Earthquake Safety in India: Challenges

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NDMA's and State's initiatives for Earthquake Risk Mitigation

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India is vulnerable to a wide range of natural hazards, one of which is earthquakes. Approximately 58.6% of the country's land is affected with different levels of severity as EQ zone II, III, IV & V (Kumar, 2015). These areas are home to approximately 80% of India's population. India's landmass can be viewed in three geographical regions, namely: (a) the Himalaya region in the north, (b) the Indo-Gangetic Plains adjoining the Himalayas, and (c) the peninsular India. The entire Himalayan region is vulnerable to earthquakes of high magnitude.

India has witnessed several destructive earthquakes in the past which led to big causalities some like 1897 Shillong (M8.7) Earthquake, 1905 Kangra (M.8.6) Earthquake, 1934 Bihar–Nepal (M8.4) Earthquake and 1950 Assam–Tibet (M 8.6), 1988 Bihar-Nepal (M6.6) Earthquake, 1991 Uttarkashi (M6.6) Earthquake, 1993 Killari (M6.4) Earthquake, 1997 Jabalpur (M6.0) Earthquake, 1999 Chamoli (M6.6) Earthquake, 2001 Bhuj (M7.9) Earthquake, 2004 Indian Ocean (M9.3) earthquake, 2005 Jammu & Kashmir (M7.6) Earthquake, 2011 Sikkim (M6.9) Earthquake and 2015 Nepal (M7.8) Earthquake.

These damaging earthquakes have exposed the high vulnerability of the built environment due to lack of a professional environment to ensure safe construction i.e., no system for code enforcement, no enforcement of techno- legal regime, no peer- review mechanism nor competence-based licensing of civil or structural engineers. In addition, gaps such as insufficient seismic hazard monitoring, inadequate preparedness, inefficient mechanism or policy to regulate developments, lack of trained and experienced engineers, architects, teachers, masons, bar-benders, lack of mechanism for training and capacity building of community, lack of proper monitoring of adhering to building bye-laws, unaddressed earthquake engineering education in colleges, inefficient response and so on are identified during various recovery and reconstruction programs. Generally, during an earthquake, buildings and the built environment put individuals at risk rather than the earthquake itself. These events necessitated the creation of earthquake-safe environments through increased awareness, capacity building, prevention, and mitigation measures.

Recently, on June 22, 2022, a strong earthquake with a magnitude of 6·1 struck the southeastern region of Afghanistan, triggered massive causalities, with over 1000 deaths, 1500 people left injured and 70% of the houses in the region were damaged. On November 9, 2022, an earthquake of 6.6 magnitude struck Doti district in the western part of Nepal left six people killed and eight injured. The shock was felt strongly in the adjoining areas, as well as in some parts of India. On 21 November 2022, 5.6 magnitude earthquake struck at a depth of 10 kilometers, left more than 160 dead and hundreds injured as buildings crumbled. Due to proximity to fault lines, the shallowness of the quake and inadequate infrastructure not being constructed using earthquake-proof methods cannot withstand earthquake, all factors

contributed to the damaged buildings. Quakes of 5.6 M usually don't cause widespread damage to well-built infrastructure.

It is heartbreaking to hear about the lives that have been lost in the earthquake, and it takes years to repair and reconstruction the devastation it caused. Additionally, the seismic disaster will exacerbate poverty, food insecurity, and other health-related problems. Recent activities are serious reminder that we are not prepared for such earthquakes even today. To make sure no more lives are lost, we must take whatever action we can.

No one can predict when or where the next earthquake will happen, therefore everyone at every level—from the Center, State, and UTs, up to the Panchayat level—must be ready and work together to create a resilient country. Prior to now, the most significant part of investments took place as part of earthquake recovery and reconstruction projects after the catastrophe. Recent earthquakes and gaps mentioned above have amplified the importance of earthquake risk mitigation. All over the world, the damage and loss caused by the earthquake have been reduced through investment in mitigation. However, we cannot continue to lose lives, thus investing in mitigation is crucial to save significant lives.

