Forensic studies of a touch pile system failure in Cochin, India

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ABSTRACT

This paper presents a case history of analysis and review of a touch pile system failure during deep excavation for a commercial building (3 basements, ground floor and 8 floors) near Metro Station Kaloor, Ernakulam, Kerala, India. Excavation to a depth of 10 m from the ground level was required to reach up to foundation level of the structure. To retain the soil to facilitate the excavation, touch pile system with strutting was adopted. As the excavation was in progress, the shoring system collapsed at 9.30pm on 19/04/2018. A technical expert committee was formed by District Disaster Management Authority, which comprised of the authors to identify and evaluate the reasons of failure. This Forensic report presents the immediate restoration steps adopted, various tests conducted to analyze the reasons for collapse, evaluation of the reasons for failure and the precautions to be adopted for such constructions in future.

Keywords: Touch Pile; Hydrostatic Pressure; Collapse, Integrity test

1. PROJECT DESCRIPTION

1.1 Specification of the proposed structure

The proposed commercial building consists of three basements, ground floor and eight floors, in which B3, B2, 7th and 8th floors are meant for parking and Basement 1, ground floor and 6 floors are for commercial use.

Floor heights:
Parking Floors = 3.30 m
Ground Floors = 4.20 m
Other Floors = 3.75 m

The project was located near Metro Station Kaloor Ernakulum, Kerala, India. An excavation up to a depth of 10 m from the ground level was required for reaching up to the foundation level of the structure.

1.2 Suggested structural and piling details

For the proposed commercial building project the recommendations were provided based on the study conducted on 5 boreholes extending up to a depth of 50 m. Standard Penetration tests were conducted at regular intervals and water table was noted at a depth of 0.40 m from GL. Based on the soil profile, to transfer heavy loads, bored RCC DMC (direct mud circulation) piles extending to depth of about 47 m terminated in very dense sand with N>100 with a minimum penetration of 2000 mm, using M35 concrete were suggested. Since the depth of excavation was about 10m, touch piles of 900 mm diameter extending up to 30 m depth with inside strutting supported on soldier piles of 600 mm diameter extending up to 30 m were adopted as soil retention system to facilitate excavation.

2. EXECUTION AT SITE

The touch pile system comprised of 337 piles of 900 mm diameter extending to a depth of 30 m depth and 28 soldier piles of 600 mm diameter extending to depth of 30 m. The touch pile system was designed as propped cantilever to resist the lateral loads. Touch piles were done at the boundary by excavating a trench of 900 mm width and 1.5 m depth in a line and level and alternate piles were done initially and then in between piles were done.

After completion of shoring works, excavation was done in 3 phases: During phase 1, excavation was carried up to 2 m and strutting work supported on soldier pile was provided, in the Phase 2, excavation was carried up to 6.50 m and in the 3rd phase, excavation was planned up to 10 m as directed by the structural consultant. Dewatering system was not suggested by the consultant considering the general impervious nature of clay in Cochin.

3. COLLAPSE

3.1 Touch pile system

When the excavation reached a depth of 9.5 m at 5.30pm on 19/04/2018, a slight deflection of 20 mm was noticed on the shoring walls towards the north (excavated area) and the deflection increased to 100 mm by 7.00pm. Excavation was completely stopped and workers were evacuated. Further shift increased to about 200mm by 8.30pm along with some creaking sound and water jets were noticed on the shoring walls and by 9.30pm the shoring piles on the southern side came down suddenly.

Fig. 1. Failure of Touch Pile System at Kaloor, Cochin

3.2 Observations after collapse

The following observations were made at the site immediately after the touch pile failure.

i) Due to the collapse of the touch pile system, the nearby road and earth had sunken by approximately 3.0 meters on the south side of the excavated area.

ii) Due to the lateral shifting of the piles the nearby earth was sunken on the south west side of the excavated area.

iii) The building near the south west corner had a slight tilt towards the east side and cracks were noted in the building and part of the foundation was exposed. This is indicative of progressive failure and may lead to sudden collapse of the building.

iv) Cracks were noted at ground level in all the other three sides of the excavated area.

v) The roads with pavement of interlocking tiles had differential settlement.

vi) The public utilities such as road traffic, electricity and water supply were adversely affected by the collapse.

vii) It also resulted in temporary halt in the working of Kochi metro since the structure was located close to the metro station Kaloor.

