1. INTRODUCTION

1.1 GENERAL

Disasters have been the bane of recent times, leaving unaccountable loss of property and life in their aftermath. Traditionally disasters have been studied individually, depending upon the region and its vulnerability to a particular type of disaster. Thus awareness and expertise on typical disasters have been restricted to particular regions. Moreover, government efforts have always been concentrated towards evacuation and minimizing the aftereffects of disasters. This has resulted in documentation and guidelines for managing post disaster effects rather than their prevention and mitigation. Various organizations and individuals have thus been trained to meet the challenge in terms of post-disaster preparedness.

The frequency of occurrence and variation of exposure to multiple calamities has left engineers and authorities requiring sufficient know-how to tackle such unpredictable and yet devastating occurrences. More efforts are now being pooled into a holistic approach for combating hazards in terms of prevention and mitigation of such occurrences from turning into disasters, besides dealing with the after-effects of the destruction.

The general public is not expected to know the specific structural requirements of safety against hazards, for their buildings. Just as the medical profession is responsible for the health of the public at large, the engineering profession is responsible for the public safety. This has been recognized the world over, as a dedicated engineering community has helped the developed countries in disaster prevention and mitigation, thus inducing technological advancement and growth in economy. Till a regulatory authority comes into enforcement as in the developed and developing nations post World War II, it is for the engineer to take upon himself the mantle of maintaining public safety with regard to the buildings that he designs and constructs. Structural safety codes do not deal with engineering fundamentals. These have been framed by engineers for bringing in uniformity of practice. Thus safety of the built environment is possible only through correct engineering practice.

A disaster occurs when a hazard results in loss of life and physical damage and destruction of built environment, including social infrastructure and livelihood assets. Natural hazards include events that have a rapid and instantaneous impact but are relatively short lived, such as land slides, cyclones, windstorms, floods and the earthquakes. India is one of the most disaster prone countries with hazards related to climate, water and geological causes visiting in different parts of the country.

Disasters are broadly classified as Geological (earthquakes, volcanic eruptions, landslide, soil erosion), Meteorological (hurricanes, typhoons, cyclones, droughts, desertification), Hydrological and Marine (tsunamis, storm surges, floods, sea level rise, marine biological hazards) and Technological hazards (fire, air and water pollution, nuclear explosions radiological accidents, terrorism). Management of these disasters from the structural point of view, includes any activity that prevents an emergency, reduces the chance of an emergency happening, or lessens the damaging effects of unavoidable emergencies and examines post scenario alternatives.

In this chapter various aspects of disasters such as their classification and zones which are vulnerable to specific disasters in India have been identified. Further, structural aspects for prevention and mitigation of such disasters, computational methods that based on the specific codes, and finally the scope and objectives based on the state-of-the-art have been defined.

1.2 DISASTER VULNERABILITY

In the last two decades natural disasters have claimed over 3 million lives and affected 800 million people worldwide, 90% being from developing countries. In

India 199 of the 599 districts are most disaster prone (UNDP) [1]. India has been affected by 3 major natural hazards of earthquakes, cyclones, and floods from time immemorial. It is estimated that about 55% of India's land area is vulnerable to seismic , 8.1% to flood and 10.2% to cyclone hazards (**Fig.1.1**).

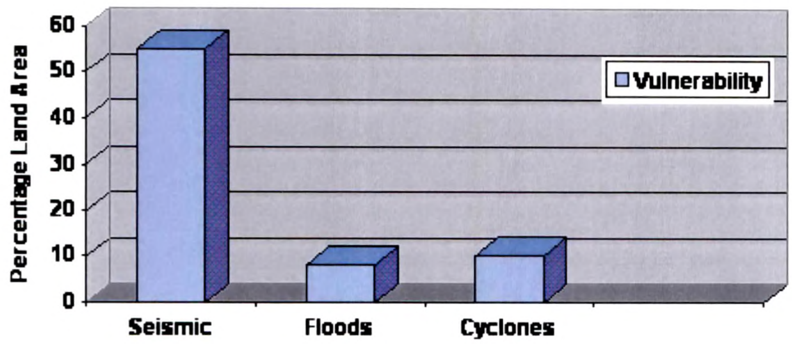

Fig. 1.1 Vulnerability to Hazards in India

Out of that exposed to seismic vulnerability, 12% of land area in India is liable to intensity higher than MSK IX, 18% to MSK VIII and 25% to MSK VII. Earthquakes of severe magnitude of 7.5 or more and MSK IX have occurred in Bhuj-Kutch, Andamans, HP, Kashmir, Uttarakhand and the North-East. There have been 5 earthquakes in which death toll has been more than 5000.

