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Effect of Peak Ground Acceleration (PGA) on Liquefaction Behavior of Subsoil: A Case Study of Rajshahi City Corporation

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Abstract

Peak ground acceleration (PGA) is equal to the maximum ground acceleration that occurred during earthquake shaking at a location. PGA is also equal to the amplitude of the largest absolute acceleration recorded on an accelerogram at a site during a particular earthquake. According to Bangladesh National Building Code (BNBC 2015), Rajshahi City Corporation is located in Zone 1 on seismic zoning map having PGA of 0.12. PGA bears a vital importance on the assessment of liquefaction behavior of subsoil. In this study, a total of sixty boreholes are selected in the Rajshahi City Corporation area on the basis of twice in each of the thirty wards located here. Liquefaction potential index (LPI) is calculated by simplified procedure for each borehole profile considering four different PGA of 0.12g, 0.20g, 0.28g and 0.36g for a design magnitude of earthquake of 6.5. Finally, Liquefaction maps are drawn by using Arc GIS software and the vulnerability due to liquefaction is categorized into three different names as liquefiable, marginally liquefiable and non-liquefiable. .

Keywords: *Peak Ground Acceleration, Liquefaction, LPI.*

1 Introduction

Earthquake is the most unpredictable natural disaster and it's occurred for a very short time but its vulnerability results in a huge amount. During earthquake hazards, usually sandy soil losses it's shear strength and increases the pore water pressure which result in liquefaction phenomenon. Several factors are involved in evaluating the most destructive and devastative phenomenon i.e., subsoil exploration reports, underground soil profiles, peak ground acceleration as a term of horizontal acceleration, earthquake magnitude etc. Rather than computing factor of safety, a new and well known method was first developed and modified further (Iwaski et al., 1978, 1982) named liquefaction potential index. Nowadays Rajshahi is developing progressively which forced to think about earthquake as well as liquefaction.

Bangladesh is divided into four categories for seismic zoning in accordance with BNBC 2010. Taken these four seismic coefficients from four zones of Bangladesh, factor of safety is determined along with a single earthquake magnitude of about 6.5. Geographical Information System (GIS) is a vastly used tool to represent any hazardous imaging through map. Rajshahi City Corporation consists of 30 wards and 60 borehole profiles were used to evaluate factor of safety against liquefaction and further analysis was done for determining liquefaction potential index considering four PGA values. This map was prepared to investigate and effect of different PGA values through GIS mapping with a fixed earthquake magnitude for RCC.

2 Previous Research Works on Bangladesh

In the developing country, liquefaction and mitigation have ripen concerned. Many authors had conducted research to trace the cause behind liquefaction and exhibited correlations to evaluate liquefaction taken many factors into account. M. Z. Rahman et al., 2015 perform their on Dhaka City taking 53 subsoil reports from different locations with a definite peak ground acceleration and earthquake magnitude of 0.15 and 7 respectively. They also considered the variation of water table to calculate liquefaction potential index. Shear wave velocity is also an important parameter for liquefaction assessment. M. Z. Rahman et al., 2016 estimates average shear wave velocity of sub-surface of second largest sea port area in Bangladesh (Chittagong City) for seismic characterization. Asad et al., 2015 conducted analytical research adopting three peak ground acceleration for

Dhaka City and its influence on the near environment. Rahman and Siddiqua, 2017 evaluates the resistance of soils against liquefaction using three most used tests in three major cities of Bangladesh. In that research, they collected in total 19 borelog profiles from Dhaka, Chittagong and Sylhet city also considered 0.15, 0.20 and 0.25 PGA to assess liquefaction.

