Assessment of SPT-Based Liquefaction Potential of Kalyani Region, Kolkata

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Abstract. Liquefaction is the phenomena in which the saturated fine sand loses its shear strength and stiffness when a cyclic or an earthquake loading. The evaluation of liquefaction potential and seismic microzonation of a certain area can be done. Ground improvement requirement of a site is conducted after the evaluation of liquefaction potential of that site.
The aim of the present study is to evaluate of liquefaction potential for AIIMS kalyani Campus, Kolkata. Kalyani is a city which comes under Nadia district, of west Bengal it is located around 50 km from Kolkata city.
The main objective of the present study is to evaluate the liquefaction potential of AIIMS Kalyani Campus for different magnitudes of earthquake i.e. 7.5, 7.0 and 6.5 and peak ground acceleration (a_{max} = 0.16g). For this purpose, the factor of safety against liquefaction was evaluated at different depths for the six sites in AIIMS Kalyani campus based on SPT-Based approached. It was found that the factor of safety against the liquefaction for magnitude of earthquake 6.5 is marginally greater than that 7.5 and 7.0 for all the sites. It can be observed that from the results that the FOS against for 6.5 magnitude earthquake is 21% greater than that for 7.0 magnitude earthquake.

Keywords: *Liquefaction Potential; Cyclic Stress Ratio; Cyclic Resistance Ratio; SPT N-Values; Kolkata City*

1. Introduction

The deformation of the soil with minimum resistance due to arising high pore water pressure is coming in liquefaction process. Generally, liquefaction occur in clean saturated fine sand and does not occur in fine grain soil [1]. One of the major causes of serious damage to the structures, foundations and structures which are constructed underground [2].
After the 1964 Alaskan and 1964 Niigata earthquakes the term Liquefaction and its phenomena was considered, many earthquakes and damages related to those have been observed in past two decade. For example, Bhuj India (2001), Chi-Chi Taiwan (1999) etc. As we look towards our past several researchers around the world have studied about the liquefaction. From [3] development began and hence was taken

gradually by [4-9]. Earlier study of liquefaction potential is done by [10] for different sites using artificial neural network. Many researchers [11-14] extended previous studies on the use of SPT data for evaluation of liquefaction resistance. Few studies for liquefaction potential based on SPT data for Kolkata region done by [2, 10] and other region i.e. Roorkee Region by [14-16] Guwahati region [17] Mumbai [18] Ahmedabad region [19] and Chandigarh region [20]. [21] Developed relationship between SPT N and Shear wave velocity for Roorkee region.

Liquefaction is the phenomena in which when a suitable intensity earthquake shakes a deposit of loose saturated cohesion less soil then the rapid loss of shear strength occurs and hence when shear strength becomes zero then Liquefaction occurs in undrained condition [1]. Liquefaction occur in saturated condition in which water is filled in pores between the soil grains. So, the force of attraction is reduced and hence soil becomes in flow condition. Considering the extreme condition, due to increase in pore water pressure the contact between the soil particles reduced and they lose their contact with each other.

Main aim of this research paper is to evaluate the Liquefaction potential for AIIMS Kalyani campus for different magnitudes of earthquake (Mw = 7.5, 7.0 and 6.5) and peak ground acceleration (PGA = 0.16g). This is done by finding the factor of safety against liquefaction. By calculating the factor of safety different zones is shown by considering the different location of the site. When the seismicity of the location is specifying then proper measures must be taken as per seismicity towards liquefaction. This research will be helpful for microzonation and Liquefaction Hazards map of Kolkata city.

