

# Mitigation of Disasters and Civil Engineering

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**Abstract**—Natural Disasters are acts of God as a result of human violation and lapses at large at innumerable levels which are never recognized and subsequently lead to irreparable damages over a period of time. Civil engineers have a great role in mitigating the effect of it and recovering the victimized areas. This can be done by development of technologies for enhancement of infrastructure, design and construction of infrastructures with high potential disaster-resistance, active participation in the recovery and redevelopment works after the disaster. Not only the planning, setting up and maintenance are the core responsibilities, it is also the responsibility of the Civil Engineer to ensure that the provisions are as per standard norms laid down by various International Relief organizations like the World Bank, International Red Cross etc. This paper aims to list the types of Disasters that frequently affect the structures, Role of Civil Engineers in Mitigation, Relief and Rehabilitation work. It also study the effect of disasters on building structures citing few examples of building disasters.

**Keywords**— Disasters, infrastructure, mitigation, standard norms, Relief and Rehabilitation.

## I. INTRODUCTION

India is declared to be a disaster prone country. India's climate and topography play a very important role in causing this havoc situation. Millions lost their property and about fifty million people are affected by some kind of disaster every year. Severe draught, sudden flood, avalanches, landslides etc are very common in India. According to the ministry of home affairs publication, we lose about 2% of our GDP on an average due to disaster. Though we call it 'an act of God', in a civil engineering perspective every disaster is one way or the other connected to the activities you performed or the activities you fail to perform. India witnessed the Himalayan tsunami in 2013. Uttarakhand is an example of disaster due to inaction of the society and their understanding and interpretation of the nature. During a large scale disaster, civil engineering structures like buildings, bridges, dams, roads, water supply projects, coastal structures, infrastructure facilities etc. are severely affected causing tremendous inconvenience to people disrupting daily life. "Prevention is better than cure" principle doesn't work in case of some natural disasters. But mitigation of the possibilities and reduction of the undesirable effects of disasters solely lie in the hands of civil engineers.

### 1.1 Objectives of study

- To understand the implication of natural and manmade disaster on structures
- To study the reasons for failure of structures
- To study the recent cases of structural failures
- To study the classification of structural failures

### 1.2 Hypothesis

The effect of natural or manmade disasters on structure can be effectively mitigated

### 1.3 Research Methodology

The study is based on secondary data and various information collected from various secondary sources. Various paper cuttings and reports are used to analyze this disparity. Different research papers, articles, doctoral theses have been also used to prepare the paper. Simple statistical tools and techniques have been used to analyze the data

## **II. DISASTER AND ITS ALARMING CONSEQUENCE IN THE WORLD**

Natural disasters like Floods, earthquakes, tornadoes, volcanic eruptions, hurricanes, tsunamis and landslides affect the world more regularly and frequently in the recent era. They burden an area financially. Earth quake results in building collapse, fires can result in other losses to men and property. Tsunamis and volcanic eruption too add to losses. Ash made out of Volcanic eruptions can make roofs collapse under its weight. Pyroclastic flows of hot volcanic ash rush down the slopes and can devastate structures in its path.

Natural disasters can be a reason for climate change. More droughts and increased intensity of storms may be the result of global surface temperature increase. More powerful storms develop when more water vapor is evaporated into atmosphere. Coastal flooding become more strong due to rise in sea level by the melting glaciers and ice caps. In their 2001 report, the Intergovernmental Panel on Climate Change stated that global warming should cause sea levels to rise 0.11 to 0.77 meters (0.36 to 2.5 feet) by 2100.

Civil engineering structures particularly building structures will be severely affected by every disaster. Few effects are discussed below

### **2.1 Effect of Cyclone or Storm on Building Structures**

A large scale wind that rotates around a centre place where the pressure is low is called a cyclone. The atmosphere with strong wind causes a disturbance around is a storm. Very high wind exerts high pressure on the building if the building is not designed for the wind load, it may cause the collapse of building structure either partially or totally.

### **2.2 Effect of flood on Building Structures**

Flood is the large-scale water due to the heavy rain. Heavy rain occurs for a short period of time and rivers or streams overflow their banks. During the flood, if the force of water is very high then it exerts high pressure on the lower part of the building. If the building is not designed for flood pressure then it may break the foundation or may cause the foundation movement in the building. Thus, the building may collapse due to the uneven stresses developed by the high water pressure of the flood.

