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Research Paper

LIQUEFACTION SUSCEPTIBILITY OF FINE GRAINED SOIL USING INDEX PROPERTIES

Yagyesh Narayan Shrivastava[1]*, R K Yadav[2] and A K Dubey[3]

Corresponding Author:* ***Yagyesh Narayan Shrivastava* ✉ *yuvi8yagyesh@gmail.com*

This study aims at assessing the liquefaction susceptibility of fine grained soil using Index properties. The purpose of this study is to develop a simplified approach to study liquefaction as the available techniques and methodologies involve tests like SPT, CPT and Tri-axial test which are costly, complicated, time consuming and need expertise too. Also studies of liquefaction were concentrated around coarse grained soil. Looking to the foregoing facts, this study is undertaken as an attempt to determine the liquefaction susceptibility of fine grained soil using Index properties. For this study, samples of soil are collected from 20 locations in Jabalpur City from different depths and tested in the laboratory for Liquid limit, Plastic limit, Sieve analysis. DFS, NMC and Plasticity Index is also calculated. The obtained results are put up in the criteria developed by Seed *et al.* (2003) and on the basis of this criteria susceptibility to liquefaction of soils of various locations is determined.

Keywords: Liquefaction susceptibility, Plasticity Index, Fine grained soil

INTRODUCTION

Liquefaction is transformation of granular material from solid state into liquefied state with a significant increase in pore water pressure until effective stress reaches to zero. This cause damage in the form of landslide and foundation failure. Soil liquefaction has drawn the attention of the world after two mighty earthquakes of Alaska and Nigata (1964). Initially research on liquefaction was based on uniform clean sand containing little or no fines, but many past earthquakes occurred in the areas containing 20% to 90% fines, this had broken the earlier myth. Thus role of fineness emerged as an important aspect in liquefaction susceptibility and is being studied by researchers all around. But the criterions developed by them are complex, time consuming and need expertise. So, here in this study an attempt has been made to develop a simplified approach to study this phenomena through Index properties.

[1] Student ME Geotechnical Engineering, Department of Civil Engineering, Jabalpur Engineering College, Jabalpur.
[2] Associate Professor, Department of Civil Engineering, Jabalpur Engineering College, Jabalpur.
[3] Professor, Department of Civil Engineering, Jabalpur Engineering College, Jabalpur.

LITERATURE REVIEW

Liquefaction is a matter of research since last 40 years in geotechnical world. First time, Seed and Idriss reported a methodolgy termed as simplified procedure in 1971.This has been further modified and improved by Seed (1979), NRC (1985). Seed and Idriss (1982), Seed *et al.* (1985) and Youd and Idriss (1997), Youd *et al.* (2001) and Idriss and Boulanger (2006) conducted studies on this aspect.

Thus, the evaluation of liquefaction of cohesionless soil is well studied and understood. On the other side fine soil was considered not susceptible to liquefaction.

First time in the world after 1999 kocaeli earthquake it was reported by Sancio *et al.* (2003) that Adapzari soil which was liquefied contained a significant amount of clay size particles which were supposed to be non liquefiable. Earlier to this Youd *et al.*(2001) in NCEER workshop highlighted that modified Chinese criteria is inadequate to define the vulnerability of fine grained soil towards liquefaction .This problem was solved by Seed *et al*. in 2003. They developed an assessment chart using Plasticity Index and Liquid limit. In this chart Two zones A and B are presented soil falling in zone A are regarded as potentially liquefiable and those falling in zone B are regarded as Potentially susceptible to liquefaction . The soil falling out of zone A and B are considered as non-liquefiable. Boulanger and Idriss (2006) recommended that fine grained soils should be divided into two sub categories for reliable results . The two sub categories are “sand - like” and clay- like fine grained soils.

Moss and Chen (2008) found that plasticity index may serve as a better indicator in distinguishing liquefaction susceptibility. PI can confidently distinguish the fine grained soil behavior either clay-like or sand like which is liquefiable.

Lade (2012) reported that the initial location of fine particles in sand grains play an important role in the stress-strain behaviour, reduce permeability and pore pressure.

City of Jabalpur falls in seismic zone III according to Institute of seismological research and has witnessed an earthquake of magnitude ranging from 5.8 to 6.2 on Richter scale in the year 1997. Signs of liquefaction were reported by Pimplikar *et al.* (2000) and Jain *et al.* (1997) reported an account of damage to the built environment of the City.

MATERIALS AND METHODS

This study was conducted in the City of Jabalpur, Madhya Pradesh, India (23^{0}09’57.8"N and 079^{0}57’05.5"), which is expanding rapidly in all directions. Looking to this fact twenty locations were selected randomly for taking samples of soil. Which are shown in the map below (Figure 1).