2. Study Area

Table 1 Location of Sites in AIIMS Kalyani campus

S. No.	Name of Sites	Bore log Depth (m)	Latitude	Longitude	Water Table Depth (m)		No. of SPT Samples
					Actual	Assumed	
1	BH-01	16.00	N22°58′12.62″	E88°31′38.44″	2.8	Ground	08
2	BH-02	16.00	N22°58′16.20″	E88°31′34.27″	3.1	Ground	08
3	BH-03	16.00	N22°58′22.27″	E88°31′42.24″	1.6	Ground	09
4	BH-04	16.00	N22°58′34.55″	E88°31′47.16″	3.3	Ground	10
5	BH-05	16.00	N22°58′30.55″	E88°31′52.90″	1.4	Ground	09
6	BH-06	16.00	N22°58′43.74″	E88°31′53.97″	1.8	Ground	09

The present study deals with the assessment of the liquefaction potential of the AIIMS Kalyani Kolkata West Bengal region. ‘Kalyani’ is a city located around 50 kilometers from Kolkata the capital of West Bengal. Kalyani lies along the east bank of Hoogly River, within the upper Ganges delta. As with most of the Indo-Gangetic plain the soil and water are predominantly alluvial in origin. According to the Bureau of Indian

standards (BIS) on scale ranging from I to V in order of increasing susceptibility to earthquakes the Kolkata city lies in seismic zone III, [22]. For the liquefaction potential of soil of AIIMS Kalyani region, soil samples of different locations of AIIMS Kalyani region has been collected. Details of locations of sites, depth of water table are shown in the Table 1. From the Table 1. Soil samples was collected with the help of SPT in order to find N values and soil profile for geotechnical investigation for AIIMS Kalyani campus.

3. Methodology

The present study generally deals with the evaluation of liquefaction potential of AIIMS kalyani region. After the collection of data obtained from the soil samples which were collected from the SPT based test the next step is evaluation of the liquefaction potential based on that data. The evaluation of liquefaction potential is done based on Youd e*t al.* (2001) procedure. The methodology of analysis includes following three steps;

(a) Evaluation of cyclic stress ratio (CSR).
(b) Evaluation of cyclic resistance ratio (CRR).
(c) Evaluation of factor of safety (FOS) against Liquefaction

3.1 Cyclic Stress Ratio

Cyclic stress ratio is the ratio of the average shear stress due to earthquake loading and the effective stress it is calculated using simplified procedure given by [23].

$$CSR = 0.65 \times \left(\frac{a_{max}}{g}\right) \times \left(\frac{\sigma_{vo}}{\sigma'_{vo}}\right) \times r_d \quad (1)$$

Where; σ_{vo} is the total stress; σ'_{vo} is the effective stress; a_{max} is peak horizontal acceleration at the ground surface (for Seismic zone-III, a_{max} = 0.16g considered); g is the acceleration due to gravity and r_d is the stress reduction coefficient, calculated from [23]. In this study to evaluate the liquefaction potential for the different earthquakes magnitudes of (M_w) 7.5, 7.0 & 6.5.

3.2 Cyclic Resistance Ratio

Cyclic resistance ratio evaluated using Eq. 3 [23]. Eq. 3 for an earthquake with magnitude other than 7.5, $CRR_{7.5}$ is multiplied by a magnitude scaling factor (MSF) as mention in Eq. 5

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

Where $(N_1)_{60CS}$ is the corrected value of N based on overburden, hammer efficiency and fine correction are calculated according to Seed and Idriss in Eq. (3)

$$(N_1)_{60cs} = \alpha + \beta(N_1)_{60} \quad (3)$$

Where α & β are the coefficients depends on the fines contents (FC). The vales of α & β are obtained from expression mention by [23].

$$CRR = CRR_{7.5} \times MSF \quad (4)$$

Where;

$$MSF = 102.24/Mw^{2.56} \quad (5)$$

3.3 Factor of Safety

The factor of safety against liquefaction is commonly used to quantify liquefaction potential of sites. The FOS is defined as the ratio of CRR to CSR. If the values of FOS are less than one, than liquefaction will occur. FOS calculated using below Eq. 6

$$FOS = \frac{CRR}{CSR} \quad (6)$$

4. Geotechnical Investigation

In the present study the Liquefaction Potential of AIIMS Kalyani region West Bengal were evaluated. For this purpose, the liquefaction potential evaluates in the term of FOS based on SPT data. Geotechnical investigation has been done, samples collected from *in-situ* tests i.e. SPT by geotechnical consultant, Centre for Advanced Engineering (CAE) Kolkata. Standard Penetration Test was performed as per the guidelines and provision of [24]. The Fig.1 Shows the SPT N and overburden corrected SPT N-Values $(N_1)_{60}$ with the depth for all the sites i.e. BH 01 to 06 which represents different sites locations.

