EFFECT OF SOIL LIQUEFACTION ON NILE RIVER BANK STABILITY

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ABSTRACT

Nile River banks have been facing erosion mechanisms since very long time. However, the construction of the High Aswan Dam has reduced the suspended sediment concentration downstream the dam and this reduction has increased the ability of the flowing water to erode banks and reduce their stability. River bank soils are subjected to volume change under the cyclic shear loading if drainage is allowed. For undrained shear loading, however, no volume change is allowed to occur and the soil tends to decrease in volume and to have positive pore pressure up to a state of soil liquefaction. The effect of soil layers liquefaction on Nile River banks was studied during this analysis. The selected site for this analysis is Kafr Nasser and it is located in Beni-Swafe Governorate from 134.370 to 134.900 km from El-Roda with a total length of 530 m. The analysis results for the selected site show the percentages of the reduced factors of safety due to liquefaction. More long and detailed analysis are required to draw some general patterns for the effect of liquefaction on Nile River bank stability. However, this analysis shows the significance of this effect.

KEYWORDS

Nile River Banks, Liquefaction, Stability, Residual Strength

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BANK EROSION

Nile River banks have been facing erosion mechanism since very long time. However, the construction of the High Aswan Dam has reduced the suspended sediment concentration downstream the dam and this reduction has increased the ability of the flowing water to erode banks and reduce their stability. Nile Research Institute is performing an annual monitoring of eroded banks to design and apply the suitable bank protection for these sites. The resulted problems from the bank erosion are many; such as economical problems since the bank erosion involves a loss of very expensive agricultural lands, some other problems are technical because of the eroded soil particles may settle in some areas causing navigational and water pump intake problems.

The factors that affect Nile River bank erosion are many; some of them are related to existing bank geometry and soil strength and some others are related to external forces acting on the banks. Some examples of these factors are listed as follows:

1- Bank height,
2- Bank slope,
3- Soil characteristics,
4- Navigation waves,
5- River bends,
6- River contractions,
7- Spur dike effects,
8- Suspended sediment concentrations,
9- Nile River and subsurface water levels, and
10- Human interventions,

RIVER BANKS LIQUEFACTION

Liquefaction

The soil liquefaction mechanism due to dynamic loads was first examined in 1936 by Casagrande (Committee on Earthquake Engineering [1]). Soil is subjected to volume change under the cyclic shear loading if drainage is allowed. For undrained shear loading, however, no volume change is allowed to occur. This means that if a sample would tend to decrease in volume, then a positive pore pressure will be induced in this sample. On the other hand, if the sample tends to increase in volume, a negative pore pressure will be induced.

For the case of a void ratio higher than the critical void ratio (which is defined as the void ratio at which the volume change at failure will be zero), the soil tends to decrease in volume and to have positive pore pressure in the undrained shear loading case. If the void ratio is less than the critical void ratio, the soil tends to increase in volume and to show negative pore pressure (Holtz and Kovacs, [2]). Positive pore pressure reduces the effective stress in the soil because the total stress is constant, and the total stress is equal to the effective stress plus the increasing pore pressure; therefore the effective stress should decrease. If it decreases until the pore-water pressure value reaches the value of the total stress, then the effective stress in this case will be equal to zero. In this case, the soil will be in the liquefaction state.

THE PROPOSED ANALYSIS

Selected Site

The purpose of the proposed analysis is to study the effect of Nile River banks liquefaction on their stability. The proposed analysis was applied to one case study to analyze this effect. The selected site is given the number of (213) by the Nile Research Institute coding system. The site name is Kafr Nasser and it is located in Beni-Swafe Governorate. It is located from 134.370 to 134.900 km from El-Roda with a total length of 530 m. Nile Research Institute has performed the hydrographic survey of 11 cross sections of the site and it has performed 3 soil bore holes along the site. For these bore holes, field and laboratory tests were performed, in addition to soil sampling. The concept for selecting a site for this analysis is illustrated in the following section.

Selection Approach

The site selection approach, used for this analysis, is performed by scanning the soil bore holes for all the available sites along the Nile River. The soil layer which has liquefaction potential has to satisfy the following criteria:
1- Sandy type soil,
2- Fine grained,
3- Loose,
4- Saturated, and
5- Limited percentage of fines.
Applying these criteria to Nile River banks soil layer, the selected site has satisfied them for all its bore holes.

