

Investigation Of Building Failure Using Structural Forensic Engineering

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Abstract— Failures and defects in a structure are common phenomena in construction industry. Negative impacts may arise towards cost, duration and resources of project. Failures and defects can cause unnecessary expenditure and delays. Furthermore, if this situation is left unanswered and untreated, it will lead to more serious problems in the future upcoming construction projects. Therefore this study is aimed to identify contribution factors to building defect and failures, which frequently occur in construction project in order to minimize time and cost involved. This study is succeeds in identifying the common contribution factors of the structural defects and the failures in construction project. Investigation details of the failure will provide many lessons to construction professionals from past failures so that replication of such failures could be eliminated or minimize. "Forensic Engineering is the study of materials, products, structures or components that fail or does not operate or function as designed, causing damage to property. This is useful to develop practices and procedures to reduce the number of failures and to provide guidelines for conducting failure investigation". This study will investigate the cause of the failure of a structurally damaged building & also investigates the strength & life of an existing building. The study examines the effect of the quality of material used for concrete production & also for the check for analysis & designing.

Index Terms— Structural Defect & Failure, Structure Forensic Engineering, Forensic Tests, Material test ,Design and analysis

1 INTRODUCTION

In today's world of fast rising era where the thing of the future boils down to a country's ability to establish world class infrastructures and magnificent skyscrapers- construction builders, engineers and architects consider the most important aspect of the project itself, the structural stability. Recently if we notice the present problems facing by civil engineers, first and foremost thing is building failure & its collapse. For this forensic study is very necessary to analyze the failure of structure. Forensic engineering can be defined as "the investigation of failures -which ranging from the serviceability to catastrophic - which may lead to legal activity, including both, civil & criminal". Therefore it includes the investigation of the materials, products, structures or the components that fail or does not operate or function as designed, causing personal injury, damage to property or economic loss. The consequences of failure may give a rise to action under either criminal or civil law together with but not limited to health and safety legislation, the laws of contract or product liability and the laws of tort. The field also deals with the retracing processes and procedures leading to the accidents in operation of vehicles or machinery. Generally, the purpose of a forensic engineering investigation is to locate the causes of failure with a view to get better performance or life of a component, or to assist a court in decide the facts of an accident. It can also involve examination of intellectual property claims, especially patents. Structure forensic engineering has various services which have shown below:-

Structural forensics services include:-

- **Building code compliance**
- Building envelope evaluations
- Cause and origin determinations
- **Construction defect analysis**
- Dock, seawall, and pier damage evaluations
- Flood depth determination
- Foundation system studies
- Hail damage assessment
- Industrial, commercial, and residential structure Investigations
- Repair design and drawing preparation
- Roof evaluation services
- Seismic evaluations
- Stucco/exterior insulation finish systems

- Underpinning design
- Vibration investigations
- Wind induced failure analysis
- Wind vs. Surge calculations

From all above forensic engineering services this study will deal with Building Code Compliance & Construction Defect Analysis.

2. What Is Construction Failure?

Construction failure may call as "an unacceptable dissimilarity between expected and observed performance". Failure of the structure, either by design or by exposure to the natural elements, can lead to compromised building performance which will carry Unacceptable aesthetic appearance, Unreasonable maintenance needs, Excessive deformation, Signs of distress, Local failure, Extensive failure but no collapse, Partial collapse, Total failure (collapse).

2.2.1 Types of Failure:-

- Failure during construction.
- Failure due to failure of services.
- Failure due to improper maintenance.

2.2.2 Causes of Failure:-

Structural breakdown does not have to be a "disastrous collapse"; it may be a "non consistency with design expectations" or an "incomplete performance". Collapse is usually the credited to inadequate strength or stability, while incomplete performance or so-called serviceability problems, and is usually the results of irregular deterioration, excessive deformation, and signs of distress.

- **Controllable Failure:** - These are the failures which can be control by an engineer, architect, quality control engineer, or by proper supervision.
- **Uncontrollable Failure:** - This kind of failure is sudden failure which is unacceptable & this kind of failure can't be controlled by anyone. For this while designing the structure there are some factors which is considered by the designer but he designed for a limit of loads according to history of location & surrounding behavior & environmental conditions. These failures are shown in Fig. 1.



Fig. 1 Controllable & Uncontrollable Failure.

2.2.3 Construction failure may also caused by human errors :-

Sometimes failure occurs due to human mistakes like somewhere he needs to take a decision but he can't take or take wrong decisions. These decisions can be taken by having experience or not having experience. It might be design error or his perception towards designing, his approach towards work. Sometimes human lapses sometimes it may be slip of mind or forgotten, sometimes his decision may get wrong.

2.3 Common Observations which are helpful to find out causes of failure:-

1. External Façade 2. Peeling of plaster and external/internal seepage marks 3. Efflorescence, plinth protection, external drainage, ground water ingress, ground water flooding 4. Overall response of plumbing 5. Building has horizontal and vertical projections 6. Terrace inspection 7. Terrace housekeeping is poor 8. Left RC column stubs 9. Innovative user observations 10. Option for waterproofing.