It is seen that the $(N_1)_{60}$ values are more than N obtained from SPT (N-SPT) initially, but they decrease with the depth. Further, around the 8.0m depth, $(N_1)_{60}$ value goes less than from N-SPT and remains to be so for further depths. This can be attributed to the over burden pressure correction (C_N).

Mainly three types of layer in AIIMS Kalyani region identified [25]. The salient features of subsoil area of this site are obtained which is as follows:

a) Depth of 1st layer is between around 3.5m to 4.5m which consist of soft to medium brownish grey clayey silt with traces of sand and kankar. The range of N value is 4 to 11.
b) Depth of 2nd layer is between 6.5m to 13m carries loose to medium grey silty fine sand and the range of N value is from 9 to 28.
c) The Strata III generally contains soil deposit from dense to very dense grey fine to medium sand with traces of silt the range of thickness is up to the maximum explored depth of 20m and range of N value is from 29 to 55.

Table 2.0 summarized of key point of soil investigation i.e. depth of borehole N-values, unit weight, specific gravity, depth of water table and numbers of SPT samples collected from all the locations in AIIMS Kalyani campus. Dry density of soil varies from 1.42 to 1.45. Specific gravity of at every site is also almost same var-

ies from 2.63 to 2.68. Maximum fine content (FC) is varying from 79% to 89% at BH-04 location.

