



## Forensic analysis of recent building collapse in India and Review of a case study on foundation failure.

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**ABSTRACT:** Foundation is a vital element of a structural system, which helps to transfer the structural load to soil uniformly. Therefore strength and stability of structure depend on the behavior and properties of soil. The collapse of any structure mainly due to the differential foundation settlement and also due to the punching shear failure is in the case of loose soil deposits. Geotechnical investigation is important to control the failure of any structures. It includes surface exploration and sub-surface exploration of the site. The cost of site investigation depends on the size of the structure, built-up area, and other factors. Even though approximately 30% of India consists of problematic soil the scope of soil investigation is underestimated. This paper aims to focus on the impact of the inadequate soil investigation report on the structural stability and financial risk caused due to over-designed foundations. The forensic analysis of a recent building collapse in India and review of foundation failure of a case study clearly shows the result of limited site investigation. The study consists of the location of the site, details of failure, common reasons and the general remedial measures to be taken to control these failures.

**Keywords:** Foundation; Punching shear; Forensic; Collapse; Exploration; Remedial measures;

### 1 Introduction

The failure can be defined as defect, flaw, imperfection, deficiency, weakness, mistake, error, and fault in building elements and component that make up a building structure. Now a days there are lots of collapse in all around the world, these are mainly due to lack of knowledge on geotechnical properties of soil. Building performance is powerfully associated with its foundation as a ground structure that gives stability and support. Foundation receives the load from superstructure and distributes evenly on the soil. Loads coming on structure will result in movement in the soil, if the movements exceed the designed permissible limit, the foundation will experience failure. It is essential to identify the failures and their reasons to provide adequate remedies and to prepare sufficient preventions. Several facts should consider while designing a new foundation for site, some of them like type of foundation provided to adjacent structures, soil profile and the overall loads from the structure.

The proper geotechnical investigation is very important in any constructions. Soil Investigation is a process used to analyze the site conditions, design and suitable construction recommendations. Major foundation failures occurred due to insufficient soil protection, improper soil investigation, ground water level fluctuation, design errors, and failed in construction sequence process. Preventive actions will reduce the

failure reasons and causes, and remedial actions are helps to mitigate the errors, which lead a good quality construction. The providence of adequate site investigation and preparation of comprehensive soil investigation report cannot be over emphasized. Overall information contained in soil investigation report has a strong influence on designing, construction practice, overall project cost, safety and resolution of transferee disputes and hence the soil investigation report must be clear, concise and accurate. Insufficient soil investigation, further effect on the expenditure of construction at every stage, means improper soil investigation may lead for deep excavation, which again uneconomical and design of structure may overestimated.

Several building collapses were reported recently in India. In the recent survey, various types of structures are collapsed in India due to foundation failures and lack of geotechnical investigations. This study aims to classify the reasons and causes of foundation failures, preventions and remediations will be addressed accordingly.

## **2 Geological features and construction practices in India**

Soil properties vary from place to place. In India wide range of soils are distributed all around the country, like alluvial soil, black cotton soil, desert soil, laterite and lateritic soil, marine soil etc. Majority of land in the country is covered by the problematic soil. Overall stability of any structures are mainly depend upon the properties of soil. Soil investigation is important for to know sub soil properties at project site is necessary for obtain several data's regarding subsoil, which helps during design and construction time.

Failure of foundation or settlement of structures occurs when the structure built on the compressible soil. So it is necessary to know the settlement criteria for design consideration. Physical properties of soil directly effects the design and construction. Lack of geotechnical knowledge and experience lead to the construction errors. Soil criteria of same locality varies from site to site and by sighting the soil it is impossible to decide the similarity between the soils. The load bearing capacity of soil depends upon the type of soil. Generally, coarser grained soil has more load bearing capacity with compare to fine grained soils.

Geotechnical failures can results from foundation factors such as fluctuation in water table, soil erosion, soil heterogeneity, different exaction activity, soil liquefaction and natural disasters such as earthquakes and landslides. Main criteria considered in foundation design are shear and settlement.

Most importantly Soil investigation is not being done before building construction in common. Before the construction, proper soil testing needs to be done and the load-bearing capacity of the site needs to be analyzed. A lot of builders just submit the soil report of some other nearby sites. Another major concern is builders are not laying a foundation deep enough to support the building. An insufficient foundation increases the risk of the entire building collapse.

## **3 Necessity of Geotechnical investigation**

The very main purpose of geotechnical investigation is to conduct soil investigation for the site where building construction needs to take place. Soil is a living material and the condition, quality, and behavior play a key role in construction projects. The soil is

the natural foundation that supports all structure and investments. As the result, geotechnical engineers and engineering geologists have to perform geotechnical investigations to obtain information on the physical and chemical properties of soil and rock underlying a site to design earthworks and foundations for proposed structures, and for repair of distress to earthworks and structures caused by soil conditions.