Selected Site Bore Holes

The site bore holes are illustrated in the following tables; Table (1) illustrates the bore hole No. (1), Table (2) illustrates the bore hole No. (2), and Table (3) illustrates the bore hole No. (3). The soil layers which have liquefaction potential were given a gray background. For soil layer in the first bore hole, the grain size distribution is given in Figure (1) and the grain size distribution for the second bore hole layer is given in Figure (2), while the grain size distribution for the third bore hole layer is given in Figure (3). It has to be mentioned that the first bore hole is serving cross sections from 1 to 3, the second bore hole is serving cross sections from 4 to 7, and the third bore hole is serving cross sections from 8 to 11 according to their locations.

Table (1) Kafr Nasser Site,bore hole No.1 soil description.

Depth	Level	Soil Description
1.00	27.80	Silt with medium to fine sand
2.00	26.80	
3.00	25.80	Fine Sand with some silt SPT=7
4.00	24.80	
5.00	23.80	Fine Sand with some silt SPT=15
6.00	22.80	
7.00	21.80	Graded sand with traces of silt SPT=32
8.00	20.80	
9.00	19.80	
10.00	18.80	
11.00	17.80	
12.00	16.80	

Table (2) Kafr Nasser Site,bore hole No.2 soil description.

Depth	Level	Soil Description
1.00	27.40	Silt with some fine sand
2.00	26.40	Silt and clay with some fine Sand
3.0	25.40	
4.00	24.40	
5.00	23.40	Fine Sand with some silt SPT=6
6.00	22.40	
7.00	21.40	Fine sand with some silt SPT=21
8.00	20.40	
9.00	19.40	Graded medium to fine sand, traces of some gravel SPT=30
10.00	18.40	
11.00	17.40	
12.00	16.40	

Table (3) Kafr Nasser Site,bore hole No.3 soil description.

Depth	Level	Soil Description
1.00	25.30	Silt and clay, traces of fine sand
2.00	24.30	
3.0	23.30	Fine Sand with some silt
4.00	22.30	SPT=6
5.00	21.30	SPT=7
6.00	20.30	
7.00	19.30	Fine Sand with some silt
8.00	18.30	SPT=13
9.00	17.30	Graded medium sand with traces of silt, traces of gravel
10.00	16.30	
11.00	15.30	
12.00	14.30	

