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Earthquake Risk Appraisal through Seismic Monitoring Structure and Guidelines of India

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Abstract: *India, a seismically active country, has maximum loss of life and property due to earthquakes in comparison to other natural disasters. The recent Nepal earthquake of April and of the past decades like that of Bhuj and Tsunami, calls India to have an effective and efficient earthquake management system. Literature review was carried out for understanding the countries seismicity, its monitoring structure and guidelines. A country having its first recorded earthquake in1819 and first seismic observatory in 1898 was found to be still coping with earthquake risk management. Thus, the objective of this conceptual paper was to comprehend Earthquake Mitigation Management System in India. Assessment of earthquakes and their management illustrated effective preparedness and mitigation steps but evaluation brought forward certain shortcomings in its implementation within India. Recommendations have been suggested for earthquake mitigation managers to minimize the rate of devastation through strict implementation of earthquake guidelines; simulation software's and scenario building for reducing risk and vulnerability.*

Keywords: *Earthquake, Guidelines, India, Mitigation, Scenario*

I. Introduction

The seismic activities in India are associated with the concept of 'Plate Tectonics'. Recent Nepal Earthquake of 7.8 on the Richter scale and aftershock with magnitude 7.3, left thousands dead and injured, once again forcing man to think of his developmental progress. Earthquakes have been considered as one of the worse natural disasters in the world. Earthquakes do not turn into a disaster till it strikes a populated area. Thus, the way humans use the nature in different activities and land –use patterns, convert these hazards into disasters [1]. Destruction caused by these natural phenomena over the decades, has multiplied manifolds due to unplanned population growth, urbanization, infrastructural development and instability of land due to high rise buildings exacerbating conditions of a disaster. Thus, globalization in the 1990's became an indicator of increased vulnerability of the society by putting more assets at risk to different type of hazards around the world [2].

Over the last three decades, India has witnessed several earthquakes. Disaster reports analysis show that 64% deaths in India were a result of earthquakes, while storms contributed to 18%, 9% deaths were a result of epidemics, floods and extreme temperatures resulted in 5% and 4% deaths respectively between 1980 to 2010 as depicted in Fig.1 below:

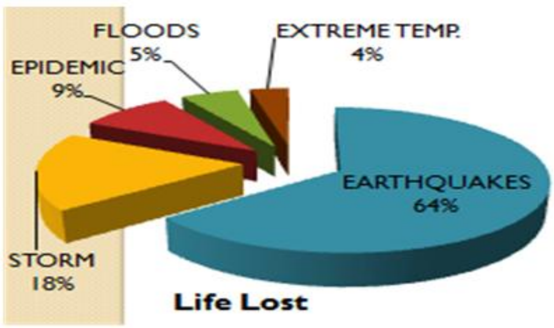

Fig 1 Natural Disasters Mortality Rate in India 1980 – 2010[3]

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Such catastrophic results of disasters tend to cause developmental momentum of the developing countries like India to be lost and slow down. Disasters like earthquake affect the administrative, social, economic and ecological aspects of the environment, creating a negative impact [3]. Hence disasters have been considered as inducers of change because they create a climate which makes a society undergo changes and bring everyday activities to a standstill [4]. Thus, emphasizing on the need of disaster management within the country.

II. Earthquake Scenario in India - 20 Years

The rising intensity of earthquakes has compelled one to understand the earthquake scenarios, for which eight major and minor earthquakes within the country over the past 20 years were taken into consideration.

The analysis of the last 20 years seismic activity in India as shown in Table -1, suggests that the average magnitude of earthquakes has been 6.9 on the Richter scale. During this period four major earthquakes took place with a Richter magnitude of 6 to 6.9, two with 7 to 7.9 and one each with above nine and below four magnitudes on the Richter scale.