4. EXPERT TECHNICAL COMMITTEE

An expert technical committee was formed by District Disaster Management Authority (DDMA) for the immediate restoration of the damages caused during collapse of road and disruption of the various public utility systems and also to study

i) Reason of collapse of touch pile system

ii) Verification of statutory government approvals

iii) Suitability of the touch piles system for further construction and scrutiny of the initial design

4.1 Immediate rectification

District collector directed the owners of the building to bear all the expenses connected with the immediate rectification works and that were carried out under supervision of the technical committee. The committee after inspection suggested the following

i) The southern portion which is excavated up to 10.0 m has to be immediately refilled up to 5.0 m below ground level by using red earth inorder to prevent the progressive failure of the surrounding area.

ii) The sunken portion of the road has to be strengthened by providing coconut timber piles extending up to 6m depth at 1m centre to centre and to be filled with red earth in layers and proper compaction has to be done up to the original level.

iii) Coconut timber piles to be driven for strengthening and protection of unaffected main water lines and public utilities such as electricity, telephone lines, water supply etc which were damaged have to be immediately restored.

iv) Double layer braced sheet piles to be provided to protect the sides of the road and the soil to be filled up to formation level.

The immediate restoration works were carried out under the supervision of public works department, with the assistance of technical committee and the remedial measures were completed by 25/04/2018 and traffic through the restored road was permitted with speed restrictions.

Fig. 2. Refilling of soil after touch pile collapse

Fig. 3. Two layer sheet pile adopted near public road

5. FORENSIC STUDIES OF THE FAILURE

In order to evaluate the reasons for the collapse of touch piles the expert committee conducted following tests

i) Concrete core test for verification of in-situ concrete strength.

ii) Pile integrity test to assess the depth at which pile failed and to check whether the actual pile depth matches the design depth.

iii) Additional soil investigation to confirm the parameters of subsoil strata adopted in design.

iv) Geotechnical & structural analysis of touch pile system was carried out using PLAXIS and STADD software's to identify the causes of failure.

5.1 Core test

The test was conducted on touch piles and tie beams to ascertain the strength of concrete in piles and tie beams. Total of 11 samples were tested, of which 8 were taken from touch pile and 3 from tie beams. It was found that cube strength values were higher than designed values.

5.2 Integrity test

Pile integrity testing (PIT) was done on 8 R.C. bored piles which were installed in the site. The results showed that the collapsed piles failed at depths around 14.50 m to 15.5 m from the ground level. And length of the standing piles was found to be approximately 30m as specified in the drawings.

5.3 Additional Soil investigation

Additional soil investigation carried out indicated that the top soil profile is of very soft nature and the overall profile is in conformity with the initial investigation conducted

5.4 Geotechnical and Structural analysis of touch pile system

Detailed analysis of the touch pile system and its stability as an earth retaining structure against lateral loads at different stages of excavation were carried out using PLAXIS and STADD software. The stability analysis of the systems comprising of touch piles, soldier piles and strutting system were analyzed for 5 m, 6 m, 7.5 m and 10 m earth retention. For excavation carried out up to 6 m depth, the touch pile system comprising of 900 mm diameter piles without strutting was adequate. When depth reaches 7.5 m, the strutting system was found to have marginal deficiency to take up the earth pressure and it was observed that for the depth of 10m, the provided touch piling system and strutting was grossly inadequate to take up the lateral thrust. The findings from the analysis are

i) The shoring pile with single strut propping system used in this project is found inadequate to take the lateral forces for the proposed depth of excavation of 10m.

ii) The reinforcement of the shoring piles is found inadequate against bending with single strut propping system at top provided for the proposed depth of excavation of 10m.

iii) The strutting system currently used is a series of trussed beams in grid pattern, but not orthogonal to each other. This will have a tendency to make the grid system skewed and to facilitate further yielding of the props.

iv) The soil at current depth of excavation has turned very soft on account of water seepage. This has caused considerable weakness of the interface soil. High thrust from the shoring pile at the interface has caused yielding of this soil. Subsequent increase in unsupported length of pile is also a reason for the failure of the pile in bending.

