Kochi Chapter

Indian Geotechnical Conference
IGC 2022
15th – 17th December, 2022, Kochi

Forensic analysis of building collapsed in Bengaluru and Review of foundation failure in shanghai.

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ABSTRACT: Foundation failure of structures is rare until the structure comes under the influence of ground water. Lack of geotechnical field knowledge may lead the structures to collapse in a short duration just after construction. It is unfortunate that many failed structures in India are not reported because they buried under the administrative procedure. This practice have influenced the constructors to neglect the soil investigation process before planning and also ignore the national building bylaws so as to obtain maximum built area to save some money. The current study discusses about the forensic analysis of building collapsed occurred in Bangalore and a review of foundation failure occurred in a 13 storey building in shanghai, china. The study consists of the location of a site, failure date, details of the structure, the casualty's occurred and general causes, geotechnical aspects and remedial measures to the failures, which would provide answers to several confusions like, what went wrong, when, why, where, how and by whom the structure faced the issue.

This paper provides strong input to accelerate future designs and importance of different civil engineering fields and expert opinions in construction and create awareness about soil investigation.

Keywords: Foundation; Failure; Forensic analysis; Causes of failure; Remedial measures.

1 Introduction

Many structures are built with foundations that are not able to suit the soil conditions existing on the site. Sometimes due to the lack of suitable land, structures are often built on insufficient bearing capacity to support the substantial weight of a structure. In civil engineering construction practice adopted are not same at all conditions so it results to build unique structures at every time. Rare case of building that is identical to the one that is already built. Even if identical buildings are constructed, nature of construction depend upon soil profile; for example, the soil on which it is located, the wind or seismic load acting on the structure and the seismic zone which it comes under, etc. may change. Hence the opportunity to build a series of mock-ups and to improve progressively till a perfect solution is obtained is not available to a civil engineer. Moreover, the design parameters and construction practices and several challenges are mainly depend upon the nature of the exposure of constructed facilities to often unpredictable natural hazards.

In such a case, it is helpful for the civil engineer to learn from past failures. Although critical situations are not frequently happen, but the problem formed is often ruinous especially for those who taken maximum responsibility. An awareness of the mistakes

made in past and the lessons learnt by that mistake will make engineers better equipped to adopt safe and convenient procedures and care should be taken to avoid mistakes that does not repeat which made on of the past.

In 2019 many structures are failed due to various reasons in Bengaluru, the BBMP had conducted a survey and identified 185 such buildings which are not in good condition, of which 10 have been demolished. The latest survey has found that the south zone has the highest number of such buildings (103) and it is followed by the west zone of 95 buildings, Bommanahalli zone from 2019 to 2021 there are 9 buildings are found to be weak. RR Nagar Zone, which had only one structurally weak building in 2019, now has 11, such buildings of the 11 buildings 9 are police quarters in Kengeri.

2 Geographical features and common foundation practices adopted in Bangalore.

Bangalore lies in the southeast of the South Indian state of Karnataka. It is in the heart of a region of the larger Precambrian Deccan Plateau at an average elevation of 920 m. Soil profile of Bangalore consists of most of the Laterite red and red soils to fine loamy to clayey soils, and the city is known for bunch of lakes which are constructed during 16^{th} century by the ruler of state for the several purpose and many holy ponds (kalyanis) are present across various regions of Bangalore most of them are nearer to the temple on that period, but in modern era those ponds are closed and covered with mud due to climatic variations and high rise buildings are constructed upon it. Regarding foundation practices, Bangalore had a pockets of hard strata although they were formed by sedimentary rocks but quite hard for the normal house construction under isolated, strap or spread footings. Some of the regions where possible to build high rise buildings based on combined footing and raft foundations and bridges are erected on pile foundations and regarding safe bearing capacity of soil is good and high almost highest in India.

2.1 Need for Soil Investigation

Geotechnical Investigation (soil investigation) is a basic need in every construction to verify the quality of the soil of construction site. It requires a proper examination for to examine the physical properties of a soil which is equally important to other constructing procedures. It help the engineer to understand the kind and behavior of soil under various temperature and pressure conditions. It provide knowledge to engineers for to increase the efficiency of a soil and improve its soil mass work bearing capacity.

3 Foundation failures

Foundation failures are very rare, and it happens unless the building is situated on expansive soils. It is because of the design and construction error happened during planning and execution period. Some the common reasons for foundation failures are listed below.