Table 1 Major Earthquake In India 1993 – 2013[4]

Disaster Dates	Geographic Location	Magnitude (Richter Scale)	Killed	Total Affected
01/05/2013	Kishtwar (Doda district, Jammu & Kashmir)	4.6	2	59350
18/09/2011	Sikkim (Sikkim –Nepal Border)	6.9	112	575200
08/10/2005	Muzaffarabad (Jammu & Kashmir)	7.6	1309	156622
26/12/2004	Eastern Coast of India, (Sumatra Earthquake)	9.3	16389	654512
26/01/2001	Kachch-Bhuj, Ahmedabad (Gujarat)	7.7	20005	6321812
29/03/1999	Chamoli, Rudraprayag (Uttarakhand)	6.8	100	477894
22/05/1997	Jabalpur (Madhya Pradesh)	6.0	43	156500
12/11/1993	Latur –Osmanabad (Maharashtra)	6.3	9748	30000

The first Tsunami that ever hit India in 2004, due to Sumatra Earthquake in the Indian Ocean, has been recorded as the highest intensity earthquake with 9.3 on the Richter scale. While on the mainland of India, 7.7 magnitude earthquake was recorded during 2001 in Kachch-Bhuj. Sikkim had recorded a 6.9 magnitude earthquake in 2011 and the Chamoli – Rudraprayag region experienced a 6.8 magnitude earthquake in 1999. The details of which are depicted in Fig. 2, as per the Indian Meteorological Department (IMD) [5]

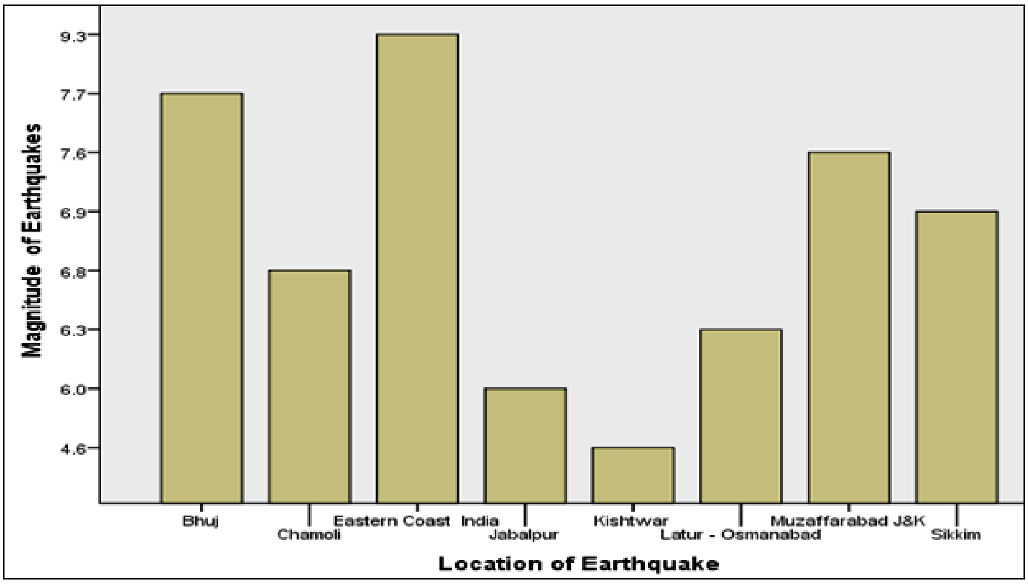

Fig 2 Earthquakes Locations in India with Magnitudes (1993-2013)

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[3] EM- DAT: The OFDA / CRED International Disaster Database. (*includes Tsunami) DM in India, Ministry of Home Affairs, pg 9

[4] IMD

Likewise a peep into the population and vulnerability effects of the affected areas of the eight earthquakes undertaken for study in Table-1, also showed alarming results.. Study showed that Bhuj earthquake of 2001 in Gujarat was the worst hit, that left about 20,005 people dead and 6321812 affected, which included large number of children as well [6]. Detail's shown in fig. 3. Correspondingly, during Tsunami of 2004 number of people dead in India were 16389 and 654512 people were affected physically, economically and socially [5]. Similarly, Latur –Osmanabad earthquake in 1993 with a 6.3 magnitude of earthquake accounted for 9748 deaths and 3000 affected population. Alike, in 2005 Muzaffarabad earthquake 1309 people died and a population of 156622 was affected. Analysis also pointed out that even though the 2013 Kishtwar Earthquake had an earthquake magnitude of 4.6 it still left with 59359 people affected, even though the death toll account was only 2 persons (Fig.3). Even the recent epicentre seismic activity of Nepal has killed more than 70 people in neighbouring states of India and left thousands affected at a magnitude of 7.8 on Richter scale.

