International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Impact Factor: 3.45 (SJIF-2015), e-ISSN: 2455-2585
Volume 3, Issue 07, July-2017

PARAMETRIC STUDY OF PILE IN LIQUEFIABLE STRATA

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Abstract— The phenomenon of liquefaction of soil has been observed since many years but it being the cause of damage of the superstructure due to earthquake came into picture after the Niigata (1964) and Alaska (1964) earthquakes. As Delhi comes in the region of zone IV, there becomes the need for the identification of liquefaction potential. In present project, an attempt is made to study the performance of the piles in non-liquefied zone and liquefied zone of Delhi Metro Viaduct in which the area from Jamia to Okhla Vihar comprised of liquefied zone and Kalindi Kunj to Jasola comprised of non-liquefied zone. With the help of collected borehole log data i.e. SPT data and peak ground acceleration likely to occur at the site, an attempt was made to assess in detail the liquefaction potential of foundation strata by simplified approach proposed by Seed and Idriss (1983-1985). A slow increase in the depth of the liquefaction strata in 2m interval is studied and depth at which the pile can sustain the liquefaction without much structural damage is estimated. With the consideration of liquefiable strata in the said portion, the variation in performance of the piles in terms of time period, fixity, shear force, bending moment is analyse.

Keywords— liquefaction, non-liquefaction, fixity depth, time period

I. INTRODUCTION

Liquefaction is a comparatively new and developing area. It would not be an overstatement to comment that this subject got emphasis after the catastrophic earthquake in 1964 Niigata and Alaska.

A state of 'soil liquefaction' occurs when the effective stress of soil is reduced to essentially zero, which means there is complete loss of shear strength.

Liquefaction also known as sand-boil effect is more likely to occur in loose to moderately saturated granular soils with poor drainage such as silty sands or sand with gravels capped or containing seams of impermeable sediments.

Structure whose foundation directly bearing on sand which liquefies will experience a sudden loss of support, which will result in drastic and irregular settlement of the building leading to structural damage, including cracking of foundations and damage to the building structure itself, or may leave the structure unserviceable afterwards, even without structural damage.

Structure whose foundation is directly bearing on sand which happens to liquefy will experience a sudden loss of support, which will result in drastic and irregular settlement of the building leading to structural damage, including cracking of foundations and damage to the building structure itself, or may leave the structure unserviceable afterwards, even without structural damage.

After the occurrence of earthquake, the non- liquefied soil layer abruptly loses its shear strength from the topmost level which means there is transition from non-liquefied state to liquefied state.

II. PROBLEM DEFINTION

An easy way to comply with the conference paper formatting requirements is to use this document as a template and simply type your text into it. In present paper, analysis of 1.2 diameter pile along with stage wise parametric analysis was performed in which the behaviour of a pile from non-liquefaction to liquefaction state were determined and consecutive results are presented. In this paper, basic data required for evaluating liquefaction potential, modulus of subgrade reaction, spring constants, etc. were calculated on the basis of following soil properties.

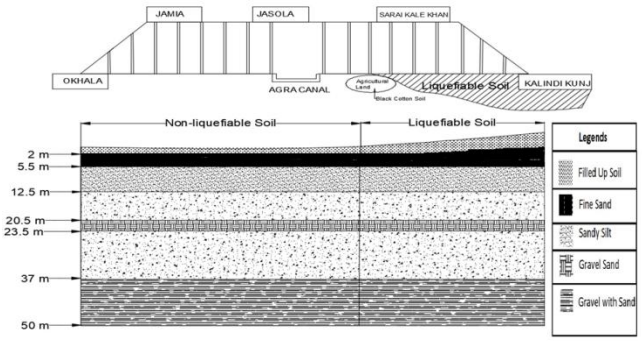


Fig. 1 Soil Profile

TABLE I
PROPERTIES OF SOIL

Depth	Type	N	w (%)	G	Υ_d (T/m³)
1.5	SM	23	10.8	2.67	1.55
3	SM	26	10.8	2.67	1.55
4.5	SM	11	10.8	2.68	1.55
6	SP-SM	20	10.8	2.68	1.55
7.5	SP-SM	23	10.8	2.68	1.55
9	SP-SM	30	10.8	2.68	1.67
10.5	SP-SM	24	10.8	2.7	1.67
12	SP-SM	44	10.8	2.7	1.67
15	SM	70	10.8	2.66	1.67
18	SM	90	10.8	2.67	1.77
19.5	SP-SM	70	10.8	2.67	1.77
22.5	SG	68	10.8	2.72	1.8
25.5	SM	65	10.8	2.69	1.79
27	SM	74	10.8	2.7	1.79

