Liquefaction Potential Evaluation of Kushi Nagar Project in U.P

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ABSTRACT:

The main aim of the present study is to evaluate the liquefaction potential and to prepare the liquefaction hazard zonation map of Kushi Nagar Project in U.P. using SPT collected from the Ratanpur sites of project by simplified procedure of Seed & Idriss, Idriss & Boulanger. Here liquefaction potential evaluation is done to find the factor of safety at different depth and different locations. The liquefaction is severe in the "Kushi Nagar Project" due to the presence of silt and poorly graded sand. So the assessment of liquefaction potential and preparation of liquefaction potential map helps us to choose a suitable ground improvement technique and foundation system for future correction in this region.

KEYWORDS**:** Liquefaction, SPT, FS, CSR, CRR.

INTRODUCTION

STUDY AREA

Liquefaction is a phenomenon of soil behavior in which a saturated soil loses of strength due to high excess pore water pressure generated and accumulated during strong earthquake ground shaking. Soil liquefaction has created the necessity for carrying out of detailed seismic hazard assessment of the city and awareness building measures to the people of Ratanpur, Kushi Nagar regarding the earthquake safety. It is also important to carry out more earthquake vulnerability reduction programs in Ratanpur, Kushi Nagar.

Objective-

The main objectives of this work is to-

- Estimate the maximum or equivalent cyclic shear stress ratio (CRR).
- Estimate the liquefaction resistance of soils using SPT and CPT data (CRR).
- Estimate the liquefaction resistance of soil by calculating factor of safety.
- Comparison of above mentioned methods.

Generation of subsurface data and data acquisition-

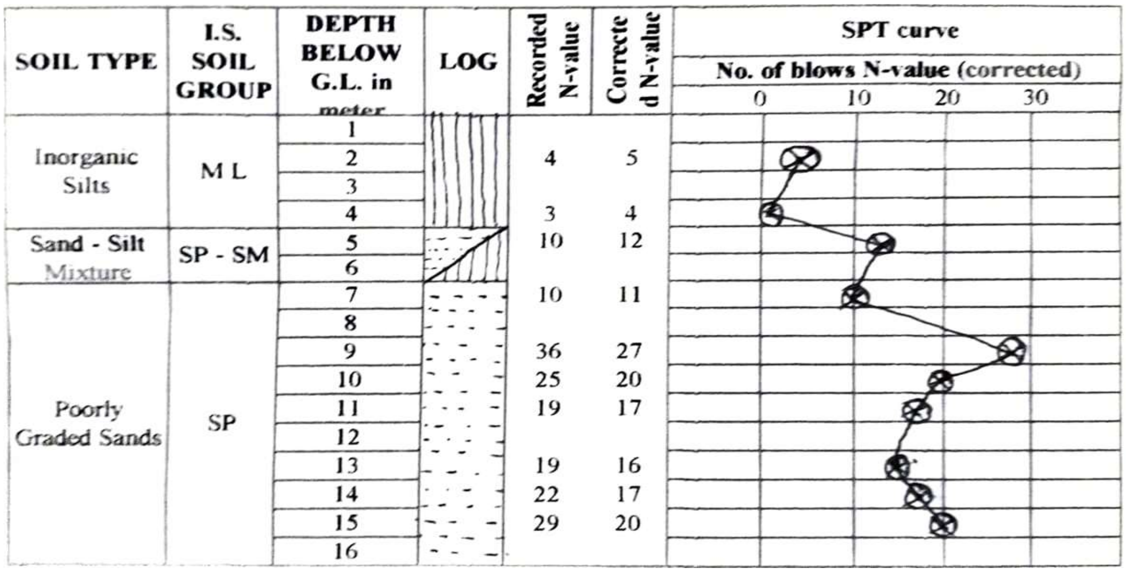
Collection and organization of data extensive borehole data is collected from various locations of Ratanpur project. The collected geotechnical data is in different formats depending upon the source of organization and the particular project. Data is then synthesized and was brought to common platform needed for the geotechnical characterization and liquefaction study. The data is given in appendix.

