**A Review of Forensic Structural Engineering in India**

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**Abstract**

The field of forensic structural engineering has evolved significantly with the advent of advanced health monitoring technologies, which play a crucial role in extending the lifespan of existing infrastructure while minimizing maintenance costs and enhancing functionality. This review paper explores failures or collapse of civil engineering structures like buildings, bridges, hoarding structures etc. with their age at the time of failure, type of structures, date of accident/failure, casualties that took place, reasons for failures, etc. are listed in tabular format.

By evaluating case studies and current practices, this review provides a comprehensive overview of how these innovative approaches contribute to more reliable and cost-effective management of structural assets. The paper aims to offer insights into future directions for research and technology integration, with the goal of advancing the field of forensic structural engineering and ensuring the durability and safety of critical infrastructure.

**Keywords:** Forensic Structural Engineering, Non- Destructive Testing, Health Monitoring Systems

# Introduction

In India, there is a concerning tendency of partially or completely collapsing under-construction structures like bridges, buildings hoarding structures, etc. Professional civil engineers as well as the general public are becoming aware of these failures since they result in loss of property and human casualties. It is concerning to see that private buildings account for the majority of these building failures during construction, where it was thought that quality assurance and control would be far better than for comparable public works. Increased confidence among Indian and foreign investors is necessary if the central government's goal of "Housing for All Missions up to 31st December 2024." is to be successful. Sound building processes, therefore, include peer and third-party evaluation, professional ethics and integrity, stringent code enforcement, clearly defined stakeholder tasks and obligations, an institution for failure investigation, and improved technical education. Failure or collapse of civil engineering structures can result in tragedies, fatalities, and occasionally environmental damage. Failures in the construction industry can lead to legal action, reputational damage, and even criminal accusations. As a result, there are many different kinds of failures in the construction sector, and these failures are rarely discussed and resolved. [2]

Defect, flaw, imperfection, deficiency, weakness, mistake, error, and fault in construction elements and components that comprise a building structure can be classified as failure. There have been multiple structures like buildings, bridges, hoarding structures, landslides, etc. collapses reported in India. According to a recent assessment, a variety of civil engineering structures failed in India as a result of poor foundations and a dearth of geotechnical studies [1]. Photographs can be used to verify your argument or disprove the other side’s argument in court. As already stated, digital pictures have to be real before they can be accepted as evidence. [4]. Visual inspection can play a significant role when starting a forensic investigation of civil engineering

structures. Visual inspection can be enormously useful in finding information to assist in developing a full investigation by destructive as well as non-destructive testing like rebound hammer, ultrasonic pulse velocity, core test, chemical tests to know the ingredients of concrete, etc. [5]. Now a days, occurrences of fire events on the premises are also increasing day by day. So, there is a need to study the effect of fire on the overall structural performance of civil structures, mostly buildings [6]. Knowledge of engineering concepts is used to find the cause failures is the specialty of forensic engineering, which is frequently done for legal reasons. Forensic engineering is reactive, seeking to identify the underlying causes of failures soon after they happen, in contrast with typical engineering disciplines, which concentrate on design, construction, and maintenance. It investigates factual data or evidence following a failure (accident, incident, etc.) and determines the reasons behind the failure. Unmanned aerial vehicles (UAVs) fixed with remote sensors have been commonly used now a days for forensic investigation (i.e., to analyse the cause of failure) [7]. The term "engineering failure analysis" was invented by the American Society of Mechanical Engineers. It demands technical expertise in engineering as well as knowledge of legal procedures. When viewed through the lens of engineering, forensic engineering is concerned with the investigation and renovation of various types of failures [8]. Forensic structural engineering is the application of engineering sciences for the examination of failures. Forensic structural engineering is a highly specialized field of engineering practice and thus requires expert knowledge of engineering and legal procedures during structural failure investigation. The forensic structural engineer's job is to identify the cause(s) of failure and to give the technical basis that allows the failure's responsibilities to be pinpointed. Forensics structural engineering services review repair estimates and assess material, product, or structural damage during structural investigations. Failures can have many different reasons, including procedural issues, human mistakes, and technical/physical issues. It can often be challenging to identify and measure the underlying causes of a failure or mishap. There could be a number of connected deficits as the causes [9]. Strictly speaking, forensic engineering helps a judge determine who is responsible for what kind of failure [10]. Forensic structural engineering exploration differs in contrast to conventional structural engineering design in its methodology [11]. A comprehensive understanding of civil engineering structures like buildings, bridges, hoarding structures, etc., including their functionality, architectural detailing, and construction, is one of the forensic investigator's essential competencies. Furthermore, the ability to gather background information, sketches, and photos and have conversations with individuals on the scene are critical to a successful diagnosis and repair.