4 nos. of 1.2m diameter piles in group equally spaced (5D) are subjected to different load combinations as per IRC 112: 2011. Vertical and lateral load acting on the pile under normal case (viz. non-liquefaction case) are 448T and 102T respectively.

III. STAGEWISE ANALYSIS

From given data, liquefaction potential depth was evaluated and for its evaluation, borehole log data was analysed. SPT value plays the most important role for evaluation of liquefaction potential depth. Other parameters on which liquefaction potential depth is dependant are CSR and CRR. With the help of the above parameters, factor of safety is found out and it represents the liquefaction potential of the layer. Another important thing is to calculate modulus of subgrade reaction which in turn help to calculate spring constants, etc. for normal case and models were analysed using STAAD Pro.V8i.

TABLE II
LIQUEFACTION POTENTIAL

Depth	CSR	CRR	FOS	Conclusion
1.5	0.34	0.33	0.97	Liquefiable
3	0.34	0.27	0.799	Liquefiable
4.5	0.33	0.16	0.467	Liquefiable
6	0.33	0.19	0.59	Liquefiable
7.5	0.32	0.21	0.649	Liquefiable
9	0.29	0.22	0.759	Liquefiable
10.5	0.28	0.19	0.679	Liquefiable
12	0.27	0.28	1.029	Non Liquefiable
15	0.24	0.41	1.663	Non Liquefiable
18	0.21	0.49	2.363	Non Liquefiable
19.5	0.20	0.32	1.656	Non Liquefiable
22.5	0.17	0.29	1.715	Non Liquefiable
25.5	0.16	0.27	1.662	Non Liquefiable
27	0.16	0.29	1.851	Non Liquefiable

There were several ways to calculate spring constants like Bowles springs, Vesic Spring, IS code. Among these the more reliable result were obtained by IS code and same were used to calculate the stiffness of soil at every 1m interval. The model were analysed by three different methods. They were by keeping fixed support at foundation level, another one was using formula given by IRC 6 code and last was STAAD model which was fixed at fixity depth. These were done

for evaluating the time period of the structure and it was found that STAAD model gave reliable results as the contribution was made from the foundation level till fixity depth along with the superstructure and substructure. With the help of time period, seismic forces both in longitudinal and transverse direction were evaluated and the overall load carrying capacity of the pile was found out.

From liquefaction potential, it was observed that for given soil condition, 10m soil gets liquefied. In stage analysis, a parametric analysis was done by initialising 2m depth interval till 10m depth as liquefaction potential was observed till 10m depth. For the same, the springs were removed with increment of the liquefaction depth which indicates that the soil has completely lost its shear strength in the said layer. With the removal of springs and increase in the fixity depth, the springs of the increased layer were calculated and assigned to the model which implies that as the liquefaction depth increases, the pile length needs to be increased.

Hence for stage wise parametric analysis or behaviour of pile for different parameter like time period, fixity depth, lateral load acting on the pile and also the moment were evaluated and compared for discussion.