## **III. CASE STUDIES OF FAILURE OF BUILDING STRUCTURES**

### **3.1 Case I**

Many buildings collapsed across the world, some deadlier than others, happened throughout the history. Unfortunately, throughout history there has been many building collapses across the world, some deadlier than others. There are a wide variety of causes, from bomb explosion causing a chain reaction that collapses the building, to poor maintenance. But all of these collapses have the same deadly end result. The only positive is that we have been able to learn from the mistakes of the past and begin to build stronger, sturdier buildings, in order to minimize the deaths from such collapses



**Fig.1 Versailles Wedding Hall, located in Talpiot, Jerusalem**

The Versailles Wedding Hall, located in Talpiot, Jerusalem, is the site of the worst civil disaster in Israel's history.

### 3.1.1 The accident details are

- the incident was taken place during the wedding of Keren and AsafDror on May 24, 2001,
- a large portion of the third floor of the four-story building collapsed.
- 23 people died on the spot through two stories, including the groom's 80-year-old grandfather and his three-year-old second cousin, the youngest victim.
- 380 were injured, it includes the bride who suffered serious pelvic injuries lead to surgery.

### 3.1.2 The findings out of these case are:

- The Pal-Kal method of constructing light-weight coffered concrete floor systems were pointed as the reason for the collapse.
- A few weeks before the collapse, the wedding hall owners decided to remove some partitions. With the load path eliminated, the floor above began to sag several inches.
- The owners viewed the sagging floor primarily as a cosmetic problem, and attempted to level it with additional grout and fill.

## 3.2 Case II

An apartment building collapse 'The Highland Towers'

### 3.2.1 The details of the collapse:

- The building collapsed on 11 December 1993 in Taman Hillview, Ulu Klang, Selangor, Malaysia.
- 48 people died due to collapse of one block
- The people of the remaining two blocks were complete evacuated due to safety concerns.

### 3.2.2 The findings are:

- The building collapse was due to the water content in the soil become over-saturated to the extent that soil had turned viscous, in effect becoming mud.
- A landslide, contained an estimated 100,000 square meters of mud, rammed onto the foundation of Block One incrementally pushing it forward.
- After a month of this constant pressure, the foundations snapped and in November 1993, residents began to see cracks forming and widening on the road around the Highland Towers, a forewarning of collapse.
- There was no further investigation before Block 1 collapsed on December 11, 1993

## 3.3 Case III



Fig.2 Residential Building Collapse, Mumbai, India

*A residential building collapsed in the Mazagaon area of Mumbai city in Maharashtra a state in India.*

### 3.3.1 The details are:

- The incident happened on September 27th 2013
- 61 people died and 32 others were injured in the disaster.
- The collapse occurred after a mezzanine floor was built without permission in an office-warehouse on the ground floor of the building.
- Officials said the families living in the building had been asked by the municipality to leave it earlier that year.

### 3.3.2 The reasons for the collapse are :

- The building was a cessed structure which pays a repair cess to MHADA.
- The SaifeeBurhaniUpliftment Trust (SBUT), which is implementing the Bhandi Bazaar redevelopment project, said the building housed a total of 13 tenants, which included 12 residential and one commercial.Out of these, the trust had already shifted seven families in 2013-14, said a statement issued by SBUT.
- The project is one of the first cluster redevelopment projects to be taken up in the city. Officials from MHADA said it had given permission for the demolition of the building on May 27, 2016.
- "Demolition permission was given for the building to SBUT in May last year. Earlier, the building was given a warning notice in March 28, 2011 asking the tenants and SBUT to vacate the building," said a MHADA official
- "MHADA notices dated 28-03-2011 and 20-05-2011 declaring the building dilapidated were issued along with offer of transit accommodation to the remaining tenants and occupants," it said.

### 3.4 Case IV



**Fig.3Thane Building Collapse, India**

A building collapsed on 4 April 2013 in Mumbai a place near to Thane in Maharashtra, India .It was one of the worst disaster among the building collapse. The death has raised to 74 people (including children) died.The builders, engineers, municipal officials and other responsible parties were arrested as the building was occupied without an occupancy certificate. Around 100to 150 families from middle income group were residing in the building.

### 3.4.1 The analysis of the collapse revealed certain shocking information:

- The failure of the authorities to take timely action – Even though the authorities were informed by a local activist with sufficient proof the Thane Municipal office, the police station and even the Chief Minister's office non took any action against the parties or stopped the construction
- The attention has taken from real problem - The Thane Municipal authorities shifted responsibilities claiming that the building was not on TMC property but on forest land and that it was the Forest Department that should have demolished the building.
- The delayed action from the court - More than three years after the collapse of an unauthorised building in the district in which 74 lives were lost, a district court here today framed charges against 27 people. The charges were framed under sections 304 (culpable homicide not amounting to murder), 120-B (criminal conspiracy) and other relevant sections of IPC, apart from the Prevention of Corruption Act.
- The builders unsensible action to distract the attention of the authorities from real issues - The building had no permissions, and people were already living in it though construction was underway. It was alleged that the builders had paid bribes to the local leaders and Thane Municipal Corporation officials to turn a blind eye to the unauthorised construction. It was also alleged that the builders encouraged people to live there so that it may not be demolished.

