LIQUEFACTION SUSCEPTIBILITY OF SOIL IN ERNAKULAM DISTRICT

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Abstract - *The phenomenon in which the strength of a saturated and cohesionless soil reduces due to the increased pore water pressure and thereby reducing the effective stress due to dynamic loading is called as liquefaction. Earthquake shaking (or other rapid loading) can reduce the strength and stiffness of cohesionless saturated soil. Due to liquefaction the soil behaves more like a viscous fluid. When liquefaction occurs the strength of soil decreases and thus ability of soil to support construction above it also decreases. This paper aims to analyze the liquefaction susceptibility of some selected sites in Ernakulam, Kerala. The standard penetration details of the selected areas are collected from different geotechnical laboratories at Ernakulam district. These details are used to determine the liquefaction susceptibility of the sites by using LiqIT software. Liquefaction analysis was carried out for a PGA of 0.2g and earthquake magnitude (Mw) of 6 using LiqIT software. The results are expressed in terms of factor of safety against liquefaction and probability of liquefaction.*

***Key Words*: Liquefaction, LiqIT software.**

1.INTRODUCTION

The phenomenon in which the strength of a saturated and cohesionless soil reduces due to the increased pore water pressure and thereby reducing the effective stress due to dynamic loading is called liquefaction. At normal conditions, the intensity of pore water pressure is relatively low and hence soil is stable. But rapid loading and earthquake can cause the water pressure to increase to the point at which soil particles can easily move with respect to one another. Other than earthquakes, blasting can also cause an increase in water pressure. Due to liquefaction the soil behaves more like a fluid than like a solid. The strength of soil will be less and soil cannot support the construction above it.

Ernakulam is called the commercial capital of the state of Kerala. The Kerala high court, the cochin stock exchange, many business firms and educational institutions are situated at Ernakulam. The major reason for heavy earthquakes in India includes the movement of Indian tectonic plate into Asian tectonic plate and the accumulation of seismic energy in the peninsular region of India. Geographical statistics of India states that about 54% of the land is divided into four seismic zones. Zone 2,3,4 and 5. Zone 2 exhibits lowest level of seismicity and zone 5 exhibits highest level of seismicity. Ernakulam the central part of Kerala lies in zone 3. The chance of a seismic event in Ernakulam region is high. Hence identification and mitigation of liquefaction are essential for this region. LiqIT is a software used for the assessment of soil liquefaction based on commonly used field data. Here we used SPT borehole data. The software first evaluates the CRR which is the soil strength according to the available field data. Then induced seismic load is estimated and expressed through CSR. At last, FOS against the liquefaction is calculated. The main objective of this paper is to analyze the liquefaction susceptibility of soil at different sites at Ernakulam district using standard penetration bore hole data collected from various geotechnical laboratories, to collect detailed information about the liquefied zones in the form of graphs, factor of safety and to obtain the CSR vs corrected SPT N value graphs to measure the vulnerability of selected sites towards the liquefaction.

