International Journal on
"Technical and Physical Problems of Engineering"
(IJTPE)
Published by International Organization of IOTPE

ISSN 2077-3528
IJTPE Journal
www.iotpe.com
ijtpe@iotpe.com

June 2018 | Issue 35 | Volume 10 | Number 2 | Pages 26-29

LIQUEFACTION POTENTIAL FOR ABSHERON PENINSULA SOILS

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Abstract- Liquefaction potential of soil is one of the essential parameters in geotechnical and civil engineering. Soil liquefaction is responsible for tremendous amounts of damage in historical earthquakes around the world. The article is dedicated to the investigation on the applicability of the Standard Penetration test results for assessment of liquefaction potential of soils in Absheron peninsula in Azerbaijan.

Keywords: Liquefaction, Seismicity, Geotechnical engineering, Evaluation.

I. INTRODUCTION

Absheron Peninsula of Azerbaijan is a densely populated industrial zone, rich with oil, but sensitive and subjected to seismicity factors. Due to intensive construction activities, the knowledge of the behaviors of structure during the earthquake is vital. The soil is the crucial part of the control over the structure response to seismic conditions.

The liquefaction phenomenon mainly occurs in sandy soil due to the tendency of a loose sand to compress under applied load. If the sandy soil layer is located below the ground water table or sea level, its pore spaces between soil grains are filled with water. When load is applied, soil compressed, the pore water pressure increases and tends to flow out from the soil to low pressure zones. If the applied load is rapid and large, or is repetitive like earthquake shaking, the pore water pressures may increase to an extent where they exceed the contact stresses between the grains of soil grains that keep them in contact with each other. The contact stresses between soil grains keep soil structure and allow to transfer loads from buildings and structures to deeper and stronger soil layers. When soil loses its structure, it loses its strength and may flow like a liquid (Figure 1).

Soil liquefaction can cause extensive damage to buildings, structures, roads and etc. Liquefaction potential of soils as a major factor for destruction was known for a long time, but it brought the attention after the Niigata earthquake and Alaska earthquake 1964. The other examples of liquefaction potential consequences were observed in San Francisco's Marina District during the Loma Prieta earthquake in 1989, and in Port of Kobe during the Great Hanshin earthquake in 1995.

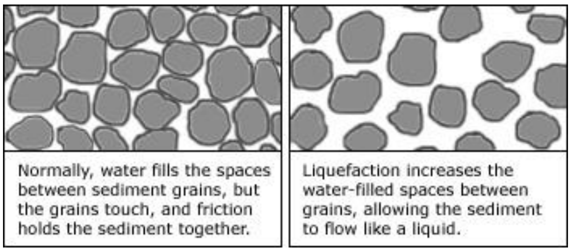

Figure 1. Change in soil grain behavior during liquefaction [1]

In modern times the building codes and standards require consideration of the effects of potential soil liquefaction for the design of new buildings and structures.

There are different techniques allowing estimating the liquefaction potential of soil such as SPT [3], CPT [4], Seismic shear wave velocity test [5], Becker Penetration test [6], etc. One them is based on Standard Penetration test results. This approach was developed by Seed and Idriss in 1967 and is used since then as one of the easiest ways of determination of soil liquefaction potential from mid-20th century.

Figure 2. Some effects of liquefaction during the 1964 Niigata earthquake (Photo Credit: National Geophysical Data Center)

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II. RELEVANCE OF SOILS SUSCEPTIBILITY TO LIQUEFACTION IN AZERBAIJAN

Azerbaijan territory as a part of the Alpine folded system, is known for its high seismic activity - 8 and 9 points according to MSK-64 scale [2]. A number of strong and catastrophic earthquakes were observed here from ancient times until modern days. These earthquakes resulted in large number of fatalities and destructions. One of the results of earthquakes causing damages is soil liquefaction occurring in saturated or partly saturated soils which may lose its strength in response to sudden change in stress condition (during earthquake), and behaves like a liquid.

Taking into account that numerous buildings and structures are constructed in Azerbaijan and especially in Baku last years, particularly those structures built in artificial islands, the likelihood from soil liquefaction should be estimated before construction stage. In this article, liquefaction potential of soil is estimated based on results of Standard Penetration Test (SPT), which is broadly distributed in the region and therefore can serve as a reliable indicator.

III. SPT AS A METHOD OF ESTIMATION OF LIQUEFACTION POTENTIAL OF SOILS

Liquefaction occurs in loose, saturated, cohesionless materials potential of soil is defined according to Seed and Idriss method [3]. This method described systematic determination of soil liquefaction potential based on Standard Penetration Test (SPT).