3.1 Reasons of Foundation Failures

There are several reasons for foundation failures and they are as follows:-

a) Fundamental errors in concept: Some structures failed due conceptual errors. Some of the unique projects are always beyond the sources or available technology. The range of the project probably outside the envelope of past experience. The project may have been situated in unpredictable environment where the prediction of environmental effects was impossible. Then those failures of this type are not belongs to engineering failures; but rather, economic failures.

b) Programming deficiencies: Failure has been defined as a typical difference between expected and observed performance. This definition implies that the designer should well-known the needs or expectations of the client, and the things must be realistic. This type of deficiencies that could be avoided through continuous communication during the programming phase of a project.

c) Site selection and site development errors: first and foremost reasons for any failure is the kind of site selection. Certain sites are more vulnerable than others to failures. Most of the examples found on the zone of seismic activity, in coastal regions, or in floodplains. Other problems are arrived from specific type of soil conditions like expansive soils or soil present in cold reasons.

d) Design errors: Design errors have contributed to many failures; these include: errors in concept of design; lack of structural redundancy, omitting several load combinations leads to failures; deficient connection details; calculation errors; lack of computer software knowledge; design detailing problems including selection of wrong assembly materials, failed to consider maintenance requirements or durability, lack of material specification or expected quality of work, and unclear communication of design intent.

e) Construction errors: Construction is a dangerous occupation. Many failures of case-in-place concrete occur during construction due to poor form work, non-maintaining curing period and premature removal of shoring, and premature loading of concrete. Precast concrete members and steel structures often undergoes stability failure when temporary bracing is inadequate. Improper construction sequencing is also a source of failure.

f) Materials deficiencies: Some would claim that materials do not fail; people fail. Although it is true that most materials problems are the results of human errors involving a lack of understanding about materials or the ignorant just a position of incompatible materials, there are failure that can be attributed to random materials inconsistencies. Designer have come to rely on modern structural materials. However, manufacturing or fabrication defects may exist in the most reliable structural materials.

g) Operational errors: Failures can occur after occupancy of a facility as a result of owner/operator errors. These may include alterations made to the structure after completion, change in use, fail to judge the things and their effects, negligent overloading, and fail to maintain properly. Some failures occur because maintenance or operation personnel do not have the require site knowledge or skills to operate the facility property.

4 Forensic observations of recently collapsed buildings of Bengaluru

4.1 Five Storey Building Collapsed in Kasturi Nagar

Fig.1. Failed structure at Kasturinagar.

Site Name: - Resident Sunshine Apartment in Kasturinagar near the Banaswadi area of North East Bengaluru.
Failure Date: - On October 7, 2021 Thursday.
Details of Structure: -Structure was built on 60ft x 40ft area and the plan was approved in 2012-13 by BBMP and the building said to be eight years old. The structure consists of ground and three floors.
Casualties: - No Casualties.

Causes of Failure:-

- The main reason found to be the size of the concrete column, minimum 8 inches is must for the high rise buildings but the builder for to reduce construction cost provided 6 inches column instead of 8 inches.
- Setbacks for the building are not met up to the limits of Building bylaws.
- Deep excavation not done properly.
- The plan was approved by the BBMP officials in 2012-13 for to build ground and two floors on them but the agency built ground and three floors on them and later an illegal construction Pent house is carried out.

Forensic observations

- **Load Transfer: -** Interconnected rigidity is absent because of that the whole load transfer through single support, due to that the size of

the footing varied which directly related to pressure distribution on subsoil.

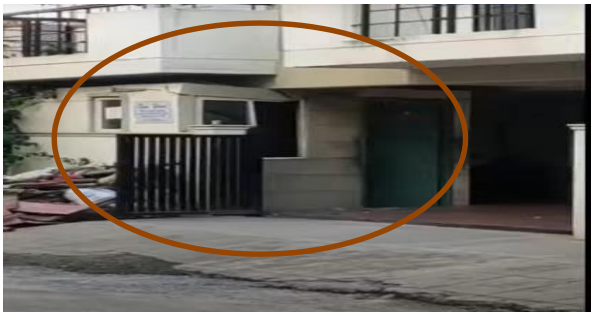

Fig.2. Load transfer through single support

- **Unequal support: -** unequal load distribution causes a differential settlement which leads to tilting of the structure.
- **Construction errors: -** Due to some poor construction practices during excavation also leads to failure in foundation and if the error occurred while construction process also cause the failure of structure.
- **Vibration Effects: -** An illegal pent house construction work carried out after 2-3 years of building completion for that certain equipment's used that created a heavy vibration in building which lead to form cracks.

Fig.3. Kasturinagar site after demolition

Fig.4. Damages caused to adjacent building.

(5.a)

(5.b)

(5.c)

Fig.1. (a, b, c). Building collapsing images at Kasturinagar.

4.2 Building Collapsed at Gandhinagar Near Kapali Theatre.

Fig.6. Failed structures at Gandhinagar.

Site Name: - Mithun guest house located behind Kapali theatre.
Failure Date: - On July 29, 2020 Tuesday.
Details of Structure: - Building was located adjacent to kapali theatre and building has ground and three floor in which two of flat turned into guest house and recreational club also present at another flat.
Casualties: - No Casualties.
Causes of Failure:- Set back rule violations, set back dimension reduced to get more rental square footage.