2. RELATED WORKS

C.P. Rajendran et al (2009) [1], through their studies on earthquake hazard in Kerala based on historical and current seismicity have portrayed some of the reasons for seismicity in Kerala especially in Central midland. Study shows that anthropogenic activities impacted the changes in hydrologic regimes helped in facilitating faster hydrostatic pressure transmission to hypo central depths. Anbazhagan et al. (2015) [2], through his study, made an attempt to make seismic intensity maps for South India and identified eight probable future earthquake zones in South India based on rupture-based seismic hazard analysis. He identified the zone through regional rupture character focusing on earthquake prone areas from past records. His study also predicts earthquake of magnitude of 6 for central Kerala. Seed and Idriss ,1971[3] through their studies on simplified procedure for evaluating liquefaction potential provided simplified equation for cyclic shear stress ratio (CSR) at a depth z below ground surface. Idriss and Boulanger, 2004[4] evaluated semi empirical procedures for finding liquefaction potential during earthquake, which is a stress based approach. They compared earthquake induced cyclic stress ratio (CSR)with cyclic resistance ratio (CRR) of soil. They recommended for using curve for magnitude scaling factor (MSF) provided by Idriss (1999) [5]. They compared over burden pressure correction factor by Hynes and Olsen (1998) [6] with its recommended curve and found to be reasonable. Stress reduction factor is taken as given by Idriss 1999 on extending work of Golesorkhi, 1989 [7]. M Akhila et al 2019 [8] provided the zone factor, reasonable estimate of effective peak ground acceleration corresponding to various seismic zones. Youd et al 1997 [9] through their studies recommended to use Idriss and seed method for fine correction. Jack Montgomery et al;2012 [10]through their analysis provided that overburden correction factor derived by Idriss and Boulanger,2004[4] continue to provide a reasonable basis for evaluating effects in clean sand on comparing it with Youd et al,1997.Seed and Idriss,1982[11]developed depth correction in SPT blow counts correction which was endorsed by Youd et al. Robertson and Wride (1998) [12] listed correction to SPT modified from Skempton,1986.Idriss and Boulanger,2010[13] has given that CRR procedures produced by Idriss and Boulanger[2]and Youd et al [7] found to be reasonable. Mert Tolon (2013) [14] through comparative study on computer aided liquefaction analysis recommends LiqIT software for solving liquefaction potential in a short time due to its success rate and simple procedure. This liquefaction analysis. software can be used for 2D analysis using both deterministic and probabilistic method of liquefaction analysis.Iwasaki.et.al (1978) [15], provided a practical method for obtaining liquefaction potential for a particular site.

PL= 0 -- Liquefaction potential is quite low and detail investigations on soil liquefaction aren't needed in general,

0<PL<= 5 -- Liquefaction potential is low.

5<PL<=15 -- Liquefaction potential is high.

15<PL -- Liquefaction potential is very high, where PL is liquefaction potential.

2. METHODOLOGY

Semi empirical field-based approach for evaluating the potential for liquefaction provided by ldriss and Boulanger (2004) was considered for the study. Components of equation include, evaluation of cyclic shear stress ratio (CSR), evaluation of cyclic resistance ratio (CRR), and there by factor of safety.

2.1 DATA COLLECTION

We procured SPT borehole data from soil investigation report of various sites collected from geotechnical laboratories. A total of 13 borehole data was collected from 5 sites.

Table -1: Field input data of soil.

Site	No of bore holes	Source
Nellikuzhi	1	DS ASSOCIATES
Kothamangalam	4	JVM ASSOCIATES
Perumbavoor	3	JVM ASSOCIATES
Nedumbassery	2	APLAB SYSTEM
Kalamassery	3	GEO FOUNDATION AND STRUCTURES PVT.LTD

2.2 LiqIT SOFTWARE

LiqIT is a software for assessment of soil liquefaction from soil exploration data. They are designed to speed up the process of performing and interpreting results of ground response analysis. Program is organized into three managers-an input mangers, a solution and an output manager.

2.3 INPUT DATA MANAGER

They include input borehole data including SPT value, depth of blow, bulk unit weight of soil, fine content and influence thickness. General parameters include Stress reduction coefficient, Magnitude Scaling Factor (MSF), earthquake parameters like PGA, peak ground acceleration and moment magnitude of earthquake and ground water table level.