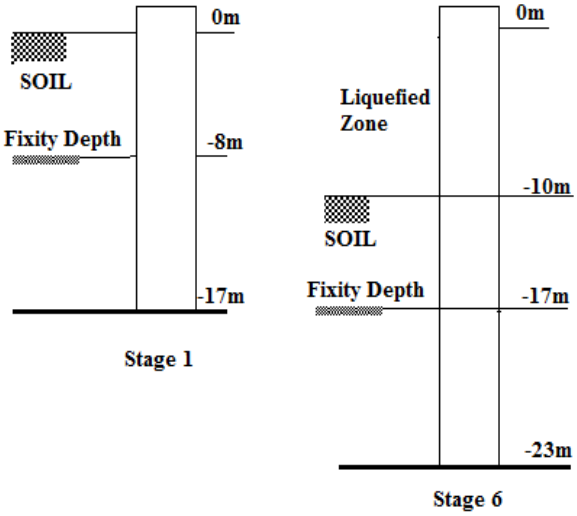
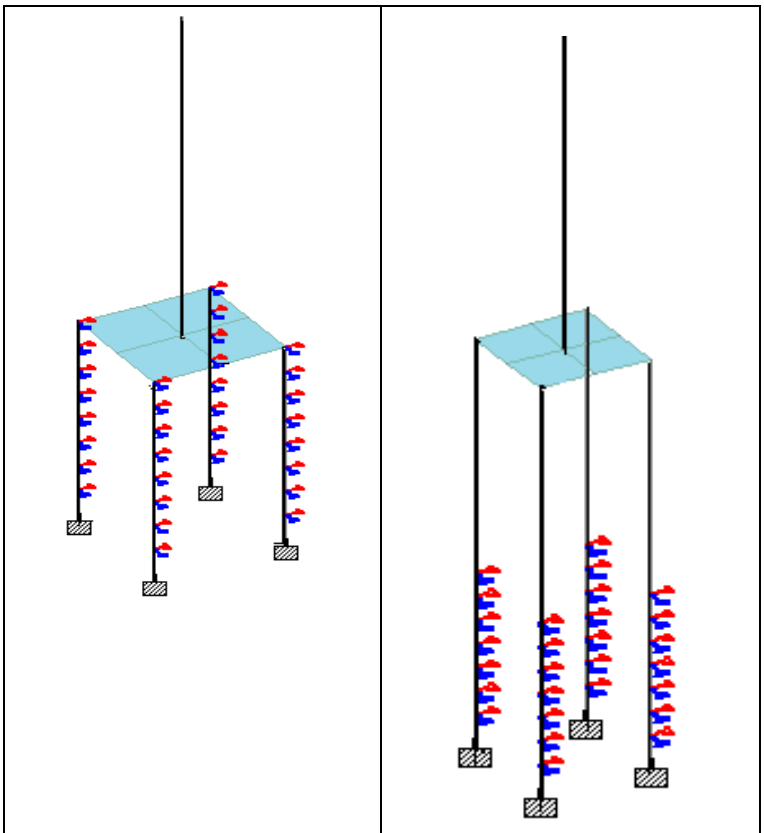


Fig. 2 Stages in Transition of Liquefaction Depth



Stage 1	*Stage 6*

Fig. 3: Stage of Analysis in STAAD

IV. RESULTS AND DISCUSSIONS

Liquefaction potential is important for analysis as soil losses its shear strength because of which capacity of pile gets decreased. For analysis purpose, the top layer of springs defining soil stiffness was removed.

A. Fixity Depth

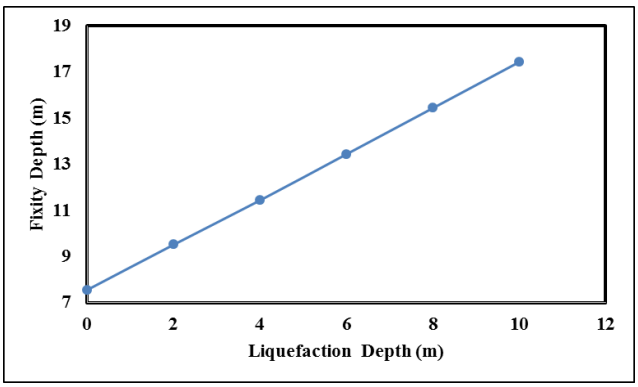


Fig. 4: Stage of Analysis in STAAD

- As liquefaction depth increases, fixity depth increases linearly.
- Due to liquefaction, the SPT value of soil decreases thereby decreasing the modulus of subgrade reaction of soil, ultimately increasing the stiffness factor of the pile, which leads in increase in the fixity depth.

