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Forensic Study and Review of Some Structural Failures -Case Studies

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Abstract— Structural failure happens when the material of the structure is stressed to its strength limit which causes extreme deformation and fracture. Structural failure can be prevented by proper design and by studying the causes of past failures. The cause of failures helps to avoid mistakes which led to that type of failure and this mistake helps in further construction. This paper includes case studies and their causes of failures. It includes four case studies of RC and masonry building, In which one case study of truss bridge and one of cold-formed steel structure. All the structures collapse during years 2018-19.

Keywords— Forensic Engineering, Collapse, Structures, Structural Failure.

I. INTRODUCTION

Forensic structural engineering is a multi-disciplinary process for investigating and reporting the cause of engineering problems which may have legal ramifications. Forensic Structural engineering can be defined as the profession of investigation the cause of failure of constructed premises. It involves simulating the structure as it is built and attempt to identify the cause of failure of a structure. It is the application of engineering principles to the investigation of failures or other performance problems. It also involves testimony on the findings of these investigations before a court of law or other judicial forum, when required.

Failure describes every unacceptable difference between actual and intended performance. Failures of structures occur all over the world, but the practice of forensic engineering is only organized in some countries. Best known examples are the United Kingdom (ICE, IStrucE, Structural-Safety) and the US (ASCE and TCFE). A survey among IABSE (International Association for Bridge and Structural Engineering) member countries leads to the conclusion that only one-third of the countries have some sort of central obligatory protocol for forensic structural engineering. In most countries, the investigation process is developed and determined on company level.

II. NEED OF FORENSIC INVESTIGATION

Forensic investigations may be conducted to identify the cause or causes of failure like (when, why, how, where did the failure occur) to facilitate the design of proper repairs, or to improve the performance or lifespan of a component, assembly, or structure. Investigations may also be conducted to avoid repeating the mistakes that led to the failure as well as aid in the determination of liability in legal proceedings. Providing expert services to assist the legal process may involve determining the facts surrounding an accident, including the cause or causes of a failure, as well as the identification of the responsible parties.

III. CASE STUDIES

Case study demonstrates that flaws in design, discrepancies in design drawings, unsafe construction practices, and/or lack of communication between engineer and contractor may lead to serious consequences, such as structural failure and fatali ty. In this section four case studies are presented. The first one is the failure of truss bridge, while the second one is failure of steel structure and third and fourth one are the failure of load bearing structure. This paper presents case studies of four major structural disasters, the 2019 mumbai foot overbridge collapse, Logi park cold store collapse, MS Hotel collapse and collapse of school building. Each case study (1) Sumarizes the causes of collapse; (2) Factors that lead to collapse (3) Witness review about the collapse.(4) Observations from the collapse.

A. Mumbai foot over bridge

On 14 March 2019, in Mumbai city of India, a part of a foot overbridge connecting north-end of Chhatrapati Shivaji Maharaj Terminus (CSMT) railway station to Badaruddin Tayabji Lane collapsed and fell on the road . Seven people died and at least 30 others were injured in the accident. This foot overbridge is a truss bridge, the life span of these bridges are 70 years but it this bridge constructed in 1983 and fell within 36 years after it's construction.

Fig. 1 Collapsed bridge

1. Structural Deficiencies During Investigation :

Several deficiencies found which may be the cause of failure of structure are :-

(1) Corrosion : Corrosion has occurred uniformly in the slab

(2) Overloading : The foot overbridge used to vibrate while walking

(3) Deterioration (lack of maintenance) : The responsible people did not maintain the foot overbridge properly that if it had been done then it would not have been seen today.

(4) In Service- overload : The foot overbridge was declared neither dangerous but it was operational for the public and the accident occurred in the current bridge itself.