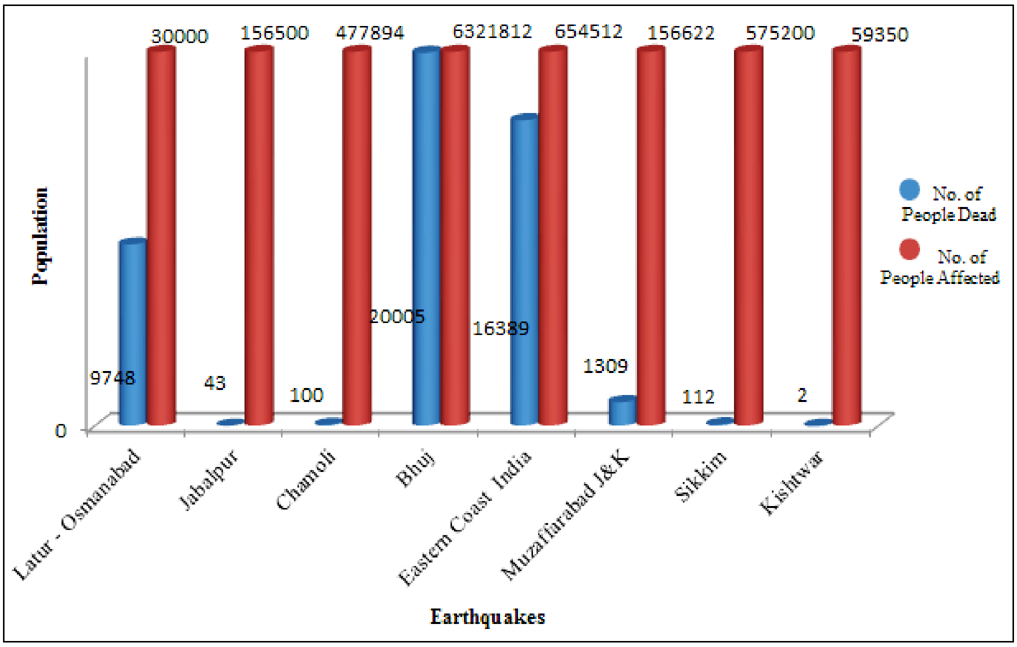

Fig 3 Number of People Dead and Affected during Earthquakes within India (1993-2013)

The analysis of earthquakes in fig.3, reveals that whatever may have been the scale of earthquake magnitude in India, it is still indicative of the extreme fragile nature of the built up environment, people's inability to cope and respond effectively to seismic activity and highly inadequate preparedness on part of the country? These devastating earthquakes are thus indicative of the physical, social, economic, cultural, technological and above all the political vulnerability existing within the country [7]. Rapid urbanization has definitely lead to expansion of the built environment in moderate or high –risk cities making them imperative to incorporate seismic risk reduction strategies in various aspects of urban planning and construction of new structures[8].

Irony of the whole thing is that recipients of both disaster and development are increasingly becoming one especially in the developing countries [9]. As vulnerability of the society to earthquakes is not voluntary but involuntary, it is necessary to have three elements of –social stability, effective governance and investment [4], for sustainable development by the mitigation managers, for a developing country like India.

It is believed that the organizations and various stakeholders should know 'what to do', 'how to do', and 'what is the best tool to use' [10] in the wake of an earthquake. Thus, these calculated results are a mirror for lack of awareness, capacity building and enforcement of earthquake guidelines in the affected areas [7].

For enhanced scientific understanding of India's seismic activity, its causes, area of influence and high rate of destruction to life and property, one need to review the earthquake monitoring structure and it's functioning within India.

III. Earthquake Monitoring Structure in India

The first recorded earthquake in India dates back to 1819 in Kutch, Gujarat with a magnitude of 8 on the Richter scale, followed by the Great Assam quake of 1867 having a magnitude of 7.5[5]. Seismic evaluation and vulnerability assessment done by seismologist indicate that 59% of India's land is prone to moderate to

[5] IMD, EMDAT

severe Earthquakes. Of which, 43% land lies in very high risk area of Zone V, 27% area lies in high risk belt of Zone IV, while moderate risk Zone III comprises of only 18% of the geographical area and 12% land lies in Zone II[5].

