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Evaluation of Liquefaction Potential of Sabkha Soil in Aziziyah Area, Khobar, KSA.

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Abstract: - Al-Khobar is one of the important and fastest growing cities in the Kingdom of Saudi Arabia . It lies on the western shorelines of the Arabian Gulf , about few hundred kilometers to the west of the active fold-fault subduction zone of Zagros mountains in Iran .

Sabkha soil , covering most parts of Aziziyah area in the southern portion of Al-Khobar city , is generally loose, saturated with sea water and consist mainly of fine, poorly graded sand to silty sand .

This paper is intended to determine the potentiality of these soils to liquefaction which is considered as a major geotechnical hazard . Therefore , the liquefaction potential of sabkha soil in Aziziyah area, southern khobar was assessed following cyclic stress approach . Data from SPT tests conducted at sites was used in assessment .

The factor of safety against liquefaction was plotted, for soil from existing surface till a depth of 25m . The results show that the soil in the upper 10m in most parts of sabkha has high susceptibility to liquefaction .

I. INTRODUCTION

This study is intended to determine the liquefaction potential of the underlying loose sabkha soil through determination of the geotechnical characteristics of sabkha the as in-situ density , groundwater level , moisture content , total and effective stresses.

Sabkha consist mainly of saturated , very loose to loose sandy soil from the existing natural ground surface till a depth of about 10m to 15m deep. Saturated loose sand is known to have low shearing strength and high compressibility . In addition to that, if this soil is subjected to low magnitude of seismic shaking, a rapid increase in pore water pressure will occur which will result in excitation of soil grains and therefore the soil will suddenly lose its strength. This phenomenon is known as liquefaction and is defined as " sudden loss of soil strength due to flotation of the individual soil grains from excess pore water pressure and ground shaking during earthquakes"(Seed & Idriss,1971).

Liquefaction is one of the major problems in geotechnical earthquake engineering where loose to medium dense sands below water table will lose its strength as a result in reduction of the soil shear strength when subjected to undrained loading.

In case of earthquakes, during shaking, the dry sand tends to compact. Saturated sand , on the other hand , behaves differently. The water in the pores cannot escape quickly enough, at least in the finer sands, to accommodate instantaneously the compaction. Therefore, stresses increase the pore water pressure and reduce the effective stresses. Sand soil usually depends on the effective stresses between the grains to mobilize shear strength and resistance to displacement. Therefore, the increasing pore water pressure leads to loss of strength.

At pore water pressure equals to the total stresses, the sand loses its shear strength completely and behaves like viscous fluid and possibly boils.

This buoyancy causes total collapse of soil structure resulting in a “liquefied mass” which does not possess any shear strength or load carrying capacity. Therefore, structures placed on this type of soil will lose support leading to tilting, settling or even total collapse.

II. SUBSURFACE CONDITIONS

The soil profile shown in Fig.1, represent the subsurface conditions as revealed from 20 boreholes drilled in two adjacent sites to depths of 15m to 25m.

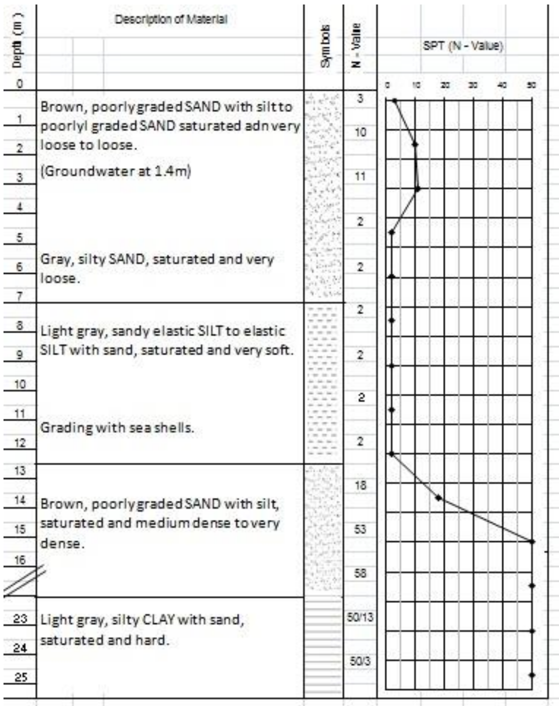

Fig.1. Subsurface soil of the study area

As shown on the profile , the subsurface soil consist of saturated, very loose to loose , poorly graded sand to silty sand from existing ground surface till a depth of 7m and 13m. A layer of saturated soft silt, is encountered below sand layer having a thickness from 1.5m to 5.5m. The bottom portion of strata , below 15m, consist of dense to very dense sand and hard clay.

Groundwater was encountered in all boreholes drilled within sabkha soil . The water levels in drilled boreholes vary from 1.0m to 1.6m.

III. ASSESSMENT OF LIQUEFACTION POTENTIAL

The first step in engineering assessment of the potential for initiation of soil liquefaction, is to determine the existence of soils that have potentially liquefiable nature at site . This is in turn, raises the important question regarding which type of soil is potentially vulnerable to soil liquefaction . It has been recognized that , relatively clean sandy soils with less fines are potentially vulnerable to seismically induced liquefaction.

Generally liquefaction of soil will occur if the following two conditions are satisfied (Seed & Idriss, 1971) : ,

- Soil type: soil with 50% or more of grain size in the range of (0.02mm) to 0.2mm are potentially liquefied when saturated.
- Intensity of ground pressure: to initiate liquefaction, the local ground acceleration shall be greater than 0.1g.

