ASSESSMENT OF LIQUEFACTION POTENTIAL USING SPT AT A SITE IN AHMEDABAD

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ABSTRACT

The common test performed for any site investigation is SPT test. For liquefaction potential analysis the value obtained from SPT can be used. Many researchers have developed different methods to investigate liquefaction potential from N value. In this paper Ahmedabad region is studied for liquefaction analysis from the N value. Site Kalupur-Relief road, Navarangpura and Meritiane hotel seems to be critical, while Ashram road and Rupali cinema are safe. Graph of Factor of safety i.e. CRR/CSR versus is plotted. For correction of N value the method given by Seed and Idriss is used while for Liquefaction analysis equation given by Youd et al. is used.

Keywords- Liquefaction Potential, Standard penetration test, factor of safety, Ahmedabad

INTRODUCTION

The development of high pore water pressures due to the ground shaking and the upward flow of water may turn the sand into a liquefied condition, which has been termed liquefaction. For this state of liquefaction, the effective stress is zero, and the individual soil particles are released from any confinement, as if the soil particles are floating in water (Ishihara 1985). There are two general approaches for the assessment of liquefaction. One is the use of laboratory testing of undisturbed samples and other is the use of empirical relationships based on correlation of observed field behavior with various in-situ tests for identifying the index properties (Cetin et al. 2004). The later approach is the dominant approach and is common in practice. The main reason for the selection of later approach is due to the experimental difficulties and high cost in the former approach. Seed and Idriss (1971) developed a method for liquefaction potential based on both laboratory and field based data. The method was called simplified method. This method was modified by Seed et al. (1985) with use of the field based SPT data only. Later, twenty experts reviewed and developed more convincing empirical approach based on SPT and related development made summarized four in-situ tests methods for over the previous decade (Youd et al. 2001).They the assessment of liquefaction. These are namely; (1) the standard penetration test

(SPT) (2) the cone penetration test (3) measurement of in-situ shear wave velocity (Vs) and (4) the Becker penetration test. Among these tests, the oldest and still the most widely used method is SPT, and in this paper also the same method is used.

The procedure widely used in the world for evaluating soil liquefaction resistance is termed as the ‘‘simplified procedure.’’ This simplified procedure was originally developed by Seed and Idriss (1971) using blow counts from the standard penetration test (SPT) correlated with a parameter called the cyclic stress ratio that represents the cyclic loading on the soil. Since 1971, this procedure has been revised and updated (Seed 979; Seed and Idriss 1982; Seed et al. 1983, 1985; Youd et al. 1997). In the mid-1980s, a parallel procedure based on the cone penetration test (CPT) was introduced by Robertson and Campanella (1985), which also has been revised and updated (Seed and de Alba 1986; Stark and Olson 1995; Olsen 1997; Robertson and Wride 1998).The purpose of this paper is to present relation between liquefaction potential and $(N_1)_{60CS}$ for Ahmedabad city.