Figure 1: Map Showing Sampling Locations

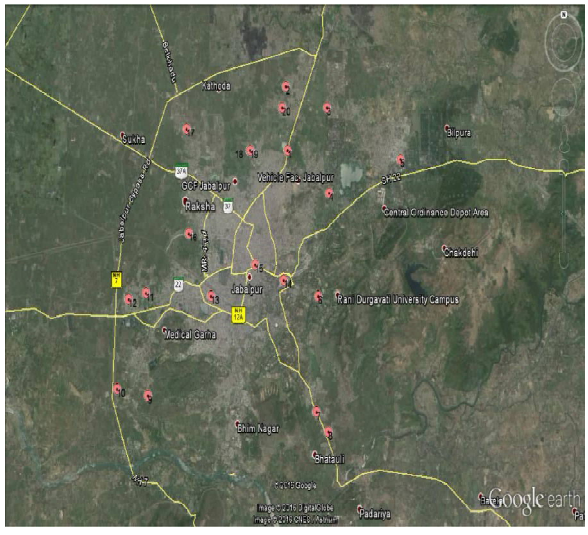


Table 1: Description of Sampling Points

S.No.	Location	Latitude	Longitude	Altitude(in ft)
1.	Housing Board colony Maharajpur	23^{0}12'29.5"	79^{0}57'14.1"	1254
2.	Maharajpur	23^{0}13'46.6"	79^{0}57'07.3"	1264
3.	Richai	23^{0}13'24.4"	79^{0}58'28.5"	1254
4.	Shobhapur	23^{0}11'40.2"	79^{0}58'30.7"	1256
5.	Khamariya	23^{0}12'19.8"	80^{0}00'50.3"	1316
6.	Science collage	23^{0}09'41.4"	79^{0}58'18.8"	1356
7.	Bilehri	23^{0}7'33.3"	79^{0}58'05.5"	1332
8.	Tilehri	23^{0}7'09.8"	79^{0}58'27.5"	1331
9.	Bargi hills	23^{0}07'50.5"	79^{0}52'54.7"	1367
10.	Sagda	23^{0}07'57.5"	79^{0}57'57.0"	1308
11.	Bhookamp colony	23^{0}09'45.0"	79^{0}52'45.2"	1271
12.	Dhanwantri Nagar	23^{0}9'36.1"	79^{0}52'45.2"	1268
13.	Kalimath	23^{0}09'43.1"	79^{0}54'48.3"	1274
14.	Railway station	23^{0}09'57.8"	79^{0}57'65.5"	1330
15.	Victoria	23^{0}10'18.2"	79^{0}56'9.7"	1301
16.	Vijay Nagar	23^{0}10'54.2"	79^{0}54'04.4"	1246
17.	Karmeta	23^{0}12'54.9"	79^{0}53'57.6"	1235
18.	Amkhera	23^{0}12'29.9"	79^{0}56'00.0"	1238
19.	Krishi Nagar Colony	23^{0}12'30.0"	79^{0}55'59.9"	1209
20.	Suhagi	23^{0}13'19.4"	79^{0}57'00.9"	1246

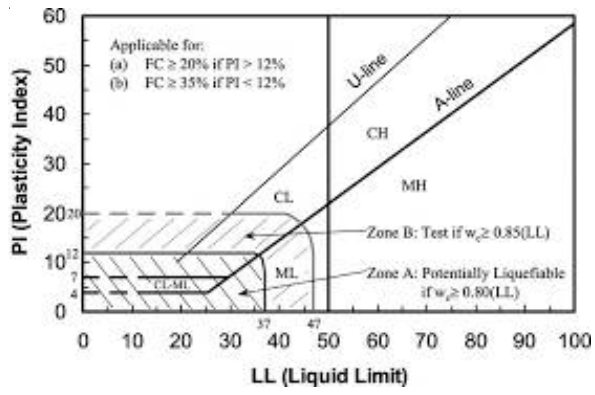
Sampling was done at two different depths at each location. The collected samples were tested in the Geotechnical Engineering laboratory of Jabalpur Engineering College for Liquid limit, Plastic limit, NMC, DFS, Sieve analysis as per the relevant IS code of practice.

In order to determine the susceptibility, the criteria developed by Seed *et al.* (2003) was used, which shows a graph between Liquid limit and Plasticity Index. In this graph (Figure 2) Two zones A and B are presented soil falling in zone A is regarded as potentially liquefiable and soil falling in zone B is regarded as potentially susceptible to liquefaction. The soil falling out of zone A and B are considered as non-liquefiable.

RESULTS AND DISCUSSION

The samples collected from 20 aforesaid locations (Table 1) were analyzed in the laboratory of the department and index properties were determined and used to find the liquefaction susceptibility through the criteria developed by Seed *et al.* (2003). The results thus obtained are presented in Table 2.