The liquefaction potential of the study area was assessed mainly by applying the "Simplified procedure " of Seed & Idriss, 1971, which was lately modified by them and other researchers.

Liquefaction phenomenon could also be evaluated by other empirical correlations based essentially on comparison of grain size distribution of the site to the grain size envelope of sites that have liquefied in the past . Based on standard penetration test (SPT), and field performance data, Seed et al,(1985), concluded that; there are three approximate potential damage ranges that can be identified Table.1.

Table 1: Potential damage

SPT $(N_1)_{60}$	Potential damage
0. - 20	High
20 - 30	Intermediate
> 30	No significant damage

IV. THE SIMPLIFIED PROCEDURE OF SEED AND IDRISS

The analytical evaluation of liquefaction potential of the sabkha soil is based originally on the work of Seed & Idriss (1971) and the latest modifications by the two authors and other researchers. As given by the “simplified procedure”, two major factors are required to be determined, first, the seismic demand on a soil

layer , expressed in terms of CSR, cyclic stress ratio and second, the capacity of the soil to resist liquefaction, expressed in terms of CRR, cyclic resistance ratio.
The final step in the evaluation of liquefaction potential is to determine the Factor of Safety against liquefaction. If the cyclic stress ratio is greater than the cyclic resistance ration , then liquefaction can occur . The higher the factor of safety , the more resistant the soil and vice versa.
The “simplified procedure” calculates the factor of safety, FS, against liquefaction in terms of the cyclic stress ratio, CSR, and the cyclic resistance ratio, CRR , according to the formula:

$$\mathbf{FS} = \left(\frac{CRR_{7.5}}{CSR}\right) MSFK_{\sigma}K_{\alpha}$$

Where:
$CRR_{7.5}$ is the cyclic resistance ratio for magnitude 7.5 earthquakes.
MSF is the Magnitude scaling factor .
$K\sigma$ is the overburden correction factor, and
$K\alpha$ is the correction factor for sloping ground.
CSR is estimated using Seed &Idriss (1971) equation multiplied by 0.65:

$$\mathbf{CSR}= 0.65 \left(\frac{a_{max}}{g}\right)\left(\frac{\sigma_{vo}}{\sigma'_{vo}}\right) r_d$$

Where: (a_{max}) is the peak horizontal acceleration at the ground surface generated by the earthquake, (g) is acceleration due to gravity, (σ_{vo} and σ'_{vo}) are the total and effective overburden stress, respectively, and, (r_d) is the stress reduction coefficient.
When the factor of safety is less than one , then liquefaction is expected , if it is one , it is at very critical state and where it is more than one , the soil is more resistant to liquefaction.

5.0 The Seismicity of the study area

The study area lies on the west side of the Arabian Gulf .The eastern side of the Gulf is known as an active zone of earthquakes along Zagros mountains in Iran . Fnais et al, (2012), stated that " Al-Dammam and Al-Khobar cities are affected by distant earthquakes from Zagros fold-fault subduction zone. These earthquakes of magnitude greater than 6.0 could produce great local site effects on the sedimentary layers, that significantly affect earthquake ground motion ".

V. EVALUATION OF LIQUEFACTION POTENTIAL

The liquefaction potential of the subsurface saturated sandy soil was assessed by the use of cyclic stress approach in conjunction the standard penetration test (SPT) procedures. The cyclic stress ratio (CSR) of the saturated sandy soil with fines less than 5% was assessed according to the established method of Seed et al (1971,1985).
Using the corrected SPT N-values, for magnitudes of earthquake intensity of (M = 5.5), the variation of the factor of safety against the liquefaction potentials with depth of the soils is plotted in Fig. 2.

As shown on the figure , the factor of safety for sabkha soil in the upper 10m to 12m, are mainly below (1). This indicate that sabkha soil has highly susceptibility to liquefaction at earthquake magnitude of (5.5) in the future.

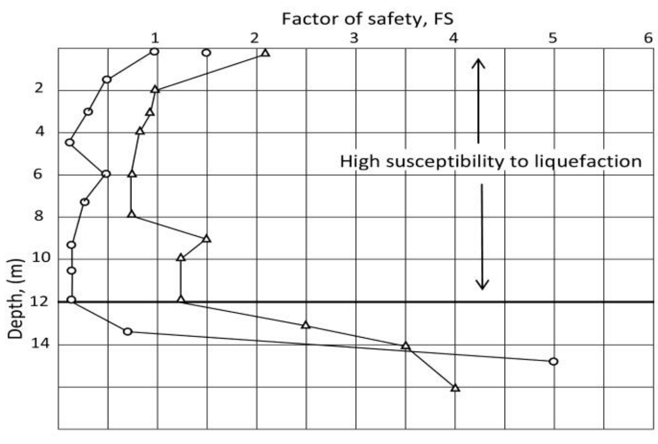

Fig. 2 : Factor of safety against liquefaction potential from different sites.

VI. CONCLUSION

The factor of safety against liquefaction, in upper 10m to 12m of sabkha soil is generally less than one . Accordingly, this portion of strata within the study area have high susceptibility to liquefaction.
The liquefaction potential could be reduced by soil improvement that can densify loose soil. Soil densification could be conducted by dynamic compaction , vibrocompaction or vibro-stone columns .

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