The purpose of this study is to categorize the causes and reasons of failures of civil engineering structures like bridges, buildings, hoarding structures, etc. behind foundation failures; remedial and prevention strategies will be tailored to the findings [1].

# Methodology

Articles/Journal publications proceedings were downloaded randomly on Google search engine using keyword searches such as "forensic structural engineering," "collapse of bridges," "collapse of buildings," “forensic civil engineering," "review of forensic structural engineering in India" from well-known academic databases such as Scopus, Web of Science, Science Direct, ASCE Library, etc. The publications, journal articles, and conference proceedings that were selected for evaluation were published between 1993 and 2024. At random, 25 publications relevant to forensic structural engineering were discovered. For this research, domains were chosen.

# Failures of Civil Engineering Structures in India

Initially planned to collect the information of all kinds of failures of civil engineering structures, but in our country, as far as our knowledge, this information is not available in consolidated form with any central or state organization or academic institutes. Here we have collected this data listed in the below table merely based on the Google search, Wikipedia, newspaper reports; for some of the cases we found the judgments of courts, etc. Below listed table 1 shows a summary of failures of civil engineering structures with their age at the time of failure, type of structures, date of accident/failure, casualties that took place, reasons for failures, etc. It's obvious that there are going to be numerous more failures civil engineering structures in reality because many of them don't involve human causality.

**Table 1.** A summary of failures of civil engineering structures in India

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **SN** | **Details** | **Age** | **Date** | **Accident Details** | **Reasons/Causes** |
| 01 | Collapse of Concrete Foot over bridge at CSMT Mumbai MH. [Ref.: ISSE] | 30 yr | 14th March 2019 | Killed 6 People, 30+ Injured | Part of Deck Slab Collapsed. An improper structural audit of the foot overbridge |
| 02 | G+4 building at Tariq Garden in Mahad Raigad MH. [Ref.: Hindustan Times/Wikipedia] | 06 yr | 24th August 2020 | Killed 16 people, 30+ buried under debris | Use of inferior construction material |
| 03 | A pedestrian suspension bridge collapse, Morbi, Gujrat.1880/ 19th Century British Era Bridge [25] | 140 + yr | 30th October 2022 | Deaths of 141 people,180 + injured | Overloading after repair works. Deck Floor Repairing is done. After repairing bridge is opened to the public with intimating local civic body. While, cable was rusted. At the time of failure 500 people are there on the bridge supposed to be 125. |
| 04 | Savithri River Bridge Mahad Raigad MH. Stone arched bridge over a river. British Era. [NDRF Website] | 106 + yr | 11th August 2016 | 40 People died, 2 buses, 10 private vehicles Dilapidated condition. | As per IIT Bombay Report, bridge did not collapse due to human error, its due to Natural calamity (i.e. due to heavy rain and causing high pressure and flooding) |
| 05 | Pamban Rail Bridge (1914) Mandapam, Tamil Nadu India [Wikipedia] | 50 yr | 23rd Dec. 1964 | --- | 1964 Rameswaram Cyclone. Train washed away killing 150 people. Multiple spans collapsed. |
| 06 | Kadalundi River rail bridge [Wikipedia] | 140 yr | 21 June 2001 | 59 killed, 200 injured | Collapsed as a Mangalore Mail passenger train was crossing it, 6 carriages derailed & 3 went into the river. |
| 07 | Rafiganj rail bridge [Wikipedia] | 66 yr | 10 Sept. 2002 | 130+ killed, 150+ injured | Possible terrorist sabotage resulting in a train derailment. |
| 08 | Veligonda Railway Bridge [Wikipedia] | --- | 29 Oct. 2005 | 114 killed | Flood washed rail bridge away |
| 09 | Pedestrian bridge Bhagalpur [Wikipedia] | 150 yr | Dec.2006 | 30 + killed | Collapsed onto a railway train as it was passing underneath |
| 10 | Flyover bridge, Punjagutta, Hyderabad, [Wikipedia] | 02 yr | 9 Seper 2007 | 15–30 killed | Failed during construction. |
| 11 | Kota Chambal Bridge  [Wikipedia] | 02 yr | 25 Dec. 2009 | 48 killed, several injured | Under-Construction Bridge  Inexperience Officials  Total Collapse |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **SN** | **Details** | **Age** | **Date** | **Accident Details** | **Reasons/Causes** |
| 12 | Cable Bridge Surat  3-Way Interchange Flyover Bridge, A part of River Bridge; Concrete and steel bridge [Times of India] | 4 yr | 10 June 2014 | 10 killed, 6 injured | Collapsed during construction, Design flaw in curvature section of a span resulted in collapse of a curved span slab during the removal of staging plates. |
| 13 | Vivekananda Flyover Bridge Kolkata Steel girder flyover bridge [Wikipedia] | 8 yr | 31 March 2016 | 27 killed, 80+ injured | Collapse of bridge under construction. Bolts holding together a section of the bridge snapped. Reason for bolt failure remains unknown. |
| 14 | Sanvordem River Bridge Curchorem, Goa Portuguese era footbridge made of steel [Wikipedia] | 14 yr | 18 May 2017 | 2 killed, 30 missing | Dilapidation, bridge was closed for use  Bridge is scheduled for demolition. |
| 15 | Majerhat Bridge collapse Kolkata. Major motorable bridge in Kolkata (Ashpalt motorway) [Wikipedia] | 50 + yr | 4 Sept. 2018 | 3 dead, 25 injured | Possibly "had become too heavy and needed to shed load" 35 m section collapsed with a bus, 5 cars and 3 bikes on the span |
| 16 | Bridge Collapse at Siliguri Phansidewa, Siliguri. [Wikipedia] | --- | 7 Sept 2018 | 1 hurt | The bridge was in a dilapidated condition |
| 17 | Seven-storey building Gangaram collapse Bengaluru, India [Wikipedia] | 3 yr | 12 Sept. 1983 | 23 dead and over 120 injured | under construction |
| 18 | Dharwad building collapse  [Wikipedia] | --- | 19 March 2019 | 19 people died & 50 more were injured | Under construction & Low-quality construction material |