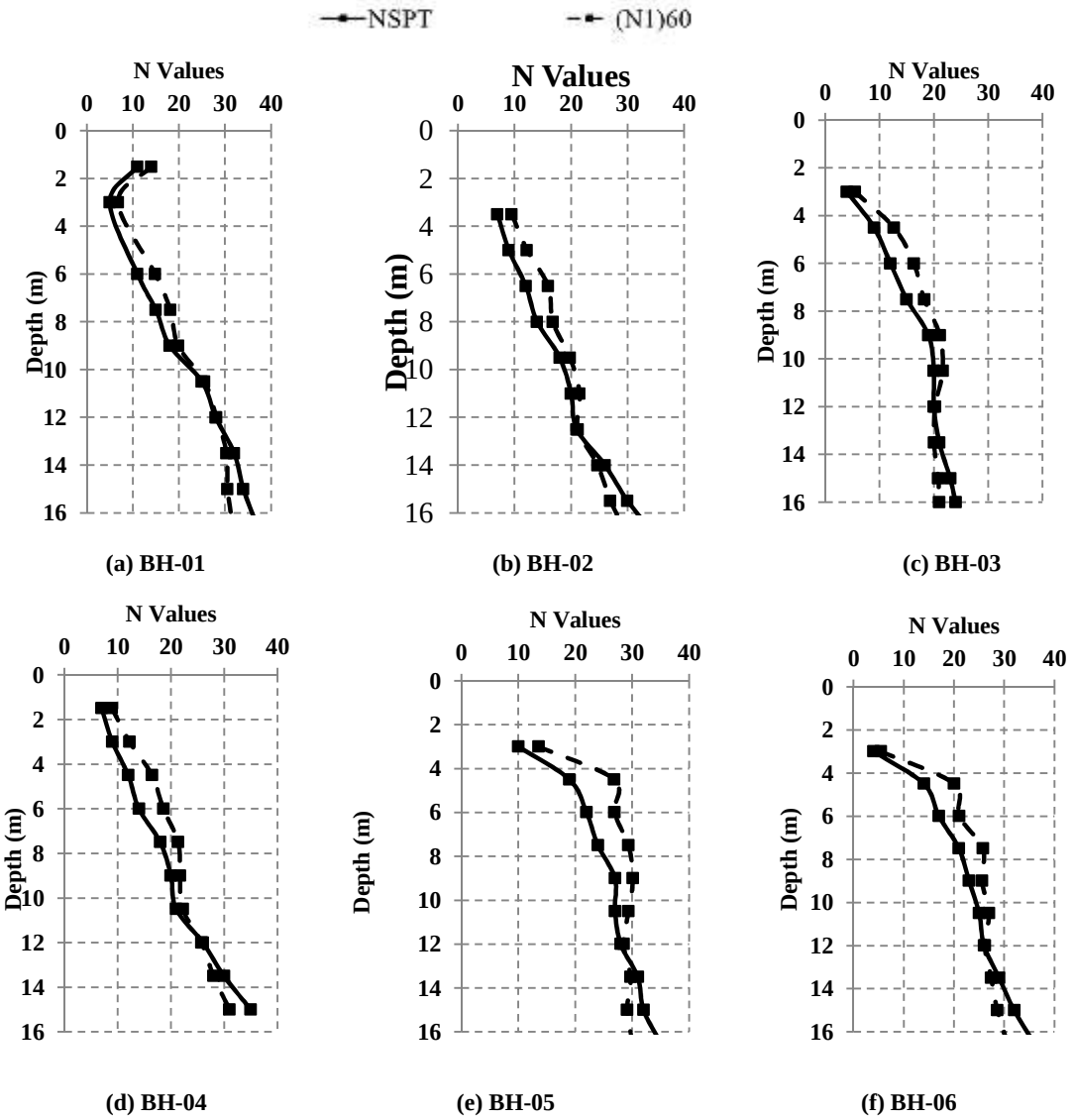

Fig.1 SPT N and $(N_1)_{60}$ with the depth for all the sites in AIIMS Kalyani

Table 2 Summary of key points of all the sites

S. No.	Name of Sites	Depth (m)	N Values	FC (%)	(kN	Specific Gravity (G)	Water Table (m)	SPT Samples
1	BH-01	16	5 - 44	10 - 88	1.45	2.64 to 2.67	2.8	08
2	BH-02	16	7 - 47	76 - 88	1.42	2.63 to 2.65	3.1	08
3	BH-03	16	4 - 29	2 - 86	1.45	2.64 to 2.68	1.6	09
4	BH-04	16	4 - 55	79 - 89	1.45	2.64 to 2.65	3.3	10
5	BH-05	16	9 - 39	3 - 90	1.44	2.63 to 2.66	1.4	09
6	BH-06	16	7 - 87	7 - 87	1.42	2.64 to 2.66	1.8	09

5. Result and Discussion

The liquefaction potential of AIIMS Kalyani region has been evaluated for six different locations for earthquake of magnitude (Mw) 7.5, 7.0, 6.5 and PGA = 0.16g. Further, the comparison between the three magnitudes having the same peak ground acceleration value is done based on the N-Values.

For

Figure 2 shows the factor of safety against liquefaction with the depth for all the sites in AIIMS Kalyani campus for Mw = 7.5 and PGA = 0.16g. it can be observed that from the Fig. 2 FOS is less than 1 up to the shallow depth (5m depth) at all the sites except few sites (BH- 05 and 06). In case of BH-04 it can be observed that FOS is less than 1 up to the depth of 4.5m after that the site fall in the safer zone up the depth of 16m except few pockets (around 12m depth). Analysis indicate that the factor of safety against liquefaction, assuming water table at the ground, PGA = 0.16g and magnitude of earthquake M = 7.5 is less than one in shallow depths at BH-01 to 04.

Similar trends were observed that for Mw = 7.0 and PGA = 0.16g is relatively greater than M = 7.5, however (44%), still less than one in shallow depths at BH 1 to 4 (Fig. 3). Thus, indicating that the BH-01 to 04 sites are likely to be liquefied but depth of liquefaction reduces. Further, the FOS for 6.5 magnitude earthquake is 21% greater than that for M = 7.0 it can be attributed due to the fact of in MSF corrections.