Geotechnical investigation is important because:

- It provide proper knowledge about the soil condition at several depth.
- It decides whether the site is suitable for construction or not, if possible means what are the parameters should follow.
- To reduce the maintenance cost where the structure built on problematic soils.
- Helps to determine several aspects of a project, which include cost effective with marginal safety.
- Detect and monitor the risk to the environment and potential harm to humans throughout project lifecycle.

## **4 Foundation failure**

Generally, failure of any structure are most likely says structural failure or foundation failure. The first type of failure occurs as a result of bearing capacity failure of foundation. And the second type of failure is due to lack of knowledge of geotechnical properties of soil. Many building foundations fail just because of improper assessment of soil conditions existing on the site. In urban areas, the buildings are constructed on small plots due to a lack of suitable land.

### **4.1 Causes for various foundation failure:**

Foundation is the major part of any structure. We are well known that the load of the structure is transmitted to the under-laying soil via the foundation. Therefore, the special concern should be given by a civil engineer while designing the foundation, so that it should not fail in any circumstances. Below listed some of the important causes of failure.

- Differential settlement in sub soil.
- Lateral movement in adjoining soil.
- Withdrawal of moisture from the sub-soil.
- Lateral pressure on the super-structure.
- Action of atmospheric agencies.
- Shear failure of soil.

## **5 Forensic observations of recently collapsed buildings of India.**

Two buildings in India that collapsed in recent years are selected by doing a news reports survey. Site visits are done to conduct Forensic observations and find out the details of collapsed buildings, the nature of building collapse, and the causes of the failure.

### 5.1 Three story building collapse in 7th main road of lakkasandra in Bengaluru.

**Failure date:** September 27th 2021

**Details-** The three story building was constructed in 1960, the age of the building was more than 60 years old was in a dilapidated state due to heavy rain, some of the major cracks are developed Adjoining structures are also get damaged during collapse. On September 26th night people noticed that the building had tilted as shown in figure. Around 11.15 am on September 27th, plaster from walls and ceiling was falling down. The building was rented out to namma metro workers and 22 persons stayed in the building. But no one was inside when the building come down. The BBMP aiming towards the owner of the building for allowing to occupy it for namma metro workers even after the poor condition of the building.



**Fig.1.** Tilted building



**Fig.2.** Collapsed building

#### **Causes of failure:**

- a) The building is very old building which was constructed in 1960, and also this was constructed using soil as a mortar along with poor quality traditional bricks.
- b) Since they have not used any binding materials like cement, it is prone to collapse.
- c) Structure foundation rested on different kind of soil, which has different bearing capacity and unequal load distribution will result in unequal settlement

that is differential settlement. The building was undergone slight differential settlement 2 years ago (2019).

- d) According to some observers, the soil behaviour is effected due to rise in ground water table.
- e) The old building was not properly maintained and hence it was deteriorated.
- f) Due to lack of structural design and geotechnical investigation, the building collapsed suddenly.

## 5.2 Four storey building collapsed in Kurla, Mumbai.

**Failure date:** 28 June 2022.

**Details:** The 50 year old building which had been in a poor condition since several years, and collapsed on 28<sup>th</sup> June at around 11:30pm. The structure built in 1975 and while failure day over 60 residents are present on that day. Casualties occurred over 19 people were killed and many others injured. The residents were served notice to vacant the building for repairs in 2013. But the residents refused to vacate instead hired a structural auditor to check the conditions of the building and to submit a report that the building was repairable, and after the report it was erased from the ‘dilapidated building’ list and included to the ‘under repairs’ list.



**Fig.3.** collapsed building



**Fig.4.** Demolition of the building

### Causes of failure

- a) The main reason for the building collapse can be due to poor structural design, poor compliance with specifications, poor quality control, faulty control methodology, insufficient foundation strength and corruption.
- b) In india, during monsoon seasons (june-sep) heavy rains weakens the poorly built foundation of the structures.
- c) The raise in ground water table loosens the soil and reduce bearing capacity of the soil and rapid falling ground water table causes the ground subsidence due to increased over burden effective stress.
- d) The improper structural maintenance and improper construction sequels was also main reason for failue.

## **6. Forensic observations of failures:**

- a) Due to urbanisation the property value will be high so that the owner does not follow the building bylaws and utilize the maximum built up area, and the setbacks between the buildings are low.
- b) The land owners often explore the option of underground basements, when the deep excavation work carried out, the owner should take care of adjacent structures, by constructing well designed retaining walls there will be large lateral deflection of the retaining wall, if he fails means which will lead to movement of ground below the foundation of adjacent building and subsequent development in cracks and leaning of the building.
- c) The concurrent damage to structure is the result of differential settlement or vertical deformation of foundation soil, this is due to lack of soil strength.
- d) The 3 story building collapsed completely during excavation and construction of and adjacent building structure. So care must be taken.
- e) There no proper geotechnical investigations for the foundation soil before construction. Therefore soil investigation should be done for any construction.
- f) In most of the codes it is recommended that soil investigation up to depth of 1.5 to 2B where B is the least lateral dimension of building should be carried out. Occurrence of failures in foundation are due to improper soil investigation and designing error should be avoided.