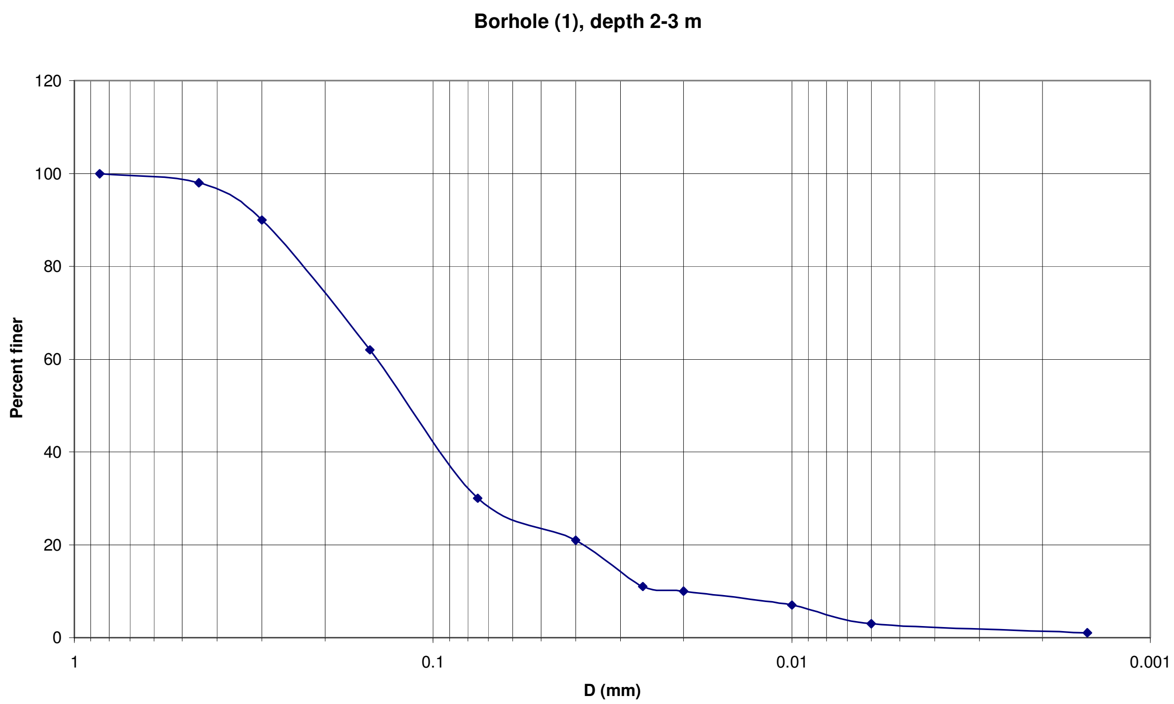

Figure 1. Grain size distribution for BH1, depth 2-3 m.

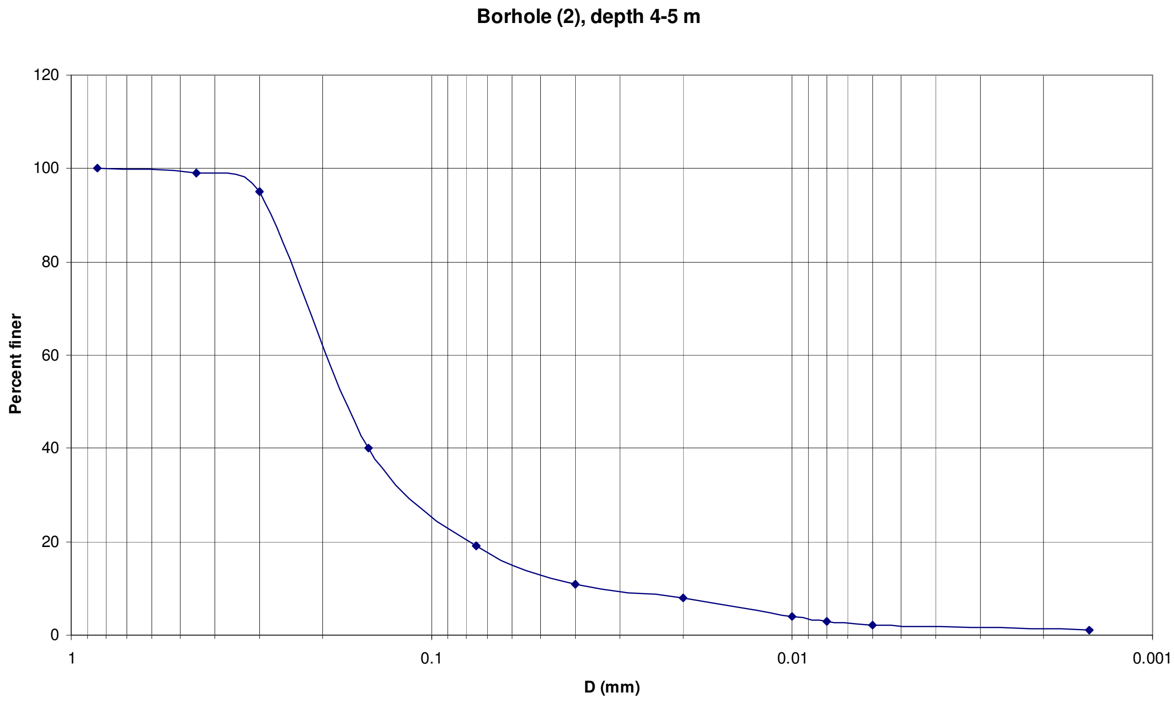

Figure 2. Grain size distribution for BH2, depth 4-5 m.