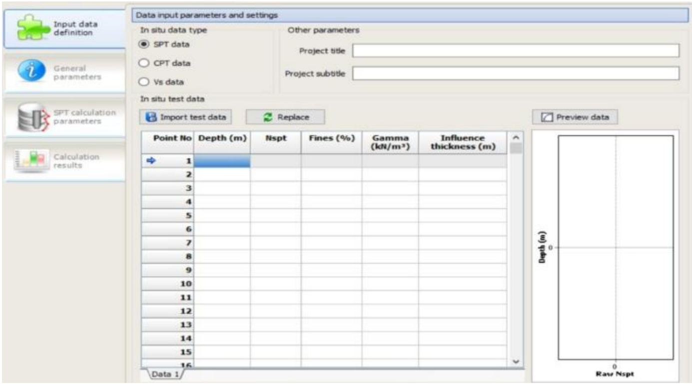

FIGURE -1 Field input data

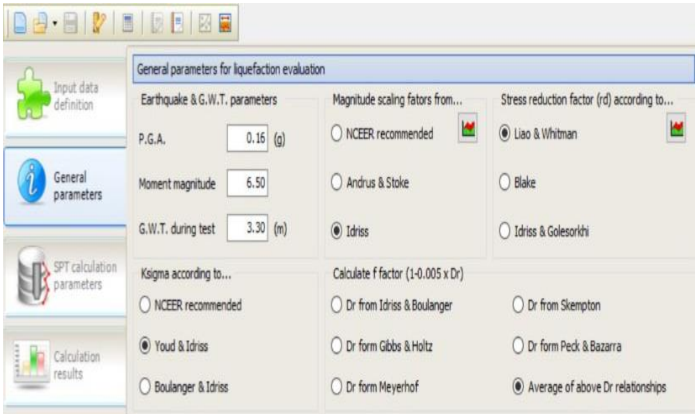

FIGURE -2 General parameter

2.4 SOLUTION MANAGER

Solution manager performs actual ground response analysis. User has to provide a valid input data. After completion of analysis, it saves the result in a file.

2.5 OUTPUT DATA MANGER

Output data included, factor of safety for each depth under consideration, graph showing variation of CSR and CRR, factor of safety, SPT (corrected and field value) variation, settlement with depth, graph showing variation of CSR with all corrected SPT value, vertical settlement and liquefaction probability. But in this study, we have taken into account factor of safety at each depth and associated graphs.

3. EXPERIMENTAL RESULTS

Table below shows the liquefaction potential and corresponding liquefaction potential risk of 13 boreholes collected from 5 sites.

Table-2: Liquefaction potential at each borehole.

Site	Borehole number	Liquefaction Potential	Risk according to Iwasaki.
Nellikuzhi	1	7.86	High
Kothamangalam	2	5.61	High
	3	2.93	Low
	4	6.2	High
	5	4.69	Low
Perumbavoor	6	0	Not probable
	7	0	Not probable
	8	0	Not probable
Nedumbassery	9	0.65	Low
	10	1.69	Low
Kalamassery	11	1.3	Low
	12	1.76	Low
	13	7	High

4. ANALYSIS OF RESULTS

4.1 NELLIKUZHI

Only one borehole was taken from here for study. For this borehole, it is found that all layers of soil are susceptible to liquefaction. At all depth SPT value is found to be <=5 and fine content obtained from laboratory test is less. From visual inspection, soil was described as sandy soil and site has a water level of 2m from ground level. It has an overall potential of liquefaction between 5 and 15,indicating high liquefaction potential.

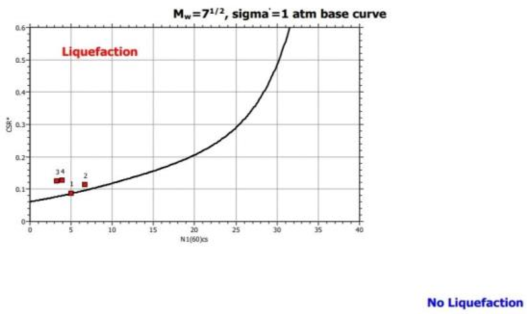

FIGURE 3: Plot between CSR and (N1)60cs.

4.2 KOTHAMANGALAM

Data's of borehole 2 to borehole 5 were collected from Kothamangalam region. 2 out of 4 boreholes are found to be having high liquefaction potential and 2 having low potential. .For borehole 2,FOS for top 2 layers was greater than 1 at depth, with top layer having a FOS equal to 5.Top 2 layers have a very low fine content in comparison to bottom layers. Beyond 2m up to 4.5 m from ground level, it is liquefaction prone. Top layers have higher SPT value indicating strength of soil.