3 Assessment of Liquefaction

From Chang et al., 2011, flowchart of seed's method (fig. 1) were taken to measure factor of safety and Luna and Frost, 1998 (eqn. no. 1, 2 and 3) were used to obtain LPI values this current assessment. In this analysis, some values like earthquake magnitude, hammer energy, fines content and depth of water table were assumed to 6.5, 60%, less than 5% and 10 ft respectively. Subsoil reports collected from different places are depicted in figure 2. Taking the SPT-N values with other geotechnical configuration, factor of safety (FS) and liquefaction potential index were calculated and shown a tubular style in table 1.

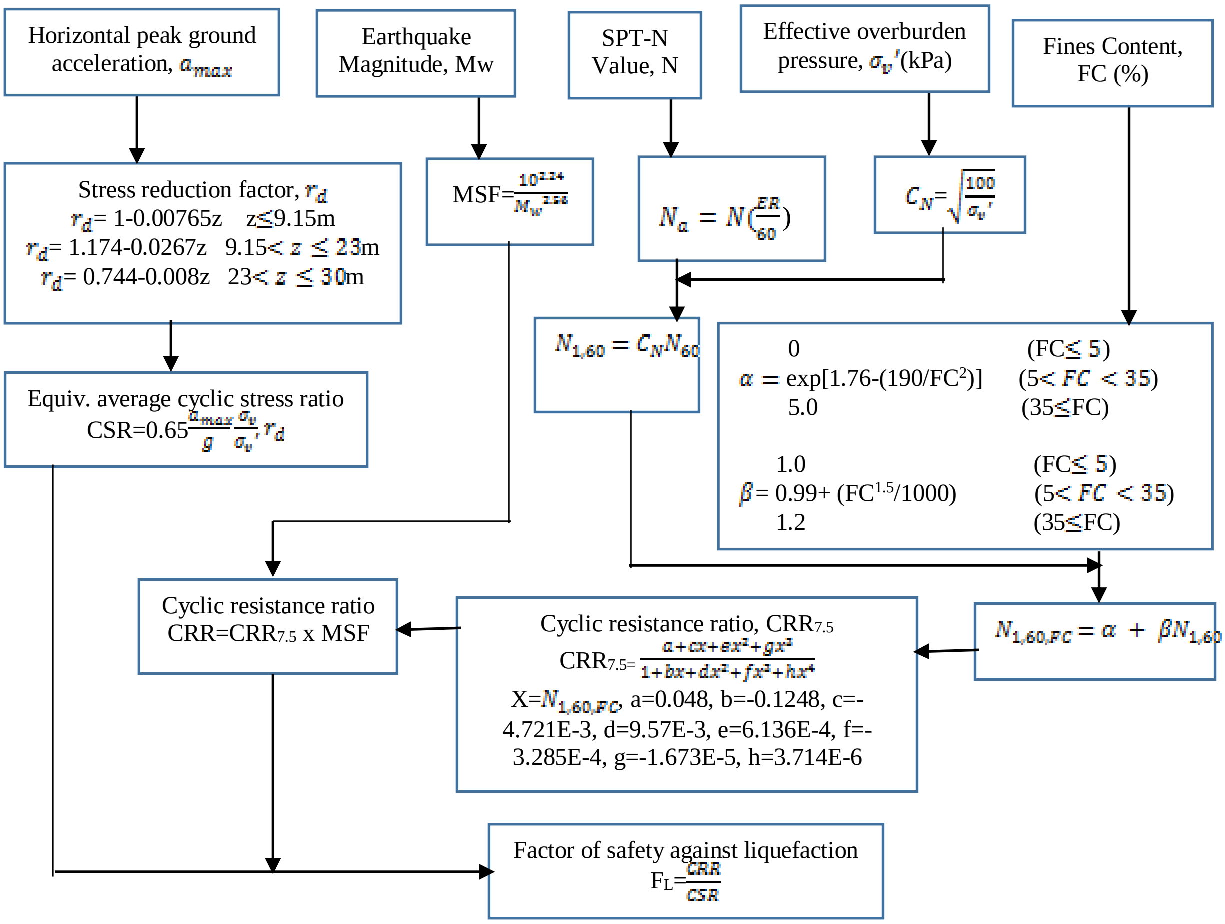


Figure 1. Flowchart of Seed's method.

