meters was classified into three main layers. The top layer is a heterogeneous fill with very high hydraulic conductivity. This layer is followed by a silt layer with an almost uniform thickness of 10m. The silt layer rests on a sandy layer that extends till the end of executed borings. Two finite element programs were developed to study the groundwater condition in the present time as well as through the next 30 years. The outcome indicated that severe deterioration of the situation is foreseen. Alternative remedy scenarios were introduced. A conservative solution had to be recommended in order to preserve the high value temple.

RÉSUMÉ

La ville d'Esna en Egypte supérieure est construite au-dessus d'une couche fortement perméable épaisse de suffisance. Dans la décennie passée, un nouveau barrage a été construit à travers le fleuve le Nil quittant la ville directement dans le côté ascendant du barrage. Au centre de la ville, un unique, de sa conception architecturale, temple de Pharos existe. Le temple tient d'entourage environ 12.00m au-dessous du niveau du sol du secteur urbanisé. L'augmentation du niveau d'eau du barrage en amont a causé une augmentation au niveau d'eaux souterraines dans toute la ville. En raison de bas niveau du temple, une quantité considérable de l'eau a continué à filtrer vers le secteur de temple et ses environnements causant des impacts rapidement croissants sur les murs de temple. Afin de diagnostiquer le problème et recommander la solution, une étude géotechnique intensive a été entreprise. Le sol dans les 30 mètres principaux a été classifié dans trois couches principales. La couche supérieure est une suffisance hétérogène avec la conductivité hydraulique très élevée. Cette couche est suivie d'une couche de vase avec une épaisseur presque uniforme des 10m. La couche de vase se repose sur une couche arénacée qui se prolonge jusqu'à l'extrémité des sondages exécutés. Deux programmes finis d'élément ont été développés pour étudier la condition d'eaux souterraines dans l'époque actuelle aussi bien qu'au cours des 30 années à venir. Les résultats ont indiqué que la détérioration grave de la situation est prévue. Des scénarios alternatifs de remède ont été présentés. Une solution conservatrice a dû être recommandée afin de préserver le temple de valeurs élevées. Mots-clés : technologie géotechnique, impacts

Keywords : geotechnical conditions, hydraulic conductivity, environmental impacts, groundwater, mathematical models

1 INTRODUCTION

The existence of the groundwater level on/or very close to ground level may cause severe environmental and engineering impacts. This phenomenon occurs frequently in urbanized areas, especially those which are highly populated. In Egypt, many important Pharos heritages are located in small cities with dense population and hence are equally subjected to severe impacts. Among these, one temple is even more unlucky as it has to face an extra source of human made burden.

2 PROBLEM DESCRIPTION

The city of Esna in Upper Egypt is built over a thick layer of highly permeable layer of fill. In the past decade, a new barrage was built across the River Nile leaving the city directly in the upstream of the barrage. In the city center, a unique, of its architectural design, Pharos temple exists. The Temple is

located about 12.00m below the surrounding urbanized area. The general layout of the building is shown in Figure 1.

The increase of water level in the barrage upstream caused an increase in the groundwater level. Due to the low level of the temple, a considerable amount of water continued to percolate towards the temple area and its surroundings causing severe impacts (Abou Rizaiza, and Hammadur, 1999). The purpose of this work is to recommend a practical solution that stops further deterioration of the situation (Burnett, A.1993).

3 GEOTECHNICAL CONDITIONS

About 50 boreholes with depths between 10m and 30m were executed in the site. Necessary field and laboratory geotechnical tests were conducted inside and outside the temple yards. It was found that the underground consists of three main layers. The top 9-11 m consists of heterogeneous fill. Below this layer, exists a cohesionless silt stratum with an angle of internal friction ranging between 11° and 22°. The lower layer consists

of fine sand with traces of silt. The angle of internal friction of this layer in some samples was as low as 21° while it reaches much higher values in other samples.

