International Conference on Case Histories in Geotechnical Engineering

(1993) - Third International Conference on Case Histories in Geotechnical Engineering

02 Jun 1993, 9:00 am - 12:00 pm

Foundation Problems in a Developing City

K. R. Saxena
A. P. Engineering Research Laboratories, India

A. S. R. Swamy
A. P. Engineering Research Laboratories, India

R. S. Murthy
A. P. Engineering Research Laboratories, India

Recommended Citation

Saxena, K. R.; Swamy, A. S. R.; and Murthy, R. S., "Foundation Problems in a Developing City" (1993). *International Conference on Case Histories in Geotechnical Engineering*. 31.
https://scholarsmine.mst.edu/icchge/3icchge/3icchge-session01/31

Proceedings: Third International Conference on Case Histories in Geotechnical Engineering, St. Louis, Missouri, June 1-4, 1993, Paper No. 1.57

Foundation Problems in a Developing City

K. R. Saxena
Joint Director (Retd), A. P. Engineering Research Laboratories, India

R. S. Murthy
Asst. Research Officer, A. P. Engineering Research Laboratories, India

A. S. R. Swamy
Research Officer, A. P. Engineering Research Laboratories, India

SYNOPSIS Foundation problems are normally associated with type of sub strata, soil, rock or any other foreign material met with, and/or if choice of foundation is not compatiable with them. In developing cities, the development stress is on highly developed congested areas, limiting the sub soil investigation, and plans to have high rise buildings ,requiring deep foundations and some times execution of these posing site problems. The collapse of a multi-storeyed structure caused, according to geotechnical engineers due to overlooking the existance of a drain and a few cases of "composite" foundations are described.

INTRODUCTION

The statement "We should not be too proud of the behaviour of our structures which apparently have satisfactory foundations. Afterall would they be able to compare to the Great Pyramid of Cheops after standing for 5000 years?" equally applies to structures built on foundations not complying to the codes of today or theories established based on research and experience.

The case histories presented are of an old city of India, Hyderabad, in the southern peninsular part of the country. This city, once a capital of a native state is presently capital of a province of the independent India, covering an area of 1200 Sq.Km with a population of about 2.5 million. With fast growth of the city, the pressure on urban development has been ever increasing resulting into vertical as well as lateral expansion. The city as founded in 1589 by the fifth Kutub Shahi King was confined to the right bank of Musi river, a tributary of River Krishna, one of the major rivers of the south. The most imposing of the buildings is the "Char minar" or "Four Minarets" erected in 1591, each 55 metres high. Subsequently sorrounding this building number of historic buildings were constructed, and all these were founded on soild granitic rock at an elevation of 500 m above M.S.L. In 1908, the river Musi experienced floods after continuous rain, resulting in collapse of the three bridges existing then across it and inundating many areas on both sides of the river and causing widespread destruction of property. About 20% of the population either lost their lives or were dislocated. Majority of people, the commoners had houses of mud which were damaged and were replaced by brick and lime structures. This flood completely changed the face of the city, as river Musi was trained to follow a certain course with high stone masonary walls running on its banks with in the city and two flood absorbing reservoirs on upstream. The inundated parts spreading to about one to two kms on either side of the river were reclaimed to construct roads and buildings. This had further impact on other parts of the city. Rise in land value, tempted the well- to-do people to part with their lands, chiefly huge gardens and farms surrounding the buildings, on the left bank of the river. As shown in Fig.(1) "new city" started growing which now exceeds in area of the "old city" on the right side of the river.

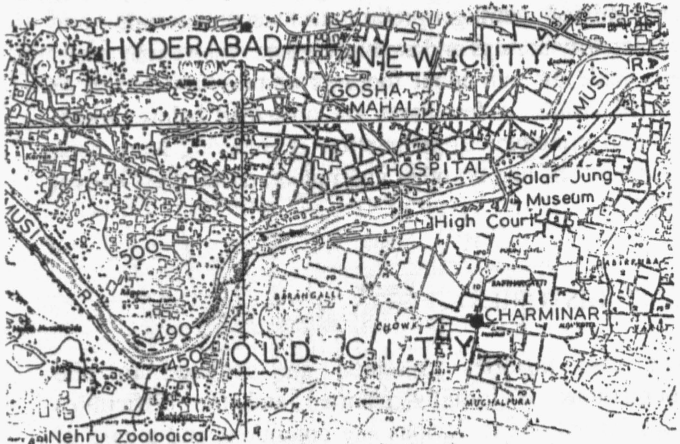

FIG.1: PLAN OF HYDERABAD CITY

FOUNDATION PROBLEMS

Foundation problems, from geotechnical points of view are of two types, those associated with "weak soils" or "problematic soils" and other associted with "hard disintegrated rocky materials", but not rocks. It is the later category of material, whose insitu properties are difficult to be determined by standard tests, and tests if performed require considerable discretionary approach, based on experience, for use of data for design of foundations. The problem while designing foundation, further gets complicated, if these formations contain large size boulders or any other foreign material irregularly distributed both indepth and inspread. Removal of these materials disturbs the natural and old deposits and if left insitu, estimation of their stability becomes a matter of guess ,as sometimes geometry of mix is not fully exposed.