A strip of 50 km width on the Eastern Coast of India is liable to severe cyclone storms 263 storms have occurred including 92 of severe type. The west coast is vulnerable too but has less activity where 33 severe cyclones have occurred during the same time out of which 20 were on the coast of Gujarat and 13 on the rest of the west coast. There have been 19 cyclone occurrences where the death toll has been more than 10,000 and two with more than 5000.

Floods in the Indo-Gangetic-Brahmaputra are an annual occurrence. 1% houses of the existing stock (actual number comes to 1 million) are damaged every year. Crores of rupees are spent on relief and rehabilitation by Centre and State Governments besides that spent by voluntary organizations.
Thus on an average 4888 people are killed, 59 million get affected and damage to 1 million houses occurs as a cumulative effect of these 3 disasters annually [2].

Discounting the cost due to losses which are unrecoverable, the total cost of reconstruction, rehabilitation and relief, comes to a huge amount of 4.6 Billion, as a burden to the economy. The tragedy caused due to loss of life is immeasurable. The memory and horror of the disaster can only be compensated by using the experience as a constant reminder of where we failed and what should be done henceforth to prevent such a huge loss.

1.3 DISASTER MITIGATION AND PREVENTION

Mitigation is the ongoing effort to lessen the impact of disasters on people, property and infrastructure. It has a broad definition of sustained actions in order to eliminate long term risks to people and property from disasters and is not just limited to engineering solutions. The mitigation measures are different for pre-disaster preparedness and post-disaster actions involving different agencies.

Though not always, but disasters cannot be treated as impossible to anticipate or prevent. Natural phenomena like earthquakes, cyclones or floods cannot be prevented, but it is perfectly possible to prevent them from turning into disasters. Following the adage "Forewarned is forearmed", technology can be put to good engineering use by hazard resistant construction, to begin with. The single major cause of loss of life and property is the structural inadequacy of buildings to take the onslaught of disasters.

Recent examples of disasters in India are the earthquakes in Chamoli, Uttarakhand, Jabalpur and Bhuj; floods in Bihar, UP, West Bengal, Surat and cyclones of Andhra Pradesh, Orissa and Gujarat. In all such disasters, those buildings were responsible for loss of life where construction was not carried out as per codes of construction practice and engineering standards.

The absence of Disaster Mitigation Technology amongst the engineering professionals pose some major issues as follows:

- Building by-laws are meant for a controlled development of the urban limits. It is possible to check their compliance even after the construction is complete. Hence it is difficult to incorporate conditions for disaster resistant design within them in a way that compliance can be checked.

- Thus one recourse for mitigation and prevention measures to be in place, is to create public awareness on a scale so large that the engineers can hold their own only if they are ethical and true to their profession.
- Such awareness has to be totally scientific and yet simple enough for the common man to understand what he should ask for in his building so that it can robustly withstand hazards and does not catapult the event into becoming a disaster.
- Engineering technology and research has to answer this need and accept the challenge of creating this awareness in the profession and public alike, as no other part of society can play the role of defender and arbitrator when a hazard turns into a disaster.
- The catch is that the structural design, construction materials and technology for safety are so complicated, diverse, fast changing that it would be impossible to update the individual engineer or the common man as to what he should check to ensure the safety of his building.

1.4 STRUCTURAL ASPECTS OF DISASTER MANAGEMENT

In order to reduce the vulnerability of the buildings at large, it is important to understand the structural aspects of each [3].

Earthquakes: The most devastating disaster across the globe. It strikes unpredictably and to kill mercilessly. Governments can no longer afford to wait till the next one strikes. New buildings have to be aseismically designed and existing buildings should be retrofitted with a commitment to the future generations. IS:1893 (2002) [4] has codified guidelines for design against earthquakes, giving elaborate dynamic analysis methods and in-built safety mechanisms to make the structure ductile. Performance based analysis is being promoted to make a fuse like structure which gives in to some extent in order to prevent a total and sudden collapse. Besides engineered housing, engineers need to take a closer look at non-engineered and pre cast construction too. Besides good practices and case studies pooled together from global occurrences, the engineering fraternity also needs to examine the aspects of ethics and responsibility to the society.