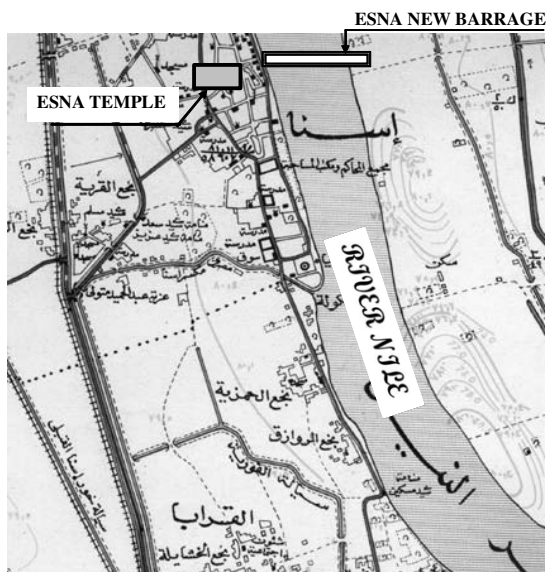


Figure 1. Map of Esna city

The hydraulic conductivity was measured in the field using the auger hole method. The top fill layer has a high average value equals 110m/d while the silt and silty sand strata have averages of 0.008m/d and 0.8m/d respectively. The variation of the hydraulic conductivity with depth for the three layers is found in Figure 2.

The water level in the city center and inside the temple yard almost coincides with ground level. A constructed water level map of the city (El Araby 1999) is illustrated in Figure 3.

4 IMPACTS OF GROUNDWATER RISE

The sudden rise of groundwater level in the city after the barrage construction caused a lot of environmental and engineering impacts (Walsh et al. 2009). The impact on the infrastructure and poorly built houses were severe. Moreover, ponding of water in the streets is seen everywhere in the city.

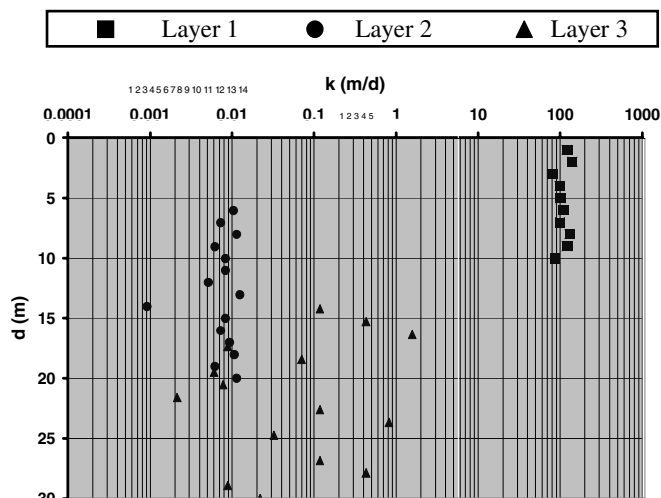


Figure 2. Variation of hydraulic conductivity with depth



Figure 3. Groundwater level contour map (El Araby 1999)

The temple and the yard retaining wall that protects the temple from the pressure of the surrounding high level ground surface are greatly affected. The signs of water percolation can be noticed in Figures 4 & 5 which includes photos of the temple and the retaining wall that surrounds it. The signs of ground water aggression are clear in the two photos.

5 CONTROL OF GROUNDWATER LEVEL

The collected geotechnical data formed a base for the construction of two mathematical models (El Nimr 1991). The first model was a two dimensional plane finite element model that simulates the groundwater flow from the River Nile to the city. The harmonic average of the hydraulic conductivity of the top 30m soil layers is applied in the model. The groundwater control is to be governed by hypothetical gravity drainage system that brings the groundwater level down to a safe level. It was foreseen that 2.00m below ground level may not cause remarkable structural effects on the building.



Figure 4. Deterioration of the temple due to groundwater rise

As the city is not served by a public sanitary network, the model is applied twice, once in the present situation and once after its completion. The present groundwater level is used as a calibration mean of the model (Akber, A. 1999).