3.1 Liquefaction Potential Index

Not also FS but also LPI indicator is extremely used parameter to evaluate liquefaction.

$$LPI= \sum_{i=1}^{n} w_i F_i H_i \quad (1)$$

Where,

$$F_i = 1- FS_i \quad \text{for } FS_i < 1.0 \quad (2)$$

$$F_i = 0 \quad \text{for } FS_i \geq 1.0 \quad (3)$$

While Hi indicates the thickness of the discretized soil layers; n is number of layers; Fi is liquefaction severity for i-th layer; FSi is the factor of safety for i-th layer; wi is the weighting factor (= 10–0.5 zi); and zi is the depth of i-th layer (m).

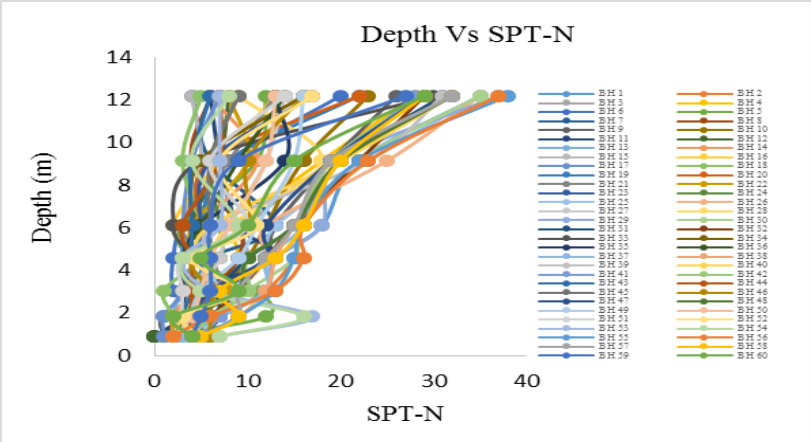


Figure 2. Variations of SPT-N value with respect to Depth.

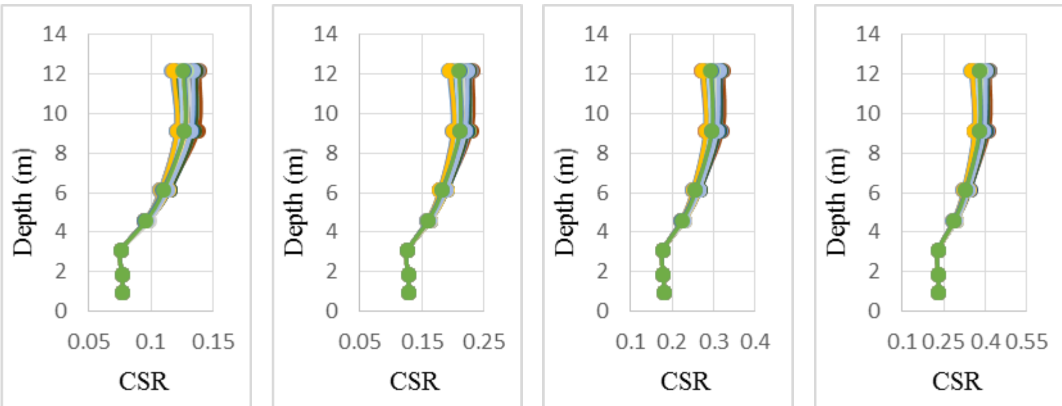
Table 1. Determination of liquefaction potential index by simplified procedure