### 3.5 Case V



**Fig.4 Hyatt Regency Walkway, Kansas City, Missouri**

#### 3.5.1 The incident happened;

- On July 17, 1981, two suspended walkways collapsed in the atrium of the Hyatt Regency Hotel in Kansas City.
- It was the deadliest structural collapse at the time in the history of the United States.
- Around 2,000 people had gathered in the atrium to participate in and watch a dance contest. Dozens stood on the walkways. One hundred fourteen people were killed.

#### 3.5.2 The observations:

- It was an accident that could have been prevented if a better coordinated engineering review had taken place in the design shop drawing process.
- The hotel's design called for walkways to span the atrium at the second and fourth floors.
- The original design specified continuous hanger rods run from the ceiling through the fourth-floor beams and on through to the second-floor beams.

#### IV. THE ANALYSIS – CAUSES OF COLLAPSE OF STRUCTURES

Buildings, like all structures, are designed to support certain loads without deforming excessively. The loads are the weights of people and objects, the weight of rain and snow and the pressure of wind--called live loads--and the dead load of the building itself. With buildings of a few floors, strength generally accompanies sufficient rigidity, and the design is mainly that of a roof that will keep the weather out while spanning large open spaces. With tall buildings of many floors, the roof is a minor matter, and the support of the weight of the building itself is the main consideration. Like long bridges, tall buildings are subject to catastrophic collapse.

##### 4.1 The causes of building collapse can be classified under general headings to facilitate analysis. These headings are:

- Bad Design
- Faulty Construction
- Foundation Failure
- Extraordinary Loads
- Unexpected Failure Modes
- Combination of Causes

**4.1.1 Bad design** does not mean only errors of computation, but a failure to take into account the loads the structure will be called upon to carry, erroneous theories, reliance on inaccurate data, ignorance of the effects of repeated or impulsive stresses, and improper choice of materials or misunderstanding of their properties. The engineer is responsible for these failures, which are created at the drawing board.

**4.1.2 Faulty construction** is a very important cause of structural failure. The engineer is also at fault here, if inspection has been lax. This includes the use of salty sand to make concrete, the substitution of inferior steel for that specified, bad riveting or even improper tightening torque of nuts, excessive use of the drift pin to make holes line up, bad welds, and other practices well known to the construction worker.

**4.1.3** No excellently designed and constructed structure will stand on a bad foundation. Although the structure will carry its loads, the earth beneath it may not. The Leaning Tower of Pisa is a famous example of bad foundations, but there are many others. The old armory in St. Paul, Minnesota, sank 20 feet or more into soft clay, but did not collapse. The displacements due to bad foundations may alter the stress distribution significantly. This was such a problem with railway bridges in America that statically-determinate trusses were greatly preferred, since they were not subject to this danger.

**4.1.4** Extraordinary loads are often natural, such as repeated heavy snowfalls, or the shaking of an earthquake, or the winds of a hurricane. A building that is intended to stand for some years should be able to meet these challenges. A flimsy flexible structure may avoid destruction in an earthquake, while a solid masonry building would be destroyed. Earthquakes may cause foundation problems when moist filled land liquefies.

**4.1.5** Unexpected failure modes are the most complex of the reasons for collapse, and we have recently had a good example. Any new type of structure is subject to unexpected failure, until its properties are well understood.

**4.1.6** The conservative, strong statically-determinate trusses were designed with pin-connected eye bars to be as strong and safe as possible. Sad experience brought the realization of stress concentration at the holes pierced in the eye bars. From earliest times, it has been recognized that tension members have no surprises. They fail by pulling apart when the tension in them becomes too high. If you know the tension, then proportioning a member is easy. A compression member, a column, is different. If it is short and squat, it bears its load until it crushes. But if you try to support a load with a 12-foot column that will just support the load with a 1-foot column, you are in for a surprise. The column bends outward, or buckles, and the load crashes to earth.