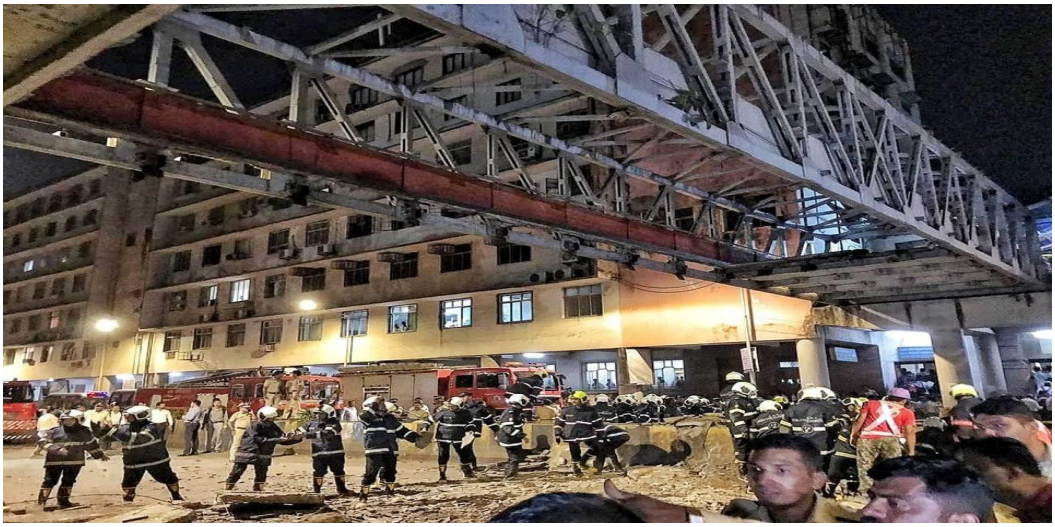

Fig. 2 Condition of bridge after collapse

2. *Audit Report :*

Negligence – Firm which carried out structure audit did not follow guidelines laid down by Indian Road Congress (IRC) and declared Bridge safe for use despite some corrosion in the structure. But they didn't know the extent of corrosion. Experts tell Structural Audit ignored the rust on beams. Corrosion didn't give warning they collapse immediately. The precast slab of the bridge rests on the beams and half of the slab collapsed. The Foot over Bridge vibrates while walking on it.

The Audit was not carried out properly the audit failed to detect bridge faults Brihan Mumbai Municipal Corporation (BMC) officers had not perform their duties and they had no records of any inspection or supervision and they are not even present on site when the bridge was being audited or repaired. They had knowledge of their jobs and due to their negligence incident took place. Repair work done by black listed company.

Before 9 months of collapse of bridge the urban planner complained about the bridge that it can ever felt anytime.

3. Witness's Reviews :

1. The bridge was being used despite the repair work on the bridge yesterday morning a witnessed said
2. First the vibrate happened and then the part of the bridge collapsed with a loud sound.
3. The bridge had been in a dilapidated condition for 6 months when we walk on it vibrate
4. The slab of bridge dropped down a witness said.

4. Observations :

To inspect the bridge properly the inspection should have to do the following-

- Define and set the frequency at which various bridges should be inspected.
- Enumerate the inspection to be carried out on different frequencies.
- Define the template and formats in which reports would be submitted.
- Define responsibilities of various bridge maintenance engineers
- Recommend such remedial actions in case the bridge is in dangerous conditions.

Repair work should have started immediately after the reports of Structural Audit.

Government officials should be present on site where the Audit to be performed at the site.

Emergency repair should be done on the structure which is in corrosion.

Don't conduct the audit of any bridge and structure like the audit conducted by the Himalya Foot over Bridge.

The repair work contract should not be given to the construction firm which was blacklisted earlier.

B. Logi park Coldstore

On 24 May 2019 The structure of a cold store being built in Shipra collapsed due to rain and storm. Four people working under him were buried, out of which one artisan was killed. This coldstore structure is Pre-Engineered Metal buildings (PEMB) and the life span of this structure is 70 years and it collapsed during construction.

Fig. 3 Typical condition of remaining structure

1. Structural Deficiencies During Investigation :

Several deficiencies found which may be the cause of failure of structure are :-

The sequence of fabrication was not followed and the joints were not sequentially connected during construction and the column was not designed for wind load.

Due to faulty design the damages to the structure can be attributed to deficiencies in structure design and construction.

Moment of inertia should have been taken care of from both sides moment of inertia did not take into account both directions. Moment of inertia was not considered in one direction.

Progressive collapse and face on one side and it fell one column fell from the wind, all of them fell because of it. If the joints were not connected, if it was connected, it would have stopped one by itself, then the other would not have fallen but it fell and it fell on it

.

Fig. 4 Collapsed Coldstore Structure

2. Audit Report :

The structure of cold storage under construction collapsed completely due to storm and rain left 1 dead 3-4 injured.

Construction Errors/ Procedural Errors or erection / execution :- The whole structure was standing on one support and the work was going on.

Design Errors :- Insufficient provisions in the design and improper sequence of procedure may cause failure for exceptional natural phenomena such as rainfall and severe wind storm.

Operational Errors :- During the structure failure the work is under construction after that it leads to loss of one life and few injured.

Fig. 5 Condition of structure

3. Witness's Reviews:

Victim Said "There was a steel structure of cold store, but the only one was strong in it. The rest of the pillar remained temporarily. Rain and thunderstorm come in Sunday afternoon due to which the structure collapse"

Another victim laborer told them that the structure had just hinged on the strong pillar. The rest of the pillars were temporarily standing. There was a work to make them permanent and build on the structure.