Depth (m)	N	Unit weight, kN/m^3	rd	CSR	N1,60	Mw	MSF	CRR	FS	LPI	Total LPI
0.91	0	14.42	0.993	0.077	0	6.5	1.44	0.069	0.9	0.89	
1.83	12	14.42	0.986	0.077	23	6.5	1.44	0.364	4.73	0	
3.05	11	14.42	0.977	0.076	17	6.5	1.44	0.264	3.47	0	
4.57	4	14.52	0.965	0.097	6	6.5	1.44	0.104	1.07	0	3.58
6.1	3	13.83	0.953	0.113	4	6.5	1.44	0.086	0.76	2.69	
9.15	11	15.11	0.93	0.132	13	6.5	1.44	0.203	1.54	0	
12.2	12	14.32	0.848	0.134	13	6.5	1.44	0.203	1.51	0	

Same analysis procedure were practiced to ascertain Cyclic Stress Ratio (CSR), Cyclic Resistance Ratio (CRR), FS and LPI for keeping peak ground acceleration of about 0.12g, 0.20g, 0.28g and 0.36g. FS is evaluated using the following equation:

$$FS = \frac{CRR}{CSR} \tag{4}$$

According to this equation FS was calculated and with help of the flowchart CSR and CRR of different peak ground acceleration were determined and delimitated in figure 3 (a, b, c and d) and figure 4. On the other hand, figure 5 shows the variation of calculated FS using four peak ground acceleration. It can be seen that the value of CSR is gradually increasing while FS is gradually decreasing. Figure 4 gives the deviations of CRR with respect to depth and since there is no impact of peak ground acceleration on the CRR, it gives one graph for all PGA.



(a) (b) (c) (d)

Figure 3. Depth versus CSR for peak ground acceleration; (a) 0.12g; (b) 0.20g; (c) 0.28g; (d) 0.36g.

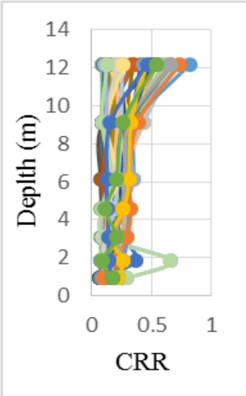
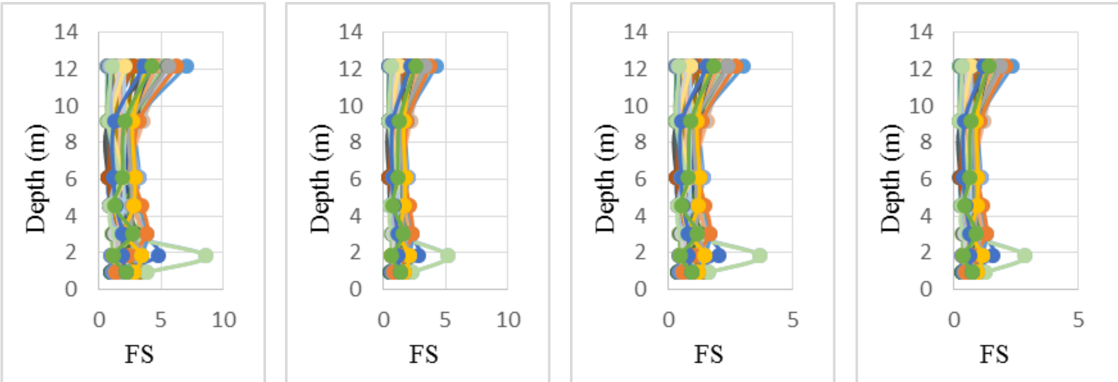


Figure 4. Depth versus CRR.



(a) (b) (c) (d)

Figure 5. Depth versus factor of safety for different peak ground acceleration; (a) 0.12g; (b) 0.20g; (c) 0.28g; (d) 0.36g.

4 Results and Discussion

With the help the diagram (fig. 1) and eqn. no. 1, 2 and 3, map from figure 6-9 were plotted using Arc GIS. Graphical representation is easily determine tool to attain knowledge of any given topics. In this view, figure 6 shows the liquefaction potentiality of RCC area at 0.12g PGA value. It is shown in the figure that RCC is quite free from liquefaction while 11 borehole locations indicated “high” susceptibility (Iwaski et al., 1978; 1982). In figure 7 displays the LPI map at 0.20g of RCC and it can easily visualized that almost half of total borelog locations are affected by liquefaction indicating “very high” prone. From figure 8 and figure 9, “very high” susceptibility is increasing as PGA value is increasing among them 35 and 45 borehole locations show the “very high” prone areas.