3.1 Reason of Earthquakes

The main reason for earthquake hazards in India is plate tectonic movement. The Indo – Australian Plate of the Gondwanaland having moved northwards after breakup has collided with the Eurasian Plate of the Angaraland. This collision has being the main cause for formation of the world's youngest and highest fold mountains 'The Himalaya' due to compression of deep sea-floor of Tethys Sea [11]. Even today this collision is the main source of stress building along these boundaries, as Indian plate is still moving northwards and penetrating under the Eurasian Plate at an estimated rate of about 50mm/year (5 to 6 cm), causing intense seismic activity around the entire region [12].

3.2 Departments of Earthquake Management

The first seismic observatory was set up in Kolkata in 1898 after the 8.1 magnitude of Shillong Earthquake in 1897 [13]. During any seismic activity the operational task of immediately estimating the limitations of earthquake source and circulating the information to all the concerned Central and State Government agencies involved in relief and rehabilitation measures is done by the apex body, Indian Metrological Department,. Seismological division of IMD, New Delhi has state-of-the art facilities for data collection, processing and broadcasting information to the concerned agencies. Graphical representation in fig.4, lists the various earthquake departments within India managing earthquake disaster mitigation.

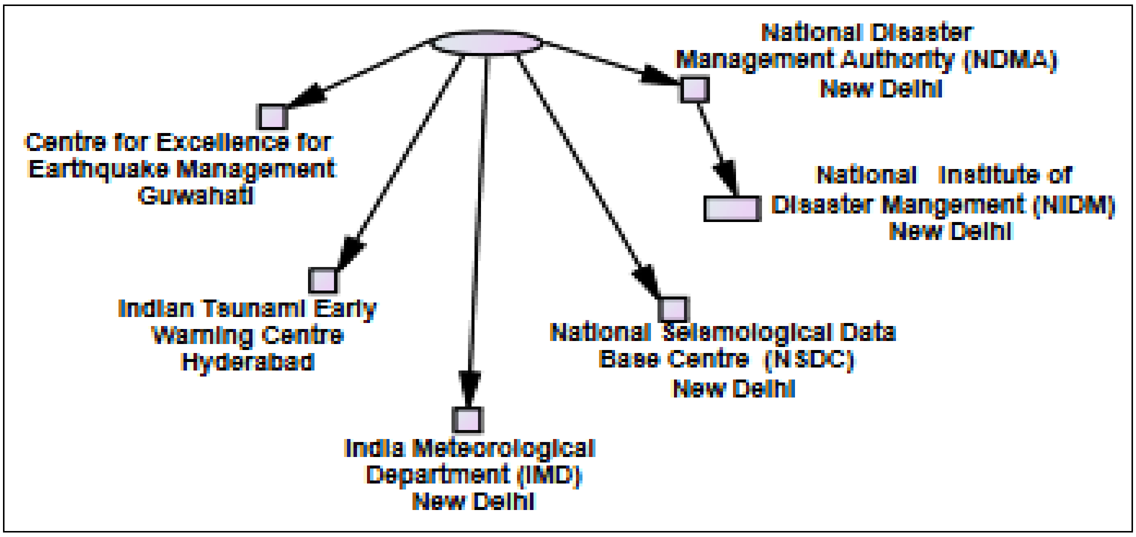

Fig 4 Earthquake Management Departments within India

Presently, India has 82 National Seismological Network (NSN) stations. These consist of 16-stations of V-SAT, based on Digital Seismic Telemetry System located around National Capital Territory (NCT), Delhi. 20- Stations of V-SAT are based on Real Time Seismic Monitoring Network located in North East region of the country, and 17-stations of Real Time Seismic Monitoring Network (RTSMN), for monitoring and reporting large magnitude of under-sea earthquakes capable of generating tsunamis are stationed around the country. While remaining 29 stations of individual/ analog type are spread around the country to monitor seismic activity [14].

All the available seismological data received from the various network stations including those operated by other agencies is compiled, processed, analysed and archived on a regular basis by the National Seismological Data Base Centre (NSDC) located at New Delhi (Fig. 4)

The first ever Tsunami of 2004 in India initiated the Ministry of Earth Sciences to establish Indian Tsunami Early Warning Centre (Fig. 4) at Indian National Centre for Ocean Information Services (INCOIS), Hyderabad that got operative in 2007 for providing advance warnings for Tsunamis affecting the country[6].

Government of India has also approved a Centre for Excellence for Earthquake Management at Guwahati, (Fig. 4) for caring out research; developing resources and to carry out networking for earthquake with institutions at international, national and regional levels [6].