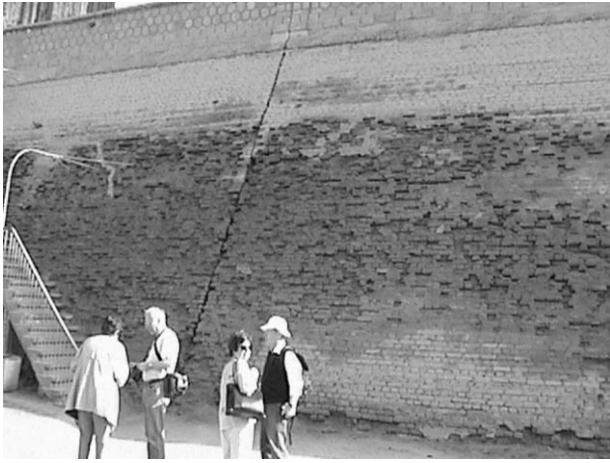


Figure 5. Groundwater aggression on the retaining wall

In order to keep the groundwater surface around the sought safe level in the case of absence of the public sanitary system, the model lead to the occurrence of locations with deep groundwater level. This endangers the buildings in these locations.

On the other hand, modeling the case with sanitary system lead to groundwater levels deep enough to reduce the present environmental impacts and in the meantime, it is high enough to avoid considerable structural effects (Bear, J. 1987). The steady state obtained groundwater level contour map corresponding to this case is found in Figure 6. This means that the application of this part of the solution should result a groundwater level in the city center that lies safely below ground level.

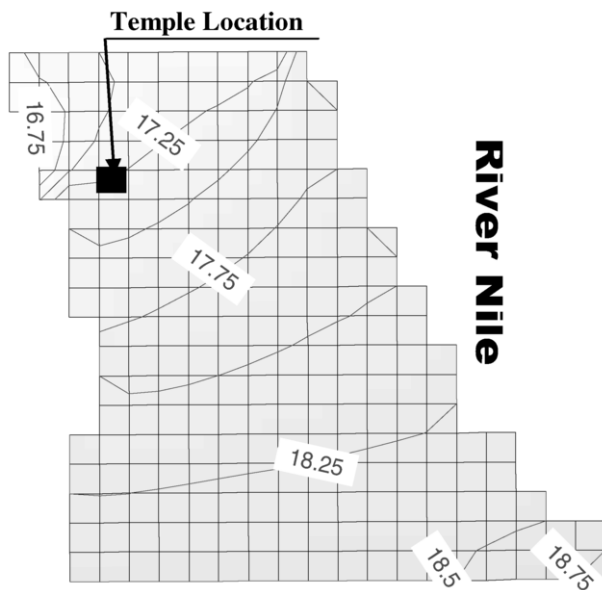


Figure 6. Steady state groundwater level in the city

While the first model adoption is expected to solve the city problem, it does not provide the same protection the deeply situated temple.

The second mathematical model simulates groundwater flow through vertical sections that start 50m east of the temple, pass through it and extend 20m to the west of the temple. The section extends downwards to a depth of 20m below the temple ground floor. This level is taken as the datum of total head. The flow is assumed to be through the top three soil beddings (Clout d'Oral 1982). Each of the strata keeps its actual average hydraulic

conductivity. The results of the plane model are used as boundary conditions to the vertical model.

Different solution scenarios were tried. It is found that the use of an inside the temple yard another drainage system and two 12m deep sheet pile walls as shown in Figure 7 leads to the most satisfactory situation. The finite element mesh for this case is shown in Figure 8.