Data management-

All the data managed in same platform. Data used to evaluate liquefaction potential of a soil, Microsoft excel 2010 and Microsoft access were used to store the borehole data which was collected during the SPT test. Firstly, the collected data were entered in the excel sheets. After the data acquisition was completed, all the boreholes were grouped according to their types and source. The deep boreholes samples and data are also used to study the geological evaluation of the site. Three tables are generated in this research work. One containing the information such as borehole id, site location, depth range, geological information. The second table includes the geotechnical information. Third table also contains to the related geotechnical information.

Table: : BORE LOG CHART & SPT CURVE

Site: Proposed OHWT at Barwa Ratanpur, District Kushi Nagar



SOIL TYPE	I.S. SOIL GROUP	DEPTH BELOW G.L. in meter	LOG	Recorded N-value	Correcte d N-value
Inorganic Silts	M L	1			
		2		4	5
		3			
		4		3	4
Sand - Silt Mixture	SP - SM	5		10	12
		6			
Poorly Graded Sands	SP	7		10	11
		8			
		9		36	27
		10		25	20
		11		19	17
		12			
		13		19	16
		14		22	17
		15		29	20
		16			

Table 2: SUMMARY OF MECHANICAL GRADING AND COSISTANCY LIMIT

S.No.	Depth of Sampling	Particle Size Distribution							Consistency Limit			Soil Classification IS: 1498 – 1970
		Gravel		Sand			Silt	Clay				
		Coarse 80-20 mm (%)	Fine 20-4.75 mm (%)	Coarse 4.75-2.0 mm (%)	Medium 2.0-0.425 mm (%)	Fine 0.425-0.075 mm (%)	0.075-0.002 mm (%)	>0.002 mm (%)	LL (%)	PL (%)	PI (%)	
1	1.85 - 2.15	0	0	0	1	25.6	73.4	0	25	20	5	ML
2	2.55 - 3.10	0	4.2	2.4	1	12.6	79.8	0	28	23	5	ML
3	3.50 - 3.80	0	0.25	0	0.5	45.25	54	0	-	-	N.P.	ML
4	4.95 - 5.25	0	0	0	3.8	85.4	10.8	0	-	-	N.P.	SP – SM
5	6.30 - 6.60	0	0	0	30	68	2	0	-	-	N.P.	SP
6	8.35 - 8.65	0	0	0	7	88	5	0	-	-	N.P.	SP
7	9.45 - 9.75	0	0	0	8	90.5	1.5	0	-	-	N.P.	SP
8	11.05 - 11.35	0	0	0	8.4	90.6	1	0	-	-	N.P.	SP
9	12.35 - 12.65	0	0	0	32	67	1	0	-	-	N.P.	SP
10	13.40 - 13.70	0	0	0.4	31.5	66.6	1.5	0	-	-	N.P.	SP
11	14.70 - 15.20	0	0	0	8.6	90.2	1.2	0	-	-	N.P.	SP

Table3: SUMMARY OF LABORATORY RESULT

S. No.	Depth of Sampling	Bulk Density t/m³	Moisture Content %	Dry Density t/m³	Shear Characteristics		Remarks
					C Kg/cm²	Φ deg	
1	1.85 - 2.15	1.8	14.39	1.57	0.16	18	
2	2.55 - 3.10	1.82	-	-	0.1	17	
3	3.50 - 3.80	1.8	-	-	0.12	18	
4	4.95 - 5.25	1.92	-	-	0	34	
5	6.30 - 6.60	1.92	-	-	0	34	
6	8.35 - 8.65	1.98	-	-	0	34.5	
7	9.45 - 9.75	1.96	-	-	0	35	
8	11.05 - 11.35	1.98	-	-	0	35	
9	12.35 - 12.65	1.99	-	-	0	37.5	
10	13.40 - 13.70	2	-	-	0	37	
11	14.70 - 15.20	2.05	-	-	0	35.5	

METHODOLOGY

Seed & Idriss and Idriss & Boulanger for SPT Method

The methodology is used to determine the liquefaction potential of Kushi Nagar using simplified procedure of seed & Idriss (1971) and Idriss &Boulanger. The following steps are followed to determine the liquefaction potential.