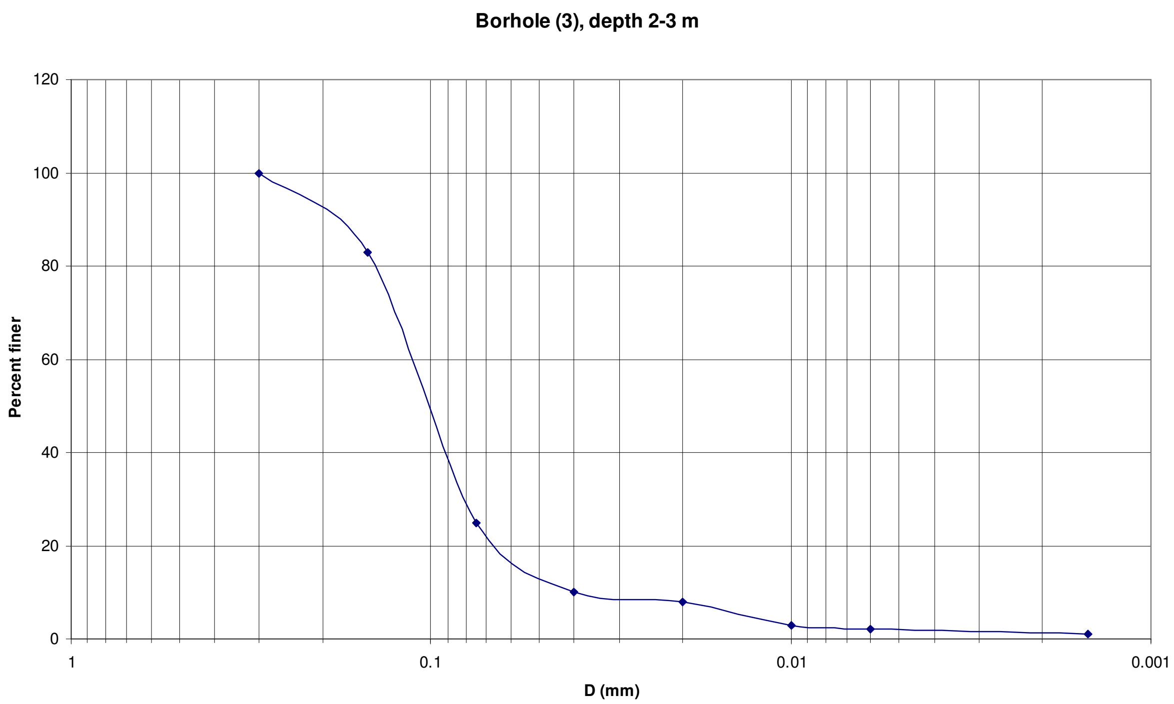

Figure 3. Grain size distribution for BH3, depth 2-3 m.

Residual Strength

In the earlier analyses of soil liquefaction, the shear strength of the liquefied materials had been considered equal to zero. Castro and Poulos [3], using the results from laboratory tests on disturbed and undisturbed samples, have shown that the residual shear strength of liquefied soil is not necessarily zero but retains some residual strength, which is estimated via laboratory tests (Marcuson, Hynes and Franklin [4]). Seed et al. [5] used the corrected standard-penetration blow counts to develop a field evaluation for the residual strength (S_r) for the liquefied materials.

Kafr Nasser Liquefied Layers Residual Strength

The residual strength of a liquefied soil layer is determined by the relationship between the corrected standard penetration test blow count, and the residual shear strength (Seed et al. [6]). The SPT corrections include, overburden pressure correction, hammer efficiency correction, and silt content. Table (4) shows the summary of these corrections and the computed residual strength for the layers subjected to liquefaction.

Table (4). SPT corrections and residual strength.