STUDY AREA

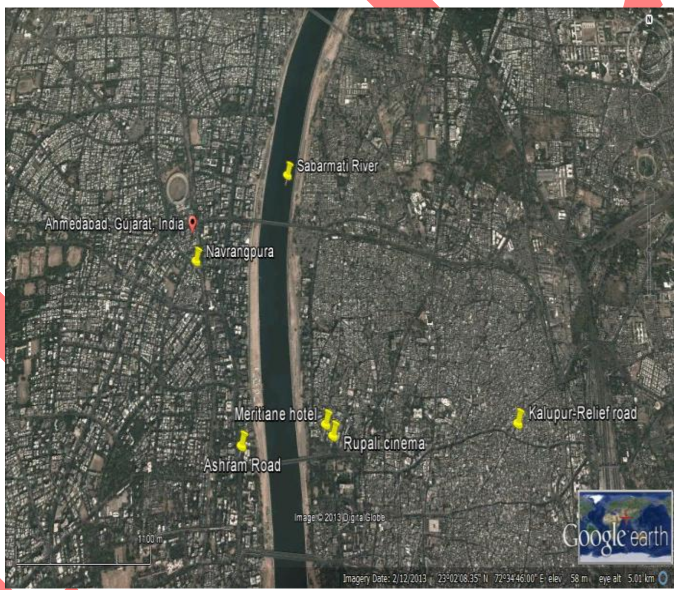

Figure 1 Site location of SPT bore hole in Ahmedabad city

Liquefaction is phenomena which occur in sandy, silty sand or sandy silt type soils. In Ahmedabad, there are several areas where there is a silty sand found. As the Sabarmati river passes through Ahmedabad city, ground water table (GWT) is low in the downstream area. Even Cambey fault line and Kutch fault line, which are active faults, are near the Ahmedabad city, which creates the probability of earthquake. Thus, this subject drew the attention for liquefaction potential analysis.

EVALUATION OF LIQUEFACTION POTENTIAL

If it is determined that the soil has the ability to liquefy during an earthquake and the soil is below or will be below the groundwater table, then the liquefaction analysis is performed in three steps. The first step in the simplified procedure for analysis is to calculate the cyclic stress ratio (CSR) that is caused by the earthquake. In the second step, cyclic resistance ratio (CRR) is calculated. And from both these values, factor of safety is calculated in third step, which is the ratio of CRR to CSR.

A. *Cyclic stress ratio (CSR)*

The cyclic stress ratio (CSR), at a particular depth in a level soil deposit is calculated from simplified procedure given by Seed and Idriss (1971) is expressed by

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

Where, a_{max}= Maximum horizontal acceleration at ground surface that is induced by the earthquake, ft/s^2 or m/s^2. The maximum horizontal acceleration is also commonly referred to as the peak ground acceleration, σ_{vo}, σ'_{vo}= total vertical stress at bottom of soil column and effective vertical stress respectively, lb/ft^2 or kPa, r_d=stress reduction factor.

For value of r_d as per the recommendation of Natonal Center for Earthquake Units Engineering search (NCEER, 1997), variation of rd with depth z is shown in Table-I.

TABLE I. VARIATION OF r_d WITH DEPTH Z

r_d	Condition
1-0.00765*Z	$Z \leq 9.15$m
1.174-0.0267*Z	$9.15 < Z \leq 23$m
0.744-0.008*Z	$23 < Z \leq 30$m
0.5	$Z > 30$m

B. *Cyclic resistance Ratio (CRR)*

SPT N value obtained from the field test is used for estimation of CRR. The measured N value is corrected by following equation,

$$(N_1)_{60}=N_{SPT}C_NC_EC_BC_RC_S$$

Where, $(N_1)_{60}$ = corrected standard penetration test blow count, N_{SPT} represents the measured standard penetration resistance. The values of other correction factors are as noted in Table II.

TABLE II. CORRECTION FACTOR OF SPT

Factor	Equipment Variable	Term	Correction
Overburden Pressure		C_N	Pa=100kPa
Energy ratio	Donut Hammer Safety Hammer Automatic-Trip Donut-Type Hammer	C_E	0.5 to 1.0 0.7 to 1.2 0.8 to 1.3
Borehole diameter	65 mm to 115 mm 150 mm 200 mm	C_B	1.0 1.05 1.15
Rod length	3 m to 4 m 4 m to 6 m 6 m to 10 m 10 m to 30 m 〉30m	C_R	0.75 0.85 0.95 1.0 〈1.0
Sampling method	Standard sampler Sampler without liners	C_S	1.0 1.1 to 1.3

The following equations were developed by I. M. Idriss with the assistance of R. B. Seed for correction of $(N_1)_{60}$ to an equivalent clean sand value, $(N_1)_{60CS}$

$$(N_1)_{60CS} = \alpha + \beta(N_1)_{60}$$

Where α and β = coefficients can be determined from the following relationship for different fine content (FC):

$\alpha = 0$ for $FC \leq 5\%$

$\alpha = \exp[1.762(190/FC)]$ for $5\% < FC < 35\%$

$\alpha = 5.0$ for $FC \geq 35\%$

$\beta = 1.0$ for $FC \leq 5\%$

$\beta = [0.991(FC/1{,}000)]$ for $5\% < FC < 35\%$

$\beta = 1.2$ for $FC \geq 35\%$

These equations are used for routine liquefaction resistance calculations.