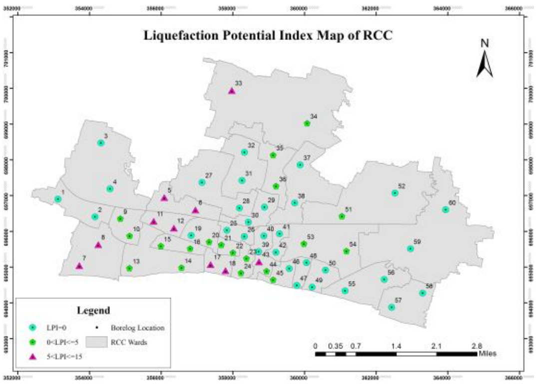


Figure 6. LPI mapping for PGA 0.12g of RCC.

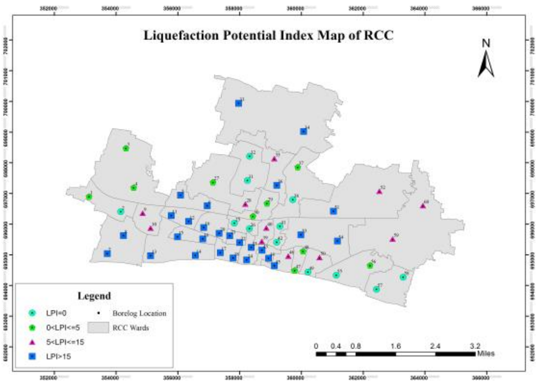


Figure 7. LPI mapping for PGA 0.20g of RCC.

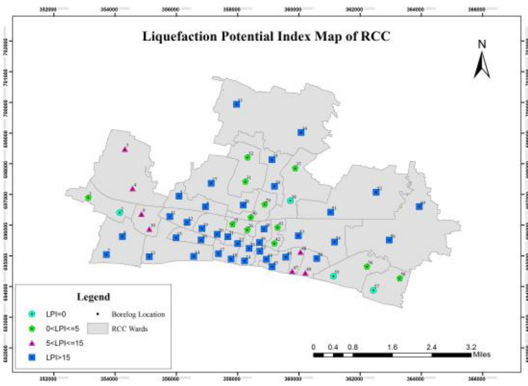


Figure 8. LPI mapping for PGA 0.28g of RCC.

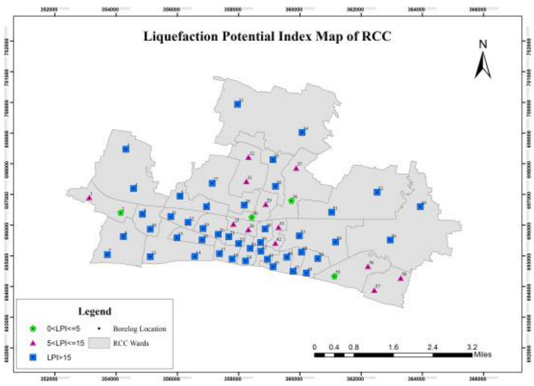


Figure 9. LPI mapping for PGA 0.36g of RCC.

5 Conclusions

From the experimental works, several conclusive points can be estimated and given below:

- LPI values have a proportional relation with PGA value as increasing of PGA indicates the increasing LPI values.
- Geological parameter (unit weight of soil) plays a vital role in evaluating LPI. More the unit weight of soil shows less LPI values.
- This prepared map would help the associated engineer, planners to gain knowledge at different PGA values abut RCC to construct and maintain any kind of infrastructure.

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