Method of Standard Penetration Test (SPT) was invented in 1927 and is one of the most used methods of obtaining information about physical properties of soils onshore and offshore. In Azerbaijan SPT test is used together with other field geotechnical tests as a unit. The main point of this test is the penetration of sampler into soil with the use of a 63.5 kg hammer falling from 760 mm height. The weight of hammer pushed the sampler into ground and number of blows driving the sampler 300 mm into soil is registered. Physical and mechanical properties of soil are determined based on the number of blows N. SPT is often used on cohesionless granular soils.

Seed and Idriss initiated the approach for liquefaction potential triggering in 1967. The basic framework, as adopted by numerous researchers, compares the cyclic stress ratios (CSR) of the soil induces by earthquake with the cyclic resistance ratios (CRR). This method was developed to evaluate various factors which may affect cyclic resistance and penetration resistance.

IV. DETERMINATION OF SOIL LIQUEFACTION POTENTIAL FROM SPT

To estimate the liquefaction potential of soil, the earthquake-induced seismic shear stress ratio SSR, at a given depth z within the soil profile, is determined as a representative value equal to 65% of the maximum seismic shear stress ratio, i.e.:

$$SSR = 0.65 r_d \left(\alpha_{\max} / g\right)\left(\sigma_{vo} / \sigma'_{vo}\right) \quad (1)$$

where, r_d is shear stress reduction factor that accounts for the dynamic response of the soil profile; $\alpha_{\max}/g$ is maximum horizontal acceleration (as a fraction of gravity) at the ground surface; σ_{v0} is vertical total stress at a particular depth where the liquefaction analysis is being performed; and σ'_{v0} is vertical effective stress at the same depth where the σ_{v0} was calculated.

$$\begin{aligned} \sigma'_{v0} &= \sigma_{v0} - U \\ \sigma_{v0} &= \gamma_1 Z_1 + \gamma_2 Z_2 \end{aligned} \quad (2)$$

where, $U = \gamma_w Z_w = 1$ g/cm^3 water level, m; Z_1 is depth below ground level for first layer of soil; Z_2 is depth below ground level for second layer of soil; Z_w is depth below groundwater table; γ_1 and γ_2 are unit weights of soil; and γ_w is unit weight of water.

The soil's seismic shear stress ratio SSR is usually correlated to a field parameter such as SPT blow count which is affected by a number of procedural details (borehole size, rod lengths, sampler details, hammer energy and etc.) and by effective overburden stress. Thus, for determination of in-situ SSR SPT data is collected and N-values are corrected for field-testing and overburden pressure according to the equation:

$$\left(N_1\right)_{60} = C_N N_{60} \left(100 / \sigma'_{v0}\right)^{0.5} N_{60} \quad (3)$$

where, N_{60} is value corrected for field test procedures.

$$N_{60} = 1.67 E_m C_b C_r N \quad (4)$$

where, E_m is hammer efficiency; C_b is borehole diameter correction; C_r is rod length correction; and N is measured SPT value.

Once the SPT $N_{1(60)}$ has been calculated, in-situ SSR corresponding to these values are found from the chart (see picture 3 below). After that, the in-situ SSR values are compared with earthquake SSR values. If the earthquake SSR values are higher than in-situ SSR values, then liquefaction can occur during the earthquake.

Sample site was chosen for the analysis of soil liquefaction potential in this paper. SPT data was collected for the upper loamy sand layer, which is suspected to be liquefiable under cyclic load, and calculation performed on this basis. The results of calculations are presented in Table 1. As it is seen from the Table 1, the loamy sand layer in boreholes BH-1 and BH-23 have potential for liquefaction during earthquake.

V. CONCERNS ASSOCIATED WITH RELATION OF SPT OBTAINED RESULTS TO OTHER METHODS

The standard Penetration Test (SPT) is well studied in Azerbaijan as the method of estimation of soils relative density. The results of SPT test carried out for the same regions show same results; therefore, this test can be used as a reliable source of data for evaluation of soils liquefaction potential.

Cone Penetration Test (CPT) method is widely used in the world as a possible substitute to SPT for soft clays, silts, and fine sands. This test method is not so popular in Azerbaijan as SPT method. However, the relationship between two testing methods is an important factor, as the analytical instruments based on each of them can be interrelated and hence soil parameter can be derived. Interconnection of SPT and CPT tests and their analytical interconnections can then extend the analytical basis of geotechnical engineer.

The main point of CPT method is penetration of standard cone into soil with the speed of 10-20 mm/sec and registration of soil resistance. Soil resistance is calculated from side friction along the perimeter of the cone and the pressure on cone tip. CPT gives information about side friction q_s and point resistance q_p. Besides, changing the equipment configuration allows to determine pore pressure and temperature of soil.