As part of its responsibility under DM Act of 2005, the National Disaster Management Authority (NDMA) conducts mega mock exercises and tabletop exercises on a regular basis to check preparedness of the State. To safeguard/ prepare people from the next earthquake-related calamity for response to take when faced with earthquake, runs TV and Radio campaign to disseminate information on do's and don'ts during earthquake. Also, Special programme such as Aapda ka Samna runs on Doordarshan where experts discuss about the prevention, mitigation measures which public should follow. NDMA has mandate to formulate programs regarding major hazards being faced by different areas of the country, towards mitigating losses in a systematic manner. To reduce the losses, following are earthquake mitigation projects that NDMA has completed or is currently working on in relation to the subject:

I. **Home Owner's guide for Earthquake & Cyclone safety (2019),** provides details to those who are constructing a house or who are buying a flat in multi-storey buildings, which are made of either masonry or reinforced concrete (RC)

II. **A Primer on Rapid Visual Screening (RVS) Consolidating Earthquake Safety Assessment Efforts in India (2020)** can be referred to as a base document to visually examine a building and identify features that affect the seismic performance.

III. **Simplified Guidelines for Earthquake Safety (2021)** provides minimum requirements that have to be complied with while constructing a earthquake resistant house.

IV. **Earthquake Disaster Risk Index:** The main objective of the project is to assess the earthquake risk in cities of India, which will help mitigate negative consequences, prepare, and respond to the next event. The risk index obtained from the study obtained will be mainly the combination of hazard, vulnerability, and exposure to the city. It will provide information to each city of their impending risk involved, and its consequences, help to reduce the social and economic consequences due to an earthquake and gave an Inter-comparison of the risk among the cities as well as guide government agencies for prioritizing disaster preparedness and response measures in the more vulnerable area of the city. NDMA has completed the phase I of the project for 50 cities in 2019 and Phase II of the project is in progress which targets next 60 cities.

V. **Creation, Periodic Review & Updation/Revision of Building Codes for Earthquake Resistant Build Environment:** NDMA has fund the R&D projects such as 'Probabilistic Seismic Hazard Map', 'Seismic Design of Pipelines–Code of Practice', 'Performance-Based Design and Seismic Design' and 'Detailing of New Structures − Steel Buildings'.

Codes along with the Probabilistic Seismic hazard map has been finalized in association with IITs and BIS.

VI. **Resource Mapping of Earthquake engineering faculties in Engineering / Architect Colleges:** The object is to map earthquake engineering resources by developing a database of earthquake experts and other relevant resources across the country and the development of the MIS platform to host the earthquake resource database. It will be used as tool to identify the seismic expert and other relevant fields.

VII. **Compendium of Traditional Earthquake Resilient Construction Practices for Knowledge Sharing and Disaster Risk Reduction: Promotion of Traditional Construction Practices (ongoing):** The main objective of the project is to identify and document the Traditional and Contemporary building typologies in Indian Himalayan Region, to study their effectiveness during earthquake, and suggesting safety measures for such kind of building typologies. Effectiveness of these traditional technologies has been clearly brought out during recent earthquake disasters.

VIII. **Development of Teaching Resource Materials on Earthquake Engineering for Undergraduate Courses in Engineering/ Architects Colleges for Technical Education (ongoing):** Engineers and architects play a major role in planning and creating a seismic resilient built environment. Educating and training the professionals about the latest technology, research, and innovation in the field of earthquake engineering from the undergraduate level is seen to be necessary. The development of these teaching recourse material will fill the gap of non-availability of essential resource material for earthquake engineering at the undergraduate level. It will also enhance the understanding of freshly graduating civil engineers and architects to enable them to produce earthquake-resistant infrastructure, thereby help in achieving the vision of 'disaster resilient India.'

IX. **Bihar, Uttar Pradesh and Uttarakhand earthquake Scenario Development for Awareness Campaign:** Scenarios are developed to visualize what would happen if one of the earlier earthquakes repeats today. NDMA by involving various stakeholders has already developed two scenarios for Mw 8 earthquake in Himachal Pradesh for north-west India and Mw 8.1 Shillong Earthquake of 1897 for north-east India to assess the multi-state preparedness. Currently, a science-based earthquake scenario for repeat of 1934 Bihar- Nepal earthquake and 1991 Uttarkashi earthquake will be developed, and outcome will be disseminated to stakeholders for improved planning for disaster preparedness and response. It also involves sensitization of local population and motivate them for participation in mega mock exercise.