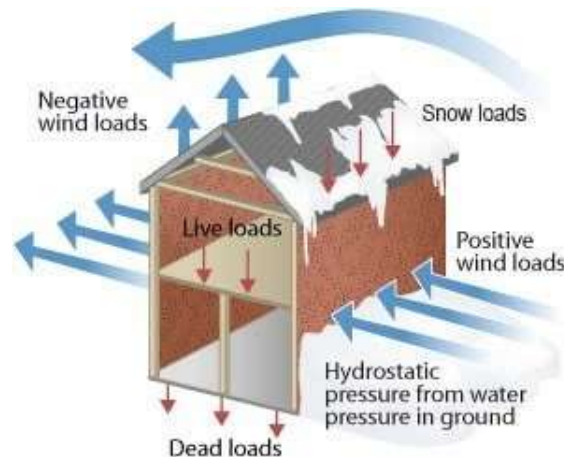
**4.1.7** Suppose you have a beam supported at the ends, with a load in the center. You know the beam will bend, and if the load is too great, it may break apart at the bottom, or crush at the top, under the load. This you expect. However, the beam may fail by

splitting into two beams longitudinally, or shearing, or by the top of the beam deflecting to one side or the other, also called buckling. In fact, a beam will usually fail by shearing or buckling before breaking.

**4.1.8** A hollow tube makes a very efficient column or beam. If you think about it, it is the material on the surface that most resists buckling and bending. A column that is modified from a compact cross-section, like a cylinder, to an extended cross-section, like a pipe, can still support the same load per unit area, but with much greater resistance to buckling. As a beam, one side is in compression and the other in tension, while the pipe cannot buckle to one side or the other. When you do bend a pipe, notice that it crushes inward reducing the cross-section to a line, which bends easily. Tubes need to be supported against buckling. Such a tube has a very high ratio of strength to weight, and hence strength to cost.

**4.1.9** Tall buildings have generally been made with a rigid steel skeleton, sheathed in the lightest materials to keep out the weather. Alternatively, reinforced concrete, where the compression-resisting and protecting concrete surrounds the tough, tension-resisting steel, integrated into a single body, has been used. Such structures have never failed (when properly built on good foundations), and stoutly resist demolition. When the lower supports of a steel skeleton are destroyed, the weight of the building seems to crush the lower parts and the upper parts descend slowly into the pile of debris. Monolithic reinforced-concrete buildings are difficult to demolish in any fashion.

## V. MITIGATION MEASURES



**Fig.5 Types of Loads**

Building should be designed in such a way that they can resist high wind pressure. Building should be designed in such a way that they can resist the high water pressure of the flood.

The buildings should be designed to resist loads due to natural disasters so they will not disturb the stability of the structure that the best way is to honour all codal provision and design in accordance with all provision of codes of structural design.

The design loads are always multiplied by a factor which is known as Factor of Safety.

The different factor of safety is applied to different load combinations in accordance with the probability of occurrence of loads. E.g.:  $(1.5) \times \text{Dead load} + (1.5) \times \text{Live load}$

There are different load combinations according to different Standards and some are listed as below:

**(1) According to Indian Standard load combinations are as given below:**

01. Limit state of collapse

Where:

- $DL \pm 1.5 LL$

- DL ± 1.5 WL
- DL ± 1.5 EL
- 0.9 DL ± 1.5 WL
- 0.9 DL ± 1.5 EL
- 1.2 DL ± 1.2 LL ± 1.2 WL
- 1.2 DL ± 1.2 LL ± 1.2 EL

## 02. Limit state of serviceability

- DL ± 1.0 LL
- DL ± 1.0 WL
- DL ± 1.0 EL
- DL ± 0.8 LL ± 0.8 WL
- DL ± 0.8 LL ± 0.8 EL

**Note:** When snow load is to be considered, replace Live load on the roof with snow load in the above combination, as snow is present on the roof.

## (2) According to American Standard load combinations are as given below:

### 01. Allowable Strength Design

- 1.0 DL + 1.0 FL
- 1.0 DL + 1.0 HL + 1.0 FL + 1.0 LL + 1.0 SF
- 1.0 DL + 1.0 HL + 1.0 FL + 1.0 (RLL or SL or RL)
- 1.0 DL + 1.0 HL + 1.0 FL + 0.75 (LL + SF) + 0.75 (RLL or SL or RL)
- 1.0 DL + 1.0 HL + 1.0 FL + (WL or 0.7 EL)
- 1.0 DL + 1.0 HL + 1.0 FL + 0.75 (WL or 0.7 EL) + 0.75 LL + 0.75 (RLL or SL or RL)
- 0.6 DL + WL + HL
- 0.6 DL + 0.7 EL + HL