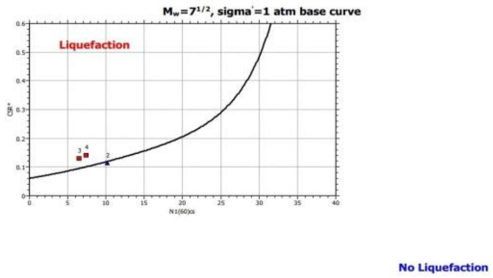

FIGURE 4: Plot between CSR and (N1)60cs.

For borehole 3,the same trend as borehole 2 is followed. Top 2 layers have FOS greater than 1 and 3 rd layer is liquefaction prone. 1st and 2nd point have higher SPT value and 3rd point of blow onwards SPT value decreases with 3rd point having a value equal to 6 having FOS very close to 1,indicating 3rd layer has lower strength. It's overall potential for liquefaction is found to be low <5 and is liquefaction prone at depth beyond 2m.

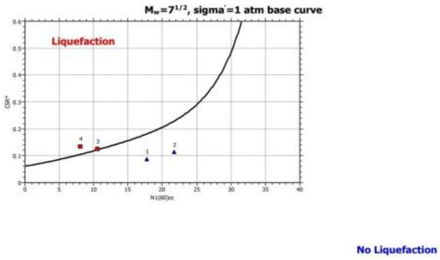

FIGURE 5: Plot between CSR and (N1)60cs.

For borehole 4, Except top layer all other layers have a FOS less than 1. All those layers have a SPT value less than 5.It's overall liquefaction probability is found to be high, in between 5 and 15,so that special investigation is required for construction of all important buildings .Beyond 1m it is liquefaction prone.

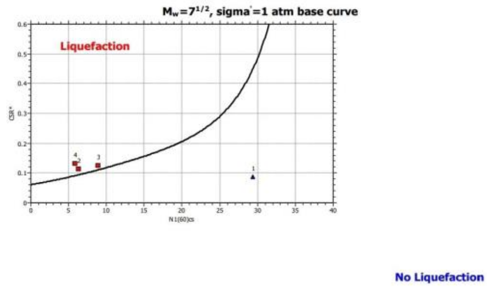

FIGURE 6: Plot between CSR and (N1)60cs.

For borehole 5,though top layers have a FOS greater than 1,there are only slight variations, SPT values for all layers are very less, indicating strength of soil is less. Even with this small value of SPT ,the top layer has a FOS 1.26,because no water is encountered in the top layer. Overall potential is less than 5 indicating its low risk. Beyond 1m from ground level, it is liquefaction prone.

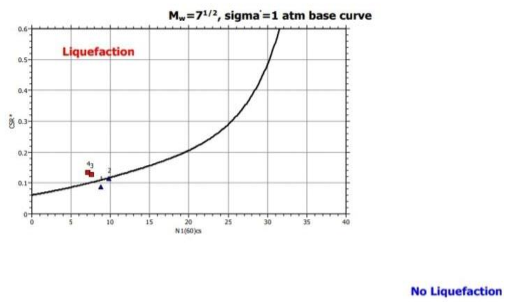

FIGURE 7: Plot between CSR and (N1)60cs.

4.3 PERUMBAVOOR

Data's of borehole 6 to borehole 8 were collected from Perumbavoor. All regions are having a FOS greater than 1.This site is least susceptible to liquefaction in this study as no layers have a FOS less than 1 .Soil found here included ,coarse sand, medium sand and fine to medium sand, all with some good amount of clay or silt shown by its fine content. Some layers have gravel or stone also. For borehole 6,all Points have resistance against liquefaction. All layers have higher SPT value indicating its strength. Besides, except the 1st layer all other layers have fine content greater than 30%. Overall potential is 0 indicating no liquefaction is probable at the site.