Figure 2: Recommendations Assessment of Liquefiable soil types (Seed et al, 2003)



It is clearly depicted from the table that the soil at Bargi Hills and Science college at 2 m depth and soil at Victoria hospital and Amkhera village at 3m depth is Potentially liquefiable. This is also indicated that soil at Railway station Jabalpur and Khamariya at 2 m depth and soil at at Shobhapur and Bargi Hills at 3 m, and Maharajpur at 4 m depth are Potentially susceptible to liquefaction. Kalimath Madan Mahal remains the only location where soil at 2 m as well as 3 m is Potentially susceptible to liquefaction. Soil at rest of the locations was found to be not susceptible to liquefaction.

Table 2: Description of Various Properties at Various Locations and Depths

S. No.	Location	Depth	Grain Size distribution			Liquid Limit	Plasticity Index	Remark
			Gravel	Sand	Fines(-75μ)			
1	Housing Board	2m	0.658	6.622	92.72	50.75	27.714	Not susceptible
	Colony Maharajpur	3m	4.372	9.742	85.886	39.5	22.108	Not susceptible
2	Maharajpur Basti	2m	1.355	25.71	72.935	46.5	28.14	Not susceptible
		3m	0.026	35.272	64.702	40.25	26.16	Not susceptible
		4m	0.558	56.077	43.365	29.1	14.55	Potentially susceptible to liquefaction
3	Richai	2m	1.532	6.436	92.032	57.15	32.543	Not susceptible
		3m	0.796	5.514	93.69	47.16	23.743	Not susceptible
4	Shobhapur	2m	0.061	16.806	83.133	48.2	29.77	Not susceptible
		3m	0.485	19.505	80.01	46.78	19.01	Potentially susceptible to liquefaction
5	Khamariya	2m	0.34	8.37	91.29	42.325	20.485	Potentially susceptible to liquefaction
		3m	0.158	2.614	97.228	46.35	24.051	Not susceptible
6	Science College	2m	0	47.27	52.73	24.9	10.767	Potentially liquefiable
		3m	1.88	48.212	49.908	40.6	23.478	Not Susceptible
7	Bilehri	2m	1.336	7.614	91.05	60	29.26	Not susceptible
		3m	0.125	10.55	89.325	55	27.183	Not susceptible
8	Tilehri	2m	0.204	2.896	96.9	57.8	40.63	Not susceptible
		3m	0	0.088	99.912	56.6	29.222	Not susceptible
9	Bargi Hills	2m	9.572	36.176	54.252	30.6	8.119	Potentially liquefiable
		3m	11.184	36.89	51.926	34.92	13.761	Potentially susceptible to liquefaction

Table 2 (cont.)

S. No.	Location	Depth	Grain Size distribution			Liquid Limit	Plastic Limit	Remark
			Gravel	Sand	Fines(-75μ)			
10	Sagda	2m	0.296	7.266	92.438	54.64	29.383	Not susceptible
		3m	5.044	14.562	80.394	55.01	33.205	Not susceptible
11	Bhookamp Colony	2m	1.492	7.02	91.488	70.92	39.6709	Not susceptible
		3m	4.68	9.904	85.416	55.6	40.316	Not susceptible
12	Dhanwantri Nagar	2m	0.112	5.502	94.386	64.22	32.477	Not susceptible
		3m	0.0984	3.0186	96.883	62.06	38.234	Not susceptible
13	Kalimath	2m	1.702	47.498	50.8	27.9	19.698	Potentially susceptible to liquefaction
		3m	1.496	46.912	51.592	30.67	16.082	Potentially susceptible to liquefaction
14	Railway Station	2m	0.146	40.393	59.461	35.9	18.73	Potentially susceptible to liquefaction
15	Victoria	2m	0.102	19.285	80.613	36.48	23.17	Not susceptible
		3m	0.148	42.203	57.649	37.8	5.55	Potentially liquefiable
16	Vijay Nagar	2m	1.077	7.866	91.064	56.47	30.211	Not susceptible
		3m	0.086	4.626	95.288	54.65	28.124	Not susceptible
17	Karmeta	2m	1.632	9.839	88.529	58.03	33.12	Not susceptible
		3m	2.497	10.179	87.324	64.95	38.3659	Not susceptible
18	Amkhera	2m	2.492	50.908	46.6	65	52.472	Not susceptible
		3m	0.308	8.74	90.952	25.17	9.622	Potentially liquefiable
19	Krishi Nagar	2m	0.618	17.709	81.673	52.1	35.11	Not susceptible
		3m	1.252	15.421	83.327	46.78	19.01	Not susceptible
20	Suhagi	2m	2.77	15.472	81.758	51.35	21.183	Not susceptible
		3m	0.904	15.056	84.04	56.2	31.839	Not susceptible

CONCLUSION

The soil in most of the areas of the City of Jabalpur was found to be non-liquefiable except at Bargi Hills, Science College, Railway Station, Khamariya and Kalimath at 2 m depth and Victoria, Amkhera, Shobhapur, Kalimath, Bargi Hills at 3 m depth and Maharajpur at 4 m.

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