X. **Pilot Project to improve earthquake Resiliency of Masonry Lifeline Structures and upcoming constructions (Ongoing):** The project aims to improve the earthquake resilience of lifeline structures in the states of Tripura, Uttarakhand, and North Delhi Municipal Corporation (NDMC), which includes retrofitting of selected masonry lifeline buildings, construction of technology demonstration unit and capacity building of engineer, bar benders, and carpenters. The main objectives of the scheme are:

- Structural safety audit of selected lifeline masonry buildings.
- Retrofitting of selected lifeline masonry buildings.
- Construction of Technology Demonstration Units to showcase the earthquake-resistant technology (one each in the project States/UT).
- Capacity Building-Training of engineers, masons, bar-benders, and artisans.
- Awareness generation of masses by promotion of IEC materials

XI. **Comprehensive National Earthquake Risk Mitigation Programme (CNERMP)**

NDMA is in process of developing an Earthquake Mitigation Project named "Comprehensive National Earthquake Risk Mitigation Programme (CNERMP)" with the goal of creating a formal safety-driven environment in India which will contribute to reducing human and economic losses caused by earthquakes. Being a national-level project, it is proposed to be implemented across 24 highly seismic States and UTs lying is seismic zone IV and V. The project proposal is based on lessons learned and experiences gained from prior earthquakes. The programme has following objectives:

- Develop competence of the technical and human resources engaged in the development of the earthquake-resistant built environment;
- Enable and empower technical institutions and build systems and processes in the States & UTs;
- Develop legal and regulatory frameworks for supporting and sustaining earthquake risk reduction in the States and UTs;
- Leverage state-of-the-art analysis, design & construction technologies, and information technologies by: (a) improving Building Codes and best practices of design & construction, and (b) outlawing use of unsafe designs and poor practices; and
- Create a technical environment (based on objectivity and formalism) in States & UTs

Proposed key developments and achievements through this programme is as follows:

Earthquake Risk Reduction Act, National Seismic Safety Commission, Earthquake Risk Insurance Pool for States & UTs, Establishing a sound Techno-Legal Regime, Professional development programmes for Teachers, Engineers, Architects and Arcticians, National Network of Earthquake Strong Motion Sensors, National Clearinghouse of Seismological and Geodetic Databases, Pilot Earthquake Early Warning System, Develop Earthquake resistant techniques and Pilot Projects for Retrofitting of Typical Structures

States and NDMA are collaborating closely in mitigating earthquake risk. Significant thrust had been developed in the States to enable and empower the needed human, technical and legal support to ensure earthquake safety. Some important State's initiatives are as follows:

- Bihar came up with the 'Earthquake Safety Clinic' which provide consultations regarding construction of resilient buildings. Local people can avail the services of this clinic. This clinic is located in NIT Patna and run by professors of IIT Patna. Training and Capacity Modules for engineers, architects and masons has been developed by BSDMA. The engineers of various line departments as well as Emergency and First Responders like police officials, ULBs, panchayat officials are also being trained up.
- National Remote Sensing Application Centre along with Arunachal Pradesh SDMA has conducted the study on vulnerability of villages in Arunachal Pradesh. From the study, it was found that major contributors for the vulnerability are weak housing/building constructions, poor communication such as road networks, difficult topography and poor socio-economic condition.
- ASDMA in collaboration with AEC and NORSAR has developed a system for estimation of Earthquake Damage for Guwahati City for Probable Earthquake Scenarios by considering 1950 and 1897 earthquake. This system makes scenario-based projections for the city which helps in the preparation of DRR and Mitigation Plans for the city. This project also incorporates GIS based earthquake damage and loss estimation. Cost-effective Retrofitting Solutions for Open Ground Storey Apartment Buildings in Guwahati has also been developed by AEC.
- DDMA Kamrup, Assam has constructed earthquake resilient DEOC building at Amingaon, using Cost-effective Base-Isolation System devised by IIT Guwahati.
- Assam has also developed a CAD based online system for permission for construction of buildings since 2015 as per the Guwahati building bye-laws of 2014 which are amended in 2020.

- Uttarakhand SDMA has conducted the Seismic vulnerability of 18,835 lifeline buildings across the State using RVS technique. 7285 Residential buildings in 03 towns (Mussoorie, Nainital, and Bageshwar) of Uttarakhand have been surveyed. Earthquake Early Warning System (EEWS) has also been developed whereby real-time earthquake warning sirens have been placed over the Uttarakhand region. A Mobile Application named Uttarakhand Bhookamp Alert has been developed. This app gives alert of Uttarakhand's earthquake having magnitude greater than 5. Building Regulation for Resilience in Uttarakhand has been developed.
- Himachal SDMA conducted Rapid Visual Survey of 376 buildings in the State. Structural Safety Audit and 40 retrofitting DPRs have been prepared by CBRI Roorkee in association with HPSDMA. Masons training has been rolled out with the help of CBRI Roorkee and HIMCOSTE. Non- Structural Mitigation has also been planned under school safety project of the State.
- Sikkim SDMA has organized a massive programme for making the Building Exit Plans for all government buildings. In collaboration with TARU, Hazard Risk Vulnerability Analysis was done for all the major towns of the State.