This method also has some weaknesses. In case of hard soils CPT procedure is complicated. Soil samples cannot be restored. And at last, CPT requires stable and flat surface for testing.

The Cone Penetration Test (CPT), in comparison with CPT is not used widely in Azerbaijan area. As it was stated above, soils in the region are not suitable for broad use of this test. Also, the cost of this test is much higher and there is no statistical database of CPT results for the same areas. Moreover, the SPT-CPT correlations were calculated in the previous paper (reference) and the results showed that values of $n=q_c/N$ (q_c is cone resistance from CPT test, N is number of blows from SPT test) calculated for Absheron peninsula soils differs from values of n calculated for other countries.

Taking into account the above mentioned conclusions, CPT results cannot be considered as a valid data for evaluation of soil liquefaction potential.

A. Study Area

The sample site was chosen for analysis of liquefaction potential of soil. Borings were drilled to the depth of 20 m, and SPT and CPT tests performed for the selected area. The saturated loamy-sandy soil layer was chosen for evaluation of liquefaction potential.

Table 1. Results of soil liquefaction potential calculations based on actual *N*-values determined from Standard Penetration Test (SPT)

Soil type	*N* value from SPT	Cyclic Resistance Ratio CRR (in situ)	Cyclic Shear Stress Ratio CSR (earthquake)	Liquefaction potential
Loamy sand	2	0.1	0.5308653	Yes
Loamy sand	12	0.26	6.6395333	Yes
Loamy sand	12	0.27	0.156498	No
Loamy sand	13	0.28	6.6395333	Yes
Loamy sand	20	0.6	0.1714162	No
Loamy sand	12	0.26	0.3905608	Yes
Loamy sand	14	0.3	0.3626123	Yes
Loamy sand	13	0.28	0.3242406	Yes
Loamy sand	5	0.13	0.1402045	Yes
Loamy sand	14	0.32	0.2188857	No

VI. CONCLUSIONS

SPT tests are widely used in Azerbaijan as a technique to evaluate soils' geotechnical capabilities. Their applicability and spread into the area of assessment the liquefaction potentials would significantly enhance our capabilities to evaluate soils responses to seismic events.

The liquefaction potential of soils calculated based on SPT values can be used for Azerbaijan soils with sufficient reliability. The full acceptance of such method

Although CPT tests are also in used in the country, the use of correlated CPT-SPT values for determination of soil liquefaction potential is not advisable, as the correlation coefficient calculated for the region differs from the same coefficient for other countries.

NOMENCLATURES

A. Acronyms

SPT: Standard Penetration Test
CPT: Cone Penetration Test
CSR: Cyclic Stress Ratio
CRR: Cyclic Resistance Ratio
SSR: Seismic Shear Stress ratio

B. Symbols / Parameters

q_s: Side friction
q_p: Point resistance
q_c: Cone resistance
N: Number of blows

REFERENCES

[1] http://earthobservatory.nasa.gov/Study/Earthquake, February 17, 2006.
[2] AzDTN 2.3-1 Construction in Seismic Zones.
[3] H.B. Seed, I.M. Idriss, "Simplified Procedure for Evaluating Soil Liquefaction Potential", Journal of Soil Mechanics and Foundations Division, ASCE, Vol. 97, No. SM9, pp. 1249-1473, 1971.
[4] P.K. Robertson, R.G. Campanella, "Liquefaction Potential of Sands Using the CPT", Journal of the Geotechnical Engineering Division, ASCE, Vol. 111, No. 3, pp. 384-403, 1988.
[5] D.A. Ronald, K.H. Stokoe, C. Hsein Juang, "Guide for Shear-Wave-Based Liquefaction Potential Evaluation", Earthquake Spectra, Vol. 20, No. 2, pp. 285-308, May 2004.
[6] NCEER 97-22, National Center for Earthquake Engineering Research, Buffalo, New York, Proceedings of the NCEER Workshop on Evaluation of Liquefaction Resistance of Soils, Salt Lake City, Utah, January 5-6, 1996.

BIOGRAPHIES

Faik T. Rzayev was born in Baku, Azerbaijan, 1953. In 1975 he graduated from Azerbaijan State Oil Academy, Baku, Azerbaijan. In 1989 he defended the Ph.D. thesis in Physics and Mathematics at Azerbaijan State University, Baku, Azerbaijan. Since 1978 he works in Institute of Physics, Azerbaijan National Academy of Sciences, Baku, Azerbaijan. At present he is also Director of Encotec Company, Baku, Azerbaijan. He has published more than 50 papers in the proceedings and journals of many countries, reports and appearances at international conferences.

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