Hyderebed city now extends about 5 to 6 kms on the left and right banks of the river Musi. The river bed elevation is RL + 450 with banks at RL + 490 on either side and rising to RL + 530 and above. The typical topography of the peninsular region is buried under roads and levelled grounds, and is highlighted in its natural form for a geotechnical engineer while exploring sub soil formations for foundations of buildings or towers. The disintegrated material locally called "morum: is resting over the bouldery strata, thickness varying from 2 to 20 meters, practically trapped in between boulders and in some places impregnated by rubbish material. Even in limited areas of buildings it does not have material of uniform quality or thickness, thus posing problems for deep foundation, like piles.

The all around development of city lead to vertical expansion in certain areas of commercial importance. This resulted in dismantling of old palaces, filling up old wells, deep sewage drains, pitfalls around boulders, all buried a few meters below the ground. Normally these are missed during preliminary reconnaisance and exploratory borings and are highlighted when excavations are made for individual footings or piles are driven or casted insitu. A few cases are presented below, where general principles of foundation engineering have been "violated" having no other alternative, taking the "known risks".

CASE HISTORIES

The case histories presented are confined to pile foundations as initially planned and the difficulties experienced due to various site conditions and a case of collapse of a structure.

Housing and Shopping complex:

Fig.2 is the layout plan of a housing and shopping complex, over a reclaimed area, ruins of old historic structures, residential palace, gardens with deep wells, parks, fountains etc. As shown in the plan a few open trial pits and deep exploratory borings were made and general sub soil profiles are given in Fig.3.

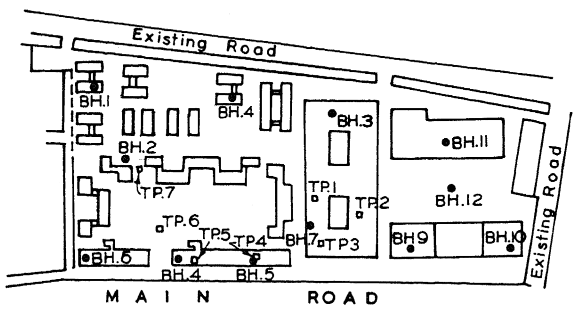

Fig. 2: Layout plan of the housing complex.

The complex contained two floor shopping blocks and muti-storeyed buildings with maximum 14 floors. In general for all structures the designers preference was single or a group of piles as foundations, with single or double under reamed bulbs of diameter 37.5 cm and 45 cm diameter, giving reduced load carrying capacity of order of 24 tones and 27 tonnes at 65 % efficiency due to high water table conditions prevailing at site. the Indian Standards Code of Practice (1973) was followed. The heterogeneous filled up or remanents of old structures, as expected in the area, presented lot of difficulties for manual auguring or under- reaming for piles and sometimes the bailing out of the material was done by sending the person inside the bore to remove chunks of hard lime-mortar of old structures. Damage to boring and under-reaming tools was experinced right through. Following three typical situations are presented, which are not common and are difficult to analyse applying geotechnical theories or practices known to the authors.

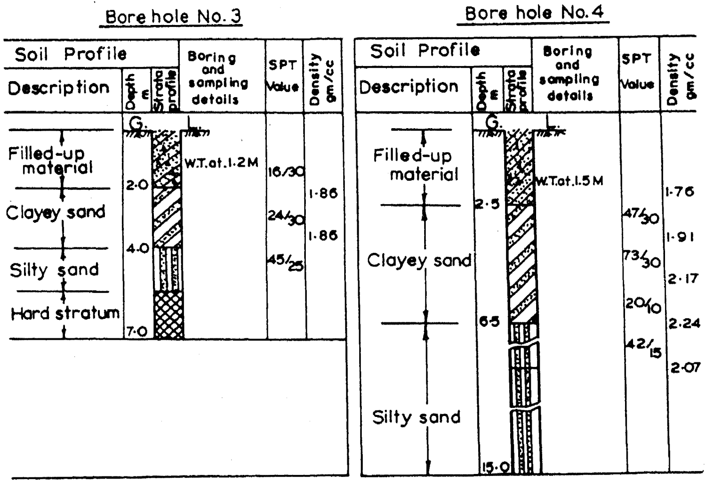

FIGURE 3: TYPICAL LOGS OF BORE HOLES

In the shopping block, where perhaps in general open footings would have taken care of loads of two storeyed complex, a group of two under-reemed piles were adopted under columns. A big boulder of size 2 to 2.5 metre in diameter, extending to more than two metres in depth, obstructing piling operation, left no other alternative except to adopt a "composite" foundation, that is an open footing of size 1.8m x 2.5m depth under one column resting over the boulder and adjacent columns resting over a group of two under-reamed piles , as shown in Fig.4. Under-reamed piles are the cost-insitu piles, and the piling was taken up one by one and hence change in design of foundations was not possible. Atleast for four columns, in the complex, similar "composite" foundations were adopted.