Steps 1: The bore hole data used to assess liquefaction susceptibility include the location of the water table, SPT N value, soil grain size, unit weight and fine content of the soil (percentage by weight passing the IS Standered Sieve No75µ.).

Steps 2: Summary of mechanical grading consistency limits and other laboratory test results such as (bulk density, moisture content dry density and shear characteristics) were obtained.

Step 3: The total vertical stress (σ_{v0}) and effective vertical stress (σ'_{v0}) for all soil layers were evaluate.

Step 4: Lio and Whiteman (1986) by the following equation can be used to evaluate the stress reduction factor (rd) seed &idriss.

$$rd = 1-0.00765z \qquad \text{for } z \leq 9.15m$$

$$rd = 1.174-0.0267z \qquad \text{for } 9.15 < z \leq 23m$$

Where, z= depth

The stress reduction factor (rd) for the dynamic response amplitude with depth. Idriss & Boulanger evaluate the stress reduction factor,

For $z \leq 34m$, $$rd = \exp[\alpha(z) + \beta(z)]$$

$$\alpha(z) = -1.012-1.126\sin\left(\frac{z}{11.73} + 5.133\right)$$

$$\beta(z) = 0.106+0.118\sin\left(\frac{z}{11.28} +5.142\right)$$

Step 5: The Magnitude scaling factor (MSF) which account for the duration effect of ground motion. The MSF for Mw <7.5 is expressed as follows (Idriss & Boulanger).

$$\text{MSF} = 6.9\exp\left(\frac{-M_w}{4}\right)-0.058 \quad \leq 1.8$$

The liquefaction resistance increases with increasing confining stress, the overburden correction factor (K_σ) was applied such that the value of CSR were adjusted to an equivalent overburden pressure σ'_v of 1 atmosphere equation.

$$(K_\sigma) = 1\text{-C}\sigma\left(\frac{ln}{\sigma_v}\right) \leq 1.0$$

Where, $$\text{C}\sigma = \left(\frac{1}{18.9-2.5507\sqrt{(N_1)_{60}}}\right) \leq 0.3$$

Step 6: The critical stress ratio, seed & Idriss (1971) Idriss & Boulanger proposed the following equation for calculating

$$\text{CSR} = \frac{\tau_{av}}{\sigma'_{v_o}} = 0.65 * r_d * \left(\frac{\sigma_{v_o}}{\sigma'_{v_o}}\right) * \left(\frac{a_{max}}{g}\right) \qquad \text{(S\&I)}$$

$$\text{CSR} = 0.65 * r_d * \left(\frac{\sigma_{v_o}}{\sigma'_{v_o}}\right) * \left(\frac{a_{max}}{g}\right) * \left(\frac{1}{K_\sigma}\right)\left(\frac{1}{MSF}\right) \qquad \text{(I\&B)}$$

Where, a_{max} = peak horizontal ground acceleration

g = acceleration due to gravity

σ_{v_o} = total effective overburden stress

σ'_{v_o}= effective vertical overburden stresses

r_d=stress reduction coefficient

Step 7: $(N_1)_{60}$ must also be corrected for fines as per following equation proposed by seed & Idriss (1971).

$$(N_1)_{60}\ \text{corrected} = \alpha+\beta\,(N_1)_{60}$$

Where, $\alpha = 0$ for FC ≤ 5%

$\alpha = \exp[1.76-(\frac{190}{FC^2})]$ for 5%<FC<35

$\alpha = 5.0$ for FC≥35%

$\beta = 1.0$ for FC≤5%

$\beta = [0.99-(\frac{FC}{1000})^{0.5}]$ for 5% <FC<35

$\beta = 1.2$ for FC≥35%

Step8: The cyclic resistance ratio (CRR) Raunch (1998) proposed the following for determining CRR based on SPT N value $(N_1)_{60}$ for an earthquake of magnitude 7.5.