Layer	N	$(N_1)_{60}$	S_r
BH1 (24.80-26.80)	7	14.5	500 psf
BH2 (22.40-24.40)	6	13.5	400 psf
BH3 (20.30-24.30)	6,7	13.5	400 psf

Stability Analysis

Stability analysis was performed to determine the safety margins for the analyzed banks. The outputs of this analysis are described by the terms: safety factors. In general, the factor of safety is determined from the following equation:

$$Factor\ of\ Safety\,(F.S.) = \frac{Shear\ Strength}{Shear\ Stress} \qquad (1)$$

Stability Analysis Results

The stability analysis was performed for all cross sections of the selected site. The traditional factors of safety were computed in addition to the computation of the factors of safety after liquefaction. Table (5) shows the results of this analysis. It shows, both safety factors for the two cases, liquefied and not liquefied, and their percentages, i.e. the percentage of the safety factor for the liquefied case over the non-liquefied case. These percentages for the selected site are ranged from a minimum of 36.36 % to a maximum of 100% with an average of 79.05 and a standard deviation of 22.16 %. It has to be mentioned here that the effect of liquefaction is not only governed by the bore hole soil layer residual strength, or the cross section geometry, but also it is highly governed by how much the failure slip surface is passing through the liquefied layers. Even though more long and detailed analysis are required to draw some general patterns for the effect of liquefaction on Nile River banks stability, this analysis shows the significance of this effect.

Table (5) Kafr Nasser liquefaction analysis results.

Cross Section	Factor of Safety Without Liquefaction	Factor of Safety With Liquefaction	Percentage F.S.liq/F.S. %
1	1.2	1.2	100.00
2	1.3	1.3	100.00
3	1.8	1.3	72.22
4	1.3	1.3	100.00
5	1.7	1.3	76.47
6	2.2	0.8	36.36
7	2.2	0.9	40.91
8	1.5	1.2	80.00
9	1.3	1.1	84.62
10	1.3	1.2	92.31
11	1.5	1.3	86.67
Average			79.05
Minimum			36.36
Maximum			100.00
Standard Deviation			22.16

Reduce and Resist liquefaction

There are a number of ways to reduce and resist liquefaction, a non-structural solution such as to abandon or relocate the structure, accepting the risk, or trying to reduce the damage if something happens. A structural solution would involve use of berms. A site solution would include in-situ densification, increases the lateral stresses, removal or replacement of the liquefiable soil, or if applicable, grouting, or any other type of stabilization. A drainage solution might involve relief wells, dewatering systems, air injection into pore-pressure drains, and ground water controls.

CONCLUSIONS

The effect of soil layers liquefaction on Nile River banks was studied during this analysis.

The selected site for this analysis is Kafr Nasser and it is located in Beni-Swafe Governorate. It is located from 134.370 to 134.900 km from El-Roda with a total length of 530 m. It was selected since its soil layers satisfy the liquefaction criteria described in this paper.

The analysis results for the selected site show that the percentage of the reduced factors of safety are ranged from a minimum of 36.36 % to a maximum of 100% with an average of 79.05 and a standard deviation of 22.16 %.

The effect of liquefaction is not only governed by the bore hole soil layer residual strength, or the cross section geometry, but also it is highly governed by how much the failure slip surface is passing through the liquefied layers.

More long and detailed analysis are required to draw some general patterns for the effect of liquefaction on Nile River banks stability.

REFERENCES

1. Committee on Earthquake Engineering, Liquefaction of soils during earthquakes, Commission on Engineering and Technical Systems, National Research Council, PP. 214, 1985.
2. Holtz, R. and Kovacs, W., An introduction to geotechnical engineering. Prentice-Hall, Inc/,Englewood Cliffs, New Jersey, PP 733, 1981.
3. Castro, G., and Poulos, S., Factors affecting liquefaction and cyclic mobility, ASCE Journal of Geotech Eng., Vol. 103, No. GT6, PP. 501-515.
4. Marcuson, W., Hynes, M., and Franklin, A., Evaluation and use of residual strength in seismic safety of embankments. Earthquake Spectra, Vol. 6, No. 3, PP. 529-572.
5. Seed, H., Seed, R., Harder, L., and Jon, H., Re-evaluation of the slides in lower San Fernando Dam in the earthquake of February 9, 1971, Report No. UCB/EERC88/04, University of California, Berkeley, California, PP. 30, 1988.
6. Seed, H., Tokimatsu, K., Harder, L., and Chung, R., The influence of SPT procedures in soil liquefaction resistance evaluations. Report No. UCB/EERC84/15, Earthquake Engineering Research Center, University of California, Berkeley, California, PP. 20, 1984.