In the multi-storeyed housing complex in the same area, a group of four piles was provided for column footings. After two piles were completed namely C 14/3 and C 14/4, as shown in Fig.5, the two piles C 14/1 and C 14/2 could not be driven due to the foundation of an old building obstructing the piling operation. This situation was tackled by removing the old strucutres by exavating a pit three to four meters deep upto hard strata and back filling it by selected gravelly material belonging to "GC"-"SC" group of soils. The two piles, C 14/1 and C 14/2 of the group, were subsequently completed but could not be driven upto the depth of other two piles C 14/3 and C 14/4 due to the hard strata met with. The piles were left, without under reaming and their bottom tips resting at different elevations. The single piles of different lenths, with and without under-reaming when tested were found to satisfy the designers. But prediction of behaviour of group of four piles, was not possible from the test piles, and even theoretical analysis was not feasible from soil properties. The matter was discussed and opinion of structural designers and geotechnical engineers deffered leaving the owners with no other choice than to stop the construction with four floors against fourteen initially planned and to wait and watch the behaviour of structure. This has been described as case of indiscriminate use of under-reamed piles by Saxena et al (1978).

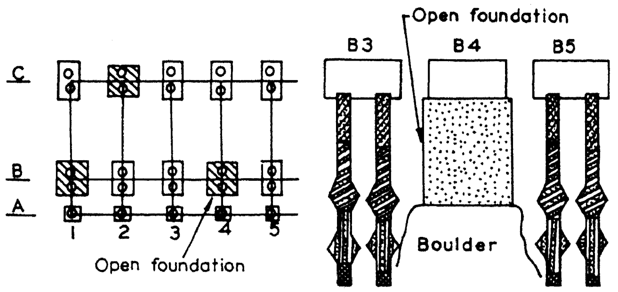

Fig.4: Under reamed piles with open foundations

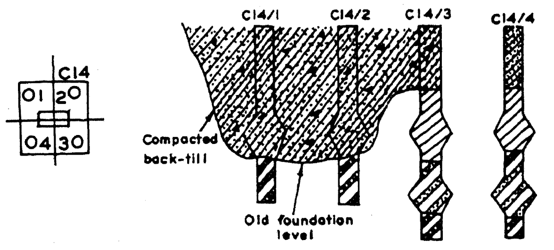

Fig. 5: Unde backfilled ground.

The monitoring of behaviour of the above structures were attempted by embedding settlement plugs, to measure any tilt by a plumb-and-bob method attached to these or by straight away recording levels of footings periodically with respect to a datum. Quoting Leonard (1982), it is not always possible to improve knowledge by investigating instabilities of structures as the objectives of the parties involved are often incompatible. The construction and design engineers wilfully damaged the monuments during completion of works, making it impossible to proceed with the study of behaviour of structures having foundations of unconventional type.

Collapse of a Multistoreyed Building

The six storeyed completed but unoccupied building which failed, was one of the seven buildings located in the area of 8000 sq.m as shown in Fig.6. The area was relatively low lying, originally under cultivation collecting drainage water of surrounding areas. A drain about metre and a half deep, originally crossed the area of the collapsed building, but was diverted to pass around the collapsed building in open land. The building rested on columns and transfered load of 50 tonnes through a group fo two under reamed piles of 37.5 cm diameter and 70 to 75 tonnes through a group of three under- reamed piles with rectangular and triangular caps respectively. The coløumns were not connected through plinth beams. The sub soil investigation report and results of tests on foundations soils and piles were not available. A few open pits and general topography of surrounding rocky and bouldery terrain seams to have guided the designers, and banking more on their experience with under-reamed piles and Codes of Practice.

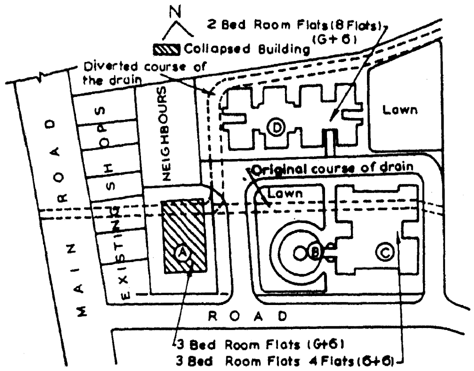

Fig.6: Plan showing collapsed building.