$$\text{CRR} = \left(\frac{1}{34-(N_1)_{60}}\right)+\left(\frac{(N_1)_{60cs}}{135}\right)+\left(\frac{50}{(10*(N_1)_{60cs}+45)^2}\right)-\left(\frac{1}{200}\right)$$

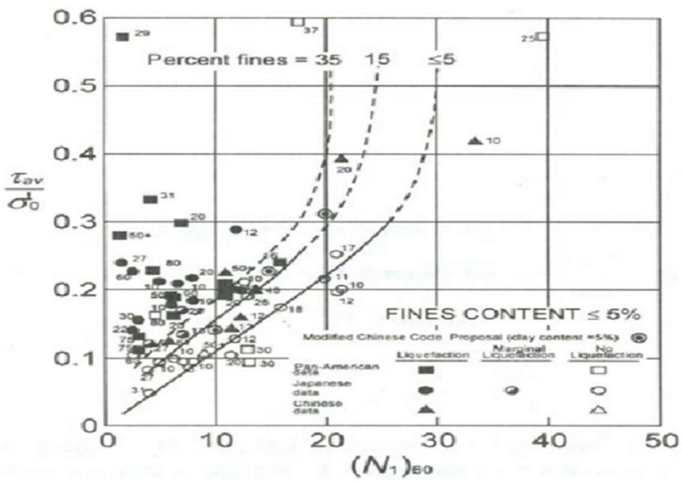


Fig.1: Relationship between CRR and $(N_1)_{60}$ for Mw 7.5 Earthquake

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. This equation may be used in spreadsheets and other analytical techniques to approximate the clean sand base curve for routine engineering calculations.

Step 9: The factor of safety against liquefaction is define as

$$FS = \left(\frac{CRR}{CSR}\right) \quad \text{(S\&I)}$$

$$FS = \left(\frac{CRR}{CSR}\right) * MSF \quad \text{(I\&B)}$$

Where, CRR=cyclic resistance ratio

CSR=cyclic stress ratio

When the design ground motion is conservative, earthquake related permanent ground deformation is generally small if FS≥1.

RESULT AND DISCUSSION

Table1: Comparision of Seed & Idriss Method and Idriss & Boulanger Method

S.No.	Depth	Seed & Idriss SPT Method		Idriss & Boulanger SPT Method	
		F.S.	Remarks	F.S.	Remarks
1	1.85	0.793545	Liquefaction	1.617996191	No Liquefaction
2	2.55	0.797879	Liquefaction	1.634530883	No Liquefaction
3	3.5	0.297461	Liquefaction	0.632345062	Liquefaction
4	4.95	0.342338	Liquefaction	0.826330205	Liquefaction
5	6.3	0.276416	Liquefaction	0.6041483	Liquefaction
6	8.35	0	Liquefaction	1.781774566	No Liquefaction
7	9.45	0.751265	Liquefaction	1.151148414	No Liquefaction
8	11.05	0.523089	Liquefaction	0.932981685	Liquefaction
9	12.35	0.447452	Liquefaction	0.811384732	Liquefaction
10	13.4	0.445748	Liquefaction	0.775294882	Liquefaction
11	14.9	0.613529	Liquefaction	0.879023268	Liquefaction