Forensic obsevations

- **Lateral loads: -** Due to improper side supports to adjecent building lateral movement of soil is occured**.** Kapali theatre located beside the building until 2017, but after theatre was taken down for a mall and multiplex having four basements, ground floor and five floors then site clearance and deep excavation process started with that simultaneously retaining walls construction work carried out other three sides of building except the side where collapsed building stands.

- Workers delayed the construction of retaining wall and it is happened during monsoon season which caused lag in work due to rain that become reason for soil displacement under the collapsed building foundation failure occurred.

Fig.7. Reason for soil displacement

- **Water level fluctuation cause liquefaction of soil: -** the site and surrounding area comes under majestic locality in which historians say there were 12 kalyanis around majestic but later as city developed those kalyanis were filled up with mud and the construction carried on it later. This become one of the reason for rise and fall in ground water level and sinkholes are formed due to overburden of effective stress and ground subsidence, Rise in ground water level reduces the bearing capacity of the soil. The engineer involved in the project believes a rise in ground water table contributed to the weak of the soil.
- **Construction errors: -** Due to some poor construction practices during deep excavation also leads to failure in foundation that is building of retaining wall and deep excavation also started simultaneously

Fig.8. construction error at site.

(9.a)

(9.b)

Fig.9a & 9b. Gandhinagar site after collapse.

(10.a)

(10.b)

(10.c)

Fig.*10. (a, b&c)*. Building collapsing images at Gandhinagar.

5 Review of Foundation Failure in Shanghai China.

Fig.11. Failed structure at Shanghai

Lotus riverside residential complex located beside the river Dingpu and the building at finishing stage. The building rests on expansive soil and foundation for the building is pile foundation of pre-stressed high strength concrete piles driven to the depth of 33 meter rested on fine sand. Total 114 piles are used for construction. On 27 June 2009 the structure collapsed and a worker died due to collapse. The main reason for unoccupied building collapse found to be pressure difference on two sides of structure.

Reasons for foundation failures:-

1. Lateral loads: - An excavation about 4.5 meter for the underground garage is carried at a distance of 7 meter from building and the vertical supports are provided with soil nailing of steel nail 7.2 m meter long, and those nails damaged the pile of structure.
2. Construction errors: - Excavated soil are disposed at other side of the building, and soil covered 36 meter wide and 10 meter thick of mass about 3000 tonne. Due to heavy surcharge load or overburden pressure occurred, the flood prevention wall constructed beside the river is in poor quality due the construction of the wall is not made of good quality material.
3. Failure of piles: - The piles located close to the dumped soil, whole 3000 tonne of surcharge load occurred on the pile head that leads to pile failure in the form of tension on dumped side and compression of concrete at excavated side. By examining this it clearly shows bearing capacity failure. By the observation, it indicates that while designing the piles surcharge load is not considered which further leads to damages in pile.

The following points should have been considered before construction.

- Due to river located beside the site and the soil is expansive there should be a proper soil investigation should be carried out for to analyse the profile and stability of soil.
- Surcharge load is not considered in the design of piles, by considering this case is an example, geotechnical engineers and contractors should better to improve their understanding the importance of surcharge load on pile.

- Construction sequels and site supervision scheme should be carried out without any third-party interference.
- Design of soil nail should be carried out as per site condition.
- The designed parameters should meet all the safety condition of geotechnical, environmental and other major engineering parameters and procedure for construction should followed as per International building standards.

6 Conclusions

Lessons from failures: The following points should have been considered before construction.

1. The shear strength of soil should have been determined before planning and construction for both Kasturinagar and Gandhinagar site.
2. Since profile of soil to be homogenous is rare and it will vary with respect to depth across the site as well, so soil test boring is done to gather subsurface information and at least three boreholes at the site have to be done for to analyses the soil formation.
3. The regulations which are represented in the National building code 2016 for to prohibit the modification of balconies (which is one of the main cause of failure of building at kasturinagar) and other byelaws which should followed during planning and construction must be verified by the agencies and BBMP officers before commencing project and it should followed during construction also.
4. To reduce the vibration effects on building an isolation system should have been adopted like active or passive isolators which helps against structural vibration caused by construction work.
5. For load transfer failure one of the commonly adopted remedial measure is Underpinning process which helps to strengthen and stabilizing the foundation of an existing building and this process could be carried out at Kasturinagar building.
6. Monitor potential sinkhole formation and control on dewatering and lower the ground water level at Gandhinagar site.
7. Soil nailing technique if may be used or proper design and construction of retaining walls at Gandhinagar site before work progress.
8. Before the start of any civil engineering the project, people should aware about the land history, formation of soil and a detailed information about water bodies near to site are to be known. If any water bodies present near to site or previously on site there should be a detailed geotechnical investigation required.
9. If site comes under filled up soil locality, there should be adoption of piles for the foundation of buildings until the pile reaches to hard strata.

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