The collapse occured in early hours of the day, after heavy rains in the area on the preceeding evening. The drain was running full and area was practically submerged. The distress in the building with spalling of plaster in the ground floor partition wells was observed 30 minutes before collapse. As reported, the north western corner of the building sank into the ground with a hissing sound. One of the versions was that soon after the water storage tanks were filled up in the morning for the first time, the distress was followed and failure took place. The demolition of the building was taken up by the owner-engineer with in 24 hours after the failure and operation was over with in 48 hours giving no time for inspection. The left over was that the North-Western columns were completely sunk in the ground, while on south-eastern side about a metre length of the columns were seen, at an inclination of 10{o} to 15{o}. There was no heaving of the ground around the foundation.

Preliminary exploration were carried out by Standard Cone Penetretion tets, in the vicinity of building and the data was supplemented with a few bores for collection of disturbed and undisturbed soil sample. 12 dynamic cone tests and 6 static cone penetration tests revealed hard strata at a depth of six meters, classified as hard disintegreted material, which on pulverization belonged to SC group having an insitu density of 1.7 to 1.9 gm/cc and "N" varying from 25 to 40 with water table one metre below ground level.

As reported by Ali et al (1982) the examination of full length of pile by open excavation was not possible due to high rate of water inflow from surrounding areas. Two distinct features were noticed with respect to piles. In some cases, the columns had pierced through the pile caps into the soil, in between the pile groups, slanting generally towards north-west. In some other cases, the piles had inclined about 25{o} from vertical towards the drain and it was noticed that bulb were about 75% of the designed diameter and shafts were irregular and number of pile in a group were less than planned.

It is experienced that bias in collecting data and interpreting results is difficult to be avoided or even minimized. Ali et al (1982) considered collapse due to the "progressive shear failure of pile caps" and due to low strength concrete. However, the other buildings, as shown in plan Fig.6 constructured by the same agency and at the same time did not suffer distress. Rao (1987) considered, the primary cause of collapse of the building was due to liquifaction of top "sandy clay" adjoining storm water drain resulting in loss of lateral support of piles. The area was highly congested even about a decade back, with very high commercial value in the new city. The history of the site, that is the once cultivated land, lowest in elevation and serving as a drain of surrounding high rise terrain and further change in urban hydrology due to increase in built up areas was completely over looked by planner and the designer. Experience with engineering is hardly a substitute of these factors.

CONCLUSIONS

The development of cities, require sub soil investigations in limited areas, and with high rise multi-storeyed buildings, normally planned today, exploration to deeper depths by boring and sampling of soils and rock is unavoidable. Such investigations are considered time consuming by owners with a view of early completion of project and quicker returns. Hence there is a tendency in designers to overlook importance of sub soil data due to site constraints in developed areas. This aspect becomes much more critical if the site happens to be reclaimed area with "buried" history as presented above.
The cases at the developing Housing and Shopping complex present the deviations from code of practices and basic principles of pile-foundation. The conjunctive use of open footing with pile foundations makes it difficult to predict the behaviour of structure and its different members. In the group of four piles resting at different elevations, as shown in one case, the basic rule, that "Piles in each group should remain symmetrical about the axis of the load has been defied. It is a matter of concern for a foundation engineer although the post construction behaviour has not been alarming so far, yet post construction analysis if made with all assumptions, results otherwise.

The collapse of structure presents the case of overlooking certain obvious facts, the history of site and existing urban hydrology and land use. The diversion of a drain on the surface does not change the old water course beneath. The investigations by different experts show the subject bias, and it may be true that a single factor might not have been responsible for failure.

REFERENCES

Indian Standard 2911 (Part III), (1973): "Code of Practice for Design and Construction fo Pile Foundations, Under -Reemed Pile Foundations.

Leonards, G.A. (1982) : "Investigating of Failures", Sixteenth Terzaghi Lecture, ASCE, Geotechnical Division No.2.

Rao, N.V. R.L.N. (1987) : "Analysis is of collapse of a Building", Short communication Indian Geotechnical Journal, 17 (4).

Saxena, K.R., Prabhu, J.S. and Swamy, A.S.R. (1978) : "Indiseriminate Use of Under- Reemed Piles - Case Histories", Proc. of Conference on Geotechnical Engineer, Indian Geotechnical Society, Gol.I, New Delhi.

Saxena, K.R., Iqbal Ali and Rama Krishna, E. (1982) : "Collapse of Multi-storeyed Building", Seminar on Lessons from Failure of Structures, ACI India Chapter, Bombay.