EVALUATION OF LIQUEFACTION POTENTIAL AS PER IS: 1893 (PART-1)-2016 FOR SPECIFIC SITES OF KAPURTHALA, PUNJAB

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ABSTRACT Kapurthala is a district of Punjab state and lies between the Beas River and the Kali-Bein River. Water logging and alkalinity in the soil is the major problem of this area. Kapurthala lies in the Zone IV of the seismic zoning map of India as per IS: 1893 (2016) Part-I and this region is vulnerable to High Damage Risk Zone. Liquefaction is an earthquake-induced ground failure phenomenon observed in saturated sand deposits. It involves generation of excess pore water pressure, partial or complete loss of shear strength of soil, volumetric contraction leading to settlement and lateral spreading. Past earthquakes have demonstrated that liquefaction – induced ground failure can lead to devastating damage to civil infrastructure including bridges, buildings, highways and slopes. Seismic response of saturated sand deposits and liquefaction phenomenon has gained significant attention after Alaska 1964 and Niigata (Japan) 1964 earthquakes. In the present study, an attempt has been made to evaluate the liquefaction potential for the 10 sites of Kapurthala. The geotechnical data has been collected from various organisation and liquefaction potential is evaluated based on the Standard Penetration Test (SPT) blow counts (N) by using simplified procedure mentioned in IS:1893 (Part 1)-2016. The Factor of Safety (FOS) against liquefaction was calculated by considering PGA value of 0.24 and it was found that 02 sites out of 10 are liable to liquefaction. Special consideration is required to be incorporated while designing foundation in the above identified liquefiable susceptible sites.

Keywords: Liquefaction, SPT-N value, Kapurthala, Punjab.

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INTRODUCTION

Natural hazards like earthquake, tsunami, flood, cyclone and landslides pose severe threat to human life and its environment. There is a huge social and economic consequence immediately after the occurrence of a natural disaster. The adverse effects of disasters are much more in developing countries where the population is very large and the socioeconomic factors force the people to live in vulnerable areas. . It is estimated, on average natural disaster claim 1000 lives and cause damage exceeding one billion US$ each week around the world.The advent of new technologies such as high speed digital computers, new computational algorithms and their applications to new regions cutting around many disciplines in science and engineering went hand in hand. In now a day's such efforts have increased phenomenally.In new era, the human life and the environment have frequently been threatened by the natural calamities like earthquake, tsunami, flood, cyclone, and landslides.A numerous investigations on field and laboratory showed that soil liquefaction may be better explained as a disastrous failure phenomenon in which saturated soil losses strength due to increase in pore water pressure and reduction in effective stress under rapid loading and the failed soil acquires a degree of mobility sufficient to permit movement from meters to kilometers. Soil liquefaction can cause ground failure in the way of sand boils, major landslides, surface settlement, lateral spreading, lateral movement of bridge supports, settling and tilting of buildings, failure of water front structure and severe damage to the lifeline systems etc.

A study observed the recent trends in natural hazards to identify the need of the present research. Case histories of different major natural disasters, occurred till 2015 around the world as well as in India, are collected from international and national disaster databases such as en.wikipedia.org, em-dat.net, ngdc.noaa.gov, nidm.net, sarcsdmc.nic.in etc.

Table 1 Showing the recent natural disasters in India

S. No.	DISASTER	YEAR	PLACE	PEOPLE
1	Bihar flood	2017	Bihar	514 people killed
2	Gujarat flood	2017	Gujrat	224 people killed
3	Assam flood	2016	Assam	28 People Died
4	Nepal Earthquake	2015	Nepal	8900 people killed
5	Chennai flood	2015	Chennai	300 people killed

Liquefaction

Liquefaction is an earthquake-induced ground failure phenomenon observed in saturated sand deposits. It involves generation of excess pore water pressure, partial or complete loss of shear strength of soil, volumetric contraction leading to settlement and lateral spreading. The liquefaction potential of a soil deposit depends on several factors, such as void ratio and relative density of soil, depth of water table, effective confining stress, and coefficient of lateral earth pressure, seismic and geologic history of the site and intensity, duration and other characteristics of ground shaking. Past earthquakes have demonstrated that liquefaction – induced ground failure can lead to devastating damage to civil infrastructure including bridges, buildings, highways and slopes. Seismic response of saturated sand deposits and liquefaction phenomenon has gained significant attention after 1964 Nigata earthquake. Other subsequent earthquakes, such as 1964 Alaska earthquake, 1989 Loma Prieta earthquake, 1995 Kobe earthquake, 1997 Northridge earthquake, 2001 Bhuj earthquake and 2011 Christchurch earthquake have also demonstrated severe damaging potential of soil liquefaction on buildings, bridges, railways, ports and other infrastructure.