3. FORENSIC STRUCTURAL ENGINEERING:-

Forensic structural engineering has, in some countries, become and, in some others, is evolving into a designated field of professional practice of determining the causes of structural failures and identifying the parties responsible. The practice involves engineering investigations, rendering opinions and, if required, giving expert testimony in judicial proceedings. Whether they occur during construction or during their service lives, failures of constructed facilities are almost always followed by engineering investigations and resolution of claims. As the findings inevitably create claims of damage and often result in disputes and legal entanglements, the forensic structural engineer operates in an adversarial environment and therefore needs not only to be able to perform the necessary investigations but also to have an understanding of the ins and outs of the practice of forensic engineering—which this paper intends to enhance. This paper is an overview of the professional practice of forensic structural engineering and includes discussions of: what structural failure is, origins and causes of failures, types of cases of failures, importance of codes and standards, the standard of care for design professionals and duty to perform for constructors, brief outline of the process of forensic investigation, with references to detailed publications, meaning and importance of “reasonable degree of engineering certainty,” forms of dispute resolutions, who is and what the role of an expert consultant/witness is, a brief look at how the practices differ in various IABSE countries, and selected reference literature

[Mel A. Underwood & Andrew W. Johnson et al 2018] The condensation forms due to high moisture, humidity & improper ventilation. According to NWFAs moisture percentage 12-13% is normal & above that, it is considered as elevated. In observation it is found that moisture percentage is about 27.2 - 37.2%. The needs for prevention

from condensation are vapour barrier sheets & code compliance for condensation.

[Michael P. Lester, P.E. et al August, 2018]

Experience shows that in review of design and construction documentation, design errors are sometimes present. Very often, the errors are inconsequential to the service life or performance of the constructed facility. Unfortunately, in other cases, design error often brings about eventual failure or misbehavior of the built environment resulting in damages to property or injury to persons.

[Robert L. P. Hodgson et al, May 2016]

This paper describes the process for prioritising assessments and the systematic approach adopted for rapid categorization of structures. It discusses the outcomes and challenges faced when working in developing countries, particularly within a politically sensitive environment generated by global media attention

[Yogen Sadashiv Masurkar¹ et al, Aug-Sept. 2014]

This paper emphasizes on the types of failures and responsible causes for constructional failures in today's construction industry. For this purpose an analysis of collapse of G+3 storey building in Khed has been done. Various tests were conducted on site to identify the cause behind the collapse. The main aim is to minimize the problem of failure from civil engineering field by taking learning lessons from these devastating incidences. Now following types of failure are.

Types Of Failure

- Failure during construction
- Failure due to failure of services
- Failure due to improper maintenance

[D.S. Bhosale et al 2013] This study gives the methods & applications of forensic engineering in construction field. Description about Destructive & Non-Destructive test. This study also suggests a checklist to avoid geotechnical failure & formwork failure.

[Nithin Krishna et al 2012] The structure collapsed due to blasting. An attempt to damage the buildings (world trade centre) by a bomb blast. The reduced structural capacity was the first ingredient in the failure. The second was the heating effect brought on by the burning jet fuel as temperature approached 1500F. The fire caused weakening of the steel and suddenly received a load for which they were not designed. Each tower contains about 1,00,000 tons of steel & concrete.

[Lekan Makanju Olanitori et al 2011] In this study failure of some parts of building occurs under construction. To determine the reason behind the failure Sieve analysis, field settlement & compression test was performed & observed that Anchorage length & spacing is not adequate. Anchorage length provided was 75mm but required was 144mm & 192mm. Spacing was 300mm provided and required spacing was 250mm.

[Chandan Ghosh et al 2011] In this study collapse of 1 column out of 12 due to seepage in basement. For this excavation of foundation, checking consistency of sub soil & checked the actual construction with design of building. Estimated load carrying capacity of column is about 108 tons for that req. footing size is 3*3 m but provided 0.5*0.6m. At some junction excessive steel was provided (1-1.2m). Floating wall was constructed which is 50% unsupported, it is a mystery. Column (L>2W) placed along the longer side & it

is against BIS code.

[M V Rohith Reddy et al 2009] At around 5:30am on June 27, 2009, an unoccupied 13-storey block of flat building, still under construction toppled over and ended up lying on its side in a muddy construction field. Cause of Failure The cause of the building collapse in Shanghai was due to a pressure difference on two sides of the structure. The collapse was caused by earth, excavated along the building on one side with a depth of 4.6 m, for an underground car park, and piled up to depths of up to 10 m on the other side of the structure. The weight of overburden earth created a pressure differential, which led to a shift in the soil structure, eventually weakening the foundations and causing them to fail. This situation might have been aggravated by several days of heavy rain leading up to the collapse, but investigators did not site this as a crucial factor.

Wang Yayong et al 2008] The building collapse due to earthquake of high intensity than designed intensity of earthquake. To prevent collapse there should be maximum numbers of internal & external redundancy. Stair case fails because structural partition of lower 1/3 length of stair segment.

- earthquake damage and seismic conceptual design
- Multiple seismic defense lines
- Strong Column-Weak Beam
- Ductile detailing and integration of confined masonry structures
- Stair shaft in masonry structures
- Loading and force transfer paths



Plastic hinges of the frame columns

4 CONCLUSION

It was observed that failure in a structure occurs due to various reasons during the construction & they are responsible for the failures. As per the study while constructing the structures, testing of soil, sand & concrete should be taken. This study will prepare a structure forensic report of an existing structure & find out the errors in design, on the basis of test results of samples this study will identify the cause of failure & the strength of the structure & this study also provides the prevention from the failure. It has been clear from the previous papers, that this kind of study is done more in foreign countries. There is no awareness in India about this

kind of study. This study is aimed to identify contribution factors to building defect and failures, which frequently occur in construction project in order to minimize time and cost involved.

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