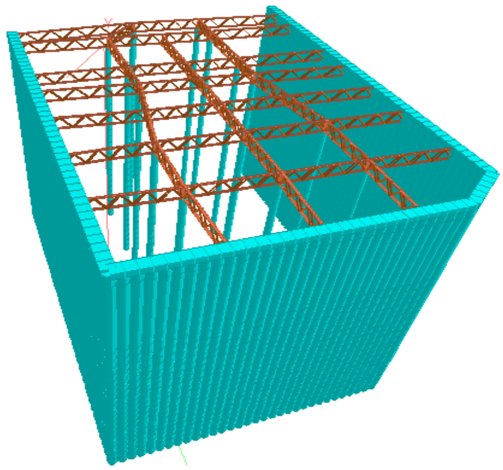

Fig.6. 3D model of provided touch pile system for 10 m retention

6. STATEMENT OF KEY STAKE HOLDERS

The committee as part of natural justice, gave opportunity to the owners of the building, project management team, architect for the project, structural engineer, foundation consultant and piling and civil contractors to present their observations or points of view regarding the failure and probable reasons that led to it and this was also considered in the analysis and evaluations.

7. CONCLUSIONS

i) As per the geotechnical and structural analysis, the failure is due to the fact that the strut system was inadequate to take up the lateral thrust from the touch piles and to provide the required stability. The soil at the dredge line has turned out to be very soft and has caused considerable loss of strength of the interface soil, high thrust from the shoring pile at the interface has caused yielding of this soil. Subsequent increase in unsupported length of pile is also a reason for the failure of pile in bending. A second tier of strut system at a lower depth could have been helpful in retaining the touch pile system in position.

ii) The team scrutinized all the approval documents needed for the project and they were found in order.

iii) With regard to the suitability of touch pile system for further construction, the present touch piles installed can take up the lateral earth pressures due to the excavation up to the proposed depth of 10m, provided adequate bracing system with higher sections and proper balanced geometry is adopted. Diagonal cross bracings especially at the corners have to be provided to bring in the required rigidity.

iv) It is also suggested that the set back of the touch pile system near the road be increased by additional four meters so that the road and the public utility systems remain unaffected.

v) The committee felt that the collapse of the touch pile system of the building should serve as a wakeup call to the authorities and engineers in the construction industry. It is only sheer luck that there was no loss of human life. There was only one building close by and this is to be dismantled now. With workers in the excavated area and with buildings close by, it would have been not just a failure but a catastrophe.

vi) It is true that the cellars are going deeper and deeper and floors going higher and higher. The construction industry is slowly getting attuned to modern design techniques and construction procedures. The trends cannot be discouraged but the authority should exercise greater caution and control when projects with such trends are approved.

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REFERENCES

Moh Z.C., Chin C.T., (1991) Deep Excavation in Soft ground, Proceedings of ASIA Construction: New Frontiers, Singapore.

Chen, L.T. and Poulos, H.G., (1997) Piles subjected to lateral soil movement, Journal of Geotechnical and Geoenvironmental Engineering, Vol. 123, No. 9, pp. 802-811.

Puller, M., (1998) Deep Excavations: A practical Manual, Thomas Telford, London, UK.

Chang-Yu Ou, (2006) Deep Excavation: Theory and Practice, Taylor and Francis Group, London, UK.

Joseph, A., Muralikrishna A, (2015) “Construction practices of deep basements” 50th Indian Geotechnical Conference, Pune.

Leung C.F. (2016) Forensic Geotechnics—Some Case Studies from Singapore. In: Rao V., Sivakumar Babu G. (eds) Forensic Geotechnical Engineering. Developments in Geotechnical Engineering. Springer, New Delhi