### 02. Load Strength Design

- 1.4 DL + 1.4 FL
- 1.2 (DL + FL + SF) + 1.6 (LL + HL) + 0.5 (RLL or SL or RL)
- 1.2 DL + 1.6 (RLL or SL or RL) + (LL or 0.8 WL)
- 1.2 DL + 1.6 WL + LL + 0.5 (RLL or SL or RL)
- 1.2 DL + 1.0 EL + 1.0 LL + 0.2 SL
- 0.9 DL + 1.6 WL + 1.6 HL
- 9 DL + 1.0 EL + 1.6 HL
- DL : Dead Load
- LL : Live Load
- WL : Wind Load
- EL : Earthquake Load
- SL : Snow Load
- RL : Rain Load
- FL : Load due to fluids with well defined pressures and maximum heights
- HL : Load due to lateral earth pressure, ground water pressure, or pressure of bulk materials
- SF : Self Straining Force
- RLL : Roof Live Load

Structural design is nothing but a selection of structural system and type, the material of construction and proportioning of structural members. So that the building is strong enough to sustain all the loads that it might have to resist over its life. Members of the structure are to be designed for sufficient capacity so that it can sustain in all conditions without excessive deformation.

Effective maintenance of buildings improves or maintains the quality of the load bearing elements and also maintains its properties which are responsible for strength of the building. Effective maintenance, in general, can be classified into servicing, repairing, remodeling and upgrading the building or structure or its different elements, basically to save them from environmental effects like heat or rain and protect the materials. It also take care of minor malfunctioning of different materials and repairs due to physical or manmade damages.

Remember all elements of the building does not have 60 or say 100 years of life. Say an electric switch might have a life of 15 to 20 year or water proofing has a life of 10 to 15 year. Hence you also need to replace them as and when needed. Similarly painting have life of 1 to 5 years depending upon its type and hence you need regular painting to walls and mild steel elements like grill, etc.

## VI. THE RESCUE AND REHABILITATION

Rescue Workers and Emergency Responders may already have experience with entering collapsed structures resulting from (1) construction catastrophes, (2) earthquakes, (3) fire and (4) weather related structural failures. Weather related structural failures typically result from rain/snow accumulations on roofs, hurricanes, tornadoes, landslides and even avalanches. Today, rescue workers and emergency responders also face the possibility of entering a structure that has collapsed following a terrorist attack. Terrorist activity may add additional hazards such as secondary devices, follow-on attack and residual radiological, biological or chemical contamination.

Regardless of the root cause of the structural failure, rescue workers and emergency responders who enter a collapsed structure in order to perform their duties should work safely.

Following a catastrophic failure of a structure for whatever reason, rescue workers and emergency responders may be required to enter the collapsed structure. Emergency responders include firefighters, police, emergency medical technicians, construction workers and government representatives. Emergency responders may be responsible for assisting survivors, extinguishing fires, shutting off utilities, assessing structural instabilities, shoring up safe paths into the structure and assessing other hazards, such as airborne contaminants. Rescue workers such as Urban Search and Rescue Teams focus on finding survivors, and later removing victims from collapsed structures.

A trained Structures Specialist from Urban Search and Rescue will be responsible for:

Evaluating the immediate structural condition of the area to be entered during rescue operations.

Determining the appropriate type and amount of structural hazard mitigation in order to minimize risks on site to rescue personnel.

Once the Incident Command System is established at a collapsed structure, the Incident Commander maintains accountability for all response personnel at the scene. A Safety Officer may also be mobilized and report directly to the Incident Commander. The Safety Officer is responsible for monitoring and assessing the safety aspects of the responders during the collapsed structure event.

## VII. CONCLUSION

In this study author analysed various cases of natural and manmade disasters, its effect on civil engineering structures, and come out with following points for mitigation and defense mechanism

Catastrophes are part of human life all over the world and over all ages

Disasters attack the civil engineering structures to a large extent particularly building structures which are more in numbers and sometimes causes swiping away of the entire locality or land or population.

Training about the national and international code practices should be taught in the student level and the designers should be penalized for any lapses consistently.

Everything said and done also calamities can take over all provisions and specifications followed as per norms

This can be solved by the preparedness and cope up strategy

Disasters which are seemingly natural has a manmade reason behind the curtain, either human or structural. All building structures should be disaster resistant and there should be policies at higher government level to ascertain proper design according to the environmental conditions. We civil engineers has a great role to playing mitigating the effect. Knowledge of preparedness and coping up strategy drives the fear from the minds and create a general ethical and vigilant attitude.

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