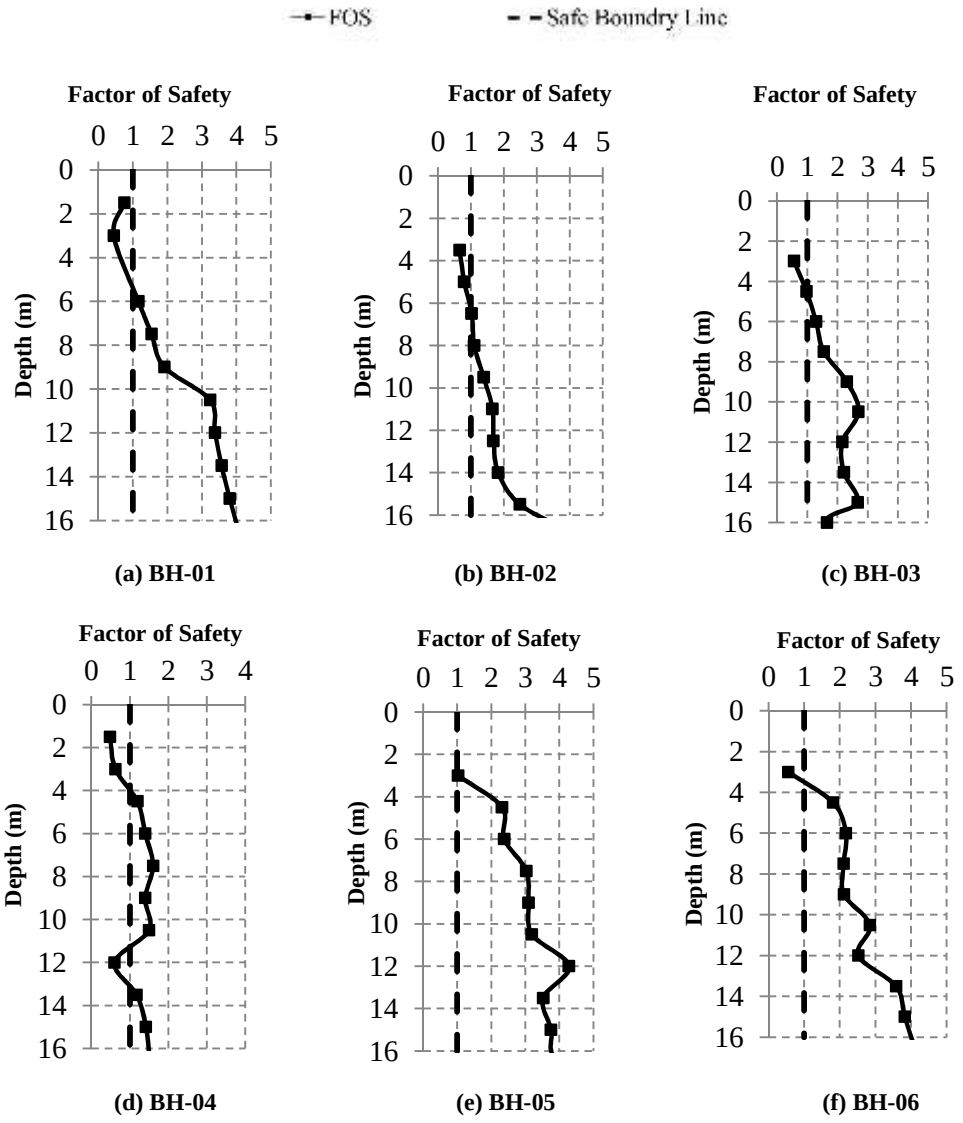

Fig 2 FOS with the depth for all the sites all the sites in AIIMS Kalyani

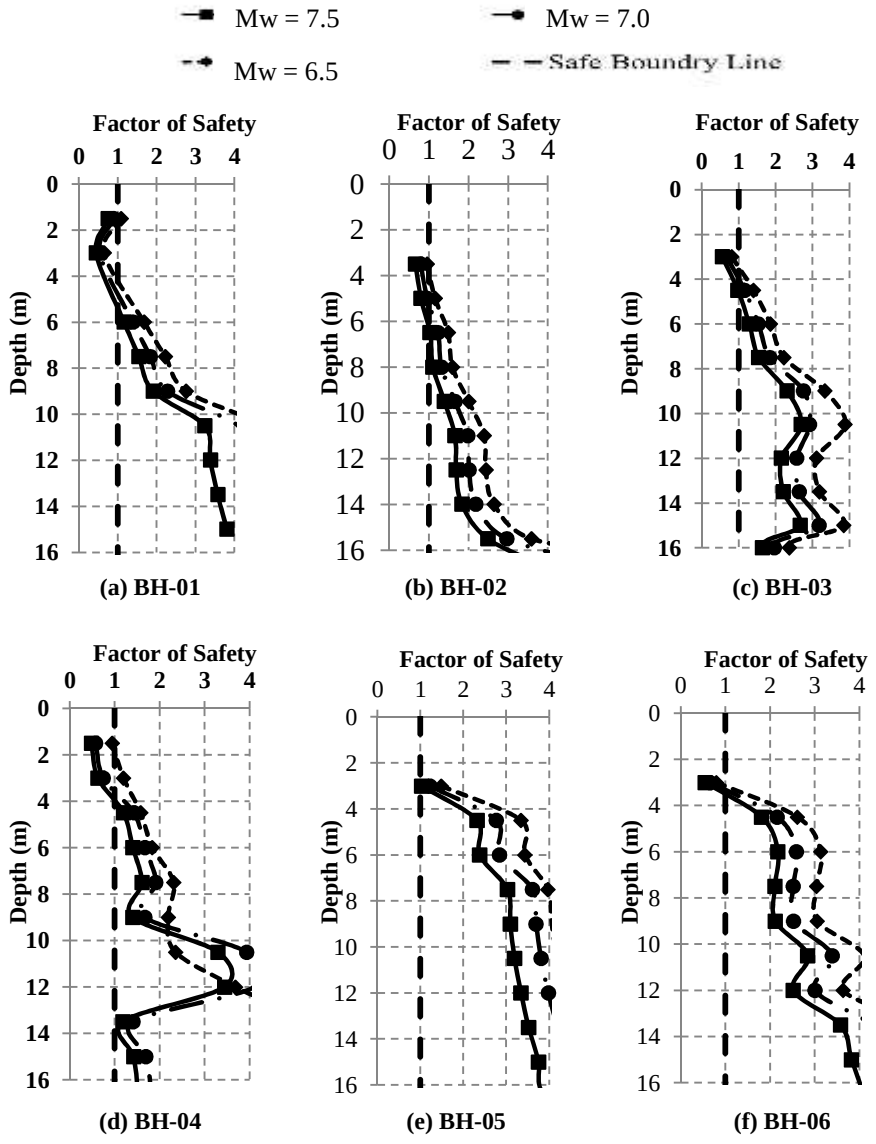

Fig. 3 FOS with the depth for all the six sites for in AIIMS Kalyani (For M = 7.5, 7.0 & 6.5 & PGA = 0.16g)

6. Summary and Conclusion

Major objective of the study is to evaluate liquefaction potential using SPT data in the AIIMS Kalyani, Kolkata. Kalyani is a city which comes under Nadia district, of west Bengal it is located around 50 km from Kolkata city. Kolkata city falls in seismic zone-IV therefore the study is important for this region. The investigation was done based on SPT data at six different locations in AIIMS Kalyani region. The major conclusions of the presents study are;

1. The factor of safety against liquefaction, assuming water table at the ground, PGA = 0.16g and magnitude of earthquake M = 7.5 is less than one in shallow depths at BH-01 to 04. Thus, BH -01 TO 04 sites are likely to be liquefied up to the shallow depth based on the results of all the in-situ tests data.
2. The factor of safety against liquefaction assuming water table at ground, PGA = 0.16g and magnitude of earthquake M = 7.0, is relatively greater than M = 7.5, however (44%), still less than one in shallow depths at BH-01 to 04. Thus, indicating that the BH-01 to 04 sites are likely to be liquefied but depth of liquefaction reduces. Further, FOS obtained are relatively greater indicating reduced potential of liquefaction. While, the FOS for 6.5 magnitude earthquake is 21% greater than that for 7.0 magnitude earthquake due to difference in MSF.

Based on the outcome of analysis done it can be recommended that ground improvement is needed to be done for the sites which are prone to liquefaction. As the site belongs to zone III which is a sensitive one so more studies should be done in order to check the soil resistance. The present work done has its direct and practical application for the design work of such as structures, foundations in AIIMS Kalyani region, Kolkata.

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