4. Observations:

1.The structure should be design to bear the extreme wind pressure.

2.Get the data of extreme wind pressure of the site and then design the structure after consideration into it.

3.All workers should work in environments where risks to their health and safety are properly controlled.

4.Readily available first-Aid supplier should be available and have proper means to transport an injured person to physician or hospital.

5.All people who are working in construction should not be work without safety equipments.

6.The construction work should not be carried out in adverse weather.

C. MS Hotel

On 31 march 2018 at least 10 people were killed and three seriously injured when a four-storey building, which also houses a hotel, collapsed near Indore's Sarvate Bus Stand. The type of structure of MS hotel is load bearing structure and it was constructed in 1938 and it's 2nd and 3rd floor are constructed later. The lifespan of load bearing structure building is 55 years and it collapsed 80 years after it's construction.

Fig. 6 General view of M.S. Hotel before the collapse

1. Structural Deficiencies During Investigation :

Several deficiencies found which may be the cause of failure of structure are :-

Deterioration (lack of maintenance) :- Various type of business activities going on but maintenance was not happening.

Negligence :- The day the building collapsed at afternoon, one side wall was damaged. Even then some some businessmen in the area had alerted his manager and staff, but hotel owner did not take it seriously.

Incompetence :- Failure to understand engineering principles or respect the technical limitations of materials or systems.

Greed :- Small pillars on the upper side of building and illegal support on this shabby hotel which was based on the support of gurdar farsi.

Fig. 7 M.S. Hotel after the collapse

2. Audit Report :

The original structure of the building was quite old. The hotel building was not getting support from one side. The wall on which the building rests have been tempered. Some people even talk about digging the basement by owner. Hotel owner was doing illegal construction. The building was ramsacked and there was no plaster in the back. There were no beam-column, RCC is not used anywhere in the entire building. The entire building was built on lime and brick.

Precautions were not taken while constructing the upper floor, due to excessive hanging, the weight of the building increases, due to the pit of the empty plot, the foundation due to seepage was also weakened. The vibration due to traffic also damage the building. Buses passes near the hotel, this causes the building trembled. Hotel building collapses due to poor construction. The way this building has fallen downright, it seems that it was a heap of debris.