IV. Earthquake Mitigation Procedure in India

The two main aims of earthquake disaster mitigation are:

- Reducing risk of deaths and injury among population, and
- Reduce damage and economic losses inflicted on public and private sector infrastructure.

History of Disaster Management (DM) in India dates back to 1878 when Ministry of Agriculture had set up Scarcity Relief Division during the British period for providing food supply to the people. After the Bhuj earthquake in 2002, DM got shifted to Ministry of Home Affairs (MHA), for the very reason of change in approach from relief to a holistic approach towards managing disasters.

DM Act was formed in 2005 for effective management. Today, the nodal agency for DM in India is National Disaster Management Authority (NDMA) (Fig. 4) which was formally established on 27th September 2006 with the honourable Prime Minister as its chairperson.

The NDMA is responsible for laying down the policies and guidelines of various disasters and measures of disaster risk reduction to be followed by the various stakeholders in the country. Earthquake Disaster Management guidelines of India, for reducing seismic effects have also been spelt out by the NDMA. These are referred to as the 6 effective pillars [6] or guidelines (Fig. 5) for earthquake mitigation especially for Zones III, IV and V.

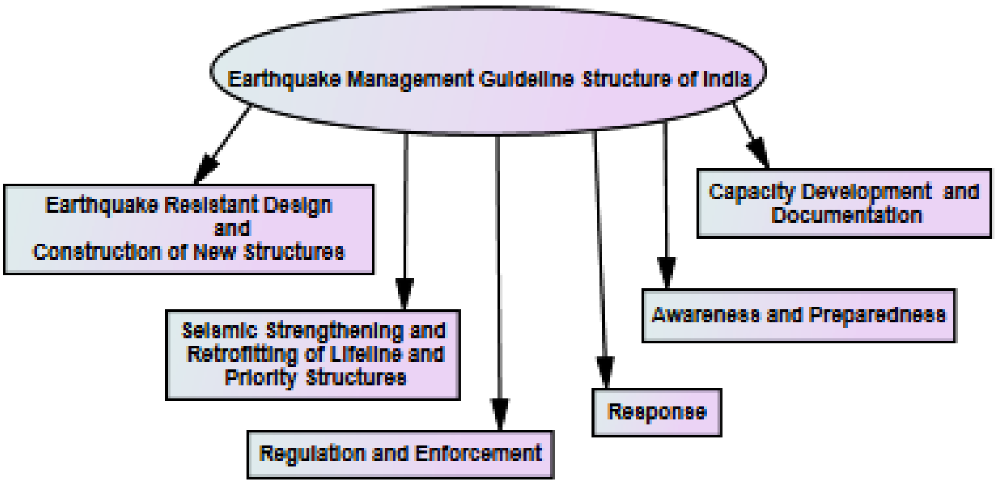

Fig 5 Six Major Guidelines of Earthquake Management System within India

A country which is seismically very active due to plate tectonic movement and rapid urbanization thus makes it prerogative that earthquake risk reduction must be met through implementation of certain guidelines as enumerated below by National Disaster Management Authority:

4.1 Earthquake Resistant Design and Construction of New Structures [14]

Studies have shown that maximum loss of life (95%) during an earthquake is due to collapsing of buildings which were not earthquake-resistant. Seismic management therefore stresses on earthquake – resistant construction for all new structures especially in III, IV and V zones through training of professionals like faculty and students of engineering and architecture colleges, IIT's and polytechnics. Also required for construction is adequate exposure to earthquake resistance designs and construction techniques; documents distribution related to earthquake - resistant designs and codes; carrying out Pilot – projects for earthquake resistant construction so others can be inspired; modifying town planning regulations and bye-laws with mandatory technical is emphasised upon by the guidelines.

For this purpose National Building Code (NBC) of India has been formed to regulate building construction activities across the country. Its first manual was published in 1970 by Planning Commission which was later revised in 1983 and amended three times, that is, twice in 1987 and once in 1997.In 2005 a revised NDC has been published. Even then the implementation of NDC has been a great challenge for the administrators.