Liquefaction Analysis as Per Is: 1893 (Part-1)-2016

Due to the difficulties in obtaining and testing undisturbed representative samples from potentially liquefiable sites, in-situ testing is the approach preferred widely for evaluating the liquefaction potential of a soil deposit. Liquefaction potential assessment procedures involving both the SPT and CPT are widely used in practice. The most common procedure used in engineering practice for the assessment of liquefaction potential of sands and silts is the simplified procedure. The most common techniques using standard penetration test (SPT) blow count follow these steps:

1) Estimation of the cyclic stress ration (CSR) induced at various depths within the soil by the earthquake.
2) Estimation of the cyclic resistance ratio (CRR) of the soil, i.e. the cyclic shear stress ratio which is required to cause initial liquefaction of the soil,
3) Evaluation of factor of safety against liquefaction potential of in situ soils.
   The factor of safety against liquefaction is defined as: FOS Liquefaction=

CRR/CSR. A soil layer with FS<1 is generally classified as liquefiable and with FS>1 is classified as non-liquefiable (Seed and Idriss, 1971). Seed and Idriss (1982) considered the soil layer with FS value between 1.25 and 1.5 as non-liquefiable.

GEOTECHNICAL CHARACTERISTICS

The geotechnical data from 10 sites is collected for the assessment of liquefaction of Kapurthala district. The depth of the borehole varies from 9m – 30m whereas maximum SPT-N value at all locations varies from 13 to 96. Also water table has been encountered at 3 locations at a depth of 1.5m, 2.1m and 16.9m at a JL7, JL8 and JL9 sites respectively. The locations of boreholes are shown in Figure 1. The soil layers for the sites of Kapurthala region were identified for liquefaction potential consists of fine to medium sand and silty sands that have classification of SP, SW, SC, SM, SP-SC. As per IS 1893 (2016) Kapurthala lies in Zone IV. The peak ground acceleration specified for Kapurthala region is 0.24 g. Liquefaction potential assessment has been done using Semi-empirical procedure mentioned in IS: 1893 (Part-1)-2016.

RESULTS AND DISCUSSION

The liquefaction potential for an area is identified on the basis of type of soils that will liquefy. The hazard associated with soil liquefaction during earthquakes has been known to be encountered in deposits consisting of fine to medium sands and sands containing low plasticity (Ishihara 1985). Occasionally however, cases are reported where liquefaction apparently occurred in gravelly soil. Seed et al. (1983) stated that based on both laboratory testing and field performance, the great majority of cohesive soils will not liquefy during earthquakes.

In this present study the soil layers of Kapurthala region, that were identified for liquefaction potential consists of fine to medium sand and silty sands that have classification of SP, SW, SC, SM, SP-SC. As per IS 1893 (2016) Kapurthala lies in Zone IV. The peak ground acceleration specified for Kapurthala region is 0.24 g. Liquefaction potential assessment has been done using Semi-empirical procedure mentioned in IS: 1893 (Part-1)-2016. Liquefaction potential for all the 10 sites of Kapurthala region and FOS has been calculated. FOS against liquefaction varies from 0.61 to 5.12 for all the 10 sites and shown in Figure 1.

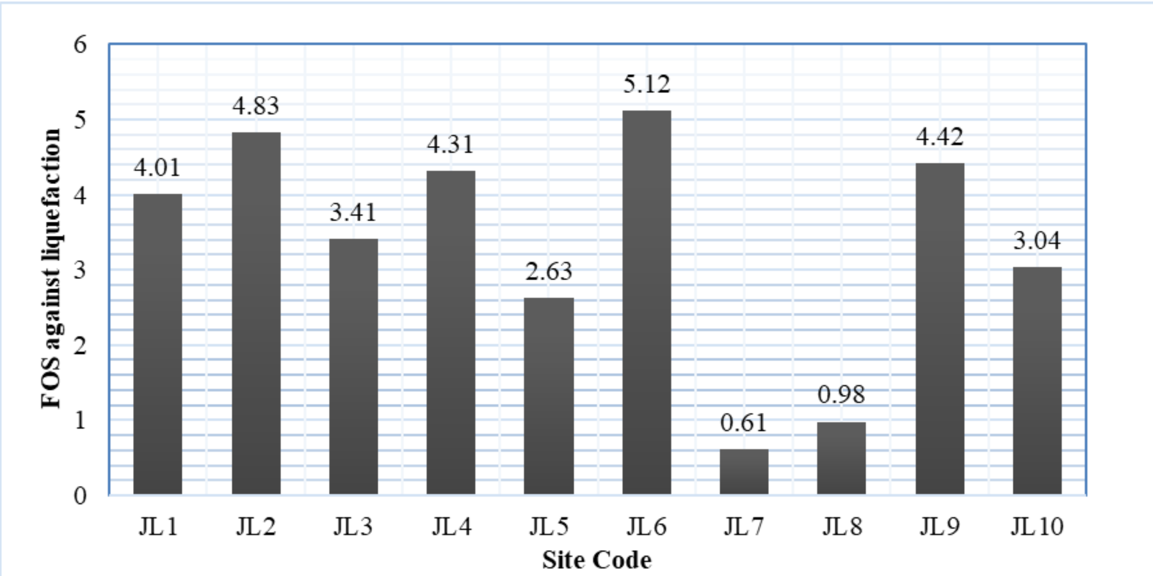

Figure 1 FOS against liquefaction for various sites of Kapurthala region

Out of 10 sites, 02 sites (JL7 & JL8) are found vulnerable to liquefaction with minimum factor of safety of 0.61 & 0.98 respectively. The detailed calculation for the evaluation of liquefaction for site JL7 & JL8 is presented in Table 1 & 2 respectively.