Cyclones: High velocity wind associated with cyclonic storms, thunder storms and dust storms, in India, tend to weaken rapidly as they cross the coasts and move in as depression. The east coast faces more severe storms of 120 km/hr compared to the west coast (60-70 km/hr). IS:875-Part 3 (1987) [5] gives the guidelines for assessment of wind speeds, and static and dynamic analysis for high wind speeds. A code revision exercise under the GSDMA-IIT-K project is examining the code vis-à-vis other international codes. Too many coefficients and too complex applicability in the codes, finally end up in producing buildings that are designed on simpler idealizations, thus rendering them vulnerable. With the metro boom in the country high rise construction is taking speed, with glass claddings and metallic missiles that will go flying around under a cyclone. Hence ground for disasters to occur is in the making if proper understanding and implementation of various aspects of Cyclones are not codified. Thus primarily sufficient gravity to prevent instability, bracing systems to carry wind shear to the foundations, anchoring of cladding sheets, ductility and strength of cladding to withstand flying missile like objects and finally dynamic analysis for tall and slender buildings, need to be examined.

Fire: Usually lethal in high rise construction without built in fire safety. As much as the construction and design aspects, fire safety measures include good and fast escape routes, fail-proof fire warning systems and handy fire-dousing systems. Fire engineering has mostly been treated outside the domain of structural engineering. But failure of critical components leads to progressive collapse, hence performance based design is needed.

Flood: Most common occurrence in all major rivers, and hence affecting most important urban areas. Flood control manuals have laid stress on construction of embankments, check dams and weirs, besides flood control plains and bypasses.

Explosions and Terrorist Attacks: Disasters from these can only be dealt with after it has occurred. But understanding of these loads may lead to ground floors and basement stories of very important buildings to be designed and constructed to withstand such explosions. Besides the structural aspects, safety and security measures also play a major role.

Land Slides: Can be prevented by geo-engineering, load balancing, piling, back tying, soil drainage to avoid back pressure and grouting.

Volcanic Eruptions and Tidal Waves: India had been spared from severe aspects of both due to its geological aspects. But Chennai was rudely awoken to the Tsunami it had never seen or heard before. Hence measures need to be taken to prepare for the threats of a recurrence and learn from Japan and the countries who have experience of dealing with this phenomenon.

1.5 SCOPE AND OBJECTIVES OF PRESENT WORK

Computational methods for various problems vary with the definition of the problem. This study is limited to structural aspects of hazardous forces on buildings. Hence analysis is done using stiffness approach for frames. Depending on the dimension and the forces involved the analysis may be required for static effects or dynamic effects. The computational methods are adopted as per code requirements for earthquake IS:1893 (2002) [4] and for wind IS:875-Part 3 (1987) [5]. Fire loads and fire resistance ratings have been examined before analyzing building as a whole for compartment fire loads. Structural analysis for earth retaining structures and embankments have been done for mitigating floods. Thus the method most suitable to the type of forces arising due to the hazard, is adopted for the purpose of understanding the behaviour of the structure under the given force. If the structure is found unable to withstand the particular hazard, additional members or retrofitting aspects are considered and the structure is reviewed after suitably strengthening it.

Combination of various software is adopted to transit from analysis, design, retrofitting and virtual reality of the various systems for different retrofit options. Each module is designed to first calculate the loads arising on the building due to the disaster, then analysis and design are carried out to check the demand versus capacity. Existing building designs are checked to decide whether retrofitting measures are required. All Retrofit options are programmed to give the user a choice as per his parameters. Finally a virtual reality component is added to the most common disasters of earthquake and wind. Evaluation of loads and analysis for forces arising in the building have been done for the disasters of earthquake, wind, fire and floods. Blast and tsunami have been covered under a special section for its implications, but no programming has been included for them. All programming has been done in VC++; once disaster loads are obtained the next module is either analysis in VC++ or through SAP2000 which reads the output from VC++. The output from SAP or VC++ is then scripted into 3DS Max to give a walk through to the user to the exact site of his interest, where he can observe the damage due to the earthquake or the different displacements of a building with various retrofit options. Thus all aspects of analysis, design and retrofitting of buildings for the major disasters of earthquake, cyclone and fire, have been taken up in this work. Code provisions of Indian and international standards have been compared and important aspects on each disaster have been highlighted.