1.2 Seismic Strengthening and Retrofitting of Lifeline and Priority Structures[14]

According to NDMA if a high intensity earthquake occurs in India like Bhuj or Tsunami (or recent Nepal) nearly 12 crore buildings already constructed in III, IV and V zones will be ruined. Reason, they are not made as per the NDC norms. Also retrofitting of such large number of buildings is not financially or otherwise possible. 26 cities have been listed by the government where first level priority seismic retrofitting is required.

According to Earthquake Guidelines, State Disaster Management Authority's (SDMA's) need to make an assessment of the constructed environs after discussion with their respective State Earthquake Management Committees (SEMC's) and Hazards Safety Cells (HSCs). Then list based upon safety audit of national importance lifeline structures is to be prepared and retrofitting of such critical structures need to be carried out under priority bases of risk to life and financial implications.

Retrofitting and its techniques along with awareness are carried out by Building Materials and Technology Promotion Council (BMTPC). It has prepared vulnerability Atlas of India with 229 districts in 21 States and Union Territories falling in Seismic Zones IV and V.

1.3 Regulation and Enforcement [14]

Another guideline for Earthquake mitigation in India for all stakeholders responsible for adopting, regulating and enforcing earthquake- resistant construction practices and seismic safety in designs is Techno-Legal and Techno- Financial mechanism. Regulation and enforcement requires:

- Seismic Design Codes.
- Municipal Acts
- Licensing and Registration of Professionals and Certification of Artisans
- Scrutiny of designs and building permissions by Urban Local Bodies' (ULB's) and Panchayati Raj
- Institution's (PRI's)
- Risk Transfer Mechanisms

Also required as per the guidelines is modification in Town and Country Planning Acts, land use and zoning regulations and Development Control Regulation's (DCR's). A set of model bye laws has been developed by the government that is technically rigorous and meet globally accepted norms laid by the Bureau of Indian Standards (BIS).

4.4 Awareness and Preparedness [14]

The earthquake severity is often under estimated. Earthquake mitigation is not possible till the various stakeholders are not educated, trained and sensitized towards the seismic risks. Therefore, concerned agencies should develop and implement awareness campaigns for safe practices before, during and after the earthquake by giving hand-outs like pamphlets, showing documentaries and video films in local languages, mock drills, preparing Earthquake Disaster Plans and Vulnerability Maps of high risk areas. There should be training and awareness programs specifically targeting groups of stakeholders like elected representatives, civil servants, school administrators, hospital management and representatives of corporate world. This can go a long way in reducing death and injury as is evident from countries like Japan and Turkey.

4.5 Capacity Development and Documentation [14]

Earthquake guideline involves education, training, research and development of skills and capacity for improving seismic education in India. This is undertaken by National Institute of Disaster Management (NIDM). It was upgraded from National Centre for Disaster Management to NIDM (Fig -4) on 16th October 2003 as a statutory organisation under the DM Act 2005.

Beside this other institutes looking into capacity development are Indian Institute of Technology's (IIT's), National Institute of Technology's (NIT's), Administrative Training Institute's (ATI's) at state level and other professional bodies in India. Earthquake education should be a multi-faceted capacity building aspects both at school and college levels. Technical training of artisans, preparing of manuals, documentaries and films on earthquake safety should also be carried out.

Guidelines of NDMA, stress on scenario analysis and simulation modelling for long-term programmes and strengthening earthquake preparedness, mitigation and response efforts. Seismic Micro-zonation studies are also stressed upon for multi-disciplinary approach towards development of land use zoning, especially for urban areas with critical structures. Similarly preparing large –scale maps and Geographic Information System (GIS) for earthquake prone areas is stressed upon by the NDMA Earthquake Guidelines.

4.6 Response [14]

Earthquakes preparedness till recently was seen from response point of view rather than from mitigation point. The first responders of any earthquake are always from within the community. Hence, the adverse consequences of earthquake require prompt, coordinated, and effective management response system by the stakeholders, especially at community levels. This requires multiple agencies to undertake earthquake response at local level, by the Incident Command System (ICS). Response stresses on formation of National Disaster Response Force (NDRF) and other emergency response teams need for emergency equipment, logistics and medical response capability for the earthquakes.

Based on Earthquake Management Guidelines NDMA has prepared an Rs 600 Crore National Earthquake Risk Mitigation Project (NERMP), [15] to be incorporated by all States and Union Territories of India in cooperation with respective governments and SDMA's. Its aim is to strengthen the structural and non-structural earthquake mitigation efforts and to look into the safety of non- engineered buildings in semi- urban and rural areas.