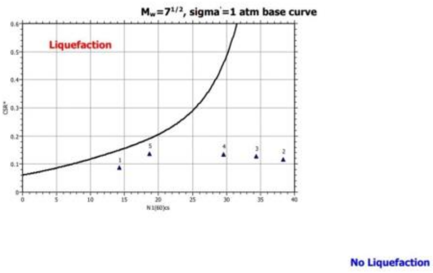

FIGURE 8: Plot between CSR and (N1)60cs.

For borehole 7,the same trend as borehole 6 is found. Fine content of some layers is as high as 50 % and except the first two layers all other layers have fine content greater than 30%.SPT values are very high for all depth. Overall potential is found to be zero here also.

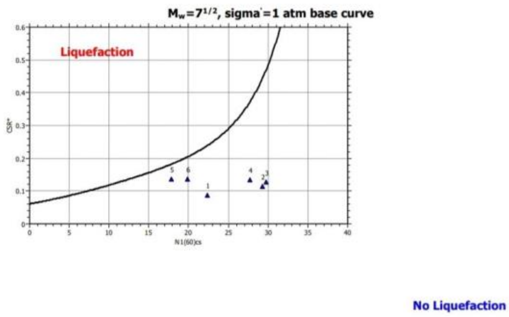

FIGURE 9: Plot between CSR and (N1)60cs.

For borehole 8,FOS is more than 1 for every point of consideration and SPT values are very high. Higher fine content is also found.

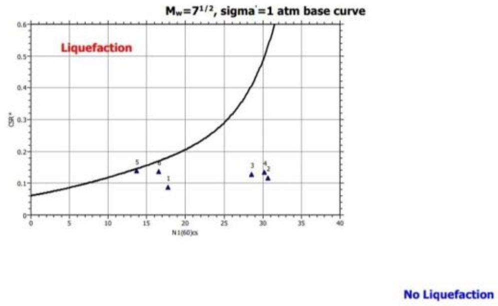

FIGURE 10: Plot between CSR and (N1)60cs.

4.4 NEDUMBASSERY

Borehole 9 and 10 are located in Nedumbassery. This region is also less prone to liquefaction of soil. SPT values for most of the depth was greater than 10 and they may even go up to 50.For borehole 9 ,except at 2 points, all others have a value of FOS greater than 1 i.e. at depth of 9m and 12m from ground. SPT value for those points are 18 and 12.Point with spt value of 18 became liquefaction prone, owing to its lower fine content. Overall potential is .65 less than 5 so a low risk still persists.

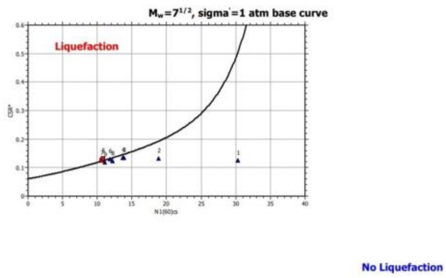

FIGURE 11:Plot between CSR and (N1)60cs.

For borehole 10,out of 10 points of blow only 3 is having FOS less than 1.All three comes under the same layer, which is visually identified as reddish brown and white sandy silty clay and they have SPT value equal to or less than 12.This layer is at a depth of 10 m almost from ground level up to 13m.Overall potential is less than 5.

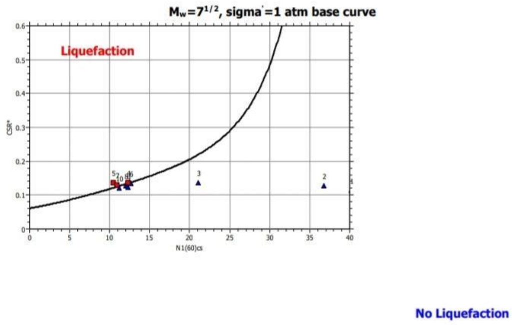

FIGURE 12:Plot between CSR and (N1)60cs.