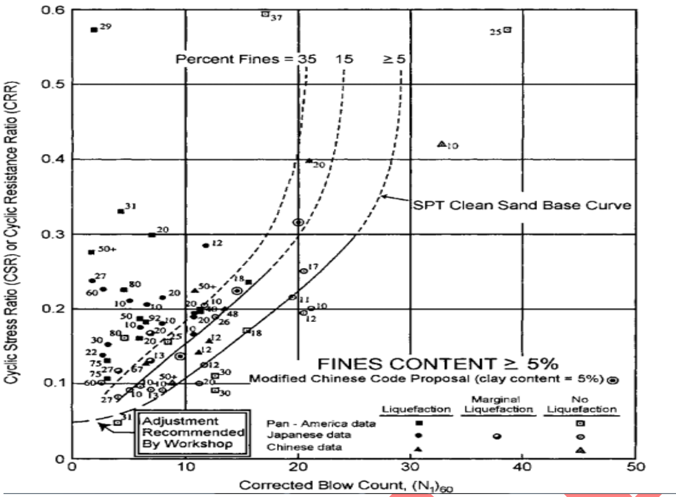

Figure 2 SPT Clean-Sand Base Curve for Magnitude 7.5 Earth-quack with Data from Case Histories (Modified from Seed et al. 1985)

CRR depends on the fine content of the soil. For fine contents equal to or more than 5%, SPT clean sand based curve with relationship between CSR and $(N_1)_{60}$, suggested by Youd et al. (2001) is used, which is shown in figure 2. And for fine contents less than 5%, CRR is calculated using following equation.

$$CRR_{7.5} = \frac{1}{34-(N_1)_{60}} + \frac{(N_1)_{60}}{135} + \frac{50}{[10(N_1)_{60}-45]^2} - \frac{1}{200}$$

This equation is valid for $(N_1)_{60} < 30$. For $(N_1)_{60} \geq 30$, clean granular soils are too dense to liquefy and are classified as non-liquefiable.

C. Factor of Safety:

The last step of analysis is calculation of factor of safety (FS). Youd et al. (2001) has suggested the following equation, in which influense of magnitude scaling factor is included.

$$FS = \left(\frac{CRR_{7.5}}{CSR}\right)MSF$$

Where, MSF is the magnitude scaling factor. For earthquake magnitude other than 7.5, we need to modify FS by multiplying it by MSF.

The value of MSF as introduced by Andrus and Stokoe (1997) can be used, which is as below,

$$MSF = \left(\frac{M_w}{7.5}\right)^{-2.56}$$

Where M_w is magnitude of earthquake. The higher the factor of safety, the more resistant the soil is to liquefaction. Liquefaction potential is defined in four parts from FS.

FS < 1.5 - Critical

FS = 1.5 to 2.5 - Moderate,

FS = 2.5 to 4 - Low critical,

FS > 4– safe

RESULT AND DATA ANALYSIS

In Ahmedabad city, boreholes of location, Ashram road, Kalupur – Relief road, Navrangpura, Meritine Hotel and Rupali Cinema are selected as GWT found to be high, which may be prone to the liquefaction.

The FS versus $(N_1)_{60}$ is calculated. For generation of graph, the FS values below the ground water table were considered for analysis. In graph, location and borehole numbers are indicated.

Equation used here is suggested by Youd et al. (2001). And thus the graph from the value calculated shows same pattern as given by the NCEER workshop on liquefaction resistance of soils.

It was observed that FS was increased with increase in $(N_1)_{60CS}$ in all borehole location (Fig. 3) except in borehole in Kalupur – Relief road area at particular depth 3.0 m, In Navarangpura at 3.5 m, Meritine hotel at 6.0 m and Rupali cinema at 3.0 m depth. For the same $(N_1)_{60CS}$ value, it is observed that there is increase in FS, which may be due to the increase in fine content.

GWT is also most important and governing factor that may causes variation in liquefaction potential. It is obvious that lower depth of GWT indicates the higher probability of liquefaction. The GWT position of different places selected are as below. Ashram road (7.0 m), Kalupur – Relief road (12.0 m), Navarangpura (12.0 m), Meritine hotel (15.0 m), and Rupali cinema (6.0 m).