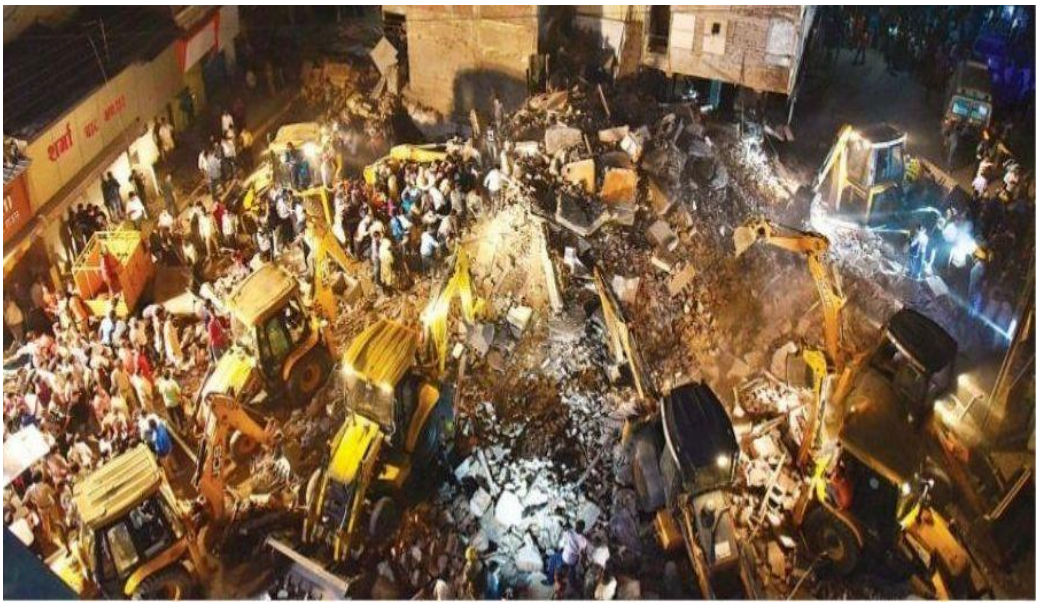

Fig. 8 People were trapped in the building during the rescue

3. Witness's Reviews :

1. According to the injured Mahesh, who was admitted to the M.Y. hospital, he was standing near the lodge with his rickshaw, in the meantime, there was a sudden explosion like earthquake and the whole building collapsed and we got buried in the rubble.
2. Mohan Sharma, who runs the juice center, has a warehouse in the lodge. According to him, he was in the warehouse with 2-3 employees at night. The building was already in Shambles, some debris was reported falling, so he came out with the staff and shortly after the building collapsed.
3. Azhar, who runs a tea shop in front, says that the situation of the building was already very bad, many times people complained but nobody improved.
4. According to eyewitnesses, there were 2 people in the car, when the car collided uncontrollably with the outer side of the pillar, it broke as soon as the four-storey building collapsed, after the collosion, two youths jumped on the inside of the building.
5. Kiran, daughter of manager Harish Soni, told that the condition of the hotel was in a bad condition. The owners were running the work only by repairing. The building's roof had fallen even 2 days ago. A room plaster fell 8 days ago but the owner did not notice.
6. Anand also died in the accident, Anand's brother told that Anand was the manager in the hotel for one and a half years, Anand had told him many times that the condition of the hotel is bad.
7. Pramod Jain, the owner of Jain Paan bhandar near the hotel, told the police that the pillar of the rear of the building had fallen on Saturday morning, the building was slightly skewed, the owner Hotel also knew about it.
8. Narendra Malviya of hotel maharaja told that when the building collapsed, dust was spread all around.

4. Observations :

- There is a need to audit the structure engineer of all the old buildings every 2-3 years at the state level.
- The building that the engineer does not certify should be processed immediately.
- If you have any dangerous building information, then Whatsapp the immediately on the number 9057531532.
- Building should not be constructed without permission.
- Old buildings should not be used as commercial, residential and industrial building.

D. Collapse of School building

On 27 August 2018 the rickety 20 feet long and 4 feet wide corridor of ill maintained building of school collapsed. The type of structure of the school is load bearing structure and lifespan of this structure is 55 years and it constructed in 1940 and it fell 78 years after it construction.

1. Structural Deficiencies During Investigation :

Several deficiencies found which may be the cause of failure of structure are :-

Negligence :- This accident occurred due to the negligence of the school management

2. Audit Report :

When the corridor of the second floor of the old building fell in the morning then just after 1st floor was also fell on the ground. Based on the approved map of the new building in 2016 they disturb the building built in 1976 that's why part of it collapsed. This part was weakened due to drills and other tampering on the old building to build a new building. In 1976 building strips were used inside the brick instead of column in the construction. The new building was approved without taking it's structure report. The structure of the old building also seem to have been tampered with.

The old building was very weak and was not in a position to bear much weight, it's weakness was not visible due to plaster and point on the broken walls, the library wall was overburdened due to which the wall fill on the veranda and it's fell down the verandah.

3. Witness's Reviews :

1. Parents outraged by the incident said that fees are increased every year but do not pay any attention to the convenience. For years no expense was spent other than point lacquer. Several complaints have been the school management did not pay attention.
2. Many parents said have the class was being organized in such shabby condition.

Fig. 10 Collapse area

Fig. 11 Condition of structure

4. Observations :

- There should be regular inspection of public places and efforts should be made to prevent such incidents in future.
- The government should keep an eye on such schools and their building and to look at them in terms of security.
- If there are complaints about any dilapidated building, then it should be acted upon immediately it must not be ignored.
- No officer should be negligent about any shabby and old buildings.

IV. CONCLUSIONS

- The forensic study helps to focus on preventing failures and the study on recent structures failures helps Engineers and researchers to study more of behavior of all the components of the structures.
- Building failures lead to waste of materials, financial and human resources, loss of lives and properties. This affects the economy.
- From the study it is concluded that failure is not caused by a single factor but multiple factors, most of which are human factors like negligence by builders and owners and inspectors.
- Insufficient provisions in the design and improper sequence of procedure may cause failure for exceptional natural phenomena such as rainfall and severe wind storm.
- Structural deficiencies such as corrosion,overloading should not be ignored.
- The audit should be properly done to detect the faults in structure and there should be proper records of inspection and supervision when the structure was being audited or repaired.
- The repair work must be started immediately after getting the structural audit report.
- During the construction of structure, the structure should be strong enough to bear wind load.
- There should be availability of safety equipments for the workers and proper means of transport for taking injured workers to physician or hospital.
- Weather condition of the area must be checked before construction.
- Seepage in soil makes the foundation weaker which will result in collapse of structure.
- The government should keep an eye on old structure and public structures and they should notify if there is any warning sign.

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