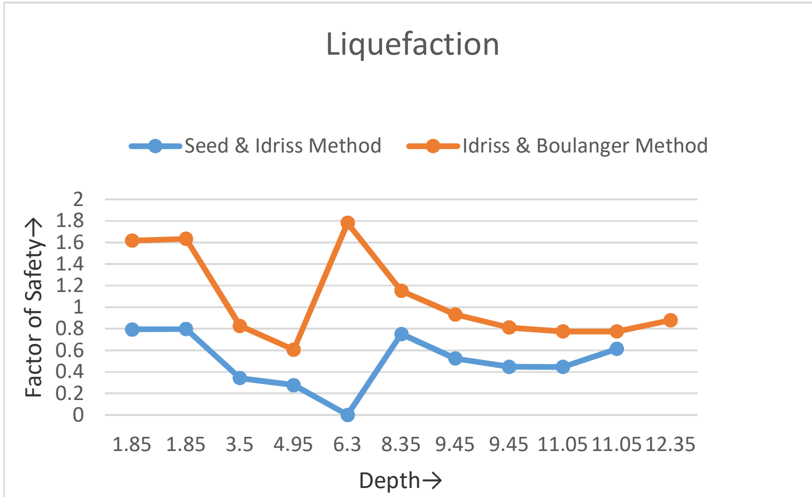


Fig.2: Depth v_s Factor of Safety

CONCLUSION

Based on the comparision of liquefaction potential on the basis of SPT for "Ratanpur, Kushi Nagar Project" it is concluded that soil of study area is susceptible to liquefaction extra care should be taken liquefaction during construction upon this type of soil. The study area being a reclaimed area has a top layer of inorganic silt followed by soft to medium sand silt mixture and poorly graded sand is also susceptible to liquefaction. In this study we concluded that if earthquake more than 7.5 magnitude occurs in kushi nagar region, it will be extensively damaged due to liquefaction.

- There is a graphical comparison between the both SPT methods (Seed & Idriss method and Idriss & Boulanger method) used in this analysis for the same bore holes.

- In the fig combined graph is drawn between factor of safety and depth of the bore holes using Seed & Idriss method and Idriss & Boulanger method. In those the graphs the soil strata whose factor of safety is less than 1 is susceptible to liquefaction and should be considered for mitigation before building a structure on it.

- The percentage of inorganic silt, sand silt mixture and poorly graded sand is high in area under "Ratanpur Kushi Nagar Project" indicating that there is a great chance of soil liquefaction. Here liquefaction potential analysis is a done to determine the factor of safety at different depth.

- There are various criteria to determine the soil's liquefaction potential in a site. According to these criteria, the soil of particular building site a characterized.

- The soil Improvement is an important method to mitigate the adverse effect of liquefaction hazards by improving the soil by improving the density, strength and drainage characteristics of the soil. Improvement of soil can be done by using various types of soil improvement techniques.

REFERENCES

T. L. Youd, I. M. Idriss, R. D. Andrus et al., “Liquefaction resistance of soils: summary report from the 1996 NCEER and 1998 NCEER/NSF workshops on evaluation of liquefaction resistance of soils,” Journal of Geotechnical and Geo-environmental Engineering, vol. 127, no. 10, pp. 817–833, 2001.

I. M. Idriss and R. W. Boulanger, “Semi-empirical procedures for evaluating liquefaction potential during earthquakes,” in Proceedings of the Joint 11th International Conference on Soil Dynamics & Earthquake Engineering and the 3rd International Conference on Earthquake Geotechnical Engineering, pp. 32–56, Berkeley, California, January 2004.

Seed, H. B., and Idriss, I. M. (1971). “Simplified procedure for evaluating soil liquefaction potential.” J. Soil Mech. Found. Div., 97(9), 1249– 1273.

Idriss, I. M., and Boulanger, R. W. (2006). “Semi-empirical procedures for evaluating liquefaction potential during earthquakes.” Soil. Dyn. Earthquake Eng., 26(2–4), 115–130.

Youd, T.L. and Idriss, I.M., eds (l997). "Proceedings of the NCEER on Evaluation of Liquefaction Resistances of Soils Tech. Report NCEER-1997-0022", Multidisciplinary Center for Earthquake Engineering Research, Buffalo, New York.

Idriss, I. M. & Boulanger, R. W. (2008). Soil liquefaction during earthquakes, Monograph MNO-12, p. 261. Oakland, CA, USA: Earthquake Engineering Research Institute.

Seed, H. B., Idriss, I. M., and Arango, I. (1983). "Evaluation of liq- uefaction potential using field performance data." 1. Geotech. Engrg., ASCE, 109(3), 458-482.