Virtual Reality aspects have been incorporated in the present work, to visualize change in the behaviour of a building under different parameters in case of earthquake and cyclone. Virtual Reality has been explored in context to structural engineering as it has a very high potential in the near future when high performance computing will not be an issue. Current work is limited to virtual reality for different aspects of damages due to earthquakes, displacements due to cyclones and compartment fire loads. A more advanced virtual reality software with full interactive capability can give the user a true life experience under the various disasters. But to exploit the full potential of virtual reality, sound, animation and rendering would involve professional expertise, time and funds. The scope in current work is limited to introduction of virtual reality in the structural computing domain, which has so far been evaded due to the tremendous amount of effort and time involved in creating it. The professional gains from such an effort have not been proved worth it so far, but as more and more systems are getting web enabled and as applications are being developed in graphical environments, structural options will shift from archaic textual outputs to animated virtual worlds which can be manipulated over the web and are sound enough to generate real time results.

Thus the main objectives of this work are:

- To study various aspects related to present topic in various international codes vis-a-vis current and proposed Indian codes.
- To create software modules for estimating the load on a structure due a particular disaster.
- To create software module for performance based analysis of structures and verify the design for the estimated disaster load.
- To automate design of retrofit strategy and compare different strategies for optimal solution.
- To program various structural aspects of disasters into virtual reality and its interfacing with structural analysis, design and retrofit software.
- To convert the 3D module for each disaster for structural aspects into Virtual reality Modeling Language (VRML) for studying either off-line or on-line and enable it on the web.
- To bring Virtual Reality into the structural engineering domain, in order to save considerable real time in examining various design and construction aspects.
- To critically review the codal aspects for each disaster and incorporate any missing parameters vis-à-vis international practices.
- To give suitable recommendations for disaster prevention, mitigation and retrofitting based on structural engineering solutions.

1.6 ORGANISATION OF THESIS

The present work is divided into separate chapters based on a particular disaster and its structural aspects, as follows:

A brief introduction to classification of disasters based on their causes and vulnerability of different land parts to various disasters has been given in the beginning of **Chapter 1**. Major issues concerning prevention, mitigation and creating awareness in the engineering community have been discussed next. A brief overview of structural aspects of various disasters is given for each disaster and finally scope and objectives have been defined in this chapter.

Chapter 2 covers the literature review for Pushover Analysis. Literature for damage and retrofit aspects of analysis for the disasters of earthquake, wind, fire, flood, blasts and tsunami, has been reviewed. Also Virtual reality aspects in structural and civil engineering have been examined for the current projects in this field.

The details of tools which have been used in current work such as Visual C++, 3DS Max and Virtual Reality have been given in **Chapter 3**. 3DS Max and virtual reality being relatively new domains and their application in structural engineering being examined for the first time, have been examined in more detail compared to Visual C++ which serves as an excellent GUI based programming language.

Chapter 4 explains in detail the philosophy and step by step procedure of Pushover analysis methodology, as this method plays an important role in the force analysis for lateral loads caused by earthquakes. The details of its computer implementation, validation of prepared software through comparison of results have been described. Comparisons have been done with SAP2000 results which takes parameters as per American codes. At the end limitations of the method have also been enumerated.

Types of deficiencies in building subjected to seismic loads and the evaluation of damage have been examined in **Chapter 5**. Various retrofit strategies have been given along with the computer implementation of each retrofit option of shear core, shear walls, bracings and jacketing. The software outputs of forces have been implemented on 3DS max platform for viewing in virtual reality the damage and retrofit options.

Software for evaluation of cyclone loads as per the current code using Gust Factor method has been prepared, details of which are given in **Chapter 6**. The

GFM is based on the dynamic nature of wind, and hence complex. The more sophisticated Dynamic Response Factor method as per the proposed revision has also been programmed and user is given choice of either. Comparative studies and recommendations for both the methods have also been given.

Chapter 7 gives the analysis and comparison for various building structures fortified against wind loads such as frames with shear core, with different locations of shear walls as also those of bracings. Once the user gets an idea of the retrofit options, the VR implementation for wind loads has also been given.

Chapter 8 describes various aspects of fire loads, structural design for fire, prescriptive fire codes, effect on concrete members, performance based analysis, fire safe design and mitigation aspects as also the retrofitting of fire damaged structures.

Structural aspects such as construction of embankments, levees and check dams for control of floods, have been given in **Chapter 9**. Typical flood disaster and its structural aspects on the two main rivers of Sabarmati and Tapi have been given along with various options that could have saved the damage.

Blast phenomena and structural response to blasts have been described in **Chapter 10**. This chapter also covers the rare yet devastating tsunami and its structural and land management.

Chapter 11 summarizes the work done along with important conclusions that were arrived at during the course of the work. Contributions arising out of the solution of the problem taken on hand have been enumerated and finally the future scope of work that may be undertaken have been highlighted.