The variation in value of FS that was observed in these study sites may also be due to the difference in GWT. From the study, it was observed that Ashram road, Kalupur – Relief road, Navrangpura, Meritine Hotel and Rupali Cinema seem to be critical liquefiable zone

Typical liquefaction analysis spread sheet is shown in Table III. From Table III, the top layer up to 9m has the corrected 'N' value of less than 25, which results in the factor of safety of less than 1.5. Which look like the site is not safe against liquefaction, but if look at the properties of filled up soil, which has plastic limit of more than 35, one can say that site is safe against liquefaction

CONCLUSION

From the study of some area of Ahmedabad city, the following conclusions were drawn from analysis The site specific liquefaction potential analysis by using empirical approach Site, Kalupur-Relief road, Navarangpura and Meritiane hotel seems to be critical, while Ashram road and Rupali cinema are safe.

i) For the same $(N_1)_{60cs}$, FS increased with increased in fine content.
ii) Graph from the calculation shows same pattern as given by the NCEER workshop on liquefaction resistance of soils.

TABLE III. CALCULATION OF FS AT ASHRAM ROAD BOREHOLE

GWT=7.0 m, a_{max}=0.3g, Mw=7.5									
Depth(m)	$(N_1)_{60cs}$	FC (%)	σ_{vo} (KN/m^2)	σ'_{vo} (KN/m^2)	r_d	CSR	CRR	Liquid limit (%)	FS
1	12	32	14.81	14.81	0.99	0.22	0.13	55	0.60
3	14	80	45.42	45.42	0.98	0.22	0.15	56	0.70
6	25	84	93.10	93.10	0.95	0.21	0.30	41	1.39
9	23	78	144.60	124.98	0.91	0.24	0.26	42	1.07
12	30	14	199.34	150.29	0.86	0.26	0.48	50	1.88

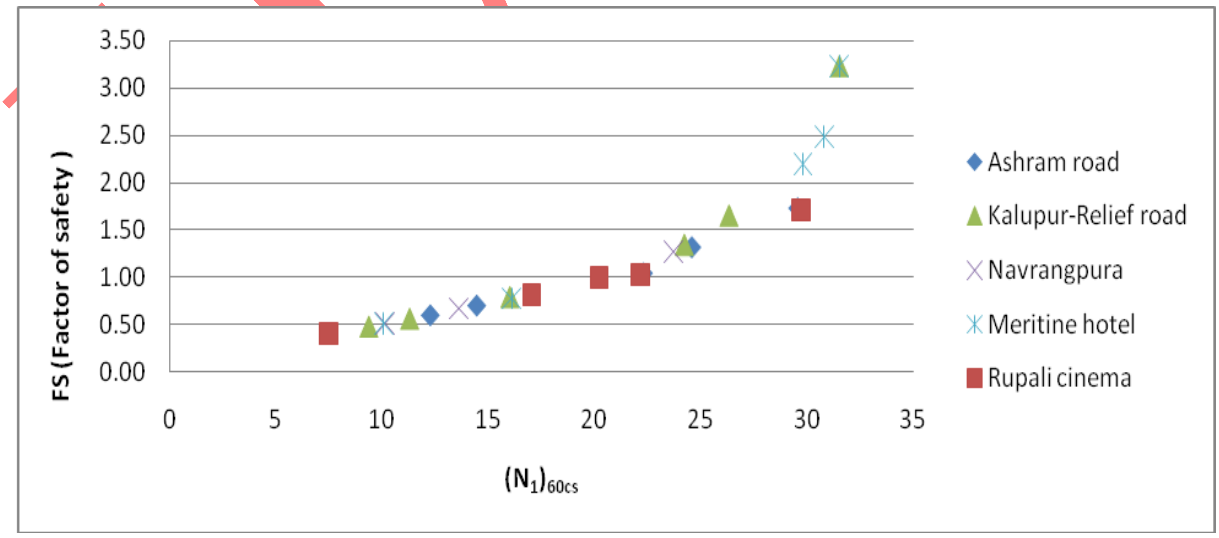

Figure 3 FS versus $(N_1)_{60cs}$

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