Hence a developing country like India having a strong democratic institution needs a robust approach towards Earthquake Disaster Risk Management.

2. Shortcomings in Earthquake Disaster Management System

Peep into the machinery of earthquake management and viewing the results of earthquakes, is indicative that India does have the means and potential to reduce the risks of earthquake, but they are not being practiced to the fullest. Study of Earthquake Management system has enunciated 'Critical Concern Areas of Earthquake Management in India', around which the government still needs to work.

Some of the mitigation limitations and apprehensions of Earthquake Management System in India that came forth have been listed below:

- Stakeholder's inadequate knowledge of risk, vulnerability and mitigation regarding seismic activities.
- Inadequate consideration in educational syllabus of professional and vocational institutes (engineering and architectural) regarding structural mitigation measures.
- Various stakeholders awareness level regarding seismic risk is very low;
- Inadequate monitoring and enforcement of earthquake-resistant building codes and town planning bye-laws;
- Absence of system of licensing for engineers and masons;
- Absence of using earthquake-resistant knowledge in non-engineered construction of suburban and rural areas;
- Among professionals inadequate formal training for earthquake-resistant construction practices;
- Inadequate preparation and capacity building among different stakeholders for seismic response.
- Lack of Risk Transfer and Sharing
- Lack or no mandatory technical audit of structures and lifelines.

As earthquakes are considered to be a matter of chance the reason for such shortcomings in earthquake mitigation can be contributed to high expenses, on retrofitting of buildings as compared to new constructions. Lack of political will for fund allocation, is not favoured by the authorities, as mitigation or decision making process is over- centralised. Socio- Cultural issues also cause people to resist the change and find it undesirable. Lack of personal responsibility and over dependency of societies also contributes to shortcomings. Similarly, risk perception is another obstacle in which people contribute only if the hazard is causing a threat. [16]. Also response to disasters at the time of their occurrence can only harvest temporary results of relief incurring high cost[17].

V. Recommendations

In the world of Globalisation, for a developing country like India, an earthquake of the Nepal scale can create a setback and exceedingly affect its socio- economic and cultural developmental progress. So to reduce death and destruction caused by earthquakes, administration must accommodate significant life changes for mitigation. Study of seismicity and Earthquake Management System of India suggest that effective preparedness and mitigation steps if taken can lead India towards more resilient society. Some recommendations have been listed below:

- More focussed and co-ordinated multi – tier and multi–sectoral organisation of Earthquake Management is required.
- Need for better training of government and other stakeholders.
- Need to involve local communities in awareness campaigns as first responder's
- Testing and renewal of certification of engineers, architects and masons from time to time.
- Panchayati Raj Institution's and Urban Local Bodies to be provided with more funds and power to mitigate earthquake disasters.
- Micro- Zonation to be carried out for proper regulation of land use.
- Digitising all documents from various agencies and saving them in electronic format.
- Use of better means of mapping of earthquake zones through GIS and simulation software's.
- Insurance coverage through risk transfer, sharing and spreading.
- Use of forecasting tools like Scenario Building and Net Assessment

VI. Conclusion

India with more than half of its landmass seismically active and large proportion of its population being highly vulnerable is in need of Earthquake Disaster Management for protecting the life and property, of every single person facing the risk, however small it may be. The country has seen an increase in rate of seismicity over the last two decades with devastating earthquakes having epicentre within and outside its borders example Bhuj 2001, Tsunami 2004 and not to forget the recent Nepal earthquake with 7.9 magnitude having had strong and repeated aftershocks. India definitely has well placed Earthquake Monitoring and Mitigation System but its management needs to be a continuous process and not end with every earthquake that transpires.

Likewise best policies and guidelines are useless, if not enforced effectively and fully. India needs to evaluate Earthquakes through modern tools of forecasting and simulation to reduce the high rate of devastation and vulnerability especially in rapidly developing unplanned urban centres. Earthquake mitigation strategies can only be successful when there is support and backing of all concerned stakeholders. Cost involved in mitigation procedures are definitely expensive but less than what would be incurred during or after the earthquake. Implementation of earthquake guidelines is the best way to insure resilience and sustainable development from long term benefits. Initiatives of Indian government towards earthquake mitigation management may be slow and small but every step taken will lead it to a better and robust India.

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