## **7. Remedial measures**

1. Site survey and soil investigation should be properly done to know the soil profile and soil strength and properties of soil present at site.
2. Site engineer or design engineer should consider all parameters present at site like surrounding environment, climatic conditions soil profile etc...
3. Recent developments in construction field and modern equipment's locally available resources should utilized properly.
4. Most of the constructions in India are unauthorized subsequently regulated by penal money. Demolition of old cracked / tilted buildings or re-strengthening and reconstruction of building with proper care is the only solution for the current situation.
5. It was found that presence of a weakly clay soil layer beneath the foundation, this clearly shows the negligence during soil investigation.

## **8. Review on Excavation collapse**

### **9. At 14<sup>th</sup> and H streets Northwest Washington D C**

Research on the foundation failures that happened in the past is studied to get some knowledge about the classical geotechnical failures and traditional remediation that is being practiced in such cases.

**Failure date:** November 19th 1990.

**Details of structure:** An open excavation, 31200 Sq. of volume 1466400 cubic ft. excavation work carried out for a 12-story office building along with four stages of parking at 14<sup>th</sup> Streets, North West of Washington, D.C., on 19<sup>th</sup> November of 1990. At night approximately 8:30 p.m. while the time of accident construction process has been stopped which leads to mitigate the casualties were going to happen. The collapse caused by a fail of the soldier beam and lagging wall at the area of collapse in open excavation site. Due to sliding of internal support, blocking and damages caused to the sidewalks along 14<sup>th</sup> and H Streets were totally lost.



**Fig.1.** Collapsed site (sighted from west)



**Fig.2.** Collapsed site (sighted from east)

#### **Causes of failure**

The following causes are found based on the investigation

- Resistance offered by the internal supporting system not able fulfil the soil load.
- Lack of design parameters regarding structural members which include the insufficient inter connection between the members.
- The spacer beams, their inter connections and the sloping wale were recognised as most stressed members and connections of the support system which lead to collapse.



- The soldier beams were significantly twisted during driving at northeast corner, where a gravel layer was encountered.

**Geotechnical analysis for failure:**

Based on the geotechnical report of the project some of the steps are to be followed they are, excavation and the surrounding locality consists of 7 feet of fill material on top surface of 40 feet of inter bedded strata of B1, B2 and partial of B3 and they are filled up with lean clay layer, sand layer and gravel layer respectively. The effective passive soil pressure which is tangential to excavation and the shoring facility provided by the sub-contractor is not up to the mark. This is the one of the reason for soldier beam failure, there will be 10 more soldier beams present which they use same soil as their part of failure wedge.

**Conclusions:**

- a) Excavation collapsed due to the failure of internal structure supporting members at north and south walls, and the external support system like tiebacks, soldier beams and wales which were in place on the west wall.
- b) Subsequent to the collapse, all soldier beams, rakers and pin piles continued to remain embedded below the final subgrade.
- c) Structural connections between three tiers presented in the north and south wall are not up to the mark to resist expected load.
- d) Reasons behind immediate cause of the collapse is that the load of failure and soil pressure which is lower than the expected or designed load.
- e) Overestimation done by shoring contractor regarding movement of passive earth resistance.
- f) Contribution part of collapse is considered as both construction deficiencies and the ground water fluctuation.

**10. Conclusions**

1. For efficient subsurface and super structure, proper soil investigation is necessary.
2. The site investigation report should provide the following information accurately
  - Type of foundation required.
  - Sufficient data from various laboratory tests to estimate the allowable load bearing capacity of foundation and to estimate the settlement criteria.
  - Location of ground water table and its fluctuations.
  - Identify the problem and proper solution to it.
3. Not only soil investigation but also some faulty design of structures leads to failure.
4. Lack in engineering ethics is one of the root causes of an engineering failure in every field.



## 11. References

1. Andy fourie and Ahmedi vawda (2010) The importance of a thorough geotechnical site investigation at the planning stage of urban development Springer publications. <https://doi.org/10.1007/BF03036539>.
2. Bowles, J. E. (1996). Foundation Analysis and Design. McGraw – Hill Publications.
3. Investigation of failures, Journal of Geotechnical Engineering, ASCE, 108, No. GT-2, 187-246.
4. IS 1892:1979 code of practice for subsurface investigation for foundations.
5. Robert W. Day, Forensic Geotechnical and Foundation Engineering (2011), Second Edition, McGraw hill Publications.
6. USACE (2001). Geotechnical Investigations. Engineering Manual No. EM 1110-1-1804.