B. Time Period

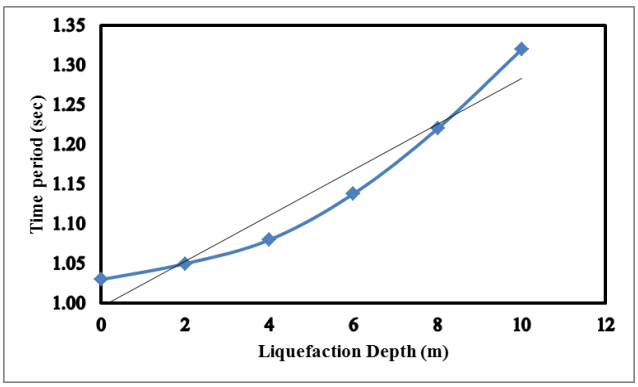


Fig. 5: Time period v/s Liquefaction Depth

- As liquefaction depth increases, time period increases non-linearly.
- Due to liquefaction, the fixity depth of the pile increases thereby increasing the time period.
- But the increase is non-linear because the stiffness of the full structure is accounted.

C. Lateral Load acting on pile

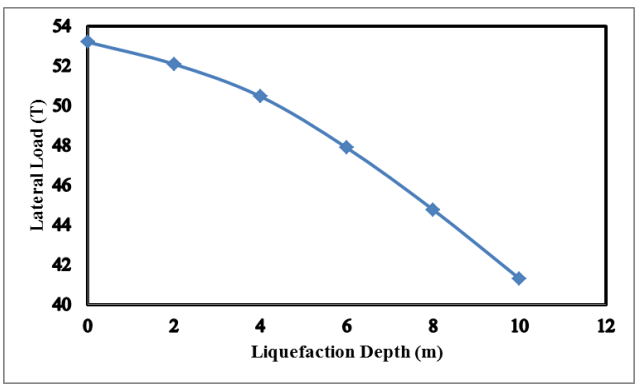


Fig. 6: Lateral Load v/s Liquefaction Depth

- As liquefaction depth increases, lateral load on the pile decreases non-linearly upto 8m liquefaction depth and later on it remains constant.
- Due to liquefaction, the time period of the structure increases thereby decreasing the lateral load acting on the pile.

D. Moment acting on the pile

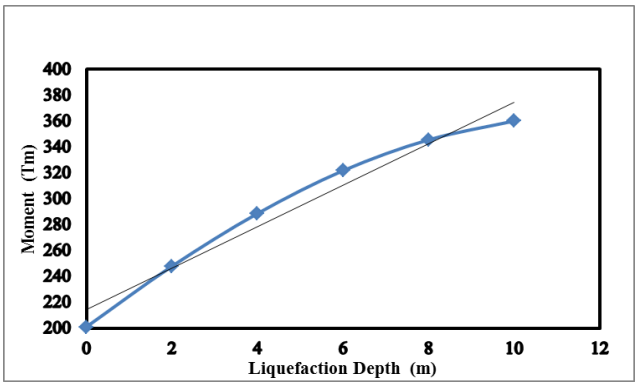


Fig. 7: Moment v/s Liquefaction Depth

- As liquefaction depth increases, lateral load on the pile decreases non-linearly upto 8m liquefaction depth and later on it remains constant.
- Due to liquefaction, the time period of the structure increases thereby decreasing the lateral load acting on the pile.

V. CONCLUSIONS

- The Liquefaction affects different parameters of piles severely like increase in fixity depth due to which time period of the structure increases. At the same time, there is loss in shear strength of soil surrounding the pile leading to decrease in lateral capacity of piles which consequently increases the moment acting on the piles.
- Comparatively, in case of non-liquefaction the design of pile is leads to having lesser fixity depth, lesser time period and can carry more lateral force will lesser moment yielding to lesser quantity of construction material.
- Liquefaction makes pile flexible hence attention is required during analysis of pile as negligence of liquefaction will lead to catastrophic failure.

ACKNOWLEDGEMENT

I express my deep sense of gratitude to my guide Dr. M. M. Murudi, Mumbai for his valuable guidance, constant encouragement and creative suggestions offered during the course of this project.
I am greatly indebted to Mr. Vivek Abhyankar Sir for his help, timely practical and industrial guidance and sharing his thoughts related to the project thereby making valuable and purposeful suggestions without which it would not have been possible to complete this work.
I am gratified for his valuable time provided and discussions made at each step of work. I am grateful to
Mr. Mohammad Raffikbasha for sharing knowledge related to Geotechnical Engineering.

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