Table 1 Evaluation of Liquefaction Potential for the Site JL7

SITE CODE	DEPTH BELOW EGL, M	TYPE OF STRATA	SPT VALUE	CYCLIC STRESS RATIO (CSR)	CYCLIC RESISTANCE RATIO (CRR)	FOS	LPI
JL7	1.5	SP	3	0.154	0.08	0.50	7.60
	3.0	SP	2	0.210	0.07	0.32	
	4.5	SP	2	0.238	0.07	0.28	
	6.0	SP	8	0.253	0.13	0.53	
	7.5	SP	10	0.262	0.15	0.57	
	9.0	SP	12	0.268	0.16	0.61	

Table 2 Evaluation of Liquefaction Potential for the Site JL8

SITE CODE	DEPTH BELOW EGL, M	TYPE OF STRATA	SPT VALUE	CYCLIC STRESS RATIO (CSR)	CYCLIC RESISTANCE RATIO (CRR)	FOS	LPI
JL 8	3.00	SP	6	0.183	0.18	0.98	17.6
	4.50	SP	5	0.213	0.16	0.73	
	6.00	SP	8	0.232	0.20	0.86	
	7.50	SP	10	0.243	0.22	0.89	
	9.00	ML	16	0.251	0.30	1.20	
	10.50	ML	24	0.253	0.38	NA	
	12.00	ML	40	0.252	NA	NA	
	13.50	ML	42	0.249	NA	NA	
	15.00	SM	40	0.240	NA	NA	
	16.50	SP	40	0.230	NA	NA	
	18.00	SP	40	0.219	NA	NA	
	19.50	SP	40	0.208	NA	NA	
	21.00	SM	40	0.196	NA	NA	
	22.50	SM	40	0.184	NA	NA	
	24.00	SM	40	0.172	0.52	NA	

For general understanding, the susceptibility level can be related to factor of safety as per the following Table 3 as proposed by Sitharam et al (2005).

Table 3 Susceptibility Index of Liquefaction Hazard

S. NO.	FACTOR OF SAFETY RANGE	SEVERITY INDEX
1	FS<1	High
2	FS 1 to 2	Moderate
3	FS 2 to 3	Low
4	FS>3	Nil
5	Non Liquefiable (NL)	Nil

In view of the above table, the susceptibility level of Liquefaction hazard for various sites of Kapurthala region are reported in Table 4 & the contour map showing the distribution of Factor of safety is presented in Figure 3. Out of the 10 Sites, 02 sites are having high severity index against liquefaction whereas 01 site relates to low severity index and rest of 7 sites are found safe against liquefaction.

Table 4 Liquefaction Potential of Kapurthala Sites.

SITE CODE	LOCATION	MAX. DEPTH (M)	FOS	SEVERITY INDEX
JL 1	Mall Road Footpath, Opp Kodak Mahindra Bank	20	4.01	Nil
JL 2	Near Main Gate Professor Colony Kapurthala	20	4.83	Nil
JL 3	Road Corner, Opp Avtar Auto Kanjali Road Kapurthala	20	3.41	Nil
JL 4	Water Tubewell-No -10 Model Town Main Road	20	4.31	Nil
JL 5	Parking Area Shamshan Ghat Near Shalimar Bagh	20	2.63	Low
JL 6	Proposed Ground Based Towers At Opp Prince Bus Office Opp Petrol Pump Kapurthala	20	5.12	Nil
JL 7	Govt. High School Building At Village Baupur Jadid Block Sultanpur, Kapurthala	9	0.61	High
JL 8	Tower No.66 (J-Type), 220 KV Line Makhu To Raishiana T.L. Location Near Vill. Alikhurd Distt. Kapurthala	25	0.98	High
JL 9	New Major Bridge At Ch: 24/031 On Kapurthala Nakodar Phillaur Road In Punjab State (Package-Ii).	30	4.42	Nil
JL 10	Provision Of Auditorium At Kapurthala	12	3.04	Nil

CONCLUDING REMARKS

Liquefaction Potential has been carried out at 10 sites of Kapurthala Region using Semi-empirical procedure mentioned in IS: 1893 (Part-1)-2016. Based on the assessment carried out for 10 sites, it has been observed that 02 sites i.e., JL7 & JL8 have been found susceptible towards liquefaction with high level of severity index. For the rest of the sites, FOS against liquefaction found greater than 1. Furthermore, the hazard map will help structural engineer to identify the liquefiable zone in Kapurthala region and required safety measures may be adopted accordingly while designing foundation for any structure lies in liquefiable zone.

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