4.5 KALAMASSERY

Data's of borehole 11,12 and 13 were from Kalamassery. Most of the boreholes have probability of liquefaction to happen. For borehole 11,the value of SPT is so high except for one layer of silty sand whose SPT value is 6,beyond 3m and having a thickness of 4.8m.All others are not liquefaction prone. Overall liquefaction potential is less than 5 indicating low risk.

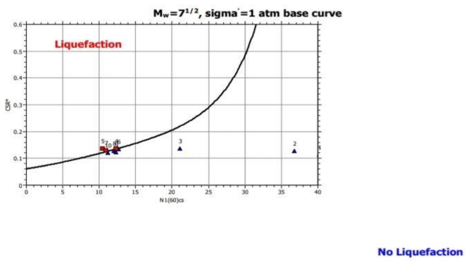

FIGURE 13:Plot between CSR and (N1)60cs.

For borehole 12, SPT values were found to be very less. Top 2 point of blow with spt value 7 and 6 is not susceptible to liquefaction. Beyond a depth of 2m it is liquefaction prone and overall potential is between 5 and 15.

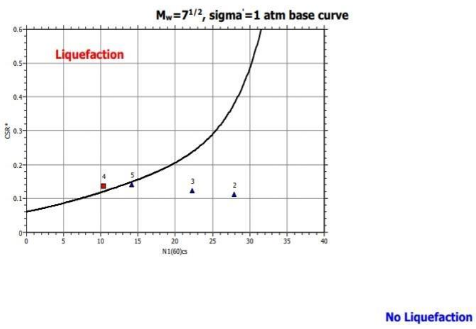

FIGURE 14:Plot between CSR and (N1)60cs.

For borehole 13,all layers except ,1st point of blow are susceptible to liquefaction ,i.e.: beyond 1m.Over all potential is between 5 and 15 .All Points have lower spt value less than or equal to 10.

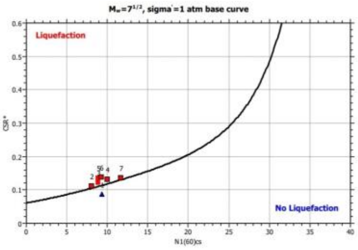

FIGURE 14: Plot between CSR and (N1)60cs.

5. CONCLUSIONS

Except Perumbavoor all other sites have liquefaction potential. Boreholes collected from Nedumbassery,2 out of 4 boreholes collected from Kothamangalam and one out of 3 boreholes collected from Kalamassery have low risk ,i.e., they have liquefaction potential less than 5. But for all other boreholes from Kothamangalam and Kalamassery along with Nellikuzhi has higher potential which requires investigating soil for all important constructions for PGA equal to 0.2g and magnitude 6. All sites which have shown higher FOS, had higher SPT value which indicates the soil characteristics. At all depth for all sites where SPT value was less than or equal to 5,FOS was less than 1.For SPT values 6 and even 18 were also found to be having FOS less than 1.But it depends on fine content and bulk unit weight of soil. Fine content can increase or decrease the factor of safety. In Nedumbassery, SPT value decreased with increase in fine content, which means lower FOS. At the same higher fine content increases Delta N value. Decreased fine content was the reason for FOS less than 1 at depth of 9m. Lower bulk unit weight increases CSR value, this is indicated by variation of FOS at points where SPT value is 6 in different sites. Depth at which SPT value is 6, exhibits higher FOS for soil layer having higher bulk unit weight due to reduced CSR value. In most cases, top layers are safe from liquefaction. This may be because none of the site has water table above ground level. For 10 out of 13 boreholes analyzed ,there is liquefaction potential, with 4 boreholes having higher risk. This can be mitigated by densifying loose deposit to increases liquefaction resistance of soil and by using stone columns to release pore water pressure and there by reducing earthquake demand of soil. Ernakulam being the commercial capital of Kerala, soil should be investigated for all important constructions.

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