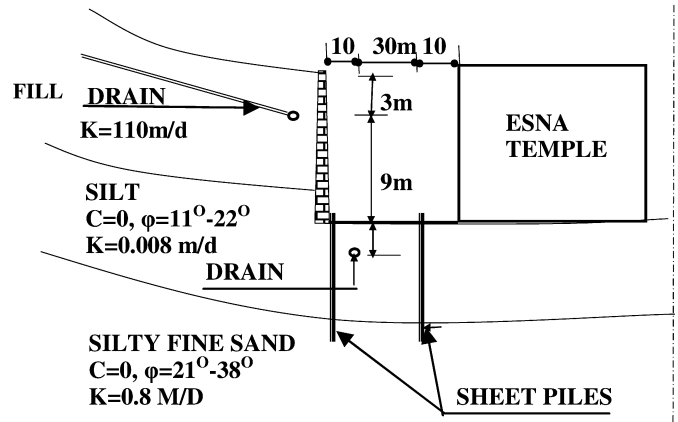


Figure 7. Physical presentation of second model

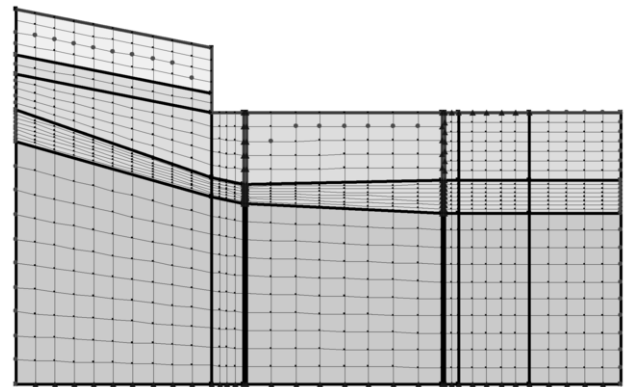


Figure 8. Finite elements mesh of the second mathematical model

The total head distribution in a typical section is illustrated in Figure 9, while the pore water pressure variation with depth at the eastern and western walls of the temple are shown in Figure10.

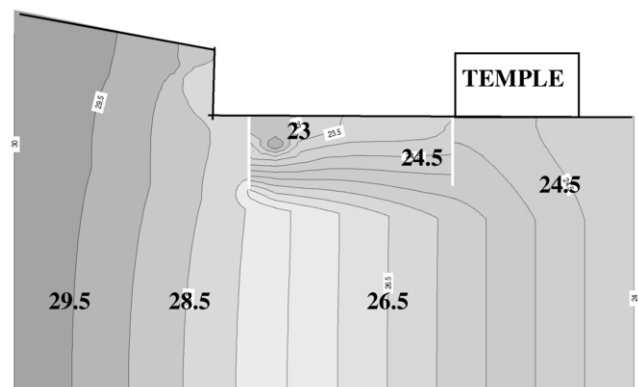
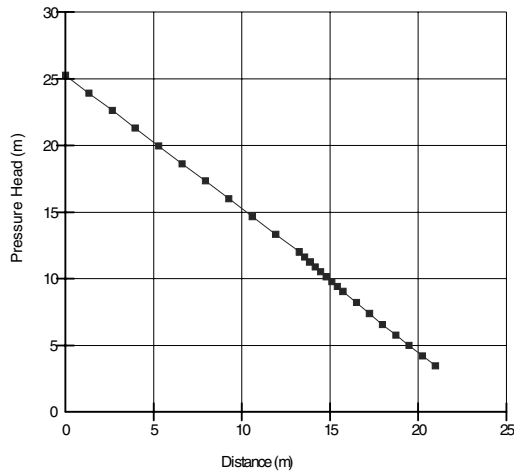
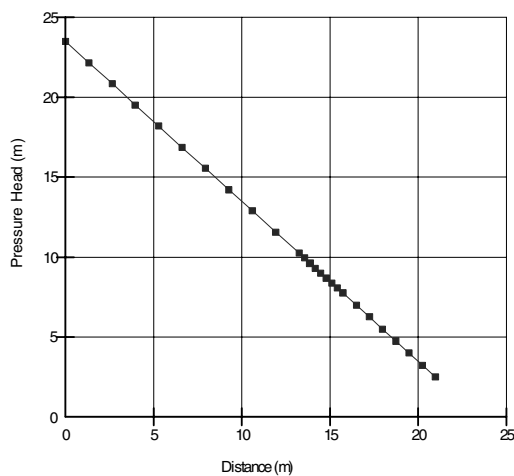


Figure 9. Total head contour lines

As it is clear from Figure 9, the contour lines reach the yard and temple flooring at total head values between 23m and 25m which means that the water surfaces lies below the flooring as the datum is taken at 30m below the temple floor.



a) East of east temple wall



b) West of temple west wall

Figure 10. Pore water pressure head variation with depth

The pore water press values at the floor level in both sides of the temple are almost equal (3.5m in eastern side and 4.5m). Taking the datum into consideration, this means that the flooring lies above the full saturated zone by enough depth.

6 CONCLUDING REMARKS

The Esna city has over 10000 inhabitants. Their way of life has been changed to the worst after the construction of the new barrage. Also, Esna temple, which is a unique temple of its architectural value, is being subjected to severe groundwater aggression for the same reason. According to the results of the presented simulation works, the proposed solution, if adopted should improve the environmental conditions as well as save the temple, the houses and infrastructure from future collapse without being subjected to considerable negative effects due to lowering the ground water level

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