The failure of the civil engineering structures as listed in the above table is mostly due to manmade, in most cases due to the use of poor-quality construction materials, inadequate structural design, human greed leading to a disregard for the environment and human life, a lack of professional integrity, no proper system to identify and penalize/punish the guilty, and finally a well-oiled system of illegal gratification, which has let such incidents recur with total disdain.

Recently almost 10 + Bridges collapsed in the state of Bihar in India with most of them are under construction one and few are old type of bridges. This shocking trend increases serious worries about the quality of construction practices, lapse and lack of responsibility within the state’s infrastructure projects. The factors responsible for failures of these structures include substandard materials, dearth of skilled labor, desilting of rivers, corruption, and scarce project management. The consequences of such failures are profound, leading to financial losses, delays in crucial connectivity projects, and, most importantly, potential loss of life. To ensure the safety and dependability of our nation's infrastructure, addressing this issue calls for strict regulatory processes, open auditing practices, and a dedication to raising overall building standards.

# Conclusion

Forensic structural engineering enables the engineering profession to learn from failures, resolve non-catastrophic failures more efficiently, and provide key services to the legal profession, thereby supporting the continued development of the wider structural engineering profession. The review of failures of civil engineering structures like buildings, bridges, etc. in India in the recent past indicates that failures are occurring in large numbers. There is no system in place in our country to collect the statistical information of all such failures with reasons of failures. Most of the failure cases ends in courts, individual researchers unable to access all these information for analysis and review. However, it is obvious that most civil engineering structures failures in India are due to dearth of focused integrity, use of poor-quality materials and procedures, lack of inspection by local civil authorities like municipal councils/corporations etc. and poor investigation and punishment for professional wrongdoing.

The professional engineers (PE) are recognized and regulated by Act at the national level in all the countries except India. Without regulation, engineers are not accountable and responsible for any defective work or failure of constructed facilities. The Engineers Bill is still pending and has not yet been passed into law. The Institution of Engineers, India (IEI) has already tabled the Engineer's Bill in Parliament, but it is still waiting to be enacted. The bill aims to regulate the engineering profession, enhance the quality of professionals, and infuse a level of accountability and standardization. Recently, this bill was introduced in the Rajya Sabha in the zero hour by one of the members of Parliament.

There is also a burning need to implement stringent procedures for quality assurance